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URE'S DICTIONARY
OF
ARTS, MANUFACTURES, AND MINES

CONTAINING

A CLEAR EXPOSITION OF THEIR PRINCIPLES AND PRACTICE

BY

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Erratum and Omissions.

Page 316 *insert* **EXOGENOUS.** A botanical term. See Brande's 'Dictionary of Science, Literature, and Art.'

„ 325 *for* Port *read* Post.

„ 534 *insert* **GALVANISM OF PLATES.** The coating of iron plates with zinc, &c.

the use of metallic oxides;' and in another he writes, 'A decoction of *Thlaspi* (Shepherd's purse), fumes of phosphorus, and particularly of sulphur, as acting on silver in the *same way as iodine*, and caloric, produce the same effect by oxidising the metal, for from this cause proceeded in all these instances their extreme *sensibility to light*.' Niepce died in July 1833. Daguerre proceeded with his experiments for nearly six years, before he succeeded in producing the desired results. The Daguerreotype process depends on the production of a very delicate chemical compound of iodine and silver on the surface of a carefully-prepared silver plate. The image is developed by the action of mercurial vapour, and lastly rendered permanent, so far as the action of light is concerned, by dissolving off the iodide of silver by hyposulphite of soda. According to the first published description by Daguerre, the process is divided into five operations. The first consists in polishing and cleaning the silver surface, by friction, with cotton fleece imbued with olive-oil, upon the plate previously dusted over with very finely-ground dry pumice-stone out of a muslin bag. The hand of the operator should be moved round in circles of various dimensions. The plates should be laid upon a sheet of paper solidly supported. The pumice must be ground to an impalpable powder upon a porphyry slab with water, and then dried. The surface is next to be rubbed with a dossil of cotton, slightly moistened with nitric acid, diluted with sixteen parts of water, by applying the tuft to the mouth of the phial of acid, and inverting it for a moment. Two or three such dossils should be used in succession. The plate is lastly to be sprinkled with pumice-powder or Venetian tripoli, and rubbed clean with cotton.

The plate is then placed in a wire frame, with the silver surface uppermost, over a spirit-lamp, meanwhile moving it so as to act equally on every part of the plate. In about five minutes a whitish coating will indicate that this operation is completed. The plate must now be laid upon a flat metal or marble slab to cool it quickly. The white surface is to be brightened by rubbing it with cotton and pumice-powder. It must be once more rubbed with the cotton imbued with acid, and afterwards dried by

A DICTIONARY

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DAGUERREOTYPE. Although this beautiful photographic process is entirely superseded by other processes, a description of it is preserved, on account of the interesting conditions involved in the production of the picture. It was discovered by M. Daguerre, a celebrated French dioramic painter, with whom was associated M. Nicéphore Niepce, and published in July 1839; the French Government having secured a pension for life of 6,000 francs on M. Daguerre, and of 4,000 francs on M. Isidore Niepce, the son of M. Nicéphore Niepce.

It is rendered clear from some of Niepce's letters, that he had abandoned all hope of succeeding by his methods (named by him Heliography), and in a letter to Daguerre, he says, 'I repeat it, sir, I do not see that we can hope to derive any advantage from this process—the use of iodine—more than from any other method which depends on the use of metallic oxides;' and in another he writes, 'A decoction of *Thlaspi* (Shepherd's purse), fumes of phosphorus, and particularly of sulphur, as acting on silver in the *same way as iodine*, and caloric, produce the same effect by oxidising the metal, for from this cause proceeded in all these instances their extreme *sensibility to light*.' Niepce died in July 1833. Daguerre proceeded with his experiments for nearly six years, before he succeeded in producing the desired results. The Daguerreotype process depends on the production of a very delicate chemical compound of iodine and silver on the surface of a carefully-prepared silver plate. The image is developed by the action of mercurial vapour, and lastly rendered permanent, so far as the action of light is concerned, by dissolving off the iodide of silver by hyposulphite of soda. According to the first published description by Daguerre, the process is divided into five operations. The first consists in polishing and cleaning the silver surface, by friction, with cotton fleece imbued with olive-oil, upon the plate previously dusted over with very finely-ground dry pumice-stone out of a muslin bag. The hand of the operator should be moved round in circles of various dimensions. The plates should be laid upon a sheet of paper solidly supported. The pumice must be ground to an impalpable powder upon a porphyry slab with water, and then dried. The surface is next to be rubbed with a dossil of cotton, slightly moistened with nitric acid, diluted with sixteen parts of water, by applying the tuft to the mouth of the phial of acid, and inverting it for a moment. Two or three such dossils should be used in succession. The plate is lastly to be sprinkled with pumice-powder or Venetian tripoli, and rubbed clean with cotton.

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The second stage is that of iodising the plate. A box is prepared, having iodine strewed over its bottom, and the silver plate, face downwards, is placed a few inches above the iodine, and the lid of the box being closed, all is left at rest for a short time. The plate must be left in this position till the surface of the silver acquires a fine golden hue, caused by the vapours of the iodine rising and condensing upon it; but it should not be allowed to assume a violet tint. The room should be darkened, and no heat should be employed. When the box is in constant use it gets impregnated with iodine, and acts more uniformly and rapidly; but in general states of the atmospheric temperature this operation will be effected in about twenty minutes. If the purple colour be produced, the plate must be repolished, and the whole process repeated.

The plate with its golden hue is to be introduced, with its frame, to the camera obscura. During this transfer the light must not be suffered to strike upon the surface of the plate; on which account, the camera obscura may be lighted briefly with a small wax taper.

The plate is now submitted to the third operation, that of the camera obscura, and with the least possible delay. The action of the solar radiations is obviously quicker the brighter the radiations which act upon it; and the more correct, according as the focus of the camera is previously accurately adjusted to the place of the plate, by moving backwards and forwards a roughened pane of glass, till the focal point be found; and the plate is to be inserted precisely there. This silver plate exactly replaces the ground glass. While the prepared plate is being fastened, the camera must be closed. The plate is now in a proper position to receive and retain the impression of the image of the objects presented the moment that the camera is opened. Experience alone can teach the proper length of time for submitting the plate to the concentrated rays of light; because that time varies with the climate, the seasons, and the time of day. More time should not be allowed to pass than what is necessary for fixing a distinct impression, because the parts meant to be clear would be apt to become clouded. The impression of the image of nature is now actually made upon the plate; but it is as yet invisible; and it is only after a lapse of several minutes, during which it is exposed to mercurial vapour, that faint tracings of the objects begin to be seen.

The fourth is the operation with quicksilver, which must follow as soon as possible the completion of the third. Here a phial of quicksilver, a spirit-lamp, and a glass funnel with a long neck, are required. The funnel is used for pouring the mercury into a cup, placed in the bottom of an apparatus which will allow of the application of heat. No daylight must be admitted to the mercury box, a small taper only being used to examine, from time to time, the effects. The plate with the dormant image is placed some distance above the mercury, which vaporising, evokes in a truly magical manner, the delicate lines which the solar pencil has traced.

After each operation, the interior of the apparatus and the black board or frame should be carefully wiped, in order to remove every particle of mercury. The picture may now be inspected in a feeble light, to see how far the process has succeeded. The plate, freed from the metallic bands, is to be placed in a box, provided with a cover and grooves, to exclude the light, till it is made to undergo the last operation. For the fifth and last operation the following articles are now required:—strong brine, or a weak solution of hyposulphite of soda; two troughs of tin plate, and a jug of distilled water. The object of this process is to fix the photographic picture. One of the troughs is to be filled with brine to the depth of an inch, and the other with pure water, both liquids being heated somewhat under the boiling point. The solution of hyposulphite of soda is preferable, and does not need to be warm. The plate is to be first immersed in the pure water for a moment, and transferred immediately to the saline solution, and moved to and fro in it to equalise the action of the liquor. Whenever the yellow tint of the iodine is removed, the plate is to be lifted out by the edges, and dipped straightway in the water-trough. The plate, when lifted out of the water-trough, is to be placed immediately on an inclined plane; and without allowing it time to dry, is to be floated over with hot distilled water from the top, so as to carry off all the saline matter. As the quicksilver which traces the images will not bear touching, the silvered plate should be secured by a cover of glass, made tight at the edges by pasting paper round them.

The Daguerreotype process as thus published, although even then an exceedingly beautiful process, was not sufficiently sensitive to enable the operator to obtain portraits from the life. A period of twenty minutes was required, even with the most favourable light, to produce the desired effect. Numerous modifications were speedily introduced, and many of them were patented.

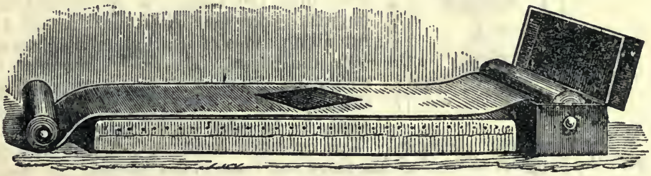
The progressive advance of this branch of the photographic art, though of great interest, cannot be dwelt on in this place. Those who are interested in the inquiry will find the information fully detailed in Hunt's 'Manual of Photography,' last edition, and more recent works. It will be sufficient here to name the more important improvements which have become generally adopted. The first advance of real importance was made by Mr. Towson, of Devonport, who has since that time distinguished himself by the introduction of his system of Great Circle Sailing. Mr. Towson suggested the use of enlarged lenses; and by acting with such Dr. Draper, of New York, was the first to procure a portrait from the life. Still this was a tedious process; but in 1840, Mr. Goddard proposed the use of bromide of iodine, by which infinitely increased sensibility was obtained. From that time the Daguerreotype was generally employed for portraiture, until the facilities of the Collodion process drove it from the field.

The improved manipulation now resolves itself into:—

Carefully polishing the silver plate after some of the methods previously described, and the application finally of the highest polish by the use of a buffer, the best form being that employed by M. Claudet.

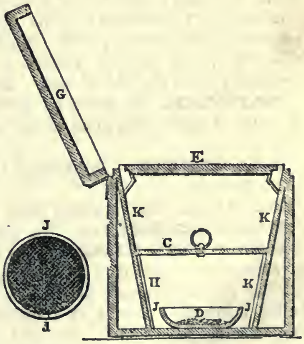
In a box on a roller, to which there is a handle, *fig.* 596, is placed a long piece of drab-coloured velvet, which can be drawn out and extended, by means of a second roller, upon a perfectly flat table. The first foot or two, for example, is drawn out; the plate which has already received its preliminary polishing is placed face downwards, and being pressed close with the fingers, a rapid circular motion is given to it, and in a few minutes it receives its highest lustre. As the velvet becomes blackened by use, it is rolled off, the portion remaining in the box being always perfectly clean and ready for use.

596



The iodising process follows: and for this purpose a box similar to that represented will be found to be very convenient (*fig.* 597). This iodising apparatus consists of a square box, with a closely-fitting square cover G: false sides are placed at an angle with this box; a cup D at the bottom contains the iodine, which is covered with a thin gauze screen J J. C is a cover which confines the iodine when it is not required for the plate; this dividing the box into two parts, H H and K K, the former being always full of iodine vapour. When it is desired to iodise a plate, the cover C is removed, the silver plate is placed at E, and the cover G closed.

597

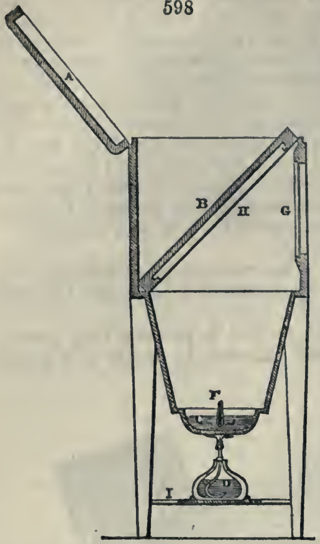


The plate is thus placed in the iodine box until it acquires a fine straw-yellow colour. In another box is placed either bromine or some of the many accelerating fluids. If bromine, or any bromide is employed, the plate should remain until it is of a rose colour. As a general rule, if the yellow colour produced by iodine be pale, the red should be pale also; if deep, the red must incline to violet. The proper time for exposing a plate to any of those chemical substances which are destined to produce the sensitive film must vary with the temperature, and it can only be determined by experience. The sensitive plate is now removed to the camera obscura, for a description of which see PHOTOGRAPHY. It is scarcely necessary to say, that the plate must be preserved in perfect darkness until exposed to the image in the camera.

A few seconds when the plate is properly prepared will be found amply sufficient to produce the best effect.

The impression must be developed in the mercury box (*fig.* 598) in the manner described by Daguerre. This mercurial box consists of a box mounted on legs, having a close-fitting cover A, and an iron bottom in which is placed the mercury C, with a small thermometer F to indicate the proper temperature. G is a piece of glass let into the side of the box through which the Daguerreotype plate H, fixed in the frame B, can be seen. D is a spirit-lamp, and I the platform on which it stands. The subject is eventually fixed by the use of hyposulphite of soda, which removes the bromo-iodide of silver and leaves a picture produced by the contrast between a combination of the silver and mercury, and the surface of the unchanged polished silver.

598



The application of chloride of gold to the finished picture was introduced by M. Fizeau.

Chloride of gold applied to the picture has the effect of fixing and enlivening the tints. A small grate being fixed by a clamp to the edge of a table, the plate is laid upon it with the image uppermost, and overspread evenly with solution of chloride of gold, by means of a fine broad camel-hair brush, without letting any drop over the edge. A spirit-lamp is now brought under the plate, and moved to and fro till a number of small steam bubbles appear upon the image. The spirit-lamp must be immediately withdrawn. The remainder of the chloride solution must be poured back into the phial, to be used on another occasion. It is lastly to be washed and examined. This operation has been repeated three or four times with the happiest effect of giving fixity and force to the picture. It may then be wiped with cotton without injury. The process of colouring these pictures is a purely artificial one, which, while it destroys the beauty of the photograph, does not in any way improve it as a picture.

Daguerreotype Engraving.—Several processes for etching the Daguerreotype plate were introduced with more or less success. Professor Grove produced a few good engravings by the action of voltaic electricity. Berard and Becquerel were also enabled to produce some promising results by a similar process. The following process by M. Claudet was carried out to some extent with every prospect of success:

A mixed acid, consisting of water, nitric acid, nitrate of potash, and common salt, in certain proportions, being poured upon a Daguerreotype picture, attacks the pure silver, forming a chloride of that metal, but does not affect the white parts, which are produced by the mercury of the picture. This action does not last long. Water of ammonia, containing a little chloride of silver in solution, dissolves the rest of that chloride, which is then washed away, leaving the naked metal to be again attacked, especially with the aid of heat. See Collodion; Heliography; Photography.

DAHLINE, the same as Inuline. The fecula obtained from elecampane and from the dahlia, analogous in many respects to starch. It has not been employed in the arts.

DALARNITE. Breithaupt's name for a Swedish variety of mispickel or arsonical pyrites.

DAMAR. See Dammar Gum.

DAMASCEENING. See Damaskeening.

DAMASCUS BLADES are swords or scimitars, presenting upon their surface a variegated appearance of *watering*, as white, silvery, or black veins, in fine lines, or fillets; fibrous, crossed, interlaced, or parallel, &c. They are brought from the East, being fabricated chiefly at Damascus, whence their name. Their excellent quality has become proverbial; for which reason these blades are much sought after by military men, and are high priced. The oriental processes have never been satisfactorily described; but of late years methods have been devised in Europe to imitate the fabric very well.

Clouet and Hachette pointed out the three following processes for producing Damascus blades: 1, that of *parallel fillets*; 2, that by *torsion*; 3, the *mosaic*. The first, which is still pursued by some French cutlers, consists in scooping out with a graving tool the faces of a piece of stuff composed of thin plates of different kinds of steel. These hollows are by a subsequent operation filled up, and brought to a level with the external faces, upon which they subsequently form tress-like figures. 2. The method of torsion, which is more generally employed at present, consists in forming a bundle of rods or slips of steel, which are welded together into a well-wrought bar, twisted several times round its axis. It is repeatedly forged, and twisted alternately; after which it is slit in the line of its axis, and the two halves are welded with their outsides in contact; by which means their faces will exhibit very various configurations. 3. The mosaic method consists in preparing a bar, as by the torsion plan, and cutting this bar into short pieces of nearly equal length, with which a faggot is formed and welded together; taking care to preserve the sections of each piece at the surface of the blade. In this way, all the variety of the design is displayed, corresponding to each fragment of the cut bar.

The blades of Clouet, independently of their excellent quality, their flexibility, and extreme elasticity, have this advantage over the oriental blades, that they exhibit in the very substance of the metal, designs, letters, inscriptions, and, generally speaking, all kinds of figures which had been delineated beforehand.

Notwithstanding these successful results of Clouet, it was pretty clear that the watered designs of the true Damascus scimitar were essentially different. M. Bréant has attempted a solution of this problem. He supposes that the substance of the oriental blades is a cast steel more highly charged with carbon than our European steel, and in which, by means of a cooling suitably conducted, a crystallisation takes place of two distinct combinations of carbon and iron. This separation is, he thinks, the essential condition; for if the melted steel be suddenly cooled in a small crucible or ingot, there is no damascene appearance.

If an excess of carbon be mixed with iron, the whole of the metal will be converted into steel; and the residuary carbon will combine in a new proportion with a portion of the steel so formed. There will be two distinct compounds; namely, pure steel, and carburetted steel or cast iron. These at first being imperfectly mixed, will tend to separate if while still fluid they be left in a state of repose; and form a crystallisation in which the particles of the two compounds will place themselves in the crucible in an order determined by their affinity and density conjoined. If a blade forged out of steel so prepared be immersed in acidulous water, it will display a very distinct Damascus appearance; the portions of pure steel becoming black, and those of carburetted steel remaining white, because the acids with difficulty disengage its carbon. The slower such a compound is cooled, the larger the Damascus veins will be. Tavernier relates that the steel crucible ingots, like those of wootz, for making the true oriental Damascus, come from Golconda, that they are the size of a halfpenny roll, and when cut in two, form two swords.

Steel combined with manganese displays the Damascus appearance very strongly.

A mixture of 100 parts of soft iron and 2 of lamp-black melts as readily as ordinary steel. Several of the best blades which M. Bréant presented to the Société d'Encouragement are the product of this combination. This is an easy way of making cast steel without previous cementation of the iron. 100 parts of filings of very grey cast iron, and 100 parts of like filings previously oxidised, produced, by their fusion together, a beautiful damascene steel, fit for forging into white arms, sabres, swords, &c. This compound is remarkable for its elasticity, an essential quality, not possessed by the old Indian steel. The greater the proportion of the oxidised cast iron the tougher is the steel. Care should be taken to stir the materials during their fusion, before they are allowed to cool; otherwise they will not afford a homogeneous damask. If the steel contains much carbon it is difficult to forge, and cannot be drawn out except within a narrow range of temperature. When heated to a red-white it crumbles under the hammer; at a cherry-red it becomes hard and brittle; and as it progressively cools it becomes still more unmalleable. It resembles completely Indian steel, which European blacksmiths cannot forge, because they are ignorant of the suitable temperature for working it. M. Bréant, by studying this point, succeeded in forging fine blades.

Experience has proved that the orbicular veins, called by the workmen *knots* or *thorns* (*ronces*), which are seen upon the finest Eastern scimitars, are the result of the manner of forging them, as well as the method of twisting the Damascus bars. If these be drawn in length, the veins will be longitudinal; if they be spread equally in all directions, the stuff will have a crystalline aspect; if they be made wavy in the two directions, undulated veins will be produced like those in the oriental Damascus.

The characteristics ascribed to the real Damascus blades are extraordinary keenness of edge, great flexibility of substance, a singular grain of fleckiness always observable on the surface, and *a peculiar musky odour* given out by any friction of the blade, either by bending or otherwise. The author of 'Manufactures in Metals' remarks:

'A gentleman who purchased one of these blades in the East Indies for a thousand piastres, remarked to the writer of this volume that, although the instrument was very flexible, and bore a very keen edge, it could not with safety be bent to more than 45° from the straight shape, and it was not nearly so sharp as a razor, yet, wielded by a skilful hand it would cut through a thick roll of sail-cloth without any apparent difficulty; a feat which could not be performed with an ordinary sword, nor, it should be observed, by the sabre itself in an ordinary hand, though the swordsman who tried it could, it appears, do nearly the same thing with a good European blade.'

Emerson, in his letters from the Ægean, says: 'I have seen some blades (scimitars) which were valued at 200 or 300 dollars; many are said to be worth triple that sum, and all retain the name of *Damascus*, though it is by no means likely that they have been manufactured there. The twisting and interwisting of the fibres of the metal are considered as the tests of excellence, but I have never seen any possessed of the perfume said to be incorporated with the steel in the real Damascus blade.'

Steel helmets and cuirasses were formed of cast and damascened steel, intermixed with pure iron, a mixture supposed to combine toughness and hardness in the greatest possible degree.

The production and use of damask steel received much attention from the late General Anossoff, of the Corps of Engineers of the Imperial Russian army, and Master of the Fabric of Arms at Zlatoust, in Siberia. His researches and successful practice have become matters of history.

At different periods these works at Zlatoust have been visited, by two English travellers, Major Abbott of the Bengal Artillery, and Mr. Atkinson, who have recorded the results of observation, experiment, and conversational intercourse, and they state severally their conviction that the damask steel produced by Anossoff rivalled in beauty and excellence any works they had ever seen in other lands. They accord to Anossoff the honour of being the reviver of the art of making damask steel in Europe, while they declare the Russian natural damask steel is not approached by the fabrics of any Eastern nation now existing. These works were also visited by the late Sir R. I. Murchison.

The Siberian swords and daggers were compared and tried with the choicest specimens, and found equal to the blades of Damascus and the sabres of Khorassan; and while these valued articles might have been selected from numbers manufactured by chances of skill and material, Anossoff united chemical analyses of ores and steel, and records of observations on progressive stages, to give a true history of the means to explain and insure success.

Major Abbott gives the following description of the damask as produced at Zlatoust. He defines it to be a modification of cast steel, by which it is impressed with a peculiar character in its crystallisation, which character betrays itself when the corrosion of acids, by acting more violently between the interstices of the structure than elsewhere, traces out the arrangement of the crystals. This property is communicated to the damask of Zlatoust by a process tending to perfect the quality of the steel, and to impress upon the cast steel the elastic properties of a softer material. The general fault of European blades is, that being forged of shear steel for the sake of elasticity, they are scarcely susceptible of the keen edge which cast steel will assume. The genius of Anossoff has triumphed over this objection, not by hardening the soft steel, but by giving elasticity to the hard; the result has been the production of weapons combining, in the very highest degree, elasticity with keenness of edge. We believe that the manufacture of damask steel is no longer carried on at Zlatoust.

Colonel Anossoff has published, in Russia, a treatise on the art of damasking steel. The following remarks are extracted and condensed from it:—

'In Russia, we understand, by *damask*, a metal harder, and supplying a material for arms of a keener edge, than ordinary steel. All the researches of chemists have, until now, failed in discovering any essential difference between the damask and ordinary steel, which, nevertheless, proves only that the analysis has been imperfect, and that it is only want of means that prevents success. Although the chemists of the present day presume that the natural damask is the effect of crystallisation, produced by retarded cooling of the heated metal, yet, not having been able to produce a damask by this means equal to the ancient work of Asia, they cannot establish this ground. If crystallisation generally is but the result of the structure of bodies under certain physical conditions, the question results, Why in the damask is it not the result of a similar cause; and since common steel acquires no visible damask by gradual refrigeration, is not this a convincing proof that the composition of damask differs from that of ordinary steel? Thus, on the one hand, the imperfection of our chemical knowledge, and on the other, the difficulty of fabricating the damask, leave Europeans still in uncertainty as to its merits.

'All steel which exhibits a surface figured with dark lines is called damask. In some of the various kinds of steel these figures appear after burnishing, whilst in others dilute acid is necessary to bring them out.

"The mere appearance of this damascene does not confer upon the steel the title of damask. On ordinary steel, similar figures may be brought out by subjecting it to corrosion, after having designed on it the figures required. This is called false damask.'

A second kind of damask, called artificial damask, is peculiar to the metal itself, so that however often it is repolished the same figures will reappear whenever it is subject to corrosion. It is composed of several sorts of steel, interlaced with iron. The beauty of such damask consists partly in the quantity of the several materials, and partly in the skill with which they are worked together. These artificial damasks are chiefly wrought in Asia, viz. in India, Turkey, and Georgia, whilst those of Europe have as yet obtained no great reputation, because the European workmen are more intent on producing elegant figures on the steel than on improving the steel itself.

The Orientals judge of the goodness of the damask in the following manner:—The first and most essential sign of the beauty of the damask or water is its being thick, defined, and fantastic. They further give us three rules whereby the quality of the damask may be judged:

1. By the form of the damask, which may be either in points, right lines, or curved, the right lines being the lowest quality, and advancing by stages into curves and points. forming, in the best damask, figures resembling grapes or network.
2. By the line of its ground: the deeper the tint the more perfect the metal.
3. By the play of colour on the metal in an oblique light. Some show no variation of tint, whilst others take on a crimson or golden hue. The more perceptible the play of colour the finer the quality of the damask.

The qualifications claimed for the most perfect damask are extreme malleability and ductility, the hardest possible substance after tempering, the keenest and firmest edge, and elasticity when properly tempered.

DAMASCUS GUN-BARRELS. See GUN-BARREL.

DAMASK is a variegated textile fabric, richly ornamented with figures of flowers, fruits, landscapes, animals, &c., woven in the loom, and is by far the most rich, elegant, and expensive species of ornamental weaving, tapestry alone excepted. The name is said to be derived from Damascus, where it was anciently made.

Damask belongs to that species of texture which is distinguished by practical men by the name of tweeling, of which it is the richest pattern. The tweel of damask is usually half that of full *satin*, and consequently consists of eight leaves moved either in regular succession or by regular intervals, eight leaves being the smallest number which will admit of alternate tweeling at equal intervals.

The generic difference of tweeling, when compared with common cloth, consists in the intersections, although uniform and equidistant, being at determinate intervals, and not between the alternate threads. Hence we have the specimens of tweeled cloth, where the intersections take place at the third, fourth, fifth, sixth, seventh, eighth, or sixteenth interval only. The threads thus deflecting only from a straight line at intervals, preserve more of their original direction, and a much greater quality of materials can be combined in an equal space, than in the alternate intersection, where the tortuous deflection, at every interval, keeps them more asunder. On this principle tweeled cloths of three and four leaves are woven with facility of combination alone. The coarser species of ornamental cloths, known by the names of dornock and diaper, usually intersect at the fifth, or half satin interval. The sixth and seventh are rarely used, and the intersection at the eighth is distinguished by the name of satin in common, and of damask in ornamental tweeling. It will further be very obvious, that where the warp and woof cross only at every eighth interval, the two sides of the cloth will present a diversity of appearance; for on one side the longitudinal or warp threads will run parallel from one end of a web to the other, and, on the other, the threads of woof will run also parallel, but in a transverse direction across the cloth, or at right angles to the former. The points of intersection being only at every eighth interval, appear only like points; and in regular tweeling these form the appearance of diagonal lines, inclined at an angle of 45° (or nearly so) to each of the former.

The appearance, therefore, of a piece of cotton tweeled cloth is very similar to that of two thin boards glued together, with the grain of the upper piece at right angles to that of the under one. That of an ornamental piece of damask may, in the same manner, be very properly assimilated to a piece of veneering, where all the wood is of the same substance and colour, and where the figures assume a diversity of appearance from the ground, merely by the grain of the one being disposed perpendicularly to that of the other.

From this statement of the principle, it results that the most unlimited variety of figures will be produced by constructing a loom by which every individual thread of warp may be placed either above or below the woof at every intersection; and to effect this, in boundless variety, is the object of the Jacquard mounting. See LOOM, JACQUARD.

The chief seat of this manufacture is the town and neighbourhood of Dunfermline, in Fifeshire, and Lisburn and Ardoyne, near Belfast, where it is considered as the staple, having proved a very profitable branch of traffic to the manufacturer, and given employment to many industrious people.

The material used there is chiefly linen, but many have been recently woven of cotton, since the introduction of that article into the manufacture of cloth has become so prevalent. The cotton damasks are considerably cheaper than those of linen, but are not considered either so elegant or durable. The cotton, also, unless frequently bleached, does not preserve the purity of the white colour nearly so well as the linen.

DAMASKEENING. The art of ornamenting iron, steel, &c., by making incisions upon its surface, and filling them up with gold or silver wire. It is chiefly used in enchasing sword-blades, guards, and grips, locks of pistols, &c.

Its name shows the place of its origin, or, at least, the place where it has been practised in the greatest perfection, viz., the city of Damascus, in Syria; though M. Félibien attributes the perfection of the art to his countryman, Cursinet, who wrought under the reign of Henry IV.

Damaskeening is partly mosaic work, partly engraving, and partly carving. As mosaic work, it consists of pieces inlaid; as engraving the metal is indented, or cut in *intaglio*; and as carving, gold and silver are wrought into it in *rilievo*.

There are two ways of damaskeening: in the first, which is the most beautiful, the artists cut into the metal with a graver, and other tools proper for engraving upon steel, and afterwards fill up the incisions, or notches, with a pretty thick silver or gold wire. In the other, which is only superficial, they content themselves to make hatches, or strokes across the iron, &c., with a cutting knife, such as is used in making small files. As to the first, it is necessary for the gravings or incisions to be made in dove-tail form, that the gold or silver wire, which is thrust forcibly into them, may adhere the more strongly. As to the second, which is the more usual, the method is this: having heated the steel till it changes to a violet, or blue colour, they hatch it over and across with a knife, then draw the ensign or ornament intended upon this hatching with a fine brass point or bodkin. This done they take fine gold wire, and conducting or chasing it according to the figures already designed, they sink it carefully into the hatches of the metal with a copper tool.

An inferior description of damaskeen work has been introduced since the discovery of the electrotype processes. The pattern has been etched on the steel, and then gold or silver deposited into the etched lines.

DAMASSIN. A kind of damask, with gold and silver flowers woven in the warp and woof, or occasionally with silk organzine.

DAMBONITE. A crystallisable saccharine substance obtained by M. Aimé Girard from a peculiar kind of caoutchouc from the Gaboon on the West coast of Africa. The botanical source of this caoutchouc is not known. Dambonite, when isolated, crystallises in white needles, which contain $C^8H^8O^6$ ($\mathbf{C^4H^8O^3}$). It is readily soluble in water and in ordinary alcohol; it melts at 374° F., (190° C.) and sublimes between 392° and 410° F., (200° and 210° C.). Dambonite is decomposed by hydriodic or by hydrochloric acid, yielding iodide or chloride of methyl, together with a sugar isomeric with glucose, containing $C^6H^6O^6$ ($\mathbf{C^3H^6O^3}$). This sugar is called *Dambose*.

DAMMAR GUM or **DAMMARA RESIN.** A pale yellow resin, somewhat resembling copal, and used like it in the manufacture of varnishes. Dammara resin is the produce of the *Dammara australis*, or Kawrie-pine of New Zealand. Large masses of the gum-resin are found in the ground at the base of the pines. Another kind of dammar is obtained from the *Dammara alba* of India, where it is usually called *Dammar Pute*, or *Cat's-eye resin*. A substance called Dammar is used in the East Indies for caulking ships. It is composed of this resin, mixed with the powdered bark of the bamboo, and a little chalk. Some Indian dammar is said to come from the *D. orientalis*,, and the Indian *Piney Dammar* is yielded by the *Vaterica Indica*.

Dammar is largely employed in the preparation of certain varnishes. 'Damar is easily dissolved in oil of turpentine, and when carefully selected is almost colourless; it makes a softer varnish than mastic; the two combined, however, form an almost colourless varnish, moderately hard and flexible, and well suited for maps and similar purposes.'—*Holtzapffel.*

Dammar varnish has been lately recommended for mounting microscopic objects in the stead of Canada balsam. The following recipe for its preparation has been given by Dr. Klein: Dissolve half an ounce of gum-dammar, in powder, in one or two ounces of turpentine, and dissolve half an ounce of gum-mastic in two ounces of chloroform;

the two solutions are then separately filtered, and mixed together. The varnish thus obtained is clear, and if exposed in a thin layer on a plate of glass it rapidly solidifies.

DAMMAR PITCH. A balsamic resin employed in India for incense, and obtained from the Sál tree, the *Shea robusta*.

DAMOURITE. A hydrated potash-mica, named after the French chemist, M. Damour.

DAMP, *in mining*, a term applied to dangerous exhalations, or rather gases,—so called from the German *Dampf*, vapour—escaping from the mineral formations, or accumulating in the workings.

Fire-Damp, which occurs in coal-mines, is *carburetted hydrogen gas*.

Choke-Damp, *After-Damp*, and *Black-Damp*, may be regarded as carbonic acid. See MINES, VENTILATION OF.

DANAITE. A cobaltiferous mispickel. It has been proposed to unite under this name all varieties of mispickel which contain cobalt. The name is complimentary to Mr. J. F. Dana.

DANALITE. A silicate of the protoxides of iron, manganese, and beryllium, with sulphide of zinc. It occurs in octahedral crystals, in granite, at Rockport, and near Gloucester, in the State of Massachusetts. The mineral takes its name from the American mineralogist, Prof. J. D. Dana, of Yale College.

DANBURITE. A silico-borate of lime, containing, when pure, silica, 48·9; boric acid, 28·4; and lime, 22·7. It is found at Danbury, Connecticut, U.S.

DANDELION. The *Taraxacum Dens Leonis*, a common British weed, belonging to the *Compositæ*. It has a milky juice, which contains a bitter principle called *Taraxacine*. Preparations of dandelion are employed in medicine as diuretics and alteratives; and dandelion root, when roasted, is sometimes used like chicory, as an addition to coffee.

DANK or **DAWK.** (*A mining term.*) Bands and beds of tough sandy clay, more or less compact and homogeneous. It is probably derived from *dough*.

DANNEMORITE. An iron- and manganese-hornblende, from the iron-mines of Dannemora, in Sweden.

DAPHNE CANNABINA. The bark of this shrub, a native of Nepaul, has been used for paper-making.

DAPHNINE. The bitter principle of the *Daphne alpina*.

DAPICHO. A spongy kind of caoutchouc, which exudes from the roots of the *Siphonia elastica*. It is used in South America for making stoppers. See CAOUTCHOUC.

DARWINITE. A mineral consisting, according to David Forbes, of copper, 88·07; silver, 0·24; and arsenic, 11·69. It is found at Potrero Grande, south-east of Copiapo, in Northern Chili.

DASH WHEELS. These are revolving wheels having dash-boards, which are much used in the washing-processes necessary in calico-printing. See BLEACHING.

DATES. (*Tamr*, a date, Arabic.) The fruit of the *Date Palm*. The date tree, *Phœnix dactylifera*, grows to the height of sixty feet. The dates are pulled before they are ripe, and are then dried in the sun. These form one of the chief parts of the usual food of the Arabs, while the seeds softened and ground down form the nourishment for their camels. The leaves are employed for making mats. The threads of the web-like integument at the basis of the leaves are twisted into ropes, while the stems, when old, are used in the construction of houses. Tadmor, in the Desert, built by Solomon, is supposed to derive its name from those trees, which grew abundantly around it.

DATHOLITE, or **DATOLITE.** A boro-silicate of lime, containing silica, 37·30; boric acid, 21·32; lime, 35·67; water, 5·71. It is found in fine glassy crystals, of complex form, at Bergen Hill, New Jersey.

DATISCA, YELLOW. A yellow dye obtained by treating the aqueous decoction of the leaves of the *Datisca cannabina*, a bastard hemp, growing in the Levant and in India, with salts of lead. This yellow is obtained in a translucent mass, soluble in water. Stuffs mordanted with alum are dyed a permanent yellow.

DATURINE. A poisonous alkaloïd found in the Thorn-apple (*Datura Stramonium*). Daturine closely resembles Atropine and Hyoscyamine.

DAUCUS CAROTA. The common carrot.

DAVIDSONITE. A greenish-yellow beryl, from Rubislaw, near Aberdeen, in Scotland.

DAVY LAMP. See SAFETY LAMP.

DAVYNE. A Vesuvian mineral, consisting of silicate of alumina, soda, potash, and lime. It is regarded as a variety of nepheline.

DEADS. Waste on or in a mine. Rubbish. Mine-stuff too poor in ore to pay for working.

DEAD DIPPING. The process of producing an agreeable pale yellow dead surface on ornamental brass work is so called. The brass work, after the final stamping with its adhering black scale from the annealing oven, is placed in dilute nitric acid, and left in it until the scale may be easily detached; it is then taken out and washed with water. Again it is plunged in dilute acid somewhat stronger than before, until the surface is covered with minute bubbles, after which it is washed in a solution of argol, and dried in hot sawdust. Dead dipping is also used in the manufacture of the ornamental parts of stoves, especially such as are intended for drawing-rooms. The brass portions of these are treated in the manner described, but the iron or steel after being polished, or ornamented by engraving, is treated with dilute sulphuric acid.

DEAD OIL. The oil which is obtained from the fractional distillation of coal-tar, after the light oil or naphtha has passed over. See NAPHTHA.

DEAD WELLS. Wells which are made to carry off refuse waters. See ARTESIAN WELLS, *Negative.*

DEADLY NIGHTSHADE. The *Atropa belladonna.* It owes its poisonous character to the alkaloïd called *atropine.* See ATROPINE; BELLADONNA.

DEAL WOOD. See PINES.

DEBRIS. A term signifying wreck or waste. It has been adopted from the French to express any accumulation of loose materials arising from the waste of rock. It is also applied to drifted accumulations of all kinds.

DECANTATION. (Eng. and Fr.; *Abgiessen,* Ger.) The act of pouring off the clear liquor from any sediment or deposit. It is much employed in the chemical arts, and is frequently effected by means of a siphon, there being less risk of disturbing the precipitate.

DECARBONISATION. Articles made of cast iron, and, consequently brittle, are decarbonised and rendered tough by being exposed to heat in contact with some peroxide of iron, as the finely-divided hematite ore. Most of the iron articles used in saddlery or harness making are now manufactured by this process.

DECHENITE. A vanadate of lead, and perhaps also of zinc. It occurs in Rhenish Bavaria, and is named after the German geologist Von Dechen.

DECIMAL. A tenth part. A *Decimal Fraction* is one whose denominator is 10 or some power of 10. It is not usual, however, to express this denominator, but a period, called a *decimal-point,* is placed between the unit and the first fractional number. Thus, 1·5 is the same as $1+\frac{5}{10}$, or one and five-tenths; in like manner 1·05 means one and five-hundredths; 1·842 signifies one unit and eight-tenths, four-hundredths, and two-thousandths of the unit; and so on.

DECIMAL COINAGE is a proposed system in which the unit is divided and subdivided decimally. The coinage of the English florin was a step towards the decimal system; the value of the florin, or two-shilling piece, being one-tenth of the sovereign. The metrical system of weights and measures is based on the decimal system; the multiplication and division of the unit always proceeding by some power of 10. See METRICAL SYSTEM.

DECKLE. A name given by the paper-maker to a thin frame of wood fitting on the shallow mould in which the paper-pulp is placed.

DECOCTION. The process of boiling a liquid with some organic body, or the liquid compound resulting from the process of boiling.

DECOMPOSITION. (Eng. and Fr.; *Zersetzung,* Ger.) The separation of bodies from each other. The methods employed are almost innumerable, and usually depend on the special reactions of the matters under examination. We shall consider a few of the most striking cases in both the grand divisions of the science, viz. inorganic and organic chemistry. In each instance we shall, for the sake of convenience, subdivide into the three classes of acids, alkalis, and neutral bodies. Previous, however, to this, we must glance at some of the reactions of which chemists avail themselves in separating the elements. The decomposition of ordinary metallic salts, with the view of making a qualitative analysis of a more or less complex mixture, is a problem, in general, of extreme simplicity, and directions for the purpose are to be found in all the numerous works on qualitative analysis. The principle on which the modern methods of qualitative analysis are founded is the separation of the metals in the first place into large groups by certain reagents, and then, by means of others, to subdivide into smaller groups, in which the individual metals can be determined by special tests. For the sake of simplicity, we shall only consider the more commonly occurring metals. The general reagents, by which the first subdivision is effected. are hydrochloric acid, sulphuretted hydrogen, sulphide of ammonium, carbonate of ammonia mixed with chloride of ammonium, and finally phosphate of soda. The substance in solution is treated with hydrochloric acid, by which mercury, silver, and lead are removed. The mercury will only be perfectly removed if it exists entirely in the state of a subsalt. Lead is only partially precipitated, and will be subsequently found in the next group. The precipitate by hydrochloric acid is to be boiled with water, which will remove the chloride of lead, and leave the chlorides of mercury and silver. The latter may be separated by means of ammonia, which will dissolve the chloride of silver and convert the mercury into a black powder, in which the metal can be detected by special tests. The fluid filtered from the precipitate by hydrochloric acid is to have a stream of hydrosulphuric acid gas (sulphuretted hydrogen) passed through it for a considerable time, or until no more precipitation occurs. By this means antimony, arsenic, tin, cadmium, gold, mercury, silver, lead, bismuth, and copper are thrown down, and must be separated from each other by special processes. The filtrate from the precipitate by hydrosulphuric acid is to have ammonia added in slight excess, and then a solution of sulphide of ammonium as long as any precipitation takes place. By this means nickel, cobalt, iron, manganese, zinc, alumina, and chromium, are thrown down; also baryta, strontia, and lime, if they happen to be in combination with phosphoric, oxalic, or boracic acids, or if united to fluorine. From the filtrate, carbonate of ammonia mixed with chloride of ammonium, precipitates baryta, strontia, and lime. The filtrate from the last precipitate can only contain magnesia, or the alkalis. The above brief description of the mode of dividing the above metals into groups will be sufficient to give an idea of the processes employed for decomposing complex mixtures into simple ones.

Inorganic acids are usually removed from metals by converting the latter into an insoluble compound, while the acid remains in solution either in the free state or combined with a body of such a nature as not to mask the reactions of the acid with reagents. This is often done in the laboratory by boiling the metallic salt with an alkaline carbonate. The metals are, consequently, either converted into oxides or carbonates insoluble in water, while the acid unites with the alkali to form a soluble salt capable of being obtained by filtration in such a condition as to permit the nature of the acid to be made known by means of appropriate tests. It is usually necessary to neutralise the solution carefully before testing for the acid.

It is seldom necessary in researches to reduce inorganic alkalis to their elements, their constitution being usually ascertained by converting their constituents into new forms capable of being weighed or measured with accuracy. If, for instance, it was necessary to ascertain the constitution of sulphuric acid, it would be sufficient to determine the quantity of baryta contained in the sulphate. On the other hand, acids susceptible of assuming, when pure, the gaseous condition may have their constitution determined by decomposing a known volume with a substance capable of combining with one ingredient and liberating the other in the gaseous state. Thus hydrosulphuric acid may be analysed by heating it with potassium, which will remove the sulphur and liberate the hydrogen.

In decomposing inorganic alkalis with the view of separating the metals contained in them, we usually have to avail ourselves of very powerful affinities. This arises from the fact, that the substances in question are, generally, produced by the union of a metal with oxygen, the metal having so strong a tendency to combine with that element, that mere exposure to the air is sufficient to determine their union into a compound of great stability. In order, therefore, to decompose the alkalis of this class, it is necessary to find some substance having a powerful tendency to combine with oxygen under certain conditions. Now it has been found that carbon, if raised to an exceedingly high temperature, and employed in great excess, is capable of removing the oxygen, even from such bodies as potassium and sodium, the affinity of which for oxygen is very great.

Inorganic neutral bodies are generally decomposed either by the ordinary processes of analysis, or, where the neutrality arises from the substance under examination being a compound of an acid and a base, by separating the two by treatment with a reagent capable of combining with one to the exclusion of the other. This is a process frequently available in quantitative analysis. As an illustration, we may take the decomposition of the carbonates by a mineral acid in an apparatus which permits the carbonic acid set free to be accurately estimated by weighing. See CARBONATES.

Another instance of the decomposition of a neutral body, by treating it with a substance capable of combining with one of the constituents and separating the other in a free state, is the decomposition of sulphate of potash by baryta. If a solution of the salt be boiled with excess of solution of baryta, sulphate of baryta is produced, and caustic potash set free. The excess of baryta is removed by boiling in the air until the whole of the latter base is converted into the insoluble carbonate. A precisely analogous process is the ordinary mode of preparing caustic potash by boiling its carbonate with quicklime.

Neutral bodies are frequently, however, so constituted, that the neutrality does not arise from the circumstance of an acid being saturated with a base, but from the energies of two elements being, to some extent, satisfied by the fact of their being in combination. Thus, water is a neutral substance, nevertheless it may be decomposed by a variety of processes, several of which are susceptible of quantitative precision. In the first place, it may be decomposed by passing steam over a metal capable of uniting with its oxygen with liberation of the hydrogen. It may also be electrolysed, and the two gases separately obtained.

Organic or inorganic neutral salts may, at times, be very completely and simply decomposed by means of the battery. Not only are the various processes in electro-metallurgy founded on this principle, but it has even been practically applied to the quantitative estimation of the metals in ores. The electrolysis of the neutral salts of the great series of organic acids of the general formula $C^nH^nO^4$ has thrown great light on some previously obscure points in the radical theory.

The decompositions undergone by organic substances in contact with reagents are so manifold, that the limits of this work preclude the possibility of doing more than glancing at a few of the most general and interesting. Perhaps of all the modes of inducing the breaking up of more complex into simpler substances, the application of heat is the most remarkable for its power and the varied and opposite character of the substances produced. It has been shown that, as a decomposing agent, heat possesses no special function. From complex organic molecules all classes of substances are formed. Individual substances belonging to every chemical type are, therefore, found among products of destructive distillation. Acids, alkalis, and neutral bodies of every kind are formed, and some of the most interesting and beautiful bodies known to chemists are found in the uninviting-looking tar of coal. Let us illustrate this by a glance at a few of the coal-tar products. Among the acids are the oxyphenic, carbolic, and cresylic. The alkaloïds represented are methylamine, ethylamine, propylamine, butylamine, amylamine, pyridine, picoline, lutidine, collidine, parvoline, chinoline, lepidine, cryptidine and aniline. Among hydrocarbons, benzole, toluole, xylole, cumole, cymole, propyle, butyle, amyle, caproyle, caproylene, œnanthylene, naphthaline, anthracene, chrysene, pyrene, acetylene, &c. This list, probably, does not include one half of the substances produced from coal by the decomposing and recomposing influence of heat.

Mineral acids exercise a powerful decomposing influence on organic substances. Of these the nitric and sulphuric are the most commonly used. Nitric acid is especially active, owing to its twofold action. By virtue of its oxidising tendencies, it breaks up great numbers of substances into more simple and less carburetted derivatives, and the hyponitric acid produced by the removal of one of the atoms of the oxygen of the acid frequently enters into the resulting compound, a substitution-product being the final result. In the latter bodies produced in this manner the hyponitric acid (NO^4) generally replaces hydrogen, the original type remaining unaltered. The production of oxalic acid from sugar; succinic, lipic, adipic, pimelic, suberic, &c., acids from oily and fatty matters by the action of nitric acid, are examples of its oxidising power; while the formation of nitrobenzole, and bodies of more or less analogous character, present instances of the replacement of hydrogen by hyponitric acid.

Sulphuric acid owes its decomposing power to its extreme tendency to combine with water. Many of the less stable organic bodies are, by this means, absolutely broken up, so that the resulting products are of a character too indefinite to allow of the changes being expressed by an equation which shall render a true account of all the substances directly or indirectly formed. On the other hand, the action may be so controlled by the careful regulation of the temperature and strength of the acid that products may be eliminated which are themselves totally broken up and destroyed by an acid of greater strength. The production of grape-sugar by the action of sulphuric acid on starch, or lignine, may be taken as an example. It not unfrequently happens, that the sulphuric acid unites with the substance acted on to form a conjugated compound. Benzole, and many other hydrocarbons, as well as oxidised bodies, behave in this manner with concentrated sulphuric acid.

Chlorine and the other halogens are powerful decomposing agents, acting chiefly by virtue of their affinity for hydrogen. The principal effects produced by them are oxidation and substitution. The oxidising action of the halogens arises from the decomposition of water; the hydrogen combining with the chlorine, &c., to form an hydracid, and the free oxygen uniting with the other substances present.

The above sketch will sufficiently indicate some of the most usual methods by which the decomposition of organic and inorganic bodies is effected; but hundreds of other decomposing agencies are at the call of the chemist, when any phenomena involving the disruptions of compounds are to be investigated.—C. G. W.

DECREPITATION (Eng. and Fr.; *Verknistern*, Ger.) is the crackling noise, attended with the flying asunder of their parts, made by several minerals and salts when heated. Sulphate of baryta, chloride of sodium, calcareous spar, nitrate of baryta, and several other bodies which contain no water, decrepitate most violently, separating at the natural joints of their crystalline structure.

DEFECATION. (Eng. and Fr.; *Klaren*, Ger.) The freeing from dregs or impurities.

DEFLAGRATION. (Eng. and Fr.; *Verpuffung*, Ger.) A rapid combustion, attended with much evolution of flame and vapour. When metals are burnt by electricity, they are said to undergo deflagration.

DEFLAGRATOR. A galvanic instrument for producing a rapid and powerful combustion, introduced by Professor Hare.

DE LAINES. Properly, fine worsted fabrics. They are indeed figured muslins, which should always be made of wool, but they are frequently made of mixed material.

DELAWARITE. A cleavable potash felspar, from Delaware County, Pennsylvania.

DELESSITE. A ferruginous chlorite, usually occurring as a dark greenish coating in the interior of amygdaloidal cavities in trap-rocks.

DELF or **DELFT.** A coarse species of pottery originally manufactured at Delft in Holland, covered with a white stanniferous enamel or glaze. See POTTERY.

DELIQUESCENT. (*Zerfliessen*, Ger.) Any solid which absorbs moisture from the air spontaneously and becomes soft or liquid, such as potash, and chloride of calcium is said to be deliquescent.

DELPHINIA. The poisonous principle of the Stavesacre (*Delphinium Staphysagria*).

DELVAUXITE. A variety of Dufrenite, or hydrous phosphate of iron.

DEMIDOFFITE or **DEMIDOVITE.** A mineral mixed with malachite, found at Nischne-Tagilsk in Russia. It contains oxide of copper 33·14, silica 31·53, magnesia 3,15, phosphoric acid 10·22, and water.

DENDRITES. Arborescent or shrub-like markings on rocks, commonly produced by oxide of manganese; thus, the ramified patterns in Mocha-stones are dendrites.—*Dendritic*, a term applied to the branching forms of certain minerals, such as native copper and native silver.

DEMY. Paper of a particular size is so called. Drawing demy is 15 inches by 20, printing demy is 17¾ inches by 22½.

DENMARK SATIN. A stout worsted stuff used for ladies' shoes.

DENSITY, the property of compactness in bodies, the closeness of their component particles. The specific gravity of bodies is taken as a measure of their densities. See SPECIFIC GRAVITY.

DENTIFRICE. Tooth-powder for the purpose of cleansing the teeth. A variety of preparations are recommended. The object being to remove acid incrustations from the teeth, and to cleanse them from feculent matter, simple preparations of chalk or magnesia are undoubtedly to be preferred. Occasionally charcoal may be used with advantage, but the particles are usually too hard, and consequently they tend to abrade the fine enamel-surface of the teeth.

DENUDATION. (*Denudo*, to lay bare.) The carrying away by the action of running water or other agent, of the superficial solid materials of the land, by which the character of the surface is altered, and the lower rocks often laid bare.

DEODORISERS. Bodies which have the power of depriving fetid and offensive effluvia of their odours. There appears to exist a general idea that these substances are, all of them, equally disinfectants. No greater mistake can be made than to suppose that because a preparation has the power of removing a disagreeable smell, that therefore it has removed all the elements of infection or disease. See DISINFECTANT.

To disguise unpleasant odours, fumigation is employed, many of the fragrant gums are burnt and fumigating pastiles employed. It is also a common practice to burn lavender and brown paper, but these merely overpower or disguise the smell; they do not in any way act upon the noxious effluvia. See PASTILES; FUMIGATION.

DEOXIDATION. The act of removing oxygen; thus, when oxide of iron is heated with carbonaceous matter the oxide is deoxidised, and metallic iron reduced.

DEPHLEGMATION. The process by which liquids are deprived of their watery particles. It is applied chiefly to spirituous liquors, but is now obsolete, as involving the alchemistical notion of a peculiar principle called *phlegm*.

DEPHLOGISTICATED, deprived of *phlogiston*, which was for a long period after the time of Stähl regarded as the principle of *levity* and of *combustion*. It may be regarded as synonymous with oxygenated. 'Others believe that *Earth* and *Phlogiston* are those principles which are the constituent parts of all corporeal substances.'

'It appears from all those experiments, that in each of them *phlogiston*, the simple inflammable principle, is present.' 'Thus much I see from the above-mentioned experiments; the air is composed of two different fluids, the one of which attracts not the *phlogiston*, and the other has the quality of attracting it.'—Scheele: *Experiments on Air and Fire.*

DEPILATORIES. Preparations for removing hair from the skin. These are said to have been much used by the ancients. In modern times they have been used as cosmetics to remove superfluous hair from the face. Lime and the tersulphuret of arsenic (orpiment) are the constituents of most of the ancient and modern depilatories; but the use of orpiment is dangerous, especially if there is any abrasion of the skin.

The best and safest depilatory is said, in Gray's 'Supplement to the Pharmacopœia,' edited by Redwood, to be a strong solution of sulphuret (sulphide) of barium made into a paste with powdered starch. It should be applied to the hair immediately after it is mixed, and allowed to remain there for five or ten minutes.

DEPOSITION OF METALS. See Electro-Metallurgy.

DERBYSHIRE SPAR. Fluor-spar, or fluoride of calcium. See Fluor-Spar.

DERMATIN. A variety of serpentine found in reniform masses, in thin coatings on the serpentine of Waldheim in Saxony.

DERRICK CRANE. The term Derrick is applied to a temporary crane, consisting of a spar supported by stays and guys, carrying a purchase for loading or unloading goods on shipboard. The Derrick crane is somewhat similar in its plan, the projecting iron beam, or derrick, of which, can be raised or lowered to any desired angle.

DESCLOIZITE. A South American vanadate of lead, named after the French crystallographer Des Cloiseaux.

DESICCATION. The act of drying.

Davison and Symington patented a process for drying or seasoning timber, by currents of heated air. Even after wood has been dried in the ordinary manner, it contains much moisture, which it is still necessary to remove. The patentees have given some curious results of this desiccating process:—

Temperature of air 214°.

Violin wood	Original weight	Weight after seasoning	Moisture removed
6 pieces small and thin . . .	3·38	2·87	8· per cent.
2 ,, larger	10·56	9·5	10·1 do.
2 ,, larger	25·25	22·93	9·25 do.

	Original weight	100° after 6 hours	120° after 10 hours	150° after 20 hours	180° after 30 hours	230° after 38 hours	Per cent.
Oak	1·84	1·76	1·71	1·59	1·56	1·51	18·1
Red pine . . .	1·5	1·4	1·38	1·33	1·28	1·25	16·6
Birch	1·2	1·09	1·05	1·01	·99	·97	19·2
Mahogany . . .	1·21	1·14	1·09	1·03	1·0	·98	19·2

White wood, lime tree.

	Original weight	170° after 6 hours	Part 140°, and part 212° after 15 hours	After 24 hours	After 34 hours	After 84 hours[1]	Per cent.
1	23·5	20·45	18·7	18·22	17·4	17·4	26·
2	25·19	21·33	19·37	18·9	18·07	18·0	28·5
3	23·67	19·7	17·83	17·6	16·82	16·75	29·2
4	20·08	17·07	15·8	15·6	15·13	15·05	25·

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[1] It will be observed, on referring to the last column of lime, that the wood, although kept in the chamber exposed to heated currents for 50 hours, weighed nothing less after the first 34 hours.—(*Whishaw.*) One application of the desiccating process for timber is to expose it for some hours to the heated currents of air, and then, in its heated state, immersing it suddenly in any of the approved antiseptics, creosote or coal-tar. The result is, that the air-vessels of the wood, if not entirely empty, contain air at so very high a temperature that a vacuum is instantly formed, and every pore is immediately charged with the cold antiseptic in which the wood is immersed.

No. 3 exposed to the atmosphere for three weeks, weighed at the end of that time 17·8, or had taken in 4·2 per cent. of moisture.

Feathers.—Feather beds, mattresses, blankets, and clothing, are not only dried, but purified by this process. A feather bed of sixty pounds weight will have no less than 100,000 cubic feet of air passed through it; and at the same time beaters are made use of, for the purpose of removing the dust. Feathers treated in this manner have their bulk and elasticity so much increased, that a second tick is found almost invariably necessary to put the feathers into.

A practical proof of the extreme powers of currents of dry heated air was given in Syria, by exposing to them sixty suits of clothes, which had belonged to persons who died of the plague. These clothes were subjected to the process alluded to, at a temperature of about 240°, and afterwards worn by sixty living persons, not one of whom ever gave the slightest symptom of being affected by the malady.—(*Whishaw.*) It has been proposed to dry coffee by currents of heated air, and subsequently to roast it by the same process.

Thick card-board, used for tea-trays and papier-maché, is now frequently dried by heated air. By the plan adopted at one establishment, previously to the introduction of Davison and Symington's method, it invariably occupied from eighteen to twenty hours to dry a room full of paper by a heating surface equal to 330 feet; whereas by the new method, the same amount of work is accomplished in four hours, and with a heating surface of only 46 feet, or one-seventh the area required by the former.

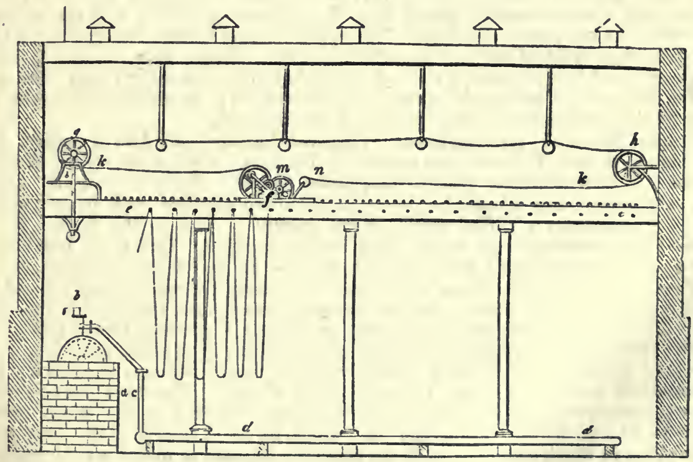
Silk.—For the purpose of drying silk, it has been usual to heat the drying chambers by large cast-iron globular stoves, the heat obtained thus was equal to 120° F., but excessively distressing to any stranger entering these apartments.

In one arrangement 7,000 cubic feet per minute are admitted at the above temperature through small perforated iron plates, let into the stone floor. As many as 3,000 pieces of silk are sometimes suspended at one time: and as each piece of silk, when wet, contains about seven ounces of water, and as the operation of drying the whole occupies but one hour, it follows that about 130 gallons of water are evaporated in that time.

Yarns.—In Scotland and other places they now dry yarns by modified applications of this process; and it is indeed extensively used in bleaching establishments, in calico-printing works, &c. See *Transactions of the Society of Arts for* 1847-8.

A DRYING HOUSE is an apartment fitted up in a peculiar manner for drying calicoes, and other textile fabrics. Mr. Southworth, of Sharples, a Lancashire bleacher, obtained a patent in 1823, for the following ingenious arrangement, which has been since generally adopted, with certain modifications, in most of our extensive bleaching and printing works. *Fig.* 599 is a section of the drying-house, where *a* is a furnace and boiler for the purpose of generating steam; it is furnished with a safety valve in the tube *b*, at top, and from this tube the steam-main *c* passes down to the floor of the basement story. From this main, a series of steam-pipes, as *d d*, extends over the surface of the floor, and from them heat is intended to be diffused for the purpose of warming the drying-house.

599



Along the middle of the building a strong beam of timber *e e* extends, and is supported by cast-iron pillars; from this beam, to bearings on the side walls, a series of rails are carried in a cross direction, over which rails the wet cloth is to be hung in folds, and the steam or vapour emitted in drying is allowed to escape through apertures or ventilators in the roof.

The mode in which the cloth is delivered on to the rails, on either side of the beam will be best understood by reference to the delivering carriage, which is shown, with its rollers partly in section.

The wet cloth is first to be coiled upon a roller, and then placed in the carriage, as at *f*, with its pivots bearing upon inclined planes. The carriage is to be placed at the commencement of the rails, running upon the middle beam, and also upon the side-bearings or railways extending along the side walls of the building, parallel to and upon a level with the same beam. It is made to travel by means of an endless band passing over two riggers *g* and *h*, in *fig.* 599, and over pulleys and a band-wheel attached to the carriage, as will be explained. The rigger *g*, which moves this endless band, is actuated by bevel gear, seen at *b*, which is put in motion by a pinion at the end of a revolving shaft leading from a steam-engine.

In the same *fig.*, *k k*, is the endless band passing over a pulley under the band-wheel, and over the pulley *n*, by which it will be perceived that the traversing of the band, as described, would cause these pulleys and wheels to revolve. On the action of the band-wheel *m*, there is a drum against which the roll of wet cloth *f* presses, and as this drum revolves, the roll of wet cloth is, by its friction, made to turn in a contrary direction, and to deliver off the cloth on to the periphery of the drum, whence it passes over a roller and descends to the rails. Upon the end of the axle of the band wheel *m*, there is a pinion which takes into the teeth of the large wheel, and upon the axle of this large wheel there is a pinion that actuates the intermediate wheel which turns another toothed wheel. This last-mentioned toothed wheel takes into cogs upon the side railway, and hence, as the train of wheels moves round, the carriage to which the wheels are attached is slowly impelled forward.

As soon as the wheels begin to move, and the carriage to advance, the wet cloth begins to uncoil, and to pass down over the first roller; a small roller attached to the carriage, as it passes over the rail in succession, holds the cloth against each rail for a short space of time, and prevents it from slipping, by which means the cloth descends in folds or loops between the rails, and is thereby made to hang in a series of folds or loops, as shown in the figure.

It will be perceived that as the pivots of the cloth roller *f* bear upon inclined planes, the roller will continually slide down as the cloth diminishes in bulk, keeping in contact with the drum, and delivering the cloth from the roller on to the several rails, as described.

In order to stop the carriage in any part of its course, or to adjust any of the folds of the cloth, a man is usually placed upon the platform travelling with the carriage, over which he has perfect command. This apparatus may be also employed for taking the cloth when dried off the rails; in which case the carriage must be made to travel backwards, and by first guiding the end of the cloth on to the roller *f*, and then putting the wheels in a retrograde motion, the cloth will be progressively coiled upon the roller *f*, in a similar way to that by which it was uncoiled.

Drying Machine (centrifugal). (*Hydro-extracteur*; *Machine à essorer*, Fr.) By this contrivance, Pentzoldt was enabled to deprive all kinds of wet clothes in a few minutes of their moisture, without compression or heat. Kelly, a dyer, and Alliott a bleacher, have since obtained a patent for the above machine with improvements. *Fig.* 600 represents a partial section of the machine. A, A, is the frame; B, the vertical shaft turning in the step *a*, fixed on the bridge *b*. This shaft bears on its upper part a friction cone *c*, from which it receives its movement of rotation, as will be presently shown; C is a drum containing two concentric compartments *d e*, of the form represented in the figure; this drum moves freely upon the shaft B, and rests when it is not in motion upon two conical projections *f*, *g*, which form a part of the shaft. These two compartments are each composed mainly of metal, and their sides consist of tinned iron wire coiled circularly at very small distances from each other, and soldered together crosswise by small strips of metal. The top which covers the inner compartment *d*, is secured by bolts and screws to a circle of iron which retains the wire sides of the same metal, but that which serves as a cover to the little compartment *e*, in which alone the goods are placed, is disposed so that it may be removed with ease, when these are to be introduced or withdrawn. It is furnished with an outer and inner border, disposed so that when the top is fixed the inner border presses upon the convex circumference of the central compartment, while the exterior border falls outside of the edges of the other compartment. While the machine is at work, the second plate is maintained in its place by pins or bolts, not shown in the figure.

The sides of the outer compartment *d*, are connected with the bottom by means of a prolongation of cross bands of metal, which unite the wires and are riveted or soldered to the two outer plates. The wires of the interior compartment are attached by an iron hoop, to which they are riveted and soldered, and are united to the bottom plate by means of a rim upon this plate; a rim somewhat flattened upon the sides, which are riveted and soldered.

D, is a regulator suspended in the inner compartment *d*, and whose two branches *h*, *h*, are loaded. These two branches having room to play around the bolts which serve as points of attachment, and which are fixed to the upper plate, terminate in kneed branches whose extremities rest upon a rope *g*, which projects from the shaft. E, is an exterior envelope secured to the frame A, A. It encloses the whole drum except at top, and serves to catch the water thrown out of the goods. At *y* there is a stop-cock for the discharge of this water, and the bottom contains besides the end of a pipe by which hot air is introduced.

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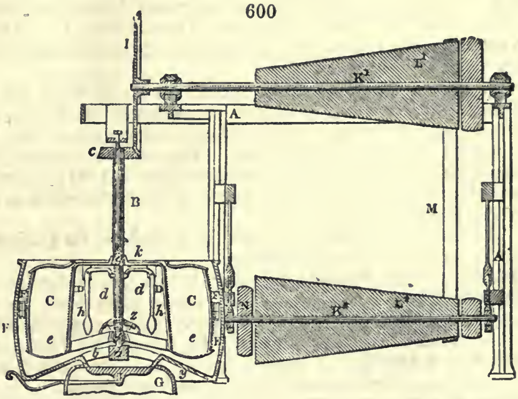


The vertical shaft B receives a movement of rotation and carries with it the drum. The more rapid this movement is the more does the centrifugal force tend to expel the water contained in the clothes or yarn to be dried. But as this force might also displace the central shaft, if the weight was not rightly distributed in the drum, and cause the dislocation of the machine when the great velocity requisite for quick drying is given to it, the regulator D is tested to prevent accident. The branches of this regulator spread wider the more the velocity is increased, and raise consequently the drum C above the conical enlargements, which permits the drum to be somewhat misplaced and to rectify its position conformably to the inequalities of its load, so that its centre of gravity may always coincide with its centre of rotation. The drum is connected with the shaft, as is shown in *z*, leaving it free to take the requisite adjustment. To hinder it from rising too suddenly, a spiral spring *k* is fixed over the shaft immediately above the conical enlargement *g*. In order to maintain the equilibrium more certainly, the apparatus is surrounded with a hollow crown F, half filled with water, and if during the revolution of the machine the weight of the goods predominates on one side, that of the water which accumulates on the other side serves the more to counterbalance it. The effect of this crown may be increased by dividing it into two compartments or more. G is a large pipe by which steam or hot air is introduced into the belly of the drum, which is pierced in this place with a great number of small holes to receive it.

The rotatory movement is transmitted to the drum in the following way:—

I, is a conical disc mounted upon the extremity of a shaft K^1 which actuates the cone C and the shaft B by means of friction; L^1 is a cone fixed upon the extremity of the shaft. K^2 L^2 'is another cone of the same dimension, but whose base fronts the top of the other, and which is placed on the shaft K^2' commanded by the prime mover. M is the belt which embraces the two cones, and whose lateral displacement, effected by means of a fork, permits the velocity of the machine to be regulated at pleasure. N is the pulley which directly receives the movement. In place of a single friction disc I, another may be employed, if judged necessary, and placed between the two, an additional friction pole, in order better to equalise the friction. In this case the disc and additional cone should turn freely upon their own shafts. We may also adopt another arrangement for the bottom of the vertical shaft. The shaft immediately above the step is surrounded by a loose rim, around which a certain quantity of lead shot, or other granular matter, is contained in the rim in the box which serves for the step. The top of this box is pierced with an opening, into which, when the machine is at rest, a cord connected with the shaft sinks, controlled by the shaft, and when the drum is raised by the action of the regulator D, this cord quits its place, which allows the shaft to displace the shot a little, and to take a position conformably to the point of the centre of gravity,

But after all, great attention should be paid to the proper working of the machine. There are many other drying machines used, some of which are described in the articles devoted to special manufactures.

DETERMA. A wood used in Guiana for masts, booms, and planking. It is very durable, insects will not attack it, and it will square from 14 to 16 feet.

DETONATION. For the mode of preparing detonating-powder for the percussion-caps of fire-arms, see FULMINATES.

DETRITUS. (*De*, from, *tero*, to rub.) Matter worn off rocks, and re-deposited.

DEUTOXIDE, literally means the second oxide, but is usually employed to denote a compound containing two atoms of oxygen to one or more of a metal. Thus we say, deutoxide of copper and deutoxide of mercury. Berzelius abbreviated this expression by adopting the principles of the French nomenclature of 1787; according to which the higher state of oxidisement is characterised by the termination *ic*, and the lower by *ous*. It is now rarely employed.

DEVIL. The name of a spiked mill, used in Yorkshire, for tearing woollen rags into fragments for the manufacture of SHODDY.

DEVILLINE. A basic sulphate of copper, known also as *Lyellite.*

DEVITRIFICATION. A process by which glass loses its characteristic vitreous properties, and becomes opaque. This change may be induced by very slow cooling, or by the prolonged heating of glass. See RÉAUMUR'S PORCELAIN.

DEVONSHIRE BATTS. A porous fine-grained sandstone, from the quarries of Black Down Cliffs, near Collumpton, in repute as a grindstone.

DEVONSHIRE OIL-STONE. This stone occurs near Huel Friendship Mine, about three miles from Tavistock, in the Devonian slates of that district. It has considerable local repute for sharpening all kinds of thin-edged broad instruments; it has not, however, become an article of commerce.—*Knight, Trans. Society of Arts.*

DEWEYLITE. A hydrous silicate of magnesia, occurring in several localities in the United States, and named after Prof. Chester Dewey.

DEW-RETTING. See FLAX.

DEXTRIN. Starch gum. There are three modes of obtaining this from starch, viz., by torrefaction, by the action of dilute acids, and by the action of *diastase.* The impure dextrin obtained by roasting is termed *roasted starch* or *leicomme.* British gum is prepared by carefully roasting wheat-starch, at a temperature of 300° Fahr. Another method of preparing dextrin consists in moistening 1,000 parts of potato-starch with 300 parts of water, to which 2 parts of nitric acid have been added. The mixture is allowed to dry spontaneously, and is afterwards heated for two or three hours in a stove, at 212° Fahr. Dextrin in many of its characters resembles ordinary gum, but it is distinguishable from it by its *right-handed rotation of a ray of plane polarised light,*—hence its name *dextrin,*—and by its yielding oxalic acid, but not mucic acid, when heated with nitric acid.

DEXTROSE, or **DEXTRO-GLUCOSE.** Names applied to ordinary glucose or grape sugar, in consequence of the power which a solution of such sugar possesses of turning the plane of polarisation of a ray of light towards the right hand. This rotation is often distinguished by the symbol +. See GRAPE-SUGAR.

DHIL MASTIC. A mixture of massicot (protoxide of lead) and eight or ten times as much brick-dust, made into a paste with linseed-oil. It is used for repairing defects in stone facings.

DHOONA PITCH. A name for Dammar Pitch. See DAMMAR GUM.

DIABASE. A fine-grained igneous rock, composed of a crystalline-granular mixture of triclinic felspar, with augite and chlorite. The felspar is generally either oligoclase or labradorite, and the augitic constituent is frequently hypersthene. The presence of chlorite gives a green colour to the rock; hence diabase is often included under the general name of *greenstone.*

DIACTINIC LENS. A name proposed to be given to the best construction of lens for the photographic camera obscura. It should be transparent to all the chemical rays, or rather, it should be a lens which unites the chemical and luminous focus in one point. The name has not been generally adopted.

DIAL. The compass used in underground surveying is called a miner's dial, and is essentially the same instrument as the circumferentor used by the land-surveyor. Improved forms of dial have been brought out by Wilton, Philipps, and others. It is beyond the purpose of this Dictionary to enter into detailed descriptions of surveying instruments, but the art of dialling will be explained. The miner may be referred to Budge's 'Practical Miners' Guide,' and to Rickard's 'Miners' Manual of Arithmetic and Surveying.' See Mine Surveying.

DIALLAGE. *Bronzite*, *Hypersthene*, and *Schiller-spar* are often confounded under this name. The name is derived from διαλλαγή, difference, alluding to dissimilar cleavage. It is thin, foliated, and easily cleavable; laminæ brittle; colour, various shades of green, grey, and brown, sometimes bronze and pearly metallic. Diallage is now included by most mineralogists under the head of pyroxene.

Of diallage-rock fine examples will be found near the Lizard Point, and beautiful crystals of diallage are to be discovered in the Serpentine rocks near Cadgwith, in the same locality.

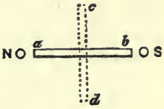
DIALLOGITE. Carbonate of manganese, a mineral usually occurring in rose-red or pinkish rhombohedral crystals. See Manganese.

DIALYSIS. The late Professor Graham applied this term to the separation of certain substances by liquid diffusion. For example, if a mixture of gum and sugar is placed in a dialyser, which is a piece of 'paper parchment' stretched upon a hoop, and this floated in water, three-fourths of the sugar will pass through the membrane in twenty-four hours, without a trace of the gum. See Watts's 'Dictionary of Chemistry.'

DIAMAGNETISM. As this term is now generally used in our scientific language, it appears necessary to give a definition of it, although it is not our purpose to enter on the consideration of any purely physical subject.

The term was introduced by the late Dr. Faraday to express those bodies which did not act as magnetic bodies do. If N and S (*fig.* 601) represent the poles of a horse-shoe magnet, any bar of a magnetic character, as iron, cobalt, or nickel, hung up between them and free to move, will by virtue of the attracting and repelling polar forces, place itself along the line joining the two poles *a b*, which is called the magnetic axis. If, instead of a bar of iron, we suspend in the same manner a rod of glass, of bismuth, or of silver, it will arrange itself equatorially, or across the line *a b*, as shown by the dotted lines, *c d*. All bodies in nature appear to exist in one of those two conditions. The prefix *dia* is used here in the same sense as in dia-meter. For a full explanation of all the diamagnetic phenomena, see De La Rive's 'Electricity,' and 'Researches on Diamagnetism and Magne-crystallic Action,' by Dr. Tyndall. (Longmans, 1870.)

601



DIAMOND. (*Diamant*, Fr.; *Diamant*, *Demant*, Ger.) Experiment has determined that this beautiful gem is a peculiar (*allotropic*) condition of carbon. By burning the diamond in oxygen-gas we produce carbonic acid; and by enclosing the gem in a mass of iron, and subjecting it to a strong heat, the metal is converted into steel, when the diamond has disappeared. It has been shown that we can, by the agency of the heat of the voltaic arc, convert the diamond into excellent coke, and into graphite; but although portions of coke are found to be sufficiently hard to cut glass, we have not yet succeeded in making diamonds from coke. Sir Humphry Davy noticed that the charcoal of one of the poles of Mr. Children's great voltaic battery was considerably hardened, and he regarded this as an advance towards the production of that gem. Recently some experiments made by a French philosopher have advanced the discovery another step: one of the poles of a voltaic battery being of charcoal and the other of platinum, it was found that the fine charcoal escaping from the carbon pole and depositing itself on the platinum pole was sufficiently hard to be used in the place of diamond dust for polishing gems. The formation of the diamond in nature is one of the problems which 'our philosophy' has not yet enabled us to solve. Time is an element which enters largely into Nature's works; she occupies a thousand, or even thousands of years to produce a result, while man in his experiments is confined to a few days, or a few years at most.

Although diamonds have been occasionally found in various parts of the globe, there are only three places which can be strictly named as diamond districts, namely, a portion of the Indian Peninsula, Brazil, and South Africa. India has been celebrated from the most remote antiquity as the country of diamonds. Its principal mines are in the kingdoms of Golconda and Visapur, extending from Cape Comorin to Bengal, at the foot of a chain of mountains called the Orixa, which appear to belong to the trap-rock formation. In all the Indian diamond-soils these gems are so dispersed that they are rarely found directly, even in searching the richest spots, because they are enveloped in an earthy crust, which must be removed before they can be seen. The stony matter is therefore broken into pieces, and is then, as well as the looser earth, washed in basins scooped out for the purpose. The gravel thus washed is collected, spread out on a smooth piece of ground, and left to dry. The diamonds are now recognised by their sparkling in the sun, and are picked out from the stone.

Diamonds are also said to come from the interior of the island of Borneo, on the banks of the river Succadan, and from the peninsula of Malacca. It is said the principal spots where diamonds are found are recognised by certain small flints, generally of a black colour, which lie upon the surface, and also by the yellow colour of the stony soil. The ground is dug in the presence of an overseer: all stones above 5 carats are claimed for the sovereign. Diamonds are found occasionally in the rivers, seldom, however, of any size.

The diamond-mines of Brazil were discovered in 1728, in the district of Serro-do-Frio. The ground in which they are embedded has the most perfect resemblance to that of the East Indies where the diamonds occur. It is a solid or friable conglomerate, consisting chiefly of a ferruginous sand, which encloses fragments of various magnitude of yellow and bluish quartz, of schist, jasper, and grains of gold, disseminated with specular iron ore: all mineral matters different from those that constitute the neighbouring mountains. This conglomerate, or species of pudding-stone, almost always superficial, occurs sometimes at a considerable height on the mountainous table-land. The most celebrated diamond-mine is that of Mandanga, on the Jigitonhonha, in the district of Serro-do-Frio to the north of Rio Janeiro. The river Jigitonhonha, three times broader than the Seine at Paris, and from 3 to 9 feet deep, is made nearly dry, by drawing the water off with sluices at a certain season; and the *cascalho*, or diamond-gravel, is removed from the channel by various mechanical means, to be washed elsewhere at leisure. This cascalho, the same as the matrix of the gold-mines, is collected in the dry season, to be searched into during the rainy; for which purpose it is formed into little mounds of 15 or 16 tons weight each. The washing is carried on beneath an oblong shed, by means of a stream of water admitted in determinate quantities into boxes containing the cascalho. A negro-washer is attached to each box; inspectors are placed at regular distances on elevated stools, and whenever a negro has found a diamond, he rises up and exhibits it. If it weighs 17½ carats, he receives his liberty. Many precautions are taken to prevent the negroes from secreting the diamonds. Each squad of workmen consists of 200 negroes, with a surgeon and an almoner or priest.

The flat lands on either side of the river are equally rich in diamonds over their whole surface, so that it becomes very easy to estimate what a piece of ground not yet washed may produce.

It is said that the diamonds surrounded by a greenish crust are of the *first* water, or are the most limpid when cut. The diamonds received in the different mines of the district are deposited once a month in the treasury of Tejuco; and the amount thus delivered, was estimated at about 18 or 19 thousand carats per annum. It appears that few of the Brazilian diamond-fields are now worked (1874).

On the banks of the torrent called Rio Pardo there is another mine of diamonds. The ground presents a great many friable rocks of pudding-stone, distributed in irregular strata. It is chiefly in the bed of this stream that masses of cascalho occur, peculiarly rich in diamonds. They are much esteemed, particularly those of a greenish-blue colour. The ores that accompany the diamonds at Rio Pardo differ somewhat from those of the washing-grounds of Mandanga, for they contain no pisiform iron ore; but a great many pebbles of slaty jasper. This table-land seems to be very high, probably not less than 5,500 feet above the level of the sea.

Tocaya, a principal village of Minas-Novas, is 34 leagues to the north-east of Tejuco, in an acute angle of the confluence of the Jigitonhonha and the Rio Grande. In the bed of the streamlets which fall westward into the Jigitonhonha, those rolled white topazes are found which are known under the name of *minas novas* with *blue topazes*, and aquamarine-beryls. In the same country are found the beautiful cymophanes or chrysoberyls so much prized in Brazil. And it is from the cantons of Indaia and Abaïte that the largest diamonds of Brazil come; yet they have not so pure a water as those of the district of Serro-do-Frio, but incline a little to the lemon-yellow.

It appears to be well established that the Brazilian diamonds occur in a quartzose rock, sometimes flexible, called *itacolumite;* and it is notable that a similar rock has been found associated with the diamond in other localities.

Within the last few years, unparalleled discoveries of diamonds have been made in South Africa. The earliest discovery dates only from 1867. Schalk van Niekerk, a Dutch farmer in the Colesberg district, having observed the children of a neighbouring boer playing with some pebbles picked up on the farm, was attracted by one of these stones different from the rest, and secured it. Having been transmitted to Dr. Atherstone, of Graham's Town, the stone was determined to be a diamond, and was then sent to the Paris Exhibition of 1867. At the close of the Exhibition it was sold for 500*l.* to Sir Philip Wodehouse, the governor of the colony. The occurrence of diamonds once known, search was extended in various directions, and other diamonds were soon detected. Although at first received with some suspicion, the truth gradually became established that South Africa contained diamond-fields rivalling those of Brazil. Numbers of adventurers were soon attracted to the chief diamond-bearing localities, and vast numbers of stones, including many of unusual size, have been brought to light. It is estimated that the total shipments of diamonds from Port Elizabeth, Table Bay, and Natal, during the year 1870 represented a value of 220,000*l.*

The South African diamonds occur chiefly in the valleys of the Vaal and Orange Rivers; the principal localities being Pniel, Hebron, Klipdrift, Du Toit's Pan, Old De Boer's Farm, and the New Rush or Colesberg Koppie. The workings are of two kinds, known as the 'river-diggings' and the 'dry-diggings.' The former are in deposits of gravel and drift, rich in pebbles of jasper, chalcedony, carnelian, agate, lydian stone, garnets, ilmenite, &c.; the diamonds are sparsely disseminated through these gravels, and are separated by simple washing. But, in addition to these drift-workings, mining has been very successfully prosecuted in dry diggings at a distance from the river. These diggings are generally opened in deposits of detrital matter, occupying circular areas, surrounded by Karoo (Trias) shales. Each of these diamond-bearing areas represents a 'pipe,' containing intrusive rocks more or less altered and frequently broken up so as to form a breccia. The diamonds are associated with garnets, green bronzite, vermiculite, and a few other minerals; a calcareous deposit, or tufa, is also commonly present in the upper part of the pipes; and fragments of schist, dolerite, and steatitic minerals are generally found in company with the diamonds. The crystals of diamond are occasionally embedded in the tufa, and are disseminated through the altered rocks which form the chief contents of the pipes; but it may be doubted whether in either case the gem occurs in its original matrix.

It unfortunately happens that by far the greater number of the Cape diamonds are 'off coloured,' that is to say, they are not of pure water, but exhibit more or less colour, a pale straw tint being especially characteristic. The crystals are commonly well formed, and often of large size; indeed the great number of unusually large diamonds is one of the most notable features in the occurrence of the South African diamonds. Thus the 'Star of South Africa' weighed 83 carats, and yielded a fine brilliant of 46½ carats. But the largest diamond hitherto discovered at the Cape is a stone now known as the 'Stewart,' which was found at Waldeck's plant in November 1872.

The Stewart is a fine octahedral crystal of pale straw colour, weighing in the rough 288⅜ carats. It is believed that this diamond is exceeded in weight by only three others in the world, namely, the Nizam, the Great Mogul, and the diamond of the Rajah of Mattan. It seems likely that a brilliant may be cut from the Stewart, which will weigh half as much again as our Koh-i-noor.[1]

Diamonds take precedence of every gem for the purpose of dress and decoration; and hence the price attached to those of pure water increases in so rapid a proportion, that, beyond a certain term, there is no rule of commercial valuation. One of the largest diamonds known seems to be that of the Rajah of Mattan in Borneo. It is of the purest water and weighs 367 carats, or at the rate of 4 grains to a carat, upwards of 3 ounces troy. It is shaped like an egg, with an indented hollow near the smaller end; it was discovered at Landak about 100 years ago; and though the possession of it has cost several wars, it remained in the Mattan family for 90 years. A governor of Batavia, after ascertaining the qualities of the gem, wished to be the purchaser, and offered 150,000 dollars for it, besides two war brigs with their guns and ammunition, together with a certain number of great guns, and a quantity of powder and shot. But this diamond possessed such celebrity in Borneo, being regarded as a talisman involving the fortunes of the Rajah and his family, that he refused to part with it at any price.

The Mogul diamond passed into the possession of the ruling family of Kabul, as has been invariably affirmed by the members of that family, and by the jewellers of Delhi and Kabul. It has been by both parties identified with the great diamond now known under the name of the *Koh-i-noor*, or *Mountain of Light*—which was displayed by its present proprietor, Her Majesty the Queen, at the Great Exhibition in 1851.

The diamond denominated the Koh-i-noor (or Mountain, *koh*, of Light, *noor*), called Kuh-i-nur by Mr. E. B. Eastlake (p. 23), has long enjoyed both Indian and European celebrity, and has accordingly been the subject of traditional fable, as well as of historical record.

According to Hindu legend, it was found in the mines of the south of India, in the days of the Great War, the subject of the heroic poem, the *Mahâbhârata*, and was worn by one of the warriors who was slain on that occasion, Karna, king of Anga:

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[1] For further information on the occurrence of diamonds in South Africa, see a lecture by Professor Tennant, 'Journal of the Society of Arts,' November 25, 1870; an article by Professor Rupert Jones, in the 'Geological Magazine,' February 1871; and a paper by Mr. E. J. Dunn, in the Quart. Journ. Geological Soc., Feb. 1874.

this would place it about 4,000 years ago, or 2100 B.C. A long interval next makes it the property of Vikramaditya, the rajah of Mjayin, 56 B.C., from whom it descended to his successors, the Rajahs of Malwa, until the principality was subverted by Mohammedan conquerors, into whose hands it fell, with other spoils of infinite value.

Whatever may be thought of the legend which gives so high an antiquity to the Koh-i-noor, we might expect some more trustworthy information when we come down so low as the beginning of the fourteenth century; Malwa having been invaded and overrun by the armies of Ala-ad-din, the sultan of Delhi, in 1306, who, according to the autobiography of the sultan Baber, acquired the jewel. That it did become the property of the sultans of Delhi is little doubtful, but when or how is matter of some uncertainty; although the grounds of the difficulty have not hitherto been investigated.

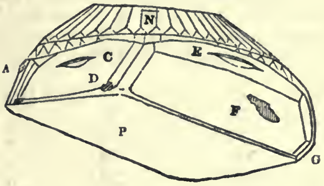
In 1665 M. Jean Baptiste Tavernier, an enterprising and intelligent traveller, and an eminent jeweller, although Ecuyer, Baron d'Aubonne, visited India especially to purchase diamonds. His profession and his personal character seem to have recommended him to the favourable attention of the nobles of the court of Delhi, and bigot as he was, of Aurungzebe himself, by whose commands M. Tavernier was permitted to inspect, handle, and weigh the jewels of the imperial cabinet. Amongst them was one which far surpassed all the rest in size and value. Tavernier describes it as rose-cut, of the shape of an egg cut in two, of good water, and weighing 319½ *ratis*, which, he says, is equal to 280 of our carats.

There is but little doubt that the diamond examined by Tavernier in the Delhi cabinet was the Koh-i-noor. Baber, the Mogul emperor, obtained a diamond, corresponding exactly with this, and it passed eventually into the possession of the ruling family of Kabul. Nadir Shah, on his occupation of Delhi in 1739, compelled Mohammed Shah, the great-grandson of Aurungzebe, to give up to him everything of value that the imperial treasury possessed, and his biographer and secretary specifies a *peshkash*, or present, by Mohammed Shah to his conqueror of several magnificent diamonds. According to the family and popular tradition, Mohammed Shah wore the Koh-i-noor in front of his turban at his interview with his conquerer, who insisted on exchanging turbans in proof of his regard. However this might have been, we need have little doubt that the great diamond of Aurungzebe was in the possession of Mohammed Shah at the time of the Persian invasion; and if it was, it most certainly changed masters, and became, as is universally asserted, the property of Nadir Shah, who is also said to have bestowed upon it the name of Koh-i-noor. After his death, the diamond which he had wrested from the unfortunate representative of the house of Timur, became the property of Ahmed Shah, the founder of the Abdali dynasty of Kabul, having been given to him, or more probably taken by him, from Shahrikh, the young son of Nadir. The jewel descended to the successors of Ahmed Shah, and when Mr. Elphinstone was at Peshawur, was worn by Shah Shuja on his arm. When Shah Shuja was driven from Kabul, he became the nominal guest and actual prisoner of Runjet Sing, who spared neither importunity nor menace, until, in 1813, he compelled the fugitive monarch to resign the precious gem, presenting him on the occasion, it is said, with a lakh and 25,000 rupees, or about 12,000*l.* sterling, According to Shah Shuja's own account, however, he assigned to him the revenues of three villages, not one rupee of which he ever realised. Runjet was highly elated by the acquisition of the diamond, and wore it as an armlet at all great festivals. When he was dying, an attempt was made by persons about him to persuade him to make the diamond a present to Jagannuth, and it is said that he intimated assent by an inclination of his head. The treasurer, however, in whose charge it was, refused to give it up without better warrant, and Runjet dying before a written order could be signed by him, the Koh-i-noor was preserved for a while for his successors. It was occasionally worn by Rhurreuk Sing and Shu Sing. After the murder of the latter, it remained in the Lahore treasury until the supercession of Dhulip Sing, and the annexation of the Punjaub by the British Government, when the civil authorities took possession of the Lahore treasury, under the stipulations previously made, that all the property of the state should be confiscated to the East India Company, in part payment of the debt due by the Lahore government and of the expenses of the war; it was at the same time stipulated that the Koh-i-noor should be presented to the Queen of England. Such is the strange history of certainly one of the most extraordinary diamonds in the world. After the Company became possessed of the gem, it was taken in charge by Lord Dalhousie, and sent by him to England in custody of two officers.—*Hunt's Handbook of the Great Exhibition of* 1851.

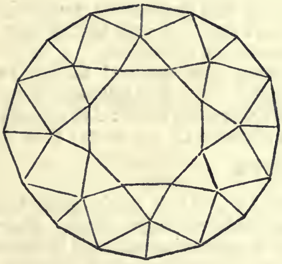
As exhibited at the Great Exhibition of 1851 in Hyde Park, the Koh-i-noor weighed $186\frac{1}{16}$ carats.

The form of the Koh-i-noor is given in *fig.* 602. P is a large plane at the base of the diamond which is a cleavage-plane. F, also a large cleavage-plane, produced by a fracture; this had not been polished, and being inclined to the plane P at an angle of 109° 28′, affords a satisfactory means for determining the direction of the cleavage-planes of the stone. A shows a flaw running parallel to the cleavage-plane F. This constituted the principal danger to be apprehended in cutting the stone, and was most skilfully ground nearly out before any of the facets were cut. This flaw seemed to proceed from a fracture marked B. C and E were little notches cut in the stone for the purpose of holding the diamond in its original setting; N, a small flaw, which almost required a glass to see it, evidently parallel to the plane P; D, a fracture from a blow or fall, showing at its base a cleavage-plane.—*Tennant.*

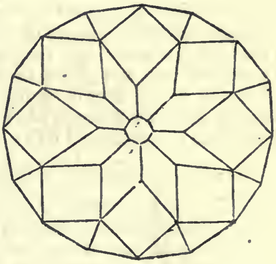
602



603



604



This fine diamond did not possess the high degree of brilliancy which was expected from its great reputation; it was consequently submitted to Messrs. Garrard to be re-cut. In the operation the weight was reduced more than one-third, but its brilliancy was greatly improved. The present state of the Koh-i-noor is shown in *figs.* 603 and 604. In this state it weighs 102½ carats. It is stated by Mr. E. B. Eastlake who has inspected the jewels of the Shah of Persia, and described them in his 'Journal of a Diplomat,' that according to Persian tradition the Daryá-i-nur, the sister jewel to the Kuh-i-nur was with it in the hilt of Afrásiab's sword, according to some, 3000 years B. C. Timúr carried it away from Persia, it having been brought there by Rustam, and Nadir brought it back. It alone is valued at two millions, and altogether the jewels cannot be worth less than six millions.

After this gem, the next in size are:—1. That of the Emperor of Russia, bought by the late empress Catherine, which weighs 193 carats. It is said to be of the size of a pigeon's egg, and to have been bought for 90,000*l.*, besides an annuity to the Greek merchant of 4,000*l.* It is reported that the above diamond formed one of the eyes of the famous statue of Sherigan, in the temple of Brama, and that a French grenadier, who had deserted into the Malabar service, found the means of robbing the pagoda of this precious gem, and escaped with it to Madras, where he disposed of it to a ship captain for 2,000*l.*, who resold it to a Jew for 12,000*l.* From him it was transferred for a large sum to the Greek merchant, 2. That of the Emperor of Austria, which weighs 139 carats, and has a slightly yellowish hue. It has, however, been valued at 100,000*l.* 3. That of the French State, called the Regent or Pitt diamond, remarkable for its form and its perfect limpidity. Although it weighs only 136 carats, its fine qualities have caused it to be valued at 160,000*l.*, though it cost only 100,000*l.*

A large diamond furnished by Brazil, now in possession of the Crown of Portugal, weighs, according to the highest estimates, 120 carats. It was found in the streamlet of Abaïte, in a clay-slate district. The largest Brazilian diamond yet found was discovered in 1853 at Bogagem, in the province of Minas Geraes. It presented the form of a distorted rhombic dodecahedron, and weighed in the rough 254½ carats. On cutting, it yielded a splendid brilliant of 125 carats. The gem was exhibited in the International Exhibition of 1862, and is known as 'The Star of the South.'

Diamonds possessed of no extraordinary magnitude, but of a good form and a pure water, may be valued by a certain standard rule. In a brilliant, or rose diamond of regular proportions, so much is cut away that the weight of the polished gem does not exceed one-half the weight of the diamond in the rough state; whence the value of a cut diamond is esteemed equal to that of a similar rough diamond of double weight exclusive of the cost of workmanship. The weight and value of diamonds are reckoned by carats of 4 grains each; and the comparative value of two diamonds of equal quality, but different weights, is as the squares of these weights respectively. The average price of rough diamonds that are worth working, is about 2*l.* for one of a single carat; but as a polished diamond of one carat must have taken one of two carats, its price in the rough state is double the square of 2*l.*, or 8*l.* Therefore to estimate the value of a wrought diamond, ascertain its weight in carats, double that weight, and multiply the square of this product by 2*l.* Hence, a wrought diamond of

1	carat is worth	£8	7	carats is worth	£392
2	,,	32	8	,,	512
3	,,	72	9	,,	612
4	,,	128	10	,,	800
5	,,	200	20	,,	3,200;
6	,,	288			

beyond which weight the price can no longer rise in this geometrical progression, from the small number of purchasers of such expensive toys. A very trifling spot or flaw of any kind lowers exceedingly the commercial value of a diamond.

The preceding rule was given by Jefferies many years ago, and though no doubt correct enough in its day, is of little or no value now. The following formula has been recently given by Schrauf, of Vienna (*Edelsteinkunde*, 1869): Let a be the weight of a given stone in carats, and b the value of a diamond of one carat; then the value of the stone of a carats is approximately $\frac{a}{2}(a+2)\,b$.

After all, it may be doubted whether any really useful rule can be given to connect weight with value; certainly there is none applicable to large stones. The market value is often capricious; at one time, stones of a particular size will be fashionable, and will therefore fetch unusually high prices. Moreover, much depends on the quality or 'water' of the gem; if the stone be 'off-coloured,' or if it contain cloudy imperfections known in the trade as 'milk' or 'salt,' its value is very greatly diminished. On the other hand, brilliantly-coloured diamonds are prized as 'fancy stones,' and are eagerly purchased at high prices.

Diamonds are used not only as decorative gems, but for more useful purposes, as for cutting glass by the glazier, and all kinds of hard stones by the lapidary.

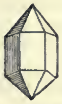
On the structure of the glaziers' diamond we possess some very interesting observations and reflections by Dr. Wollaston. He remarks, that the hardest substances brought to a sharp point scratch glass, indeed, but do not cut it, and that diamonds alone possess that property; which he ascribes to the peculiarity of its crystallisation in rounded faces, and curvilinear edges. For glass-cutting, those rough diamonds are always selected which are sharply crystallised, hence called diamond sparks; but cut diamonds are never used. The inclination to be given to a set diamond in cutting glass is comprised within very narrow limits; and it ought, moreover, to be moved in the direction of one of its angles. The curvilinear edge adjoining the curved faces, entering as a wedge into the furrow opened up by itself, thus tends to separate the parts of the glass; and in order that the crack which causes the separation of the vitreous particles may take place, the diamond must be held almost perpendicular to the surface of the glass. The Doctor proved this theory by an experiment. If, by suitable cutting with the wheel, we make the edges of a spinel, ruby, or corundum-telesie (sapphire), curvilinear, and the adjacent faces curved, these stones will cut glass as well as a glaziers' diamond, but being less hard than it, they will not preserve this property so long. He found that upon giving the surface of even a fragment of flint the same shape as that of the cutting diamond, it acquired the same property; but, from its relative softness, was of little duration. The depth to which the fissure caused by the glaziers' diamond penetrates does not seem to exceed the two-hundredth of an inch.

The following remarks by Mr. Tennant cannot fail to be of interest, and, as pointing out the errors which have been frequently committed through ignorance, are of great value:—

'By attending to the forms of the crystal, we are quite sure that we shall not find the emerald, sapphire, zircon, or topaz in the form of a cube, octahedron, tetrahedron, or rhombic dodecahedron; nor the *diamond*, spinel, or garnet in that of a six-sided prism, and so on with other gems. For want of a knowledge of the crystalline form of the diamond a gentleman in California offered 200*l.* for a small specimen of quartz. He knew nothing of the substance, except that it was a bright, shining mineral, excessively hard, not to be scratched by the file, and which would scratch glass. Presuming that these qualities belonged only to the diamond, he conceived that he was offering a fair price for the gem; but the owner declined the offer. Had he known that the diamond was never found as a six-sided prism, terminated at each end by a six-sided pyramid, he would have been able to detect the fact that what he was offered 200*l.* for, was really not worth more than half-a-crown.'—*Tennant's Lecture on Gems.*

The accompanying forms (*figs.* 605 and 606) may serve to guide those who are ignorant of crystallography:—

605

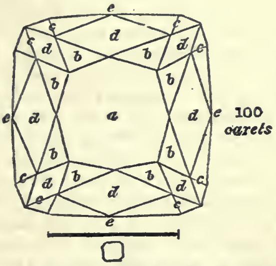


Quartz.

606

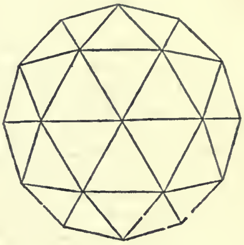
Diamond.

607 Brilliant (upper side).



a, table; *b*, star-facets; *c*, skill-facets; *d*, lozenges; *e*, girdle.

608 Rose.



The following technical terms are applied to the different faces of diamonds:—

Bezils: the upper sides and corners of the *brilliant*, lying between the edge of the table and the girdle.

Collet: the small horizontal plane or face, at the bottom of the *brilliant.*

Crown: the upper work of the rose, which all centres in the point at the top, and is bounded by the horizontal ribs.

Facets: small triangular faces or planes, both in *brilliants* and *roses.* In *brilliants* there are two sorts, *skew-* or *skill*-facets, and *star*-facets. Skill-facets are divided into *upper* and *under.* Upper skill-facets are wrought on the lower part of the bezil, and terminate in the girdle; under skill-facets are wrought on the pavilions, and terminate in the girdle; star-facets are wrought on the upper part of the bezil, and terminate in the table.

Girdle: the line which encompasses the stone parallel to the horizon; or, which determines the greatest horizontal expansion of the stone.

Lozenges: are common to *brilliants* and *roses.* In *brilliants* they are formed by the meeting of the skill- and star-facets on the bezil. In *roses* by the meeting of the facets in the horizontal ribs of the crown.

Pavilions: the under sides and corners of *brilliants*, lying between the girdle and the collet.

Ribs: the lines or ridges, which distinguish the several parts of the work, both in *brilliants* and *roses.*

Table: the large horizontal plane, or face, at the top of the *brilliant.*

Fig. 607 represents a brilliant, and *fig.* 608 a rose-cut diamond.

The rose-diamond is flat beneath, like all weak stones, while the upper face rises into a dome and is cut into facets. Most usually six facets are put on the central region which are in the form of triangles, and unite at their summits; their bases abut upon another range of triangles, which being set in an inverse position to the preceding, present their bases to them, while their summits terminate at the sharp margin of the stone. The latter triangles leave spaces between them which are likewise cut each into two facets. By this distribution the rose-diamond is cut into 24 facets; the surface of the diamond being divided into two portions, of which the upper is called the crown, and that forming the contour, beneath the former, is called *dentelle* (lace) by the French artists.

According to Mr. Jefferies, in his 'Treatise on Diamonds,' the regular rose-diamond is formed by inscribing a regular octagon in the centre of the table side of the stone, and bordering it by eight right-angled triangles, the bases of which correspond with the sides of the octagon; beyond these is a chain of 8 trapeziums, and another of 16 triangles. The collet side also consists of a minute central octagon, from every angle of which proceeds a ray to the edge of the girdle, forming the whole surface into 8 trapeziums, each of which is again subdivided by a salient angle (whose apex touches the girdle) into one irregular pentagon and two triangles.

To fashion a rough diamond into a brilliant the first step is to modify the faces of the original octahedron, so that the plane formed by the junction of the two pyramids shall be an exact square, and the axis of the crystal precisely twice the length of one of the sides of the square. The octahedron being thus rectified, a section is to be made parallel to the common base or *girdle*, so as to cut off $\frac{5}{18}$ths of the whole height from the upper pyramid and $\frac{1}{18}$th from the lower one. The superior and larger plane thus produced is called the *table*, and the inferior and smaller one is called the *collet*; in this state it is termed a *complete square table diamond.* To convert it into a brilliant, two triangular facets are placed on each side of the table, thus changing it from a square to an octagon; a lozenge-shaped facet is also placed at each of the four corners of the table, and another lozenge extending lengthwise along the whole of each side of the original square of the table, which, with two triangular facets set on the base of each lozenge, completes the whole number of facets on the table side of the diamond: viz. 8 lozenges and 24 triangles. On the collet side are formed 4 irregular pentagons, alternating with as many irregular lozenges radiating from the collet as a centre, and bordered by 16 triangular facets adjoining the girdle. The brilliant being thus completed, is set with the table side uppermost, and the collet side implanted in the cavity made to receive the diamond. The brilliant is always three times as thick as the rose diamond. In France, the thickness of the brilliant is set off into two unequal portions; one third is reserved for the upper part or table of the diamond, and the remaining two-thirds for the lower part or collet (*culasse*). The table has eight planes, and its circumference is cut into facets, of which some are triangles and other lozenges. The collet is also cut into facets called *pavillons.* It is of consequence that the pavillons lie in the same order as the upper facets, and that they correspond to each other, so that the symmetry be perfect, for otherwise the play of the light would be false.

Although the rose diamond often projects bright beams of light in more extensive proportion than the brilliant, yet the latter shows an incomparably greater play, from the difference of its cutting. In executing this, there are formed 32 faces of different figures, and inclined at different angles all round the table, on the upper side of the stone. On the collet (*culasse*) 24 other faces are made round a small table, which converts the culasse into a truncated pyramid. These 24 facets, like the 32 above, are differently inclined and present different figures. It is essential that the faces of the top and the bottom correspond together in sufficiently exact proportions to multiply the reflections and refractions, so as to produce the colours of the prismatic spectrum.

Diamonds, cutting of. Although the diamond is the hardest of all known substances, yet it may be split by a steel tool, provided a blow be applied; but this requires a perfect knowledge of the structure, because it will only yield to such means in certain directions. This circumstance prevents the workman from forming facets or planes generally, by the process of splitting; he is therefore obliged to resort to the process of abrasion, which is technically called cutting. The process of cutting is effected by fixing the diamond to be cut on the end of a stick, or handle, in a small ball of cement, that part which is to be reduced being left to project. Another diamond is also fixed in a similar manner; and the two stones being rubbed against each other with considerable force, they are mutually abraded, flat surfaces, or facets, being thereby produced. Other facets are formed by shifting the diamonds into fresh positions in the cement, and when a sufficient number are produced they are fit for polishing. The stones, when cut, are fixed for this purpose by imbedding them in soft solder, contained in a small copper cup, the part or facet to be polished being left to protrude.

A flat circular plate of cast iron is then charged with the powder produced during the abrasion of the diamonds; and by this means a tool is formed which is capable of producing the exquisite lustre so much admired on a finely-polished gem. Those diamonds that are unfit for working on account of the imperfection of their lustre or colour, are sold, for various purposes, under the technical name of Bort. Stones of this kind are frequently broken in a steel mortar, by repeated blows, until they are reduced to a fine powder, which is used to charge metal plates of various kinds, for the use of jewellers, lapidaries, and others. Bort, in this state of preparation, is incapable of polishing any gems; but it is used to produce flat surfaces on rubies and other precious stones.

Fine drills are made of small splinters of bort, which are used for drilling small holes in rubies, and other hard stones, for the use of watch-jewellers, gold and silver wire-drawers, and others who require very fine holes drilled in such substances. These drills are also used to pierce holes in china, where rivets are to be inserted;

also for piercing holes in artificial enamel teeth, or any vitreous substances, however hard.

The following description furnished to Mr. Tennant, by Messrs. Garrard, of the cutting of the Koh-i-noor will fully explain the peculiar conditions of the process, and also show that there are some remarkable differences in the physical condition of the gem in its different planes. The letters refer to the cut of the Koh-i-noor, *fig.* 602, (p. 23):—

'In cutting diamonds from the rough, the process is so uncertain that the cutters think themselves fortunate in retaining one-half the original weight. The Koh-i-noor, on its arrival in England, was merely surface cut, no attempt having been made to produce the regular form of a brilliant by which alone lustre is obtained. By reference to the figures, which are the exact size of the Koh-i-noor, it will be clearly understood that it was necessary to remove a large portion of the stone in order to obtain the desired effect, by which means the apparent surface was increased rather than diminished, and the flaws and yellow tinge were removed.

'The process of diamond cutting is effected by a horizontal iron plate of about ten inches diameter, called a *schyf* or *mill* which revolves from two thousand to three thousand times per minute. The diamond is fixed in a ball of pewter at the end of an arm, resting upon the table in which the plate revolves; the other end, at which the ball containing the diamond is fixed, is pressed upon the wheel by moveable weights at the discretion of the workmen. The weight applied varies from 2 to 30 lbs. according to the size of the facets intended to be cut. The recutting of the Koh-i-noor was commenced on July 16, 1852, His Grace the late Duke of Wellington being the first person to place it on the mill. The portion first worked upon was that at which the planes P and F meet, as it was necessary to reduce the stone at that part, and so to level the set of the stone before the table could be formed; the intention being to turn the stone rather on one side, and take the incision or flaw at E, and a fracture on the other side of the stone, not shown in the engraving, as the boundaries or sides of the girdle. The next important step was the attempt to remove an incision or flaw at C, described by Professor Tennant and the Rev. W. Mitchell as having been made for the purpose of holding the stone more firmly in its setting, but pronounced by the cutters (after having cut into and examined it) to be a natural flaw of a yellow tinge, a defect often met with in small stones. The next step was cutting a facet on the top of the stone immediately above the last-mentioned flaw. Here the difference in the hardness of the stone first manifested itself; for while cutting this facet, the lapidary noticing that the work did not proceed so fast as hitherto, allowed the diamond to remain on the mill rather longer than usual, without taking it off to cool; the consequence was, that the diamond became so hot from the continual friction and greater weight applied, that it melted the pewter in which it was imbedded. Again, while cutting the same facet, the mill became so hot from the extreme hardness of the stone, that particles of iron mixed with diamond powder and oil ignited. The probable cause of the diamond proving so hard at this part is, that the lapidary was obliged to cut directly upon the angle at which two cleavage planes meet, cutting across the grain of the stone. Another step that was thus considered to be important by the cutters was removing a flaw at G. This flaw was not thought by Professor Tennant and Mr. Mitchell to be dangerous, because if it were allowed to run according to the cleavage, it would only take off a small piece, which it was necessary to remove in order to acquire the present shape. The cutters, however, had an idea that it might not take the desired direction, and, therefore, began to cut into it from both sides, and afterwards directly upon it, and thus they succeeded in getting rid of it. While cutting, the stone appeared to become harder and harder the further it was cut into, especially just above the flaw at A, which part became so hard, that, after working the mill at the medium rate of 2,400 times per minute, for six hours, little impression had been made; the speed was therefore increased to more than 3,000, at which rate the work gradually proceeded. When the back (or former top) of the stone was cut, it proved to be much softer, so that a facet was made in three hours, which would have occupied more than a day, if the hardness had been equal to that on the other side; nevertheless, the stone afterwards became gradually harder, especially underneath the flaw at A, which part was nearly as hard as that directly above it. The flaw at N did not interfere at all with the cutting. An attempt was made to cut out the flaw at A, but it was found not desirable on account of its length. The diamond was finished on September 7th, having taken thirty-eight days to cut, working twelve hours per day without cessation.' The weight of the Koh-i-noor since cutting is 102½ carats.

DIAMOND BORER. See BORING.

DIAMOND BORON. See BORON.

DIAMOND DUST. The use of diamond dust within a few years has increased very materially, on account of the increased demand for all articles that are wrought by it, such as cameos, intaglios, &c. There has been a discovery made of the peculiar power of diamond dust upon steel; it gives the finest edge to all kinds of cutlery, and threatened at one time to displace the hone of Hungary. Finely-powdered corundum, however, now occupies its place. It is well known that in cutting a diamond, the dust is placed on the teeth of the saw, to which it adheres. To this dust is to be attributed solely the power of man to make brilliant from rough diamonds.

Diamond dust can be made by voltaic electricity but not economically.

DIAMOND MICROSCOPES were first suggested by Dr. Goring, and have been well executed by Mr. Pritchard. Among the different crystalline forms of the diamond, probably the octahedron and the cube are the only ones that will give a single vision. It will, in many cases, be advisable to grind diamond lenses plano-convex, both because this figure gives a low spherical aberration, and because it saves the trouble of grinding one side of the gem. A concave tool of cast iron, paved with diamond powder, hammered into it by a hardened steel punch, was employed by Mr. Pritchard. This ingenious artist succeeded in completing a double convex of equal radii, of about $\frac{1}{25}$th of an inch focus, bearing an aperture of $\frac{1}{30}$th of an inch with distinctness upon opaque objects, and its entire diameter upon transparent ones.

DIAMOND SPAR. A name given to corundum, as it is next to the diamond the hardest known mineral. See Corundum.

DIAMOND TOOLS. 1. *The Glaziers' diamond* is the natural diamond, so set that one of its edges is brought to bear on the glass.

The extreme point of any diamond will *scratch* glass, making a white streak; but when the rounded edge of a diamond is slid over a sheet of glass with but slight pressure, it produces *a cut*, which is scarcely visible, but which readily extends through the mass.

Dr. Wollaston succeeded in giving to the ruby, topaz, and rock crystal forms similar to those of the diamond, and with those he succeeded in *cutting* glass; proving that this useful property of the diamond depended on its form. Although the primitive form of the diamond is that of a regular octahedron, the Duke de Bournon published upwards of one hundred forms of crystallisation of the diamond. The irregular octahedrons with round facets are those proper for glaziers' diamonds.

Notwithstanding the hardness of the diamond, yet, in large glass works, as many as one and two dozens are worn out every week: from being convex, they become rapidly concave, and the cutting power is lost.

2. *Diamond drills* are made of various shapes; these are either found amongst imperfect diamonds, or, selected from fragments split off from good stones in their manufacture for jewelling.

For description of the diamond-mounted borers, used for rock-drilling, see Boring.

DIAPER is the name of a kind of cloth, used chiefly for table-linen. It is known among the French by the name of *Toile fourré*, and is ornamented with the most extensive figures of any kind of tweeled cloth, excepting damask. The mounting of a loom for working diaper is, in principle, much the same as a draw-loom, but the figures being less extensive, the mounting is more simple, and is wrought entirely by the weaver, without the aid of any other person. As tweeled cloths, of any number of leaves, are only interwoven at those intervals when one of the leaves is raised, the woof above and the warp below are kept floating or flushed, until the intersection takes place. Of consequence the floating yarn above appears across the fabric, and that below longitudinally. This property of tweeled cloths is applied to form the ornamental figures of all kinds of tweeled goods, merely by reversing the floating yarn when necessary. In the simpler patterns this is effected by a few additional leaves of treddles; but when the range of pattern becomes too great to render this convenient, an apparatus called a *black harness* is employed, and the cloth woven with this mounting is called diaper. Diapers are generally five-leaf tweels, that is to say, every warp floats under four threads of woof, and is raised, and of course interwoven with the fifth. This is done either successively, forming diagonals at 45° upon the cloth, or by intervals of two threads, which is called the broken tweel. The latter is generally, if not universally, adopted in the manufacture of diaper. The reason of preferring the broken to the regular tweel, where ornaments are to be formed, is very obvious. The whole depending upon reversed flushing, to give the appearance of oblique or diagonal lines through either, would destroy much of the effect, and materially injure the beauty of the fabric. The broken tweel, on the contrary, restores to the tweeled cloth a great similarity of appearance to plain or alternately interwoven fabrics, and at the same time preserves the facility of producing ornaments by reversing the flushing.

DIAPHANOUS. Transparent to light.

DIASPORE. A native hydrate of alumina, frequently found with emery and corundum. It occurs in Asia Minor; in the Grecian Archipelago; at Schemnitz, in Hungary; and in Chester Co., Pennsylvania.

DIASTASE. A white and tasteless nitrogenous substance, obtained by moistening pounded malt, and squeezing the water through a bag. Albumen is precipitated from the turbid fluid by alcohol, and filtered. Then the diastase is precipitated by an additional quantity of alcohol, and purified by re-solution and re-precipitation.

Diastase has the property of acting like a ferment on starch, and converting it into dextrine or into sugar, thus reducing the starch to a soluble form. One part of diastase will convert 2,000 parts of starch into dextrine, and 1,000 parts into sugar.

DIATHERMANOUS. Transparent to radiant heat, as rock-salt.

DICHROISCOPE. An instrument invented by Haidinger for examining the dichroism, or pleochroism, of crystals. It consists of a rhombohedron of Iceland spar, having a glass prism of 18° cemented to each end. This is enclosed in a brass tube, one end of which carries a convex lens, whilst the other end is furnished with a screen having a square aperture. On looking through this crystal two images of the aperture are seen, and if a transparent dichroic crystal be held in front of the aperture the two images appear of different tints. The dichroiscope may be used with advantage for the discrimination of certain gems. If, for example, a stone be found to give two differently-coloured images, we know at once that it cannot belong to the cubic system. Thus, Oriental ruby may be distinguished from spinel-ruby, the former being doubly refracting and dichroic, whilst the latter crystallises in the cubic system, and is therefore not dichroic. See Gems.

DICHROISM. The property of exhibiting two colours. Many of the phenomena belong to the conditions producing fluorescence. Some of the phenomena have been referred to polarisation, but this requires examination. See Fluorescence.

DICHROITE. A mineral otherwise known as *Iolite* or *Cordierite.* It is called *Dichroite* in allusion to its marked dichroism, or decided difference of colour observable in its crystals when viewed in different directions. Chemically, it is a silicate of alumina, magnesia, and protoxide of iron.

DIDYMIUM. One of the rarer metals. It is found in connection with *Lanthanum* and *Cerium.*

Solutions of salts of didymium give a characteristic absorption-spectrum containing two black lines enclosing a very bright space. Mr. Greville Williams has detected didymium in churchite by means of spectrum analysis, and has called attention to the presence of this metal in some varieties of apatite.

DIE-EARTH. A local term—used in Coalbrookdale for the Wenlock Shale—because it lies below all the mining ground.

DIES FOR STAMPING. (*Coins,* Fr.; *Münzstämpeln,* Ger.) The first circumstance that claims particular attention in the manufacture of dies is the selection of the best kind of steel for the purpose, and this must in some measure be left to the experience of the die-forger, who, if well skilled in his art, will be able to form a tolerably correct judgment of the fitness of the metal for the purpose, by the manner in which it works upon the anvil. It should be rather fine-grained than otherwise, and above all things perfectly even and uniform in its texture, and free from spots and patches finer or coarser than the general mass. But the very fine and uniform steel with a silky fracture, which is so much esteemed for some of the purposes of cutlery, is unfit for our present purpose, from the extreme facility with which it acquires great hardness by pressure, and its liability to cracks and flaws. The very cross-grained, or highly crystalline steel, is also equally objectionable; it acquires fissures under the die-press, and seldom admits of being equally and properly hardened. The object, therefore, is to select a steel of a medium quality as to fineness of texture, not easily acted upon by dilute sulphuric acid, and exhibiting an uniform texture when its surface is washed over with a little aquafortis, by which its freedom from pins of iron, and other irregularities of composition, is sufficiently indicated.

The best kind of steel being thus selected, and properly forged at a high heat into the rough die, it is softened by very careful annealing, and in that state, having been smoothed externally, and brought to a table in the turning lathe, it is delivered to the engraver.

The process of annealing the die consists in heating it to a bright cherry red, and suffering it to cool gradually, which is best effected by bedding it in a crucible or iron pot of coarsely-powdered charcoal. In this operation it is sometimes supposed that the die, or at least its superficial part, becomes super-carbonised or highly-converted steel, as it is sometimes called; but experience does not justify such an opinion, and probably the composition of the die is scarcely, certainly not materially, affected by the process, for it does not remain long enough in the fire for the purpose.

The engraver usually commences his labours by working out the device with small steel tools *in intaglio*; he rarely begins in relief (though this is sometimes done); and having ultimately completed his design, and satisfied himself of its general effect and correctness, by impressions in clay, and dabs, or casts in type-metal, the die is ready for the important operation of hardening, which, from various causes, a few of which will be enumerated, is a process of much risk and difficulty; for should any accident now occur, the labour of many months may be seriously injured, or even rendered quite useless.

The process of hardening soft steel is in itself very simple, though not very easily explained upon mechanical or chemical principles. We know by experience that it is a property of this highly valuable substance to become excessively hard, if heated and suddenly cooled; if, therefore, we heat a bar of soft malleable and ductile steel red hot, and then suddenly quench it in a large quantity of cold water, it not only becomes hard, but fragile and brittle. But as a die is a mass of steel of considerable dimensions, this hardening is an operation attended by many and peculiar difficulties, more especially as we have at the same time to attend to the careful preservation of the engraving. This is effected by covering the engraved face of the die with a protecting face, composed of fixed oil of any kind, thickened with animal charcoal: some persons add pipe-clay, others use a pulp of garlic, but pure lamp-black and linseed-oil answer the purpose perfectly. This is thinly spread upon the work of the die, which, if requisite, may be further defended by an iron ring; the die is then placed with its face downwards in a crucible, and completely surrounded by animal charcoal. It is heated to a suitable temperature, that is, about cherry red, and in that state is taken out with proper tongs, and plunged into a body of cold water, of such magnitude as not to become materially increased in temperature; here it is rapidly moved about, until all noise ceases, and then left in the water till quite cool. In this process it should produce a bubbling and hissing noise; if it pipes and sings, we may generally apprehend a crack or fissure.

No process has been found to answer better than the above simple and common mode of hardening dies, though others have had repeated and fair trials. It has been proposed to keep up currents and eddies of cold water in the hardening cistern, by means of delivery-pipes coming from a height; and to subject the hot die, with its face uppermost, to a sudden and copious current of water, let fall upon it from a large pipe, supplied from a high reservoir; but these means have not in any way proved more successful, either in saving the die, or in giving it any good qualities. It will be recollected, from the form of the die, that it is necessarily only, as it were, case-hardened, the hardest strata being outside, and the softer ones within, which envelope a core, something in the manner of the successive coats of an onion; an arrangement which we sometimes have an opportunity of seeing displayed in dies which have been smashed by a violent blow.

The hardening having been effected, and the die being for the time safe, some further steps may be taken for its protection; one of these consists in a very mild kind of tempering, produced by putting it into water, gradually raised to the boiling point, till heated throughout, and then suffering it gradually to cool. This operation renders the die less apt to crack in very cold weather. A great safeguard is also obtained by thrusting the cold die into a red-hot iron ring, which just fits it in that state, and which, by contracting as it cools, keeps its parts together under considerable pressure, preventing the spreading of external cracks and fissures, and often enabling us to employ a split or die for obtaining punches, which would break to pieces without the protecting ring.

If the die has been successfully hardened, and the protecting paste has done its duty by preserving the face from all injury and oxidisement, or burning, as it is usually called, it is now to be cleaned and polished, and in this state constitutes what is technically called a *matrix*; it may of course be used as a multiplier of medals, coins, or impressions, but it is not generally thus employed, for fear of accidents happening to it in the coining press, and because the artist has seldom perfected his work upon it in this state. It is therefore resorted to for the purpose of furnishing a *punch*, or steel impression for relief. For this purpose a proper block of steel is selected, of the same quality, and with the same precautions as before, and being carefully annealed, or softened, is turned like the matrix, perfectly true and flat at the bottom, and obtusely conical at top. In this state, its conical surface is carefully compressed by powerful and proper machinery upon the matrix, which, being very hard, soon allows it to receive the commencement of an impression; but in thus receiving the impression, it becomes itself so hard by condensation of texture as to require during the operation to be repeatedly annealed, or softened, otherwise it would split into small superficial fissures, or would injure the matrix; much practical skill is therefore required in taking the impression, and the punch, at each annealing, must be carefully protected, so that the work may not be injured.

Thus, after repeated blows in the die-press, and frequent annealing, the impression from the matrix is at length perfected, or brought completely up, and having been retouched by the engraver, is turned, hardened, and collared, like the matrix, of which it is now a complete impression in relief, and, as we have before said, is called a punch.

This punch becomes an inexhaustible parent of dies, without further reference to the original matrix; for now by impressing upon it plugs of soft steel, and by pursuing with them an exactly similar operation to that by which the punch itself was obtained, we procure impressions from it to any amount, which, of course are fac-similes of the matrix, and these dies being turned, hardened, polished, and, if necessary, tempered, are employed for the purposes of coinage.

The distinction between striking medals and common coin is very essential, and the work upon the dies is accordingly adjusted to each. Medals are usually in very high relief, and the effect is produced by a succession of blows; and as the metal in which they are struck, be it gold, silver, or copper, acquires considerable hardness at each stroke of the press, they are repeatedly annealed during the process of bringing them up. In a beautiful medal, which Mr. Wyon executed for the Royal Naval College, the obverse represents the head of the King, in very bold relief; it required thirty blows of a very powerful press to complete the impression, and it was necessary to anneal each medal after every third blow, so that they went ten times into the fire for that purpose. In striking a coin or medal, the lateral spread of the metal, which otherwise would ooze out as it were from between the dies, is prevented by the application of a steel collar, accurately turned to the dimensions of the dies, and which, when left plain, gives to the edge of the piece a finished and polished appearance; it is sometimes grooved, or milled, or otherwise ornamented, and occasionally lettered, in which case it is made in three separate and moveable pieces, confined by a ring, into which they are most accurately fitted, and so adjusted that the metal may be forced into the letters by its lateral spread, at the same time that the coin receives the blow of the screw-press.

Coins are generally completed by one blow of the coining-press. These presses are worked in the Royal Mint by machinery, so contrived that they shall strike, upon an average, sixty blows in a minute; the blank piece, previously properly prepared and annealed, being placed between the dies by part of the same mechanism.

The number of pieces which may be struck by a pair of dies of good steel, properly hardened and duly tempered, not unfrequently amounts at the Mint to between one and two hundred thousand; but the average consumption of dies is of course much greater, owing to the variable qualities of steel, and to the casualties to which the dies are liable; thus, the upper and lower die are sometimes struck together, owing to an error in the layer-on, or in that part of the machinery which ought to put the blank into its place, but which now and then fails so to do. This accident very commonly arises from the boy who superintends the press neglecting to feed the hopper of the layer-on with blank pieces. If a die is too hard, it is apt to break or split, and is especially subject to fissures, which run from letter to letter upon the edge. If too soft, it swells, and the collar will not rise and fall upon it, or it sinks in the centre, and the work becomes distorted and faulty. He, therefore, who supplies the dies for an extensive coinage, has many accidents and difficulties to encounter. There are eight presses at the Mint, frequently at work for ten hours each day, and the destruction of eight pair of dies per day (one pair for each press) may be considered a fair average result, though they much more frequently fall short of, than exceed this proportion. It must be remembered, that each press produces 3,600 pieces per hour; but making allowance for occasional stoppages, we may reckon the daily produce of each press at 30,000 pieces; the eight presses, therefore, will furnish a diurnal average of 240,000 pieces.

DIES, hardening of. See STEEL, HARDENING OF.

DIFFUSION. As the principles of diffusion are sometimes involved in processes of manufacture, a short notice of the phenomena appears to properly find its place in this Dictonary. To no one do we owe so much for elucidating this subject as to the late Prof. Graham, and from his 'Elements of Chemistry' the following notices have been selected. When light and heavy gases are mixed together, they do not exhibit any tendency to separate again on standing at rest, differing in this respect from mixed liquids, many of which speedily separate and arrange themselves according to their densities, the lightest uppermost, the heaviest undermost, as in the familiar example of oil and water, unless they have combined together. This peculiar property of gases has repeatedly been made the subject of careful experiment. Common air, for instance, is essentially a mixture of two gases, differing in weight in the proportion of 971 to 1,105; but the air in a tall close tube of glass, several feet in length, kept upright in a still place, has been found sensibly the same in composition at the top and bottom of the tube after a lapse of months. Hence, there is no reason to imagine that the upper stratum of air differs in composition from the lower, or that a light gas, such as hydrogen, escaping into the atmosphere, will rise and ultimately possess the higher regions; suppositions which have been the groundwork of meteorological theories at different times.

The earliest observations we possess on this subject are those of Dr. Priestley, to whom pneumatic chemistry stands so much indebted. Having repeated occasion to transmit a gas through stoneware tubes, surrounded by burning fuel, he perceived that the tubes were porous, and that gas escaped outwards into the fire, while, at the same time, the gases of the fire penetrated into the tube, although the gas within the tube was in a compressed state.

'In entering upon this inquiry, I found, first: that gases diffuse into the atmosphere, and into each other, with different degrees of ease and rapidity. This was observed by allowing each gas to diffuse from a bottle into the air through a narrow tube, taking care, when the gas was lighter than the air, that it was allowed to escape from the lower part of the vessel, and when heavier from the upper, so that it had on no occasion any disposition to flow out, but was constrained to diffuse in opposition to the effect of gravity. The result was, that the same volume of different gases escapes in times which are exceedingly unequal, but have a relation to the specific gravity of the gas. The light gases diffuse or escape most rapidly; thus, hydrogen escapes five times quicker than carbonic acid, which is twenty-two times heavier than that gas. Secondly, in an intimate mixture of two gases, the most diffusive gas separates from the other, and leaves in the receiver the greater proportion. Hence, by availing ourselves of the tendency of mixed gases to diffuse with different degrees of rapidity, a sort of mechanical separation of gases may be effected. The mixture must be allowed to diffuse for a certain time into a confined gaseous or vaporous atmosphere, of such a kind as may be afterwards condensed or absorbed with facility.

'But the nature of the process of diffusion is best illustrated when the gases communicate with each other through minute pores or apertures of insensible magnitude.

'A singular observation belonging to this subject was made by Professor Döbereiner, of Jena, on the escape of hydrogen gas by a fissure or crack in glass receivers. Having occasion to collect large quantities of that light gas, he had accidentally made use of a jar with a slight fissure in it. He was surprised that the water in the pneumatic trough rose into this jar one and a half inches in twelve hours; and that after twenty-four hours the height of the water was two inches two-thirds above the level of that in the trough. During the experiment, neither the height of the barometer nor the temperature of the place had sensibly altered. He ascribed the phenomenon to capillary action, and supposed that hydrogen only is attracted by the fissures, and escapes through them on account of the extreme smallness of its atoms. It is unnecessary to examine this explanation, as Döbereiner did not observe the whole phenomenon. On repeating the experiment, and varying the circumstances, it appeared to me that hydrogen never escapes outwards by the fissure without a certain portion of air penetrating at the same time inwards, amounting to between one-fourth and one-fifth of the volume of the hydrogen which leaves the receiver. It was found, by an instrument which admits of much greater precision than a fissured jar, that when hydrogen gas communicates with the air through such a chink, the air and hydrogen exhibit a powerful disposition to exchange places with each other; a particle of air, however. does not exchange with a particle of hydrogen of the same magnitude, but of 3·83 times its magnitude. We may adopt the word *diffusion-volume* to express this diversity of disposition in gases to interchange particles, and say that the diffusion-volume of air being 1, that of hydrogen gas is 3·83. Now, every gas has a diffusion-volume peculiar to itself, and depending upon its specific gravity. Of those gases which are lighter than air, the diffusion-volume is greater than 1; and of those which are heavier, the diffusion-volume is less than 1. The diffusion-volumes are, indeed, inversely as the square root of the densities of the gases. Hence, the times of the effusion and diffusion of gases follow the same law.' See Watts's 'Dictionary of Chemistry;' Graham's 'Elements of Chemistry;' and papers in 'Philosophical Transactions of the Royal Society.'

DIGESTER is the name of a kettle or pot of small dimensions, made very strong, and mounted with a safety valve in its top. Papin, the contriver of this apparatus, used it for subjecting bones, cartilage, &c., to the solvent action of high-pressure steam, or highly-heated water, whereby he proposed to facilitate their digestion in the stomach. This contrivance is the origin of the French cookery pans, called *autoclaves*, because the lid is self-keyed, or becomes steam-tight by turning it round under clamps or ears at the sides, having been previously ground with emery to fit the edge of the pot exactly. In some autoclaves the lid is merely laid on with a fillet of linen as a lute, and then secured in its place by means of a screw bearing down upon its centre from an arch bar above. The safety valve is loaded either by a weight placed vertically upon it, or by a lever of the second kind pressing near its fulcrum, and acted upon by a weight which may be made to bear upon any point of its graduated arm.

Chevreul made a useful application of the digester to vegetable analysis. His instrument consists of a strong copper cylinder, into which enters a tight cylinder of silver, having its edge turned over at right angles to the axis of the cylinder, so as to form the rim of the digester. A segment of a copper sphere, also lined with silver, stops the aperture of the silver cylinder, being applied closely to its rim. It has a conical valve pressed with a spiral spring, of any desired force, estimated by a steelyard. This spring is enclosed within a brass box, perforated with four holes, which may be screwed into a tapped orifice in the top of the digester. A tube screwed into another hole serves to conduct away the condensible vapours at pleasure into a Woulfe's apparatus.

DIKA-BREAD. A food made from the fruit of the *Mangifera Gabonensis*, a tree indigenous to the country from Sierra Leone to the Gaboon. It is one of the *Anacardiaceæ*. White almond kernels are found in the fruit; these are bruised and pressed to form the Dika-bread.

DIKE. See Dyke.

DILATATION. The increase of size produced in bodies by the agency of heat. See Expansion.

DILL. The *Anethum graveolens*, an umbelliferous plant, containing an essential oil.

DILLNITE. A hydrous silicate of alumina, occurring with diaspore at Dilln, near Schemnitz, in Hungary.

DILUVIUM. Those accumulations of gravel and loose materials, which, by some geologists, are said to have been produced by the action of a diluvian wave or deluge sweeping over the surface of the earth.—*Lyell.*

The term was formerly applied to the superficial deposits, now commonly called 'drift,' and was used to distinguish them from the still more recent accumulations known as *alluvium.*

DIMITY is a kind of cotton cloth originally imported from India, and now manufactured in great quantities in various parts of Britain, especially in Lancashire. Dr. Johnson calls it *dimmity*, and describes it as a kind of fustian. The distinction between fustian and dimity seems to be, that the former designates a common tweeled cotton cloth of a stout fabric, which receives no ornament in the loom, but is most frequently dyed after being woven, Dimity is also a stout cotton cloth, but not usually of so thick a texture; and is ornamented in the loom, either with raised stripes or fancy figures: it is seldom dyed, but usually employed white, as for bed and bed-room furniture. The striped dimities are the most common; they require less labour in weaving than the others; and the mounting of the loom being more simple, and consequently less expensive, they can be sold at much lower rates.

DIMORPHISM. (*dis*, two; *morphe*, form.) This name is applied to bodies which will crystallise in two forms. Sulphur, for example, will usually crystallise in the rhombic system; but will when melted under certain conditions form monoclinohedric crystals. Carbon appears in nature as the diamond and graphite, and carbonate of lime as calc-spar and aragonite. Many chemical compounds of the same compositions are susceptible of crystallisation in two essentially distinct forms.

In Biology, the tendency of some organisms to exhibit two distinct forms in their essential organs is called dimorphism. Thus Mr. Darwin has shown that some species of *Primula* are dimorphic, one form having a long style and short stamens, and the other form having a short style and long stamens. A check is thus given to self-fertilisation; perfect fertilisation occurring only when the two dimorphic forms are crossed, the pollen of the short-stamened variety being applied to the stigma of the short-styled form, and conversely the pollen of the long-stamened variety to the stigma of the long-styled form.

DIMORPHITE. A sulphide of arsenic, containing As^2S^3 ($\mathbf{As^4S^3}$). It occurs at the Solfatara, near Naples.

DINAS BRICKS. Fire-bricks made of Dinas sand, and much used in the construction of the copper-smelting furnaces of South Wales. The rock known as 'Dinas sand' is found in the Vale of Neath in Glamorganshire, and consists almost wholly of silica. Having been ground, the material is mixed with water, with addition of about one per cent. of lime, and is pressed into the shape of bricks, which are then fired. The granules of quartz are cemented together by a slightly-fusible compound formed by the action of the lime.

DIOPSIDE. A name applied to a clear green crystalline variety of pyroxene or augite. It has occasionally been cut as a gem-stone, but is too soft to be of much value.

DIOPTASE, or *Emerald Copper*, occurs in fine emerald green transparent crystals. It is a silicate of protoxide of copper, and is found in veins in limestone in the Kirghis Steppes. See Copper.

DIOPTRIC LIGHTHOUSES. See Lighthouses.

DIORITE. An igneous rock composed of a crystalline-granular mixture of a triclinic felspar and hornblende. It is often so fine-grained in texture that it is difficult to determine the component minerals. Diorite generally presents a dark green colour, and is one of the rocks commonly included under the general name of 'greenstone.'

DIP. When any stratum, mineral vein, or dyke, does not lie horizontally it is said to dip E. W. N. or S., as the case may be. The angle which it makes with the horizon is called the angle of the dip.

DIPPEL'S ANIMAL OIL. A fetid volatile oil obtained when animal substances, such as bone, are subjected to distillation. That which is found in commerce is obtained in the manufacture of bone-black.

DIPPING. Ornamental works in brass are usually brightened by a process called *dipping*. After the work has been properly fitted together and the grease removed, either by the action of heat, or by boiling in a pearlash-lye, it is *pickled* in a bath of dilute aqua fortis. It is then scoured bright with sand and water, and being well washed is plunged into the dipping bath, which consists of pure nitric acid, commonly known as *dipping aqua fortis*, for an instant only, and is then well washed with cold and hot water to remove every trace of acid from the surface, after which the work is put into dry beech or box wood sawdust, &c., well rubbed until it is quite dry, and then burnished and lacquered. See Dead-Dipping.

DISCRASE or **DISCRASITE.** An antimonial silver ore, of rare occurrence.

DISINFECTANT. A substance which removes the putrid or infected condition of bodies. It is well not to confound it with antiseptic, which applies to those bodies which prevent putrefaction. The word 'disinfectant' has lately become somewhat uncertain in its meaning, on account of a word being used as its equivalent, viz. deodoriser. This latter means a substance which removes odours. In reality, however, there are no such substances known to us as a class. There are, of course, some substances which destroy certain others having an odour, but in all cases the removal of the smell and the destruction or neutralisation of the vapour or gas causing the smell must be simultaneous. There is, however, a large class of substances that destroy putrefaction, and the name 'disinfectant' is therefore distinctly needed. The gases which rise from putrefying bodies are not all capable of being perceived by the senses in their ordinary condition, but sometimes they are perceived. A disinfectant puts a stop to them and deodorises simultaneously. If any substance were to remove the smell of these gases, it would remove the gases too, as they are inseparable from their property of affecting the nose. A deodoriser would therefore be, and is, a disinfectant of that gas the smell of which it removes. But it has been suggested that it may remove those gases which smell, and allow the most deleterious to pass, they having no smell. Whenever we find such a class of substances, it will be well to give them the name of 'deodorisers.' There may be some truth in the hypothesis that metallic salts remove the sulphur, and by preventing the escape of sulphuretted hydrogen cause less odour, without complete disinfection. So far as we know, however, there is a disinfecting action along with the deodorising. Any solution having the effect here supposed would at the least be a partial disinfectant, inasmuch as the decomposition would be so far put a stop to, as to prevent at least one obnoxious gas. To prevent the formation of one gas is to arrest decomposition or to alter the whole character of the change which is producing the gases. The most deleterious of emanations have no smell at all to the ordinary senses, and we can only judge of the evil by its ulterior effects, or the fact that the substances capable of producing it are near, or by the analysis of the air. The cases where sulphuretted hydrogen accompanies the offensive matter are chiefly connected with fecal decomposition. This gas is a useful indication of the presence of other substances. So far as is known, the destruction of the one causes the destruction of the other. But the presence of sulphuretted hydrogen is no proof of the presence of infectious matter, nor is its absence a proof of the absence of infectious matter, it being only an occasional accompaniment. When the infectious matter and the odoriferous matter are one, then to deodorise is to disinfect. We can find no line of duty to be performed by deodorisers, and no class of bodies that can bear the name, although there may be a few cases where the word may be found convenient. If, for example, we destroy one smell by superadding a greater, that might in one sense be deodorising. If we added an acid metallic salt, and removed the sulphuretted hydrogen, letting loose those organic vapours which for awhile accompany this act, we might, to those who were not very near, completely destroy smell, and still send a substance into the air by no means wholesome; but in such a case decomposition is stopped, at least for awhile. The word 'deodorisers' may be used for such substances as remove the odour and the putrefaction of the moment but allow them to begin again. Even in this case deodorisers become temporary disinfectants, which character all removers of smell must more or less have.

Antiseptics, or colytic agents. Substances which prevent decomposition. The words *colysis* and *colytic* come from *κωλύω, to arrest, restrain, cut short.* This word was proposed by the writer to apply to cases such as are included under antiseptics, antiferments, and similar words. There was needed a word for the general idea. A colytic force manifests itself towards living persons in anæsthetics, anodynes, and narcotics, as well probably, as in other ways. Colytics may probably act from different causes, but these causes not being separately distinguished, a name for the whole class can alone be given. The action of *colysis* is entirely opposed to *catalysis,* which is a loosening up of a compound. *Colysis* arrests *catalysis,* as well also as other processes of decomposition, ordinary oxidation for example. Disinfectants, in their character of restraining further decomposition, are included under *colytics.* One of the most remarkable substances for arresting decomposition is creosote. It has been used in some condition or mixture from the earliest times, The ancient oil of cedar has been called with good reason turpentine, which has strong disinfecting properties, but the word has evidently been used in many senses, as there are many liquids to be obtained from cedar. It is used for the first liquid from the distillation of wood; and Berzelius for that reason says that the Egyptians used the pyroligneous acid, which, containing some creosote, was a great antiseptic. But addition of this acid to soda would be of little value in embalming, nor is it probable that they would add a volatile liquid like turpentine along with caustic soda. It is expressly said (in Pliny) that pitch was reboiled, or in other words, the tar was boiled and distilled, the product being collected in the wool of fleeces, from which again it was removed by pressure. In doing this the light oils or naphtha would be evaporated, and the heavy oil of tar, containing the carbolic acid, or creosote, would remain. It was called picenum, as if made of pitch or pissenum, and pisselæum or pitch-oil, a more appropriate name than that of Runge's carbolic acid or coal-oil, and still more appropriate than the most recent, which by following up a theory, has converted it into phenic acid. The distillation was made in copper vessels, and must have been carried very far, as they obtained 'a reddish pitch, very clammy, and much fatter than other pitch.' This was the *anthracene, chrysene,* and *pyrene* of modern chemistry. The remaining hard pitch was called *palimpissa,* or second pitch, which we call pitch in contradistinction to tar. By the second pitch, however, was sometimes meant the product of distillation instead of what was left in the still. Some confusion, therefore, exists in the names, but not more than with us. The pitch oil was resinous fat, and of yellow colour, according to some. This oil, containing creosote, was used for toothache—a colytic action applied to living bodies—and for skin diseases of cattle, for which it is found valuable. They also used it for preserving hams.—*Disinfectants, by the Writer. Jour. Soc. of Arts,* 1857, *and separate volume* 1869.

It is quite possible that creosote may be the chief agent in most empyreumatic substances which act as antiseptics. But it is not the only agent. Hydrocarbons of various kinds act as antiseptics, as well as alcohol and methylic alcohol, which contain little oxygen. To this class belong essential oils and substances termed perfumes, which are used for fumigation, and have also a colytic action. It is exceedingly probable that the true theory of this action is connected with the want of oxygen. These substances do not rapidly oxidise, but, on the contrary, only very slowly, and that chiefly by the aid of other bodies. Their atoms are, therefore, in a state of tension, ready to unite when assisted. As an example, carbolic acid and creosote unite with oxygen when a base is present, and form rosolic acid. We can scarcely suppose that an explanation, commonly resorted to by some to explain the action of sulphurous acid, would suit them; viz., that it takes up the oxygen, and so keeps it from the putrescible substance. It is supposible that the molecular condition acts on the putrescible body. For, as the state of motion of a putrefying substance is transferred to another, so may the state of immobility.

In 1750 Sir John Pringle wrote his 'Experiments on Septic and Antiseptic Substances, with remarks relating to their Use in the Theory of Medicine.' He recommended salts of various kinds, and astringent and gummy parts of vegetables and fermenting liquors. Dr. Macbride followed him with numerous experiments. He speaks of acids being the long-prescribed agents as antiseptics. He found them antiseptic even when diluted to a great extent. Alkalis also he found antiseptic, and salts in general. Also 'gum-resins, such as myrrh, assafœtida, aloes, and terra japonica,' besides 'decoctions of Virginia snake-root, pepper, ginger, saffron, contrayerva root, sage, valerian root, and rhubarb, with mint, angelica, senna, and common wormwood.' Many of the common vegetables also were included as to some extent antiseptic; such as horse-radish, mustard, carrots, turnips, garlic, onions, celery, cabbage, colewort. Lime was found to prevent, but not to remove putrefaction. We are inclined at present very much to qualify some of these observations. Animal fluids, he observes, will remain for a long time without putridity if kept from the air. He says that astringent mineral acids and ardent spirits 'not only absorb the matter from the putrescent substances, but likewise crisp up its fibres, and thereby render it so hard and durable that no change of combination will take place for many years.' He adds also molasses to the antiseptics. In 1767 the Academy of Dijon gave a prize for the use of nitrate of potash in ventilation, driving off the oxygen by heat. This may have given the first idea to Carmichael Smyth using the nitrous fumes. Guyton-Morveau came later with a volume of valuable experiments on acids chiefly muriatic.

An *antiseptic* preserves from putrefaction, but does not necessarily remove the odour caused by that which has previously putrefied. Many of the substances described as disinfectants here might equally be called antiseptics. When they remove the putrid matter, they are disinfectants; when they prevent decomposition, they are antiseptics. But when the smell is removed by a substance which is known to destroy putrefactive decomposition, and to preserve organic matter entire, then we have the most thorough disinfection; then we know that the removal of the smell is merely an indication of the removal of the evil.

Disinfectants are of various kinds. Nature seems to use soil as one of the most active. All the dejecta of the animals on the surface of the earth fall on the soil, and are rapidly made perfectly innoxious. Absorption distinguishes porous bodies, and the soil has peculiar facilities for the purpose. But if saturated, it could disinfect no longer. This is not allowed to occur; the soil absorbs air also, and oxidises the organic matter which it has received into its pores, and the offensive matter is either converted into food for plants and absorbed by them, or is made an innocent ingredient of the air, or, if the weather be moist, of the water. The air is, therefore, in conjunction with the soil, one of the greatest disinfectants, but it acts also quite alone and independent of the soil. Its power of oxidising must be very great. The amount of organic effluvium sent into large towns is remarkable, and yet it seldom accumulates so as to be strongly perceptible to the senses. The air begins to oxidise it almost as rapidly as it rises; this is hastened apparently by the peculiar agent in the air, ozone, which has a greater capacity of oxidation than the common air; when this is exhausted, it is highly probable that the oxidisation will be much slower, and this exhaustion does take place in a very short time in our large and smoky towns. So rapid is the oxidation, that the wind, even blowing at the rate of fifteen to twenty miles an hour, is entirely deprived of its ozone by passing over less than a mile of Manchester. In London this does not take place so rapidly, at least near the Thames. But when the ozone is removed, it is probable that the rate of increase of the organic matter will be much greater. We may by this means, then, readily gauge the condition of a town up to a certain point by the removal of the ozone: but it requires another agent to gauge it afterwards or thoroughly.

It is in connection with each other that the air and the soil best disinfect. When manure is thrown upon land without mixing with the soil, it may require a very long period to obtain thorough disinfection, but when the atmosphere is moist, or rain falls, then the air is rapidly transferred into every portion of the porous earth, and the organic matter becomes rapidly oxidised. To prevent a smell of manure, and with it also the loss of ammonia, it is then needful that as soon as possible the manure should be mixed with the soil. The same power of oxidation is common to all porous bodies, to charcoal, and especially, as Dr. Stenhouse has shown, to platinised charcoal. Disinfection by the use of porous bodies is at first a process of preservation, but soon it may change to that of slow destruction. It has been shown by the last-mentioned chemist that charcoal produces an oxidation in which all the escaping gases are so thoroughly oxidised, that none of them have any smell or any offensive property. But being so, the body disinfected must necessarily decay, and in reality the process of decay is remarkably increased. All such bodies must therefore be avoided when manures are to be disinfected, and when they are not to be put on the land immediately. Stenhouse has employed charcoal for disinfecting the air. The air is passed through the charcoal either on a large scale for a hospital or on a small scale as a respirator for the mouth. Care must be taken, however, to keep the charcoal dry: wet charcoal is not capable of absorbing air until that air is dissolved in the water. This absorption takes places less rapidly in water. Wet charcoal is therefore a filter for fluids chiefly, and dry charcoal for vapours. Its destructive action on manures will, however, always prevent charcoal from being much used as a disinfectant for such purposes, or, indeed, any other substance which acts principally by its porosity or by oxidation. This the soil does only partially, as it has another power, viz. that of retaining organic substances fit to be the food of plants. Although air acts partly in conjunction with the soil and the rain to cause disinfection, and partly by its own power, it also acts mechanically as a means of removing all noxious vapours. The wind and other currents of the air are continually ventilating the ground, and when these movements are not sufficiently rapid, or when they are interrupted by our mode of building, we are compelled to cause them artificially, and thus we arrive at the art of ventilation. The addition of one-tenth per cent. of carbonic acid to the air may be perceived, at least if accompanied with the amount of organic matter usually given out at the same time in the breath, and as we exhale in a day 12–16 cubic feet of that gas, we can injure the quality of 16,000 cubic feet of air in that time. The great value of a constant change of air is therefore readily proved, and the instinctive love which we have of fresh air is a sufficient corroboration.

Cold is a great natural disinfectant. The flesh of animals may be preserved as far as we know for thousands of years in ice; putrefying emanations are completely arrested by freezing, but the mobility of the particles, or chemical action, is also retarded by a degree of cold much less than freezing, and beginning at 54° Fahr.

Heat is also a disinfectant, when it rises to about 140° of Fahrenheit, according to Dr. Henry. But as a means of producing dryness it is a disinfectant at various temperatures. Nothing which is perfectly dry can undergo putrefaction. On the other hand heat with moisture below 140° is a condition very highly productive of decomposition and all its resulting evils. Disinfection by heat is used at quarantine stations. Light is undoubtedly a great disinfectant; so far as we know, it acts by hastening chemical decomposition. In all cases of ventilation, it is essential to allow the rays of light to enter as well as the currents of air. Its effect on the vitality of the human being is abundantly proved, and is continually asserting itself in vegetation. The true disinfecting property of light exists in all probability in the chemical rays which cause compositions and decompositions. Water is scarcely to be called a disinfectant itself except indirectly, for it increases putrefaction, but as a mechanical agent of purity the most remarkable, and there is no other capable of taking its place actively. Wherever animals, even human beings, live, there are emanations of organic matter, even from the purest. The whole surface of the house, furniture, floor, and walls, becomes coated by degrees with a thin covering, and this gradually decomposes, and gives off unpleasant vapours. Sometimes it becomes planted with fungi, and so feeds plants of this kind. But long before this occurs a small amount of vapour is given off sufficiently disagreeable to affect the senses, and sometimes affecting the spirits and the health before the senses distinctly perceive it. This must be removed. In most cases this film is removed by water, and we have the ordinary result of household cleanliness; but in other cases when the furniture is such as will be injured by water, the removal is made by friction or by oil or turpentine, and other substances used to polish. Water as a disinfectant is used also in washing of clothes; for this purpose nothing whatever can supply its place, although it requires the assistance both of soap and friction, or agitation and heat. Water is also used as a mechanical agent for removing filth generally, and the method which Hercules devised of using a river to wash away filth is now adopted in all the most advanced plans of cleansing towns. It is only by means of water that the refuse of towns can be conveyed away in covered and impervious passages, whilst none whatever is allowed to remain in the town itself. In cases where this cannot be done, it is much to be desired that some disinfecting agent should be used to prevent decomposition. Where water is not used, as in water-closets, there is generally a great amount of matter stored up in middens, and the town is of course continually exposed to the effluvia. Beside these methods of acting, water disinfects partly by preventing effluvia from arising from bodies, simply because it keeps them in solution. This action is not a perfect one, but one of great value. The water gives off the impurity slowly, sometimes so slowly as to be of no injury, or it keeps it so long that complete oxidation takes place. The oxygen for this purpose is supplied by the air, which the water absorbs without ceasing. To act in this way, water must be delivered in abundance. Bodies decompose rapidly under water, and it acts also as a great opponent to disinfection by rising up in vapour loaded with the products of decomposition.

Mere drying is known to arrest decay, as the mobility of the particles in decomposition is stayed by the want of water. We are told in Andersson's Travels in S. Africa, that the Damaras cut their meat into strips, and dry it in the sun, by which means it is preserved fresh. A similar custom is found in S. America. Certain days prevent this, and decomposition sets in rapidly. A little overclouding of the sky, or a little more moisture in the air, quickly stops the process.

The above may be called natural disinfectants, or imitations of natural processes, charcoal being introduced as an example of a more decided character of porous action.

They show both mechanical and chemical action. The mechanical, when water or air removes, dilutes, or covers the septic bodies: the chemical, when porous bodies act as conveyers of oxygen: or an union of both, when cold and heat prevent the mobility of the particles. The action by oxidation causes a destruction of the offensive material. The other method is antiseptic. It is much to be desired that all impurities should be got rid of by some of these methods, but especially by the air, the water, and the soil. There are, however, conditions in which difficulties interfere with the action. Large towns may be purified by water, but what is to be done with the water which contains all the impurity? If put upon land, capable of absorbing it, it is very soon disinfected, but on its way to the land it may do much mischief. It has been proposed to disinfect it on its passage, and even in the sewers themselves; by this means the town itself is freed from the nuisance, and the water may be used where it is needed without fear. This introduces artificial disinfectants. There are other cases where such are required; when the refuse matter of a town is allowed to lie either in exposed or in underground receptacles; in this case a town is exposed to an immense surface of impurity, and disinfectants would greatly diminish the evil, if not entirely remove it. There are besides, special cases without end continually occurring, where impurities cannot be at once removed, and where treatment with artificial disinfectants is required.

Artificial disinfectants which destroy the compound are of various kinds. *Heat* is one of the most powerful. A putrid body, when heated so as to be deprived of all volatile particles, cannot any longer decompose. It is however possible that the vapours may become putrid, and if not carefully treated, this will happen. It was the custom of some of the wealthy among the ancients to burn the dead, and it is still the custom in India; but although the form is kept up amongst all classes, the expense is too great for the poor. The bodies are singed, or even less touched by fire, and thrown if possible into the river. This process has been recommended here, but the quality of the gaseous matter rising from a dead body is most disgusting to our physical, and still more to our moral senses, and the amount is enormous. It is of course possible so to burn it, that only pure carbonic acid, water, and nitrogen, shall escape, but the probability of preventing all escape is small enough to be deemed an impossibility, and the escape of one per cent. would cause a rising of the whole neighbourhood. To effect the combustion of the dead of a great city, such a large work, furnished with great and powerful furnaces, would be required, that it would add one of the most frightful blots to modern civilisation, instead of the calm and peaceful churchyard where our bones are preserved as long at least as those who care for us live, and then gradually return to the earth. In burning the dead some prefer to burn the whole body to pure ash. This was the ancient method; but it is highly probable that the ashes which they obtained were a delusion in most cases. The amount of ash found in the urns is often extremely small. The body cannot be reduced to an infinitesimal ash, as is supposed; eight to twelve pounds of matter remain from an average man when all is over. A second plan, is to drive off all volatile matter, and leave a cinder. This disgusting plan leaves the body black and incorruptible. It can never, in any time known to us, mix with its mother earth, and yet it ceases at once to resemble humanity in the slightest degree; it will not even for a long time assist us by adding its composition to the fertility of the soil. The burning of bodies never could have been general, and never can be general. Fire has only a limited use as a disinfectant. It cannot at present be economically used in the daily disinfection of the dejecta of animals, and is applied only occasionally, where the most rapid destruction is the most desirable, either because the substance has no value, or it is too disgusting to exist, or the products after burning are not offensive. There are two methods of using fire, charring or burning to ashes. The second is an act of—

Oxidation.—This is effected either by rapid combustion called fire; by slow combustion, the natural action of the air; or by chemical agency, assisted by mechanical, as in porous bodies. Slow oxidation in the soil is a process which is desirable for most offensive matters, and it would be well if we could bring it all into this condition; the ammonia is preserved, or it is in part oxidised into nitric acid and water, both the ammonia and nitric acid being food for plants. Sometimes this process is hastened by mixing up the manure with alkaline substances, raising it in heaps, and watering, by this means forming nitrates, a process performed abundantly in warm countries upon the materials of plants and animals, and imitated even in temperate regions with success. This amount of oxidation destroys a good deal of the carbonaceous substances, and leaves less for the land. It is only valuable when saltpetre is to be prepared.

One of the most thorough methods of oxidation, is by the use of the manganates or permanganates. They transfer their oxygen to organic substances with great rapidity, and completely destroy them. They are therefore complete disinfectants. They destroy the odour of putrid matter rapidly, and oxidise sulphuretted hydrogen, and phosphuretted hydrogen, as well as many purely organic substances having offensive smells. As they do this by oxidation at a low temperature, they are the mildest form of the destructive disinfectants, and their application to putrid liquids of every kind gives most satisfactory results. The quantities treated at a time should not be great, and the amount of material used must be only to the point of stopping the smell, or at least not much more, because both pure and impure matter act on the manganates, and an enormous amount of the material may be used in destroying that which is not all offensive. The manganates do not prevent decay from beginning again. Their use has been patented by Mr. Condy. A similar action takes place with various high oxides and other oxides which are not high. Sometimes, however, a deleterious gas is produced as a secondary result by oxidation, as when sulphuric acid in the sulphates oxidises organic matter, allowing sulphuretted hydrogen to escape. In this case it is highly probable that a true disinfection takes place, or a destruction of the putrid substance, and all offensive purely organic substances; still the amount of sulphuretted hydrogen given off is of itself sufficiently offensive and deleterious, but not properly speaking an infectious or putrid gas, although an occasional accompaniment.

Nitric acid is another agent of destruction or oxidation, although it has qualities which might cause it to be ranked amongst those which prevent the decomposition by entering into new combinations. But properly speaking, it is not nitric acid which is the disinfectant of Carmichael Smyth, but nitric oxide, which is a powerful oxidiser, and most rapidly destroys organic matter. For very bad cases, in which gaseous fumigation is applicable, nothing can be more rapid and effective in its action than this gas. Care must be taken that there is no one present to breathe it, as it has a powerful action on the lungs, killing without due warning, and care must be taken that metallic surfaces which are to be preserved clean, be well covered with a coating of varnish. This was used with great effect in ships and hospitals for some years, beginning with 1780, and so much good did it do, that the Parliament in 1802 voted Dr. C. Smyth a pension for it. Guyton-Morveau was vexed at this, and wrote an interesting volume concerning his mode of fumigating by acids; but in reality acids alone are insufficient, and his favourite muriatic acid has no such effect as nitrous fumes, which so readily part with their oxygen. On the whole, nitrous fumes are too dangerous for general use.

Chlorine is another destructive agent, and its peculiar action may be called an oxidation. When used as a gas, it has a great power of penetration, like nitrous fumes, and stops all putrefaction. It has a more actively destructive power than oxygen alone, even when its action is that of oxidation only. It decomposes compounds of ammonia and organic substances containing nitrogen into water and nitrogen, and as putrefactive matter is united with, or composed partly of nitrogen, it destroys the very germ of the evil. By the same power it destroys the most expensive part of a manure, the ammonia. It cannot therefore be used where the offensive matter is to be retained for manure. When chlorine is united with lime or soda, it may be used either as a solution or a powder. This latter acts as the gaseous chlorine, but the power of destroying ammonia is greater. As a liquid, it acts too rapidly; as a solid, the chloride of lime soon attracts moisture and soon loses its power. Some people use the chloride of lime as a source of chlorine; they pour sulphuric acid on it, and so cause it to give out chlorine, which escapes as a gas, and acts as aforesaid. Too much is given out at first, too little at last. It is said to have increased the lung diseases at hospitals, where it was much used in Paris. When only a minute quantity of gas is given out, as at bleach works, it certainly causes a peculiar freshness of feeling, and the appearance of the people is much in its favour, nor has it ever there been known to affect the lungs. For violent action, in cases of great impurity, it is a great disinfectant, and to be preferred to nitrous fumes, probably causing a less powerful action on the lungs: at least, it gives good warning. Mixed with alum, without ammonia, it gives off chlorine slowly. *Eau de javelle* is a chloride of potash used in Paris. Mr. Daniel Stone uses muriatic acid with a small crystal of chlorate of potash to give out a slight chlorine vapour slowly.

Sometimes oxygen, or at least air, is used alone, to remove both colour and smell, oils having it pumped into them. Sometimes acids alone are used for disinfection. As putrid compounds contain ammonia or organic bases, they may be removed, or at least they may be retained in combination, and in this way restrained from further evaporation. This seems to be the way in which muriatic acid acts, and all other merely acid agents. This acid, so much valued at one time, is now entirely disused, as it ought to be, because it is exceedingly disagreeable to breathe, and destructive of nearly all useful substances which it touches, being at the same time a very indirect disinfectant. Acids poured on putrid matters, no doubt destroy the true putrefaction, but they cause the evolution of gases exceedingly nauseous, and of course unwholesome, This evolution does not last long, but long enough to make them useless as disinfectants when used so strong. Vinegar is the best of the purely acid disinfectants; wood vinegar the best of the vinegars, because it unites to the acidity a little creosote. Vinegar is a very old and well-established agent; it has been used in the case of the plague and various pestilences from time immemorial. It is used to preserve eatables of various kinds. For fumigation no acid vapour used is pleasant except vinegar, and in cases where the impurity is not of the most violent kind, it may be used with great advantage. Even this, however, acts on some bright surfaces, a disadvantage attending most fumigations.

Sulphurous acid, or the fumes of burning sulphur, may be treated under this head, although in reality it does not act as a mere acid combining with a base and doing no more. It certainly unites with bases so that it has the advantage of an acid, but it also decomposes by precipitating its sulphur, as when it meets sulphuretted hydrogen. It therefore acts as an oxidiser in some cases, but it is generally believed, from its desire to obtain oxygen, that it acts by being oxidised, thus showing the peculiar characteristics of a deoxidiser. We can certainly believe that bodies may be disinfected both by oxidation and deoxidation. The solutions of sulphurous acid act as a restraint on oxidation, and preserve like vinegar. Its compounds with bases, such as its salts of soda, potash, &c., preserve also like vinegar, saltpetre, &c.; probably from their affinity for oxygen, taking what comes into the liquid before the organic matter can obtain it. But it is not probable that this rivalry exists to a great extent; the presence of the sulphurous acid in all probability puts some of the particles of oxygen in the organic matter in a state of tension or inclination to combine with it, so that the tension of the particles which are inclined to combine with the oxygen of the air is removed.

Sulphur fumes are amongst the most ancient disinfectants held sacred in early times from their wonderful efficacy, and still surpassed by none. With sulphur the shepherd purified or disinfected his flocks, and with sulphur Ulysses disinfected the suitors which he had slain in his house. No acid fumigation is less injurious generally, vinegar excepted, to the lungs or furniture, and its great efficiency marks it out as the most desirable, although much laid aside in modern times. The amount arising from burning coal must have a great effect in disinfecting the putrid air of our streets, and rendering coal-burning towns in some respects less unpleasant; this is one of the advantages which that substance brings along with it, besides, it must be confessed, greater evils. It is curious that this compound of sulphur should be one of the most efficient agents in destroying sulphuretted hydrogen, another compound of sulphur. Sulphurous acid prevents decomposition, and also preserves the valuable principle of a manure, so that it belongs partly to the class of disinfectants, and partly to antiseptics.

The peculiar actions of sulphites and carbolic acid have been united in that called 'Mc Dougall's Disinfecting Powder'; where it is desirable not to use liquids, these two have been united into a powder, which assists also in removing moisture, as water is often a great cause of discomfort and disease in stables and cowhouses. When they are used in this manner the acids are united with lime and magnesia. The cattle are, it is said, freed from a great amount of illness, not only because the air of the stable is purified, but that it is dried at the same time. It does not seem well to use excess of water in our climate, and it is then that a disinfecting powder becomes so valuable, and where our towns are so badly supplied with water-closets that disinfectants are wanted for the middens.

It has been proposed to disinfect sewers, as well as sewage, by the same substances; not, however, in the state of a powder. The acids are applied to the sewage water in the sewers themselves, and so cause the impure water to pass disinfected through the town; by this means the towns and sewers are to be purified together. Besides the above-mentioned powder, there are Calvert's disinfecting powder containing carbolic acid, and Mudie's disinfecting powder with metallic salts.

Lime is used for precipitating sewage water, and acts as a disinfectant as far as the removal of the precipitate extends, and also by absorbing sulphuretted hydrogen, which, however, it allows again to pass off gradually. The other substances proposed for sewers have chiefly relation to the precipitation, and do not so readily come under this article. Charcoal has been mentioned. Alum has been proposed, and it certainly does act as a disinfectant and precipitant. None of these substances have been tried on a great scale, excepting lime, and carbolic acid or tar products, the first at Leicester, the second at Carlisle.

Absence of air is an antiseptic of great value. The process of preserving meat, called Appert's process, is by putting it in tin vessels with water, boiling off a good deal of steam, to drive out the air, and then closing the aperture with solder. Schroeder and De Dusch prevented putrefaction for months by allowing no air to approach the meat without passing through cotton; so also veils are found to be a protection against some miasmas. *Salts*, or compounds of acids with bases, are valuable antiseptics; some of them are also disinfectants, that is, they remove the state of putrefaction after it has begun. An antiseptic prevents it, but does not necessarily remove it. Common salt is well known as a preserver of flesh; nitrate of potash, or saltpetre, is a still more powerful one. Some of these salts act by removing the water. Meat, treated with these salts, gives out its moisture, and a strong solution of brine is formed. Chloride of calcium prevents, to some extent, the putrefaction of wood. Alum, or the sulphate of alumina, is not a very efficient preserver; but chloride of aluminium seems to have been found more valuable. It is sometimes injected into animals by the carotid artery and jugular vein. Meat, usually keeps a fortnight: if well packed, cleaned, and washed with a solution of chloride of aluminium, it will keep three months. This salt is sold as *chloralum*.

But in reality the salts of the heavier metals are of more activity as disinfectants. It has been supposed that their efficiency arose from their inclination to unite with sulphur and phosphorus, and there is no doubt that this is one of their valuable properties, by which they are capable of removing a large portion of the impure smell of bodies; but they have also an inclination to combine with organic substances, and by this means they prevent them from undergoing the changes to which they are most prone. The actual relative value of solutions it is not easy to tell. Most experiments have been made on solutions not sufficiently definite in quantity. Salts of mercury have been found highly antiseptic. Such a salt is used for preserving wood; the process is known as that of Kyan's, or kyanising. A solution of corrosive sublimate, containing about 1½ per cent. of the salt, is pressed into the wood either by a forcing pump or by means of a vacuum. The albumen is the substance most apt to go into putrefaction, and when in that condition it conveys the action to the wood. It is no doubt by its action on the albumen that the mercury chiefly acts. Thin pieces of pine wood, saturated for four weeks in a solution of 1 to 25 water, with the following salts, were found, after two years, to be preserved in this order:—1. Wood alone, brown and crumbling. 2. Alum, like No. 1. 3. Sulphate of manganese, like 1. 4. Chloride of zinc, like 1. 5. Nitrate of lead, somewhat firmer. 6. Sulphate of copper, less brown, firm. 7. Corrosive sublimate, reddish yellow and still firmer. In an experiment, in which linen was buried with similar salts, the linen was quite consumed, even the specimen with corrosive sublimate. Other experiments showed salts of copper and mercury to protect best.—*Gmelin*.

Nevertheless, all these metallic salts are found true preservers under other conditions. Chloride of manganese, a substance frequently thrown away, may be used, as Gay-Lussac and Mr. Young have shown, with great advantage, and Mr. Boucherie has shown the value of the acetate of iron. Mr. Boucherie's process is very peculiar. He feeds the tree, when living, with the acetate of iron, by pouring it into a trough dug around the root. The tree, when cut down, has its pores filled with the salt, and the albumen in the sap is prevented from decomposing. For preservation of vegetable and animal substances, see PUTREFACTION, PREVENTION OF.

The chloride of zinc of Sir William Burnett is also a valuable disinfectant, and has more power than it would seem to possess from the experiments quoted above. Wood, cords, and canvas have been preserved by it under water for many years. It has the advantage also of being so soluble as to take up less room than most other salts, although liquids generally are inconvenient as disinfectants in many places.

Nitrate of lead is a disinfectant of a similar kind; it lays hold of sulphur and organic compounds. All these metals are too expensive for general use, and can only be applied to the preservation of valuable materials. Even iron is expensive as a disinfectant for materials to be thrown on the fields as manure. All are apt to be very acid, a state to be avoided in a disinfectant, unless when it is applied to substances in a very dilute state, or in an active putrid state, and giving out ammonia.—R.A.S. See Dr. Angus Smith's Tables, pp. 45 to 47.

This subject is further developed by the writer in his report to the Cattle Plague Commission, 1866; and in 'Disinfectants:' Edmondston and Douglas, 1869.

The importance of this subject appears to give considerable prominence to the report made to Her Majesty's Commissioners on the Cattle Plague by Mr. Wm. Crookes, F.R.S. We therefore select the more important portions. Referring especially to the Cattle Plague, Mr. Crookes says:—

'The specific disease-producing particles must, moreover, be organised, and possess vitality; they must partake of the nature of *virus* rather than of *poison*.[1] No poison yet known to chemists can approach, even in a faint degree, the tremendous energy of the active agent of infectious diseases. A poison may be organic, but it is not organised. It may kill with far greater rapidity than the virus of infection, but,

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[1] The words *virus* and *poison* are generally regarded as synonymous. It would be more convenient, and would tend to promote accuracy of thought, were the distinction here made generally adopted.

unlike this virus, it cannot multiply itself in the animal economy to such an extent as to endow within a few hours every portion of its juices with the power of producing similar results. A virus, on the contrary, renders the liquids of an infected animal as virulent as the original germ. Strychnine may be regarded as the type of a poison, and vaccine matter as the type of a virus.

'Many considerations tend to show that the virus of cattle plague is a body similar to vaccine lymph, and consists of germinal matter, or living cells, possessing physiological individuality, which, if not exposed to extremes of heat, cold, or dryness, are capable of preserving their activity for a certain time outside the living organism, of adhering to material objects, and of being carried from one place to another by currents of air; each, when introduced into the blood, requires a certain time (known as the period of incubation) during which the septic germs develope and multiply, until they have so far poisoned the blood that the ordinary symptoms of disease become manifest.

'The blood poisoning thus set up may legitimately be called "fermentation"; it is a decomposition caused by the act of nutrition of the living cell, whereby it reproduces in incalculable numbers the specific septic germs which have given it birth. These gradually infest the blood and other animal liquids, and as the disease progresses are discharged from the skin, throat, glands, &c.; the breath, perspiration, and excreta of the animals forming vehicles for the distribution of the virus. By "living" cells, is not meant living, in the sense in which an animal, or even a low form of infusoria, lives; but living as a seed, or as vaccine matter, even when dried, may be living, inasmuch as it still possesses reproductive vitality.

'It is by no means certain that the multiplication of these individual cells is the immediate cause of the blood poisoning. The analogy of the action of virus on the blood, to that of yeast on sugar, renders it more probable that this is not the fact. In the case of the best-known ferment—yeast—its cells multiply by feeding upon the sugar in the liquid; alcohol and carbonic acid being their excretions. It is therefore probable that during the multiplication of the virus cells, they, in a similar manner, impoverish and weaken the blood, by feeding upon some element in it, whilst at the same time they excrete a poison to which the symptoms of the disease may be immediately due.'

Passing over that portion of the report which deals with the usual disinfectants which have been already dealt with by Dr. Angus Smith, the passages, which especially relate to the Tar acids are selected on account of the value of the experimental evidence they give.

'*The Tar Acids* (*Carbolic and Cresylic Acids*).—These two bodies are so commonly known under the name of acids, that I shall continue so to designate them, although by chemists they are more generally classed with the alcohols. They have great similarity, and only within the last few months have they been met with separately in commerce, having hitherto been both called carbolic acid. Creosote, (*κρέας σώζειν*, to preserve flesh), prepared from coal-tar, one of the most powerful antiseptics known, was thought to be impure carbolic acid, until 1854, when Professor Williamson and Mr. Fairlie, in an investigation of it, discovered that it was a mixture of carbolic and cresylic acids. It was then taken for granted that Reichenbach's creosote, from wood-tar, had a similar composition, until Hlasiwetz, in 1858, showed that this creosote was a different body from carbolic or cresylic acids. Finally, Dr. Hugo Müller, in 1864, discovered that true creosote, and its analogue guaiacol, belonged to a different class of bodies, and consisted of methyl-oxy-phenic and methyl-oxy-cresylic acids. No experiments on the large scale have yet been tried with true creosote, as I have only been aware within the last few weeks that this compound could be obtained in quantity.

'Pure carbolic acid is a white crystalline solid, melting at 34° C., and distilling at 180° C.; a trace of water or oily impurity renders it liquid, and for disinfecting purposes it is always supplied in this form, to avoid the extra expense and trouble needed for the separation of the last traces of impurity; cresylic acid is liquid, it boils at 203° C., and closely resembles carbolic acid in odour and other properties. Before the commencement of these inquiries it was thought to be of little or no value as a disinfectant, but Dr. Angus Smith has lately shown that it rivals, if it does not surpass, carbolic acid in antiseptic properties. For the present purpose of cattle-plague disinfection it is immaterial which acid is used, and to avoid unnecessary repetition I shall use the term "carbolic acid" to express either acid, or the commercial mixture of the two acids.

'From time immemorial carbolic acid, creosote, or bodies containing them, have been used as antiseptics. Passages in Pliny, read by the light of chemical science, show that the Egyptians used for embalming their mummies a compound made from pitch, which must have contained large quantities of creosote. Carbolic acid is the active agent in tar, which, either in its ordinary state or burnt as a fumigator, has always held high rank amongst disinfectants. Pitch and tar were the most popular medicines in use against the cattle plague when it visited this island in the last century; the animals being preserved against contagion by having their noses and jaws rubbed with tar, whilst the cowhouses were disinfected by burning pitch and tar in them (in which process a certain quantity of the vapours of carbolic acid would escape combustion). The almost universal custom of burning gum resins and odoriferous woods in connection with religious ceremonies may have originally arisen from the disinfecting powers of the creosote in the smoke. The well-known efficacy of smoke in preserving meat is entirely due to the presence in it of this agent.

'Pitch oil, oil of tar, and similar products owe their value entirely to carbolic acid. This body may, in fact, be called the active principle of tar, just as quinine is the active principle of bark, or morphia of opium, and it has the great advantage of being easily prepared in any country where coal or wood can be obtained.'

After describing some experiments with sulphurous acid, Mr. Crookes proceeds to describe some made by himself with carbolic acid:—

'A piece of fresh meat was soaked in a one-per-cent. aqueous solution of carbolic acid for one hour; it was then wrapped in paper and hung up in a sitting-room in which there was a fire almost daily; at the end of ten weeks it was examined. It had dried up to about one-fourth of its original size, but looked and smelt perfectly good and fresh, a very faint odour of carbolic acid being all that was perceptible. It was soaked for twenty-four hours in water, and then stewed with appropriate condiments and eaten; it was perfectly sweet, and scarcely distinguishable from fresh meat, except by possessing a very faint flavour of carbolic acid, not strong enough to be unpleasant.

'Animal membranes in the forms of gut, skin, and bladder, were perfectly preserved if immersed direct in aqueous solution containing 1 per cent. of carbolic acid; but if previously moistened with water, and then immersed in dilute carbolic acid, the preservation of the skins was not so complete.

'Animal size and glue, mixed, in the form of solution, with small quantities of carbolic acid, were perfectly preserved from change even in hot weather.

'These are important experiments. They point out in a striking manner the difference between mere deodorisers and antiseptics. Hitherto attention has been almost entirely confined to the deodorisation of gases arising from putrescence. The effect has been combated, whilst the removal of the cause has received scarcely any attention. Chloride of lime, one of the strongest of the class of deodorisers, acts, as has been shown, only on the gases of existing putrefaction, but it has no influence over the future. Carbolic acid, on the other hand, has scarcely any action on the fœtid gases; but it attacks the cause which produces them, and, at the same time, puts the organic matter in such a state that it never re-acquires its tendency to putrefy.

'It became now a matter of considerable interest to ascertain in what way carbolic acid acted in arresting decomposition, and the following experiments were made, with the object of clearing up this point:—

'Albumen was mixed with four times its bulk of water, and a one-per-cent. solution of pure carbolic acid was added to it. No change took place for the first few minutes, but after a little time a white cloudiness was formed, which gradually collected together into a coagulum. On separating this, and exposing it freely to the air, it entirely resisted putrefactive decomposition. The solution strained from the coagulum still contained carbolic acid and uncoagulated albumen.

'The same experiment was repeated with pure cresylic acid. This acid had still less affinity for albumen, the mixed solutions remaining clear for nearly half-an hour.

'It is evident, therefore, that the tar acids do not owe their special action to their coagulating powers on albumen, for the last two experiments show, contrary to the generally received opinion, that their affinity for this body is but slight.

'A few drops of carbolic acid, added to half a pint of sugar syrup, and yeast in full action, immediately put a stop to the fermentation.

Fresh brewers' yeast was washed with a solution of one per cent. of carbolic acid, and then with water. Its power of inducing fermentation in a solution of sugar was entirely destroyed, although no perceptible change in the appearance of the yeast-cells could be detected under the microscope. This experiment was repeated several times, and always with the same result, although when the yeast was simply washed in water it readily induced fermentation.

'The odour of carbolic acid adhered most pertinaciously to the yeast, and by no ordinary amount of washing and exposure to the air could it be removed.

'Strychnine was added to a mixture of yeast and sugar solution in full fermentation. No visible effect was produced, the evolution of carbonic acid continuing as brisk as before.

'The above experiments, some of which were performed by my friend Mr. Spiller, prove conclusively that carbolic acid has a special action on the fermentation induced by organised matter; it not only arrests it instantly when in progress, but it prevents the development of future fermentation.

'The action of the tar acids was now examined on certain chemical bodies, which are supposed to act by fermentation, in order to see if they were influenced in the same manner.

'A solution of diastase (infusion of malt) was mixed with thick starch paste, and a one-per-cent. solution of carbolic acid. On gently heating for a short time, the starch was converted into dextrine, as completely as if no carbolic acid had been present.

'Amygdalin was mixed with synaptase (emulsion of sweet almonds) in the presence of carbolic acid. The formation of the essential oil took place with apparently the same readiness as if carbolic acid had been absent.[1]

'The foregoing results show that carbolic acid has no action on purely chemical ferments. These consist of definite nitrogenous compounds acting simply by chemical affinity, and therefore ought not to be classed with true ferments, which are living bodies. It therefore appears that carbolic acid acts by attacking vitality in some mysterious way, and where an effect is merely due to so-called catalytic force, it exerts no interfering action.

'The action of carbolic acid on vitality was then tested in other ways:—

'Cheese mites were immersed in water, where they lived for several hours. A few drops of a solution of carbolic acid containing one per cent. added to the liquid, killed them instantly.

'An aqueous solution of carbolic acid was added to water in which a small fish was swimming. It proved fatal in a few minutes.

'A very minute quantity of a weak solution of carbolic acid was added, under the microscope, to water containing various infusoria, such as bacteria, vibrios, spirilla, amœbæa, monads, euglenæa, paramecia, rotifera, and vorticellæ. The acid proved instantly fatal, arresting the movements of the animalcules at once.

'These animalcules are the almost invariable accompaniments of putrefactive fermentation. The above experiment has been tried with putrid blood, sour paste, and decayed cheese, and in every instance the destruction of vitality and the arrest of putrefaction has been simultaneous.

'Caterpillars, beetles, crickets, fleas, moths, and gnats were covered with a glass, the inside of which was smeared with carbolic acid. The vapour proved quickly fatal. It allays the pain caused by the stings of bees, wasps, hornets, and gnats, if applied pure, or in strong solution, to the wounded part.

'I find it recorded by Dr. Lemaire and other observers that carbolic acid vapour will also kill flies, ants and their eggs, lice, bugs, tics, acari, mosquitoes, aphides, butterflies, earwigs, wood-lice, cockchafers, centipedes, and other insects of this size; its vapour, however, does not appear to be strong enough to act injuriously on animals larger than mice. When such animals are killed with it, their bodies dry up in the air, and resist putrefaction for some time.

'From the intense aversion shown by all insects to the odour of carbolic acid, it is probable that the plentiful use of this agent would effectually preserve cattle from those terrible scourges met with in certain parts of Africa, the zimb and tsetse-fly. The effects following the bite of the latter have been described to me as being almost identical with the symptoms of cattle plague.

'M. Lucien Biard, in speaking of the invasions of the large ants of Mexico, says that when one of their battalions threatens his house, he sprinkles a little carbolic acid in front of it. The army immediatety makes a detour to avoid the obstacle.

'When an animal is killed by the injection of a saturated aqueous solution of carbolic acid into its veins, circulation is instantly arrested, the blood is not coagulated, and no alteration, either in the shape or the appearance of the globules, is detected under the microscope. The only apparent change consists in the immobility of the globules.

'In the 'Annales de Chemie et de Physique' for October 1865, there is a letter from M. Béchamp to M. Dumas, in which it is said that creosote appears to be the agent which most strongly opposes the development of organic ferments, but that it does not interfere with the living ferments or animacules when they are once developed. This assertion is in direct opposition to all my experiments, about the accuracy of which I have no doubt whatever, having submitted them to repeated tests. The powerful action which carbolic acid exerts on the phenomena of life is the most remarkable property which it possesses. It may be looked upon as the test proper for distinguishing vital from purely physical phenomena, and in most cases its action is characterised by the certainty and definiteness of a chemical re-agent. In the

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[1] These last two experiments are confirmatory of a statement in Dr. Lemaire's work, 'Sur l'Acide phénique.'

presence of carbolic acid the development of embryotic life is impossible, and before its powerful influence all minute forms of animal life must inevitably perish.

'It may be considered as definitely proved that the vapour of carbolic acid, in the atmosphere, exerts a special selective power on all minute organisms possessing life. If the contagious matter of cattle plague is possessed of organic vitality, as must be now admitted, it will be destroyed, beyond the possibility of revival, when brought into contact with the vapour. French experimentalists have repeatedly tested the influence of carbolic acid on vaccine lymph. They have employed lymph both pure and mixed with a trace of carbolic acid. The vaccination with pure lymph was followed by the usual results, but in no single instance was any effect produced by the lymph containing carbolic acid.

'*On the Adulterations of Carbolic Acid, and their Detection.*

'The official recommendations have naturally brought into the market many substitutions for carbolic acid, in which the valuable agent is diluted with cheap inert bodies, while the price charged, in some cases, is higher than that of the genuine article. Specimens of two such substitutions, called cresyline and carboline, were forwarded to the Royal Cattle Plague Commission for approval, "as being more certain disinfectants than most of the carbolic acids now being sold to the public, many of which contain but a very small percentage of that acid." It was stated that the preparations contained over 60 per cent. of carbolic acid, and were miscible with water. As it was possible from these and other reputed advantages that the prepara-

TABLES OF DISINFECTION, FROM REPORT TO COMMISSIONERS ON CATTLE PLAGUE, 1867, AND 'DISINFECTANTS' BY DR. ANGUS SMITH, 1869.

Gases evolved with various Disinfectants acting in Water.

	CO_2	HS	N	Rate per Week
Blood alone	86·72	13·28	...	52 cubic cent.
,, ,, ...	69·00	6·68	24·32	38 ,,
,, disinfected by:				
McDougall's powder $\frac{1}{1000}$	70·56	4·74	24·70	105 ,,
,, ,, $\frac{1}{500}$	82·16	10·40	7·44	57 ,,
,, ,, $\frac{1}{250}$	76·66	16·38	6·96	57 ,,
Common salt $\frac{1}{1000}$, 1st portion . .	84·26	4·62	11·12	25·2 ,,
,, ,, 2nd portion . .	94·93	2·53	2·64	34·3 ,,
,, ,, 3rd portion . .	81·07	1·92	17·01	
Carbolic acid $\frac{1}{10000}$	29·02	7·31	63·67	18·96 ,,
,, $\frac{1}{1000}$	69·89	6·80	23·31	26·7 ,,
,, $\frac{1}{250}$	64·42	4·52	31·06	60·3 ,,
Cresylic acid and sulphite of soda $\frac{1}{1000}$	57·85	6·66	35·49	73·5 ,,
,, ,, ,, ,, $\frac{1}{500}$.	71·02	10·00	18·98	25·2 ,,
Chloride of lime and sulphuric acid $\frac{1}{1000}$	45·22	4·64	49·74	37·9 ,,
,, ,, $\frac{1}{1000}$	78·61	4·20	17·19	30·3 ,,
Cresylic acid $\frac{1}{1000}$	66·99	3·96	29·05	28·0 ,,
Chloride of iron $\frac{1}{1000}$	17·64		82·36	70 ,,
Sulphite of soda $\frac{1}{1000}$	82·72	4·30	12·98	59·5 ,,
Nitrate of lead $\frac{1}{1000}$	87·84	4·72	7·44	51 ,,
Lime $\frac{1}{1000}$	75·79	5·10	19·11	70 ,,
Chlorate of potash $\frac{1}{1000}$	61·83	1·77	36·40	31·3 ,,
Common salt $\frac{1}{500}$	85·21	7·11	7·68	40·25 ,,
Nitrate of iron $\frac{1}{1000}$	62·37	7·02	30·61	23·3 ,,
Sulphate of iron $\frac{1}{1000}$	89·53	10·47	...	23·3 ,,
,, alumina $\frac{1}{1000}$	39·58	9·63	50·79	23·3 ,,
Iodide of potassium $\frac{1}{1000}$	42·97	10·59	34·45	78 ,,
Sulphite of soda and carbolic acid .	78·00	10·32	11·68	26·8 ,,
Chloride of iron $\frac{1}{1000}$	85·36	9·94	4·70	
Phenyl alcohol $\frac{1}{500}$	51·17	4·26	44·57	54 ,,
Blood treated with $\frac{1}{1000}$:				23 ,,
Chloride of zinc	Not sufficient evolved for analysis			1·4 ,,
Arsenious acid				1·6 ,,
Bichloride of mercury				4·5 ,,
Sulphate of copper				3·1 ,,

tions might be of considerable value, they were forwarded to me for examination. Cresyline consists of alkaline water, and tar oils boiling above 370° C., therefore containing little or no carbolic or cresylic acids. Carboline is a dilute solution of caustic soda, containing 4·1 per cent. of carbolic acid. The price of these preparations is higher than that ordinarily charged for good commercial carbolic and cresylic acids.

'Other creosote samples from different makers were found to contain, respectively 4·5, 2·6, 5·9 and 4·2, per cent. of carbolic acid, the rest being tar oils. In other instances, articles have been sold as commercially pure carbolic acid, which were found to contain from 30 to 50 per cent. Frequently a very fœtid sulphur compound is allowed to remain. This should be avoided, as although the antiseptic powers of the liquid are great, the offensive odour which it diffuses round the neighbourhood is excessively nauseous.

'It is by no means difficult to detect the adulterations referred to above. Commercial carbolic acid is soluble in from 20 to 70 parts of water, or in twice its bulk of

Second Day.—Temperature 50°–60° *F.*

Substance used	Quantity	Odour	Sulphuretted hydrogen
	grammes		
Carbolic acid	0·01	Slight odour of blood	None
	0·025	" "	"
	0·05	Very faint odour	"
Cresylic acid	0·01	Slight odour of blood	"
	0·025	Very faint odour	"
	0·05	" "	"
Hydrochloric acid (Sp. gr. 1·03.)	0·01	Odour of stale blood	"
	0·025	" "	"
	0·05	" "	"
Nitric acid (Sp. gr. 1·08.)	0·01	Slight odour of blood	"
	0·025	" "	"
	0·05	" "	"
Sulphuric acid (Sp. gr. 1·17.)	0·01	Odour of stale blood	"
	0·025	" "	"
	0·05	" "	"
McDougall's powder	0·01	Strong odour of stale blood	"
	0·025	Slight odour of stale blood	"
	0·05	Odour of stale blood	"
Heavy oil of tar (Soda-solution.)	0·01	Slight odour of blood and tar	"
	0·025	Odour of blood and tar.	"
	0·05	" "	"
Heavy oil of tar (Water-solution.)	0·01	Odour of stale blood	"
	0·025	" "	"
	0·05	" "	"
Sulphate of alumina and ammonia. (Alum.)	0·01	Slight odour of blood	"
	0·025	Very slight odour of blood	"
	0·05	" " "	"
Bichromate of potash	0·01	Sour odour	"
	0·025	"	"
	0·05	Odour of fermenting sugar	"
Chloride of aluminium	0·01	Slight odour of stale blood	"
	0·025	" " "	"
	0·05	" " "	"
Chloride of lime	0·01	Slight odour of stale blood	"
	0·025	Slight odour	"
	0·05	Very faint odour	"
Sulphite of soda	0·01	Slight odour.	"
	0·025	"	"
	0·05	"	"

a solution of caustic soda, while oil of tar is nearly insoluble; but if the amount of carbolic acid be increased some remains undissolved.

'To apply the tests: 1. Put a teaspoonful of the carbolic acid in a bottle, pour on it half a pint of warm water, and shake the bottle at intervals for half an hour, when the amount of oily residue will show the impurity. Or, dissolve one part of caustic soda in ten parts of warm water, and shake it up with five parts of the carbolic acid. As before, the residue will indicate the amount of impurity.

'These tests will show whether tar oils have been used as adulterants; but to ascertain whether the liquid consists of a mere solution of carbolic acid in water or alkali, or whether it contains sulpho-carbolic or sulpho-cresylic acids, another test must be

Tenth Day.—Temperature 80°–86° *F.*

Substance used	Quantity	Odour	Sulphuretted hydrogen
	grammes		
Carbolic acid	0·01	Slightly putrescent warm blood	Trace
	0·025	„ „ „	Distinct
	0·05	Spicy odour	Large
Cresylic acid	0·01	Warm stale blood	Distinct
	0·025	Sour odour mixed with cresylic acid	„
	0·05	Fœtid HS odour	Very large
Hydrochloric acid (Sp. gr. 1·03.)	0·01		
	0·025		
	0·05		
Nitric acid (Sp. gr. 1·08.)	0·01	Mild spicy odour	Large
	0·025	Strong spicy odour	„
	0·05	Peculiar faint spicy odour	Little
Sulphuric acid	0·01		
	0·025		
	0·05		
McDougall's powder	0·01	Slight odour of carbolic acid	Trace
	0·025	Putrescent odour of carbolic acid	Distinct
	0·05	Sulphuretted hydrogen	Very very large
Heavy oil of tar (Soda-solution.)	0·01	Slight odour of warm stale blood	None
	0·025	Strong odour of warm stale blood	„
	0·05	Tar and stale blood odour	Large
Heavy oil of tar (Water-solution.)	0·01	Sour warm stale blood odour	None
	0·025	Sour sewage odour	Distinct
	0·05	Odour of warm stale blood	Large
	0·01	Warm stale blood odour	None
	0·025	The same, but slightly putrescent	A little
	0·05	The same, putrescent odour mixed with that of tar	„
Sulphate of alumina and ammonia (Alum.)	0·01	Warm stale blood odour	Trace
	0·025	Putrescent odour	Distinct
	0·05	Sour putrescent warm stale blood	Very large
Bichromate of potash	0·01	Slight garlic odour	None
	0·025	Strong sour spicy odour	„
	0·05	„ „	„
Chloride of aluminium	0·01		
	0·025	Sour warm blood odour	A little
	0·05	Sour odour	Distinct
Chloride of lime	0·01	Sour warm blood odour	Slight
	0·025	Sour odour	Distinct
	0·05	Sour fishy odour	„
Sulphite of soda	0·01	Farmyard manure	Distinct
	0·025	Sour warm stale blood	Very large
	0·05	Fœtid warm blood odour	„

used, based upon the solubility of these, and the insolubility of carbolic acid, in a small quantity of water. In this case proceed as follows:—2. Put a wine-glassful of the liquid to be tested in a bottle, and pour on it half a pint of warm water. If the greater part dissolves, it is an adulterated article. Test the liquid in the bottle with litmus-paper; if strongly acid, it will show the probable presence of sulpho-acids, whilst if alkaline it will show that caustic soda has been probably used as a solvent.'

DISINTEGRATION. The mechanical breaking up of rock under the action of atmospheric influences. It is distinguished from decomposition, which always refers to some chemical action.

DISTHENE. A name given to *Cyanite*, in allusion to the unequal degree of hardness which crystals of this mineral exhibit in different directions. See Cyanite.

DISTILLATION. Distillation consists in the conversion of any substance into vapour, in a vessel so arranged that the vapours are condensed again and collected in a vessel apart.

The word is derived from the Latin *dis* and *stillo*, I drop, meaning originally to drop or fall in drops, and is very applicable to the process, since the condensation generally takes place dropwise.

It is distinguished from *sublimation* by the confinement of the latter term to cases of distillation in which the product is solid, or, in fact, where a solid is vaporised and condensed without visible liquefaction.

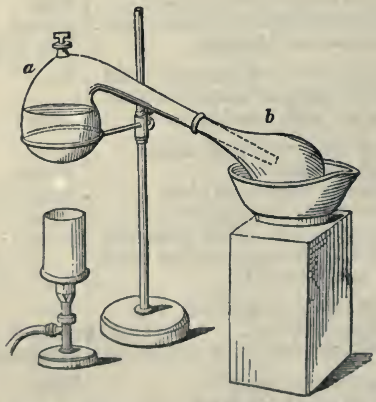
The operation may simply consist in raising the temperature of a mixture sufficiently to evaporate the volatile ingredients; or it may involve the decomposition of the substance heated, and the condensation of the products of decomposition, when it is termed *destructive distillation*; in most cases of destructive distillation the bodies operated upon are *solid*, and the products liquid or gaseous; it is then called *dry distillation.*

In consequence of the diversity of temperatures at which various bodies pass into vapour, and also according to the scale on which the operation has to be carried out, an almost endless variety of apparatus may be employed.

Whatever be the variety of form, it consists essentially of three parts: the *retort* or *still*, the *condenser*, and the *receiver*.

On the small scale, in the chemical laboratory, distillation is performed in the simplest way by means of the common glass retort *a*, and receiver *b*, as in *fig.* 609. The great advantages of the glass retort are that it admits of constant observation of the materials within, that it is acted upon or injured by but a few substances, and may be cleaned generally with facility. Its great disadvantage is its brittleness.

609



610

The retort may be either simple, as in *fig.* 610, or tubulated, as in *fig.* 611.

Retorts should generally be chosen sufficiently convex in all parts, the degree of curvature of one part passing gradually into that of the neighbouring portions, as is represented in the figure; the part to be heated should, moreover, be as uniform in point of thickness as possible. The tubulated retort is more liable to crack than the plain one, on account of the necessarily greater thickness of the glass in the neighbourhood of the tubulature; nevertheless, it is very convenient on account of the facility which it offers for the introduction of the materials.

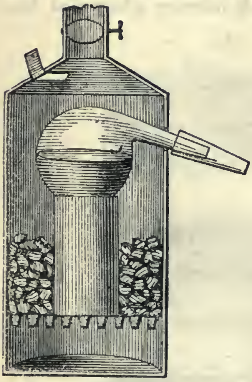
In charging retorts if plain, a funnel with a long stem should be employed, to avoid soiling the neck with the liquid to be distilled; when a solid has to be introduced, it is preferable to employ a tubulated retort; and if a powdered solid is to be mixed with a fluid, it is preferable to introduce the fluid first.

Heat may be applied to the retort either by the argand gas flame, as in *fig.* 609, or a water-, oil-, or sand-bath may be employed.

In distilling various substances, *e. g.*, sulphuric acid, great inconvenience is experienced, and even danger incurred, by the phenomenon termed 'bumping.' This consists in the accumulation of large bubbles of vapour at the bottom of the liquid, which bursting cause a forcible expulsion of the liquid from the retort. It is prevented by the introduction of a few angular fragments of solid matter of such a nature as not to be acted upon by the liquid which is to be distilled. Nothing answers this purpose better than a piece of platinum foil cut into a fringe, or even a coil of platinum wire introduced into the cold liquid before the distillation is commenced. Even with this precaution the distillation of sulphuric acid, which it is often desirable to perform for the purpose of its purification, is not unattended with difficulty and danger.

Dr. Mohr suggests the following method:—A glass retort of about two pounds capacity, is placed on a cylinder of sheet iron in the centre of a small iron furnace, while its neck protrudes through an opening in the side of the furnace (*fig.* 611). Ignited charcoal is placed round the cylinder, without being allowed to come in contact with the glass, and a current of hot air is thus made to play on all parts of the retort, excepting the bottom, which is protected by its support. There is a valve in the flue of the furnace for regulating the draught, and three small doors in the cupola or head, for supplying fresh fuel on every side, and for observing the progress of the distillation.

611



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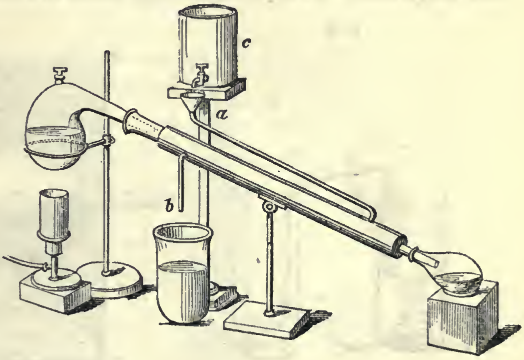

Instead of the sheet-iron cylinder a Hessian crucible may be employed, and this, if requisite, elevated by placing it on a brick. If the vapour be very readily condensed, nothing more is necessary than to insert the extremity of the retort into a glass receiver as in *fig.* 609.

If a more efficient condensing arrangement be requisite, nothing is more convenient for use on the small scale than a Liebig's condenser, shown in *fig.* 612. It consists simply of a long glass tube into which the neck of the retort is fitted, and the opposite extremity of which passes into the mouth of the receiver; round this tube is fitted another either of glass or metal, and between the two a current of water is made to flow, entering at *a* and passing out at *b*. The temperature of this water may be lowered to any required degree by putting ice into the reservoir *c*, or by dissolving salt in it. (See Freezing.)

Even on the small scale it is sometimes necessary to employ distillatory apparatus constructed of other materials besides glass.

Earthenware retorts are now constructed of very convenient sizes and shapes. There is one kind—which is very useful when it is required to pass a gas into the retort at the same time that the distillation is going on, as in the preparation of chloride of aluminium, &c.—which has a tube passing down into it also made of earthenware, as in *fig.* 613. The closest are of Wedgwood ware, but a common clay retort may be made impermeable to gases, by washing the surface with a solution of borax, then carefully drying and heating it.

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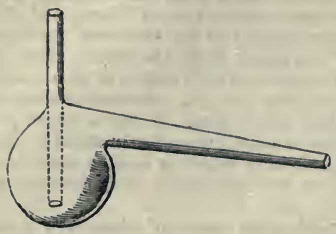
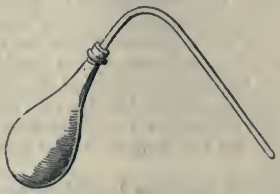
[1] Mohr and Redwood's 'Practical Pharmacy.'

Retorts, or flasks with bent tubes, which screw in thus (*fig.* 614), of copper, are employed when it is requisite to produce high temperatures, as for the preparation of benzole from benzoic acid and baryta, or in making marsh gas from an acetate, &c.

613



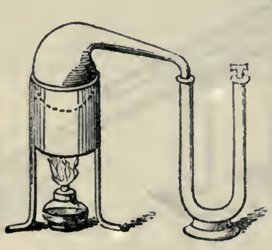
614



In distilling hydrofluoric acid the whole apparatus should be constructed in lead; the receiver consisting of a U-shaped tube of lead, which is fitted with leaden stoppers so as to serve for keeping the acid when prepared; or a receiver of gutta percha may be employed with a stopper of the same material. (*Fig.* 615.)

For many purposes in the laboratory as, for instance, the preparation of oxygen by heating binoxide of manganese,—in the manufacture of potassium, &c. &c.; where high temperatures are required, the iron bottles in which mercury is imported from Spain may be employed, a common gun-barrel being screwed into them to act as a delivery tube or condenser. (*Fig.* 616.)

615



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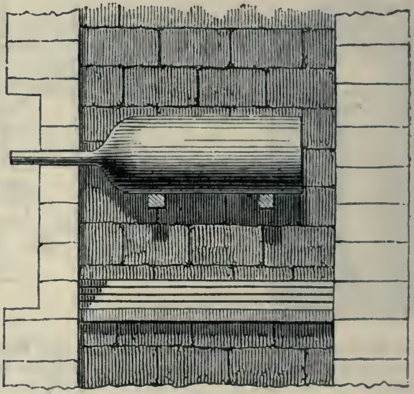


On a large scale an almost endless variety of stills have been and are still employed, which are constructed of different materials.

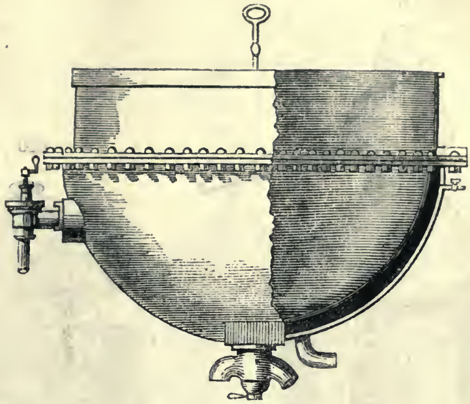
The common 'still' consists of a retort or still proper, in which the substance is heated; and a condenser commonly called a 'worm' on account of its having frequently a spiral shape. The retort or still is generally made in two parts: the *pan* or *copper*, which is the part to which heat is applied, and is commonly set in a furnace of brickwork, and the '*head*,' which is generally removed after each operation, and refixed and luted upon the pan when again used. The condenser or worm is commonly placed in a tube or other vessel of water. (See *fig.* 619.)

The still may be either constructed of earthenware, or, as is very commonly the case, of copper, either plain or electro-plated with silver, according to circumstances; less frequently platinum is employed.

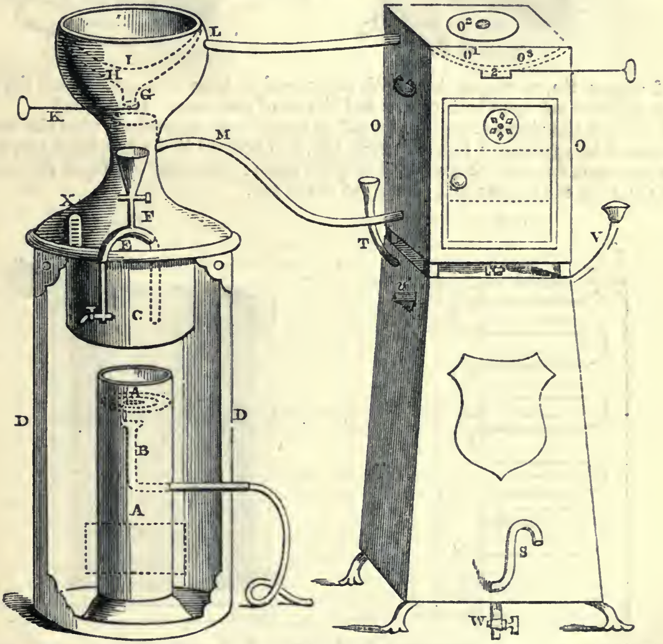
The still is either heated by an open fire, as in *fig.* 615, or, as is now very commonly the case, by steam. The still-pan (*fig.* 617) is surrounded by an outer copper jacket, and steam is admitted between them from a steam-boiler under any required pressure. In this way the temperature may be regulated with the greatest nicety.

Various adaptations for heating by steam have been appropriately arranged in a very convenient form by Mr. Coffey, of Bunhill Row, Finsbury, in his so-called Esculapian Still. It is, in fact, a veritable *multum in parvo*, being intended to afford to the pharmaceutical chemist the means of conducting the processes of ebullition, distillation, evaporation, desiccation, &c., on the small scale, by the heat of a gas-furnace. *Fig.* 618 represents this apparatus.

617



618

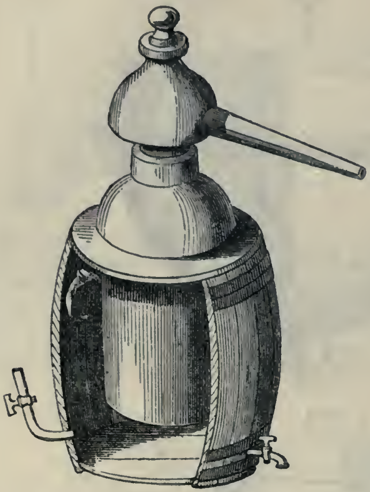


B, a burner supplied with gas by a flexible tube. C, the boiler or still. I, an evaporating pan, fixed over the boiler and forming the top of the still-head. K, a valve for shutting off the steam from I, when it passes through the tube M, otherwise it would pass through L, and communicate heat to the drying-closet O O, and from thence to the condenser T T. O is a second evaporating pan over the drying-closet. Another arrangement for distilling by steam is shown in *fig.* 619.

Sometimes also distillation is effected by passing hot steam through a worm contained *within* the still, instead of, or in addition to, the application of heat from without.

The worm or condenser is frequently constructed of earthenware, and set in an earthenware vessel; these are very convenient when the operation is not to be conducted on a very large scale, and only at a moderate temperature. They are now to be obtained of all manufacturers of stone-ware articles. More commonly the worm is of copper, tin, or copper lined with silver, and in some rare cases where the liquids to be distilled act upon both copper and silver, of platinum. (*Fig.* 620.)

619



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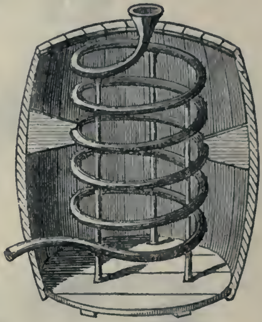
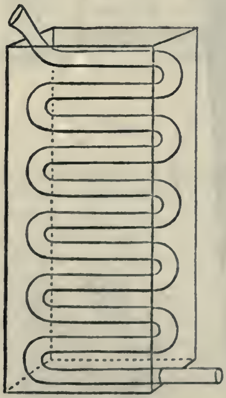


A tube of the shape shown in *fig.* 621 is found more convenient than the worm, on account of its exposing a larger surface, and also because it can be placed into a vessel of a prismatic form which occupies but little space: the water employed for condensation enters at the bottom and passes out at the top.

621



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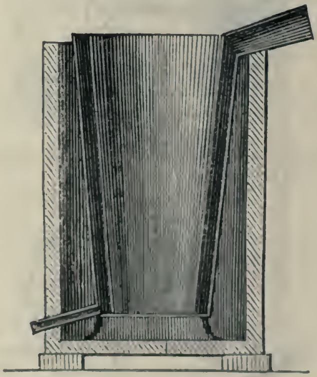


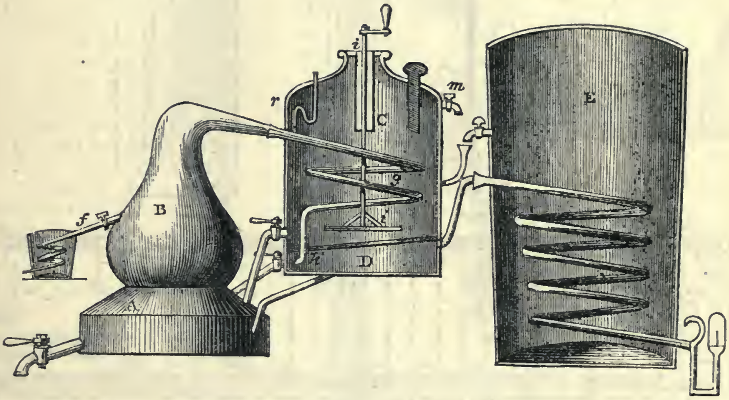
Gadda's condenser is represented in *fig.* 622. It consists of two conical vessels of metal, of unequal size, the smaller being fixed within the other, and the space between them closed at the bottom. These are placed in a tub filled with cold water, which comes in contact with the inner and outer surfaces of the cones, while the space between is occupied by the vapour to be condensed. This condenser is subject to the objection which applies to the common worm, that it cannot be easily and efficiently cleaned.

To obviate this, Professor Mitscherlich has proposed a very simple modification in its form, in which the inner cone is moveable, so that, when taken out, the intervening space between it and the outer cone can be cleaned, and then the inner cone replaced previously to commencing an operation.

Distillation of Spirits.—In the manufacture of *ardent spirits*, the alcoholic liquor obtained by fermentation of a saccharine solution is submitted to distillation; the alcohol being more volatile than the water passes over first, but invariably a considerable proportion of water is evaporated and condensed with the alcohol. To separate this water to the required extent it is necessary either to submit the product to redistillation, or to contrive an apparatus such that the product of this first distillation is returned to the still until a spirit of the required strength is obtained.

One of the earliest and simplest contrivances for effecting the latter object is the still invented by Dorn, which is employed up to the present time in Germany (*fig.* 623). A is the still, heated by the direct action of the fire; B the head, from which

623



r conveys vapour to a small refrigerator, for the purpose of testing the strength of the distillate; E is an ordinary condenser, containing worm, &c. The intermediate copper vessel answers two purposes: the upper part C forming a heater for the wash, while the lower compartment D acts as a rectifier. The heater C, when filled up to the level of the cock *m*, contains the exact measure of wash for charging the still; the contents can be constantly agitated by the rouser *i*. The still and heater being both charged, the vapour will at first be completely condensed in passing through the worm *g*, and flowing into D will close the aperture. When the contents of C become so hot that no more condensation occurs, the vapour will escape by bubbling through the liquid in D, which latter rapidly becomes heated to the boiling point, and evolves vapours richer in alcohol, which in their turn are condensed in E.

In this manner, by one operation, spirit containing about 60 per cent. of alcohol is obtained.

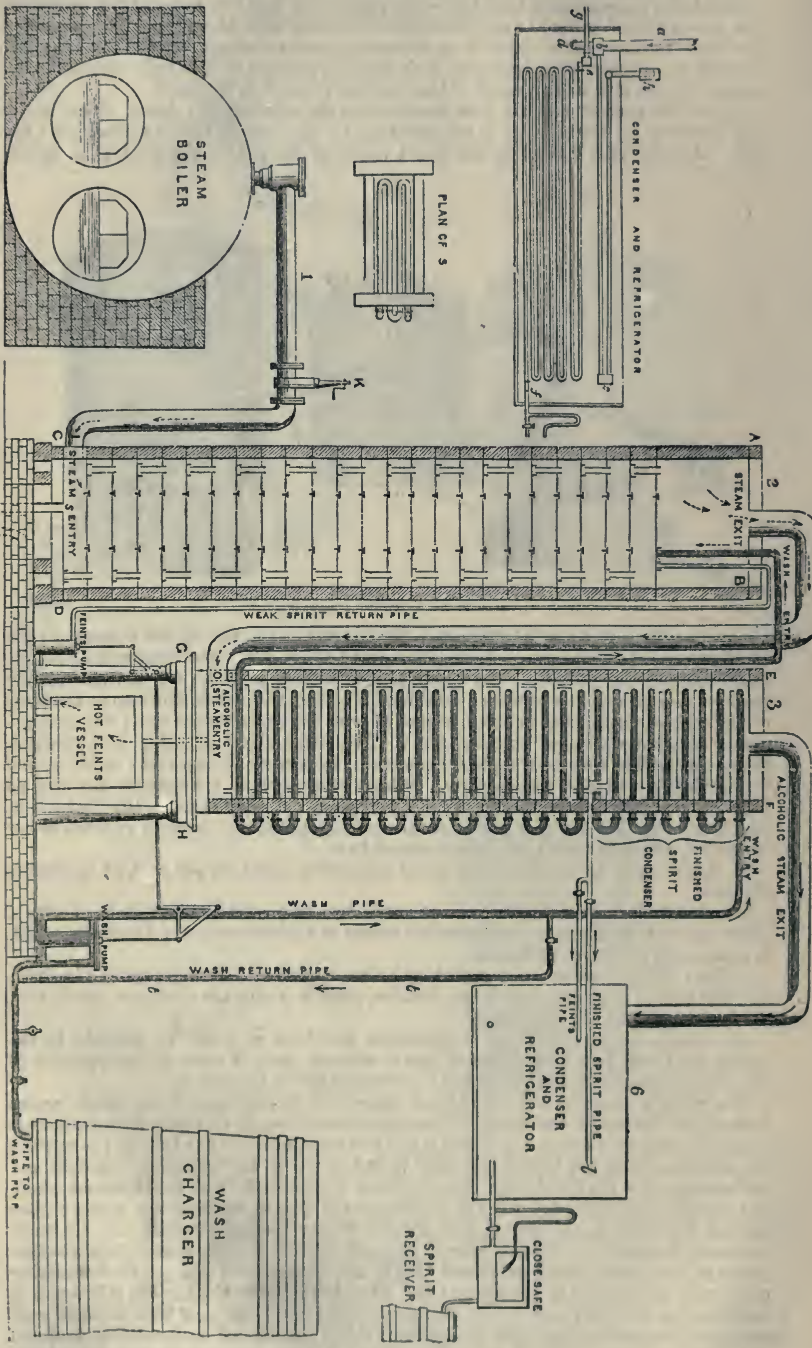
Of the recent improvements on Dorn's still two only need be described: Coffey's, which has in a great measure replaced all others in this country; and Derosne's, which is extensively employed in France.

Coffey's Still far surpasses any of those before described. It was patented in 1832, and has proved most valuable to the distiller, since it yields the strongest spirit that can be obtained on the large scale.

Its objects are twofold: 1st, to economise the heat, as much as possible, by exposing the liquid to a very extended heated surface; 2nd, to cause the evaporation of the alcohol from the wash by passing a current of steam through it.

The wash is pumped from the 'wash charger' into the worm tube, which passes from top to bottom of the rectifier. In circulating through this tube its temperature is raised to a certain extent. Arrived at the last convolution of the tube in the rectifier the wash passes by the tube M (*fig.* 624) in at the top of the 'analyser.' It falls and collects upon the top shelf until this overflows, whence it falls on to the second shelf, and so on to the bottom. All the while steam is passed up from the steam boiler through fine holes in the shelves, and through valves opening upwards. As the wash gradually descends in the analyser it becomes rapidly weaker, partly from condensation of the steam which is passed into it, and partly from loss of alcohol, either evaporated or expelled by the steam; till, when it arrives at the bottom, it has parted with the last traces of spirit. At the same time the vapour, as it rises through each shelf of the analyser, becomes continuously richer in alcohol, and contains less and less water in consequence of its condensation; it then passes from the top of the

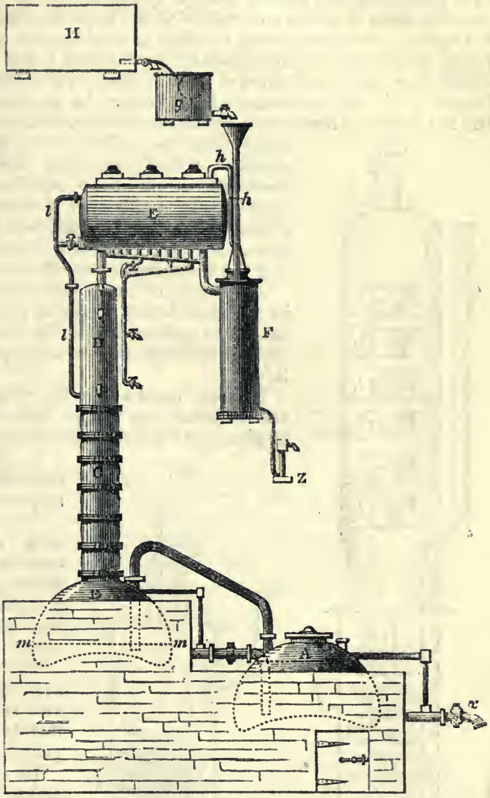
624



IMPROVED APPARATUS OF ÆNEAS COFFEY AND SONS, OF BROMLEY, NEAR BOW, FOR THE DISTILLATION OF SPIRIT.

analyser in at the bottom of the lower compartment of the rectifier. Here it ascends in a similar way, bubbling through the descending wash, until it arrives at F, above which it merely circulates round the earlier windings of the wash pipe, the low temperature of which condenses the spirit, which, collecting on the shelf at F, flows off by the tube into the finished spirit condenser.

625



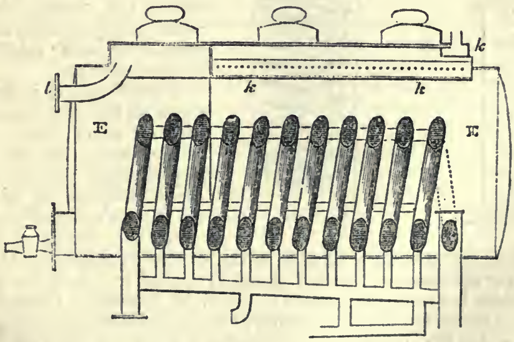
In order still further to economise heat, the water for supplying the boiler is made to pass through a long coil of pipe, immersed in boiling hot spent wash, by which means its temperature is raised before it enters the boiler. In fact, the saving of fuel by the employment of this still is so great, that only about three-fourths of the quantity is consumed that would be requisite for distilling any given quantity of alcohol in the ordinary still; and Dr. Muspratt estimates that in this way a saving will be effected throughout the kingdom of no less than 140,000 tons of coal per annum.

Very few persons have any idea of the enormous size of some of the distilleries. One of Mr. Coffey's stills at Inverkeithing works off 2,000 gallons of wash per hour, and one, more recently erected at Leith, upwards of 3,000 gallons.

Derosne's Still is very similar, in the principle of its action, to Coffey's, differing in fact only in the mechanical details by means of which the result is obtained.

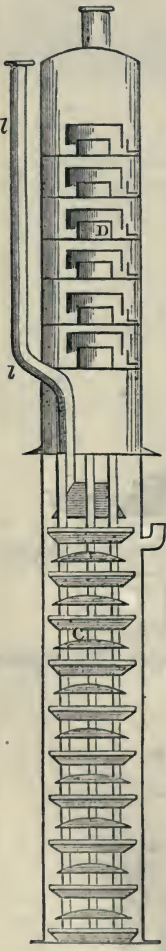
It consists of two stills, A and B, *fig.* 625. The mixture of steam and alcohol vapour from A passes into the liquid in B, which it raises to the boiling point. The vapours from B rise through the *distillatory* column C, and D (the *rectificatory* column); hence they traverse the coils of tubing in E (the *condenser* and *wine-heater*), and the alcohol

626



is finally condensed by traversing the worm in F (the *refrigerator*), whence it is delivered at Z. At the same time a steady current of the original alcoholic liquor is admitted from the reservoir H, into the exterior portion of the condenser F, by means of the tap, the flow from which is regulated by the ball-cock *g*. Whilst condensing the spirit in the worm the wash has its temperature raised, especially in the upper part, and thence it ascends by the tube *h* into the heater E, by the small orifices *k k*, *fig.* 626, where it is still further heated by the current of heated alcohol which has risen into the worm from the still, whilst at the same time assisting in the condensation of the spirit. After performing its office of condensation, and when nearly at the boiling point, the alcoholic liquor passes out by the tube *l*, and is conducted to the top of the distillatory column C. Here it trickles down over a series of lenticular discs of metal (shown in *fig.* 626), so contrived as to retard its progress into the still B, and yet permit the ascent of the steam. In this distillatory column (C, *fig.* 628) it meets the steam rising from the still B. The greater part of its alcohol is expelled, which, traversing the series of condensers before described, is ultimately liquefied and collected at Z; but, to complete the rectification, it descends into the still B, and, when above a certain level (*m m*), into A, which stills being heated by a furnace beneath, the final expulsion of alcohol is accomplished, and the spent liquor run off at *x*.

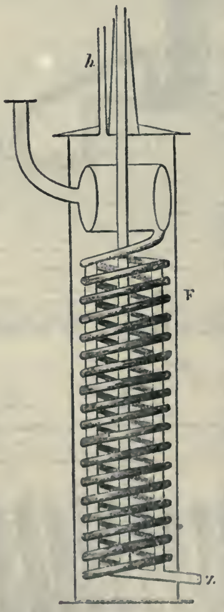
628



The details of the construction of the apparatus employed in the distillation of spirits have been here given, since this process is perhaps one of the most important of the kind; but various modifications are employed in the distillation of other liquids.

In some cases unusually effectual condensing arrangements are required, as in the manufacture of ether, chloroform, bisulphide of carbon, and bichloride of carbon.

627



In others higher temperatures are necessary, as in the distillation of sulphuric acid.

When the liquids to be distilled are acid, or otherwise corrosive, great care has to be taken especially that the worm or other condenser is of a material not acted upon by the acid. See ACETIC ACID, and SULPHURIC ACID.

The term 'distillation' is sometimes applied to cases of the volatilisation and subsequent condensation of the metals either in their preparation or purification.

In cases like mercury, potassium, and sodium, where they are condensed in the liquid state, or visibly pass through this state before volatilisation, this term is quite appropriate; but where the fusing and vaporising points nearly coincide, as in the case of arsenic, the term 'sublimation' would be more suitable.

Nevertheless, it is difficult to draw a precise line of demarcation between the two terms; for, in the cases of zinc, cadmium, &c., the metals being melted before volatilisation, and condensed likewise in the liquid state, the term is certainly correct.

For the details of construction of the distillatory apparatus we must refer to the articles on these several metals.

Distillatio per descensum is a term improperly applied to certain cases of distillation where the vapour is dense, and may be collected by descending through a tube which has an opening in the top of the distillatory vessels, and descends through the body of the vessel in which the operation of evaporation is going on, being collected below.

This is clearly merely due to the fact of the vapour being even at a high temperature more dense than atmospheric air, and might be performed with any body forming a dense vapour, such as mercury, iodine, zinc, &c.

It has, however, practically been confined to the English process of refining zinc. See ZINC.

The two most remarkable cases in which the process of destructive distillation is carried out on a manufacturing scale, are the dry distillation of wood, for the manufacture of wood charcoal, acetic acid, and pyroxilic spirit; and of coal, for the purpose of obtaining coal-gas, and coke. This process will be found fully described in the article on GAS, COAL.

Distillation of Essential Oils or Essences.—The separation of volatile flavouring oils from plants, &c., by distillation with water, will be fully treated under another head. See PERFUMERY; ESSENCES.

Fractional Distillation.—A process for the separation of volatile organic substances (such as oils) is very extensively employed in our naphtha works under this name.

If we have two volatile bodies together, but differing appreciably in their boiling points, we find, on submitting them to distillation in a retort, through the tubulature of which a thermometer is fixed, so that its bulb dips into the liquid, that the temperature remains constant (or nearly so) at the point at which the more volatile constituent of the mixture boils, and the distillate consists chiefly of this more volatile ingredient; and only after nearly the whole of it has passed over, the temperature rises to the point at which the less volatile body boils. Before this point has been reached, the receiver is changed, and the second distillate collected apart. By submitting the first product to repeated redistillation, as long as its boiling-point remains constant, the more volatile constituent of the mixture is ultimately obtained in a state of absolute purity. See NAPHTHA.

This method may in fact be adopted when the mixture contains several bodies; and by changing the receiver with each distinct rise of temperature, and repeating the process several times, a *fractional* separation of the constituents of the mixture may be effected.—H. M. W.

DISTILLATION, DESTRUCTIVE. Organic matters may be divided into two groups, founded on their capability of withstanding high temperatures without undergoing molecular changes. Bodies that distil unchanged form the one, and those which break up into new and simpler forms, the other. The manner in which heat acts upon organic substances differs not only with the nature of the matters operated upon, but also with the temperature employed. We shall study the subject under the following heads:—

1. *Apparatus for destructive distillation.*
2. *Destructive distillation of vegetable matters.*
3. *Destructive distillation of animal matters.*
4. *Destructive distillation of acids.*
5. *Destructive distillation of bases.*
6. *General remarks.*

1. *Apparatus for destructive distillation.*—Destructive distillation on a large scale is most conveniently performed in the cast-iron retorts used in gas-works. Where quantities of materials not exceeding fifteen or twenty pounds are to be operated on, for the purpose of research, a more handy apparatus can be made from one of the stout cast-iron pots sold at the iron wharves. They are semi-cylindrical, and have a broad flange round the edge. The cover should be made to fit in the manner of a saucepan-lid. The aperture by which the products of distillation are to be carried away should be of good size, and the exit pipe must not rise too high above the top of the pot before it turns down again. This is very essential in order to prevent the less volatile portion of the distillate from condensing and falling back. The exit tube should conduct the products to a receiver of considerable capacity, and of such a form as to enable the solid and fluid portions of the distillate to be easily got at for the purpose of examination. From the last vessel another tube should conduct the more volatile products to a good worm supplied with an ample stream of cold water. If it be intended to examine the gaseous substances yielded by the substances under examination, the exit pipe of the worm must be connected with another apparatus, the nature of which must depend on the class of bodies which are expected to come over. If the most volatile portions are expected to be basic, it will be proper to allow them to stream through one or more Woulfe's bottles half filled with dilute hydrochloric acid. Any very volatile hydrocarbons of the C^nH^n family which escape may be arrested by means of bromine water contained in another Woulfe's bottle. The pressure in the Woulfe's bottles must be prevented from becoming too great, or the leakage between the flange of the pot and its cover will be very considerable. The luting may consist of finely-sifted Stourbridge clay, worked up with a little horse-dung. A few heavy

weights should be placed on various parts of the lid of the pot, so as to keep it close, and render the leakage as little as possible. For the destructive distillation of small quantities of substances, I have been accustomed for a long time to employ a small still made from a glue pot, and having a copper head made to fit it. The luting for all temperatures not reaching above 700° may be a mixture of $\frac{3}{4}$ths linseed and $\frac{1}{4}$th almond meal, made into a mass of the consistency of putty. For the apparatus employed in the destructive distillation of wood, coal, bones, &c., on the large scale, the various articles in this work on the products obtained from those substances must be consulted.

2. *Destructive distillation of vegetable matters.*—The principal vegetable matters which are distilled on the large scale are wood and coal. We shall consider these separately.

Destructive distillation of wood.—The products obtained in the ordinary process of working are acetic acid, wood spirit or methylic alcohol, acetone, pyroxanthine, xylite, lignine, paraffine, creosote or phenic acid, oxyphenic acid, pittacal, several homologues of benzole, with ammonia, and methylamine. There are also several other bodies of which the true nature is imperfectly known. The greater part of the above substances are fully described in separate articles in this work. See ACETIC ACID; PARAFFINE, &c.

Peat appears to yield products almost identical with those from wood.

Destructive distillation of coal.—The number of substances yielded by the distillation of coal is astonishing. It is very remarkable that the fluid hydrocarbons produced at a low temperature are very different to those distilling when a more powerful heat is employed. The principal fluid hydrocarbons produced by the distillation and subsequent rectification of ordinary gas-tar are benzole and its homologues.—See HYDROCARBONS. But if the distillate is procured at as low a temperature as possible, or Boghead coal be employed, the naphtha is lighter, and the hydrocarbons which make its chief bulk belong to other series. See NAPHTHA.

3. *Destructive distillation of animal matters.*—Bones are the principal animal substances distilled on the large scale. The naphthas which come over are excessively fœtid, and are very troublesome to render clean enough for use. The products contained in bone-oil will be described in the article NAPHTHA. Horn and wool have been examined with reference to the basic products yielded on distilling them with potash. Horn under these circumstances yields ammonia and amylamine. Wool I find to afford ammonia, pyrrol, butylamine, and amylamine. My experiments on feathers, made some years ago, although not carried so far as those on wool, appear to indicate a very similar decomposition.

The products yielded by animal matters, when distilled *per se*, are very different to those obtained when a powerful alkali is added previous to the application of heat. If feathers or wool be distilled alone, a disgustingly-fœtid gas is evolved, containing a large quantity of sulphur. Part of the sulphur is in the state of sulphide of carbon. But if an alkali be added previous to the distillation, the sulphur is retained, and the odour evolved, although powerful, is by no means offensive. During the whole period of the distillation of ordinary organic matters containing nitrogen, pyrrol is given off, and may be recognised by the reaction afforded with a slip of deal wood dipped in hydrochloric acid. An interesting experiment, showing the formation of pyrrol from animal matters, may at any time be made with a lock of hair, or the feather of a quill. For this purpose the nitrogenous animal matter is to be placed at the bottom of a test tube, and a little filtering paper is to be placed half way up the tube, to prevent the water formed during the experiment from returning and fracturing the glass. The end of the tube is now to be cautiously heated with a spirit lamp, and, as soon as a dark yellowish smoke is copiously evolved, a slip of deal previously moistened with concentrated hydrochloric acid is to be exposed to the vapour. In a few seconds the wood will acquire a deep crimson colour. The fact of the presence of sulphur in wool, hair, or other albuminous compounds of that description, may be made very evident to an audience by the following experiment. Dissolve the animal matter in very concentrated solution of potash in a silver or platinum basin, with the aid of heat. Evaporate to dryness, and raise the heat at the end to fuse the potash and destroy most of the organic matters. When cold, dissolve in water, and filter into a flask half full of distilled water. To the clear liquid add a little of Dr. Playfair's nitroprusside of sodium; a magnificent purple tint will be immediately produced, indicative of the presence of sulphur. A very small quantity of hair or flannel will suffice to yield the reaction.

The above remarks on destructive distillation apply principally to highly complex bodies, the molecular constitution of which is either doubtful, as in the case of albuminous substances, or totally unknown, as with coals and shales. The destructive distillation of organic substances of comparatively simple constitution, such as acids and alkalis, sometimes yields products, the relation of which to the parent substance can be clearly made out. This holds more especially in the case of organic acids; the bases too often yield such complex results, that the decomposition cannot be expressed by an equation giving an account of all the products. We shall study a few cases separately.

4. *Destructive distillation of acids.*—The destructive distillation of acids takes place in a totally different manner, according as we have a base present, or the operation is carried on without any addition. Many if distilled *per se* undergo a very simple reaction, consisting in the elimination of carbonic acid, and the formation of a *pyroacid.* But if an excess of base be present, the decomposition often results in the formation of a ketone. We shall offer a few examples of these decompositions. Gallic acid, heated to about 419° Fahr., is decomposed into pyrogallic and carbonic acids, thus:

$$\underbrace{C^{14}H^6O^{10}}_{\text{Gallic acid.}} = \underbrace{C^{12}H^6O^6}_{\text{Pyrogallic acid.}} + 2CO^2$$

$$\mathbf{C^7H^6O^5 = C^6H^6O^3 + CO^2.}$$

There are cases in which the action of heat upon organic acids results in the formation of two substances, not produced simultaneously, but in two epochs or stages. In reactions like this, the first effect is the removal of two equivalents of carbonic acid, and by submitting the resulting acid to heat again, two more are separated. Under these circumstances, it is the second which is generally called the pyroacid. As an example, we will take meconic acid, which breaks up in the manner seen in the annexed equations:

$$\underbrace{C^{14}H^4O^{14}}_{\text{Meconic acid.}} = \underbrace{C^{12}H^4O^{10}}_{\text{Comenic acid.}} + 2CO^2 \qquad \underbrace{C^{12}H^4O^{10}}_{\text{Comenic acid.}} = \underbrace{C^{10}H^4O^6}_{\text{Pyromeconic acid.}} + 2CO^2$$

$$\mathbf{C^7H^4O^7 = C^6H^4O^5 + CO^2} \qquad \mathbf{C^6H^4O^5 = C^5H^4O^3 + CO^2.}$$

It will be seen that the hydrogen remains unaffected. Perhaps the name pyrocomenic acid would be preferable to pyromeconic acid, inasmuch as it is derived from comenic acid in the same manner as pyrogallic from gallic acid.

But pyroacids are not always derived from the parent acid by the mere elimination of carbonic acid; thus mucic acid, in passing into pyromucic acid, loses two equivalents of carbonic acid, and six equivalents of water, thus:

$$\underbrace{C^{12}H^{10}O^{16}}_{\text{Mucic acid.}} = \underbrace{C^{10}H^4O^6}_{\text{Pyromucic acid.}} + 2CO^2 + 6HO$$

$$\mathbf{C^6H^{10}O^8 = C^5H^4O^3 + CO^2 + 3H^2O.}$$

It does not invariably happen that the destructive distillation of acids *per se* results in the formation of a pyroacid; the disruption is sometimes more profound, the products being numerous and somewhat complex. Let us take, as an illustration, a case where all the results can be reduced to an equation. Oxalic acid, when heated in a retort without addition, yields water, oxide of carbon, carbonic and formic acids, in accordance with the annexed equation:

$$\underbrace{4(C^2O^3,HO)}_{\text{Oxalic acid.}} = 4\,CO^2 + 2\,CO^2 + 2\,HO + \underbrace{C^2HO^3,HO}_{\text{Formic acid.}}$$

$$\mathbf{2\,(C^2H^2O^4) = 2\,CO^2 + CO + H^2O + CH^2O^2.}$$

The admixture of sand, pulverised pumice-stone, or any other inert substance in a state of fine division, often remarkably assists in rendering the decomposition more easy and definite. Thus, if pure sand be mixed with oxalic acid, the quantity of formic acid is so increased, that the process is sometimes employed in the laboratory as a means of affording a pure and tolerably strong acid.

We have said that the destructive distillation of acids proceeds in a very different manner according as we operate upon the acid itself, or a salt of the acid. The distillation of the pure salt yields different products to those which are obtained when the salt or dry acid is mixed with a large excess of a dry base (such as quicklime), before the application of heat. If, in the former mode of proceeding, two atoms of the acid are decomposed, yielding a body containing for four volumes of vapour, the elements of two atoms of carbonic acid and two of water less than the parent acid, such body is called a ketone. Thus when two atoms of acetate of lime are distilled, the products are one atom of acetone and two of carbonic acid. Of course the carbonic acid combines with the lime, thus:

$$2(\underbrace{C^4H^3CaO^4}) = C^6H^6O^2 + 2(CaO,CO^2).$$

Acetate of lime. Acetone.

$$\mathbf{C^4H^6CaO^4 = C^3H^6O + CaCO^3}.$$

If, however, the salt is not of a very low atomic weight, and the quantities operated on are at all considerable, secondary products are formed, as in the dry distillation of butyrate of lime, when, if the substance is not in very small quantity, carbon is deposited, and a certain quantity of butyral, $C^8H^8O^2$ ($\mathbf{C^4H^8O}$) is formed, and probably other substances.

As an illustration of the decomposition undergone when acids are distilled with a great excess of dry base, we shall select that of benzoic acid, which under the circumstances alluded to yields benzole and carbonate of the base:

$$\underbrace{C^{14}H^6O^4} = C^{12}H^6 + 2(CO^2)$$

Benzoic acid. Benzole.

$$\mathbf{C^7H^6O^2 = C^6H^6 + CO^2}.$$

5. *Destructive distillation of bases.*—It has been found that the organic bases undergo a much simpler and more direct decomposition when subjected to destructive distillation in presence of alkalis than when they are exposed to heat without admixture. There are two bodies almost invariably found among the resulting products, namely, ammonia and pyrrol. In this respect, therefore, the organic alkalis behave like other nitrogenised animal and vegetable products. The decomposition is almost always rather complex, and it is very rare that the products are sufficiently definite to be arranged in the form of an equation. The most common substances found, are the alcohol bases, and these are almost invariably of low atomic weight. One great difficulty connected with researches on this subject, is owing to the fact of its being seldom that the products are in sufficient quantity to enable a thorough knowledge of the molecular constitution to be arrived at. Unfortunately this information is much wanted in consequence of the numerous cases of isomerism to be met with among the alcohol bases. Thus it is difficult, when working in very small quantities, to distinguish between bimethylamine and ethylamine, both of which have the formula C^4H^7N ($\mathbf{C^2H^7N}$). See FORMULÆ, CHEMICAL.

It is remarkable that there is a great similarity between the products of the destructive distillation of some of the most unlike nitrogenous substances. This is conspicuously seen in the case of bones, or rather the gelatinous tissues of bones, shale, and coal naphthas, and cinchonine. An inspection of the following table, compiled from a paper (by the writer of this article), 'On some of the Basic Constituents of Coal Naphtha,' will render this evident:—

Gelatinous Tissues.	Shale Naphtha.	Coal Naphtha.	Cinchonine.
Pyrrol.	Pyrrol.	Pyrrol.	Pyrrol.
Pyridine.	Pyridine.	Pyridine.	Pyridine.
Picoline.	Picoline.	Picoline.	Picoline.
Lutidine.	Lutidine.	Lutidine.	Lutidine.
Collidine.	Collidine.	Collidine.	Collidine.
. .	Parvoline.	. .	. .
. .	. .	Chinoline.	Chinoline.
. .	. .	Lepidine.	Lepidine.
. .	. .	Cryptidine.	. .
Aniline.	. .	Aniline.	. .

It is very possible that some of the above bases, having the same formulæ, but derived from different sources, will, in course of time, prove to be merely isomeric, and not absolutely identical. The author of this article has found that the chinoline of coal-tar is certainly not identical with that from cinchonine. The base from the latter source yields a magnificent and fast blue dye upon silk, when treated by a process which gives no reaction if the coal-base be substituted. It is unfortunate that the reaction is with the latter instead of the former, as it would have added one more to the list of gorgeous dyeing materials yielded by coal-tar.

6. *General Remarks.*—The tendency of numerous researches, made during the last few years, has been to show that there is no organic substance, capable of resisting high temperatures, which may not be found to exist among products of destructive distillation. By varying the nature of the substance to be distilled, and also the circumstances under which the operation is conducted, we can obtain an almost infinite variety of products. Acids, bases, and neutral substances, solid, liquid, and fluid hydrocarbons, organic positive, negative, and derived radicals, organo-metallic bodies

—all may be produced by the action of high temperatures on more or less complicated bodies. Much has already been done, but the facts at present accumulated relate merely to the superficial and more salient substances. On penetrating further below the surface far more valuable and interesting facts will came to light.—C.G.W.

DISTILLED WATER. Water converted into vapour by heat, and subsequently condensed. See WATER.

DITTANY. The root of the *Dictamnus Fraxinella*, a plant belonging to the Rue order, or *Rutaceæ*, formerly much used in medicine.

DISSOCIATION. The resolution of certain compounds at a high temperature into their constituents; the elements of which they are composed being capable of existing together under these conditions, without entering into combination. Thus, carbonic oxide is dissociated at a high temperature, oxygen being set free and combining with unaltered carbonic oxide to form carbonic acid gas, whilst free carbon is deposited. According to Mr. I. Lowthian Bell, this decomposition is of much importance in the reactions which accompany iron smelting in the blast-furnace. As dissociation is a purely physical phenomenon, hardly within the limits of this Dictionary, we may refer the reader to 'Leçons sur la Dissociation' (1864), by M. Henri Sainte-Claire Deville, who has made this subject peculiarly his own.

DIVI-DIVI, or *Libi-Davi*, is the pod of a leguminous shrub, the *Cæsalpinia coriaria*, which is indigenous to Jamaica, and some parts of South America. Mr. Rootsey obtained a mean produce of 6·625 grs. of leather from 60 grs. of divi-divi, while the same quantity of the best Aleppo galls yielded only a mean produce of 4·625. It appears, too, from Sir Humphry Davy's estimate, that 60 grs. of divi-divi contain 3·0475 grs. or 5·079 per cent. of tannin, and 60 grs. of galls, 2·12704 grs., or 3·450 per cent. Sixty grs. of oak bark yielded only 1·75 grain of leather; whence it follows that it contains but 0·805 of a grain of tannin to the drachm, or not more than 1·34166.

It has been tried as a dye instead of galls or sumach, but its use for this purpose is almost entirely abandoned. See LEATHER.

DIVING BELL. As it is frequently desirable to raise objects from the bottom of the sea or rivers, and to lay the foundation of piers and similar structures, some contrivance was desired to enable man to descend below the water, and to sustain himself while there. The first method adopted was the very simple one of letting down a heavily-weighted bell vertically into the water. As the bell descended, the air got overpressed, and the water rose in the bell, but never to the top, and within that space the man was sustained for some time. The air, however, was vitiated by the process of respiration, and the man had to be drawn up. It is curious to find that as early as 1693 a very complete system of diving without a bell was devised, as the following quotation will show:—

A. D. 1693. 'William and Mary, by the Grace, &c. &c. Whereas John Stapleton, gentleman, hath by his great study and expence invented a new and extraordinary engine of copper, iron or other mettal, with glasses for light joints, and so contrived as to permit a person enclosed to move and walk freely with under water, and yet so closely covered over with leather as sufficiently to defend him from all the jumpes of it. Also invented a way to force air into any depth of water, whereby the person in the aforesaid engine may be supplied with a continual current of fresh aire, which not only serve him for respiracon, *but may alsoe be useful for continuing a lamp burning, which he may carry about with him in his hand.* . . . Likewise a way to make the same again serviceable for respiracon, and by continually repeating the operacon, a man may remain a long time under water, in either of the said engines, without any other air than the sayd engines do contayne, whereby he shall be preserved from suffocation if any extraordinary accident should interrupt the current of fresh air afore menconed.'—*Letters Patent. Rolls Chapel. Edited by Bennet Woodcroft.*

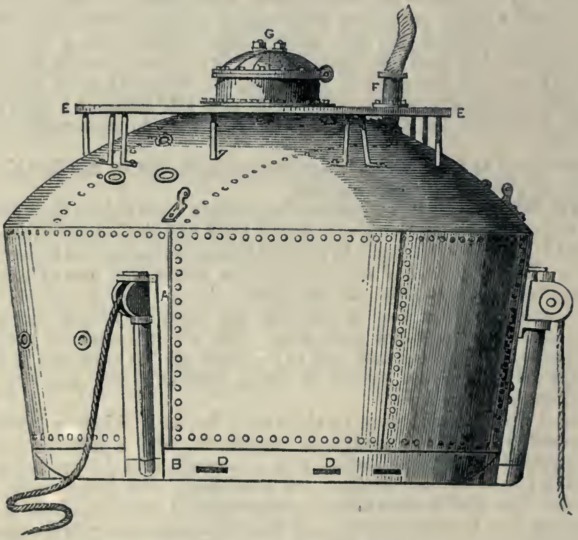
The defects were many in this apparatus, and Dr. Halley invented a bell the object of which was to remedy them.

Dr. Halley's bell was of wood coated with lead, and having strong glass windows above, to allow the passage of light to the diver. In order to supply air, a barrel was taken with an open hole in the bottom, and a weighted hose hanging by, and fitting into a hole at the top. From this barrel the air of the bell was supplied as frequently as it became vitiated, the barrels of air being sent down from above. Spalding improved upon Halley's bell, and again Friewald made some improvements on Spalding's, but in principle these bells were all alike. The modern bells are usually large and strong iron bells, with windows in the upper part. By means of an air-pump, placed on the surface, air is sent down to the divers in the bell, and the vitiated air is as regularly removed from the bell by other tubes through which it escapes. These diving bells are lowered by means of cranes, and are moved about in the water by those above, signals being given by the men below. The difficulty of moving this machine, renders it still inconvenient, and attempts were made to obviate this, by the construction of a diving bell upon principles entirely different. This new diving bell, to which the name of THE NAUTILUS was applied, proved useful in the construction of some parts of the Victoria Docks, and some works on the Seine. Although it is not now much used, a description of it is appended.

The nautilus machine is entirely independent of suspension; its movements are entirely dependent on the will of those within it, and without reference to those who may be stationed without; it possesses the power of lifting large weights *per se*, and at the same time is perfectly safe, by common care in its operations. This latter is the greatest desideratum of all. These advantages must strike all as combining those requisites of success which have been always wanting in the present known means for constructing works under water.

The form of the machine is not arbitrary, but depends entirely on the nature of the work to be performed, adapting itself to the various circumstances attending any given position. By reference to the annexed figures it will be perceived that when at rest, being entirely enclosed, its displacement of water being greater than its own weight, it must float to the surface (see *fig.* 629). Entering through a man-hole at the top (which is closed either from the inside or outside), you descend into the interior of the machine, portions of which are walled off on either side, forming chambers; these chambers are connected at or near the bottom of a pipe *a a* (*fig.* 630), which opens by a cock *b*, outwards to the external surrounding water. An opening in the bottom of the machine of variable dimensions is closed by a door or doors susceptible of being opened or closed at pleasure. The chambers W W, are likewise connected at top by a smaller pipe *c c*, which opens through the top of the machine, and to which opening is affixed a flexible pipe, with coils of wire spirally enclosed. Branches on this latter pipe T, allow also communication with the larger or working chamber.

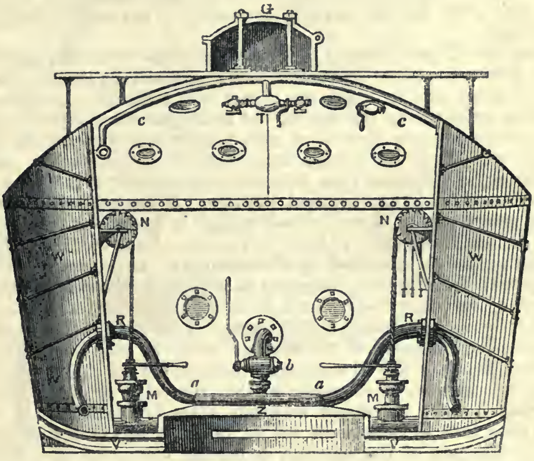
629



At the surface of the water placed on a float or vessel for the purpose, is a receiver of variable dimensions, to which is attached at one end a hollow drum or reel, to the barrel of which is affixed the other end of the flexible pipe *a*, leading to the top of the nautilus. At the other end of, and in connection with the receiver, is a powerful air-condensing pump. This combination represents the nautilus as adapted to engineering work.

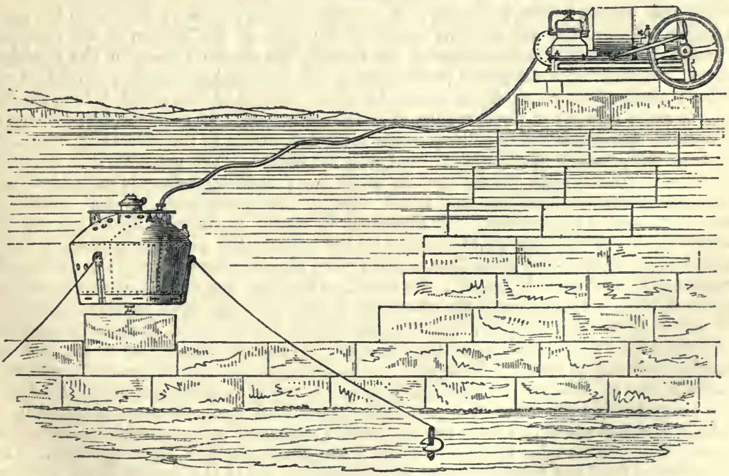
As to the *modus operandi*:—The operator with his assistants enters the machine through the top, which is then closed. To descend, the water-cock *b* is opened, and the external water flows into the chambers W W; at the same time a cock, on a pipe opening from the chambers outwards, is opened, in order that, the air escaping, an uninterrupted flow of water may take place into the chambers. The weight of water entering the chambers causes a destruction of the buoyancy of the machine, and the nautilus gradually sinks. As soon as it is fairly under water, in order that the descent may be quiet and without shock, the water-cock *b*, is closed. The receiver at the surface being previously charged by the air-pump to a density somewhat greater than that of the water at the depth proposed to attain, one of the branch-cocks on the pipe *c c*, connecting the chambers at top, is opened, and the air rushes into the working chamber, gradually condensing until a density equal to the density of the water without is attained; this is indicated by proper air and water gauges. These gauges marking equal points, showing the equilibrium of forces without and within, the cover to the bottom *z* is removed or raised, and communication is made with the under water surface, on which the nautilus is resting. In order to move about in localities where tides or currents do not affect operations, it is only necessary for the workman to step out of the bottom of the nautilus, and placing the hands against its sides, the operator may move it (by pushing) in any direction.

630



Where currents or tides, however, have sway, it becomes necessary to depend upon fixed points from which movements may be made in any direction. This is accomplished by placing, in the bottom of the nautilus, stuffing boxes of peculiar construction (M M, *fig.* 630), through which cables may pass over pulleys to the external sides,

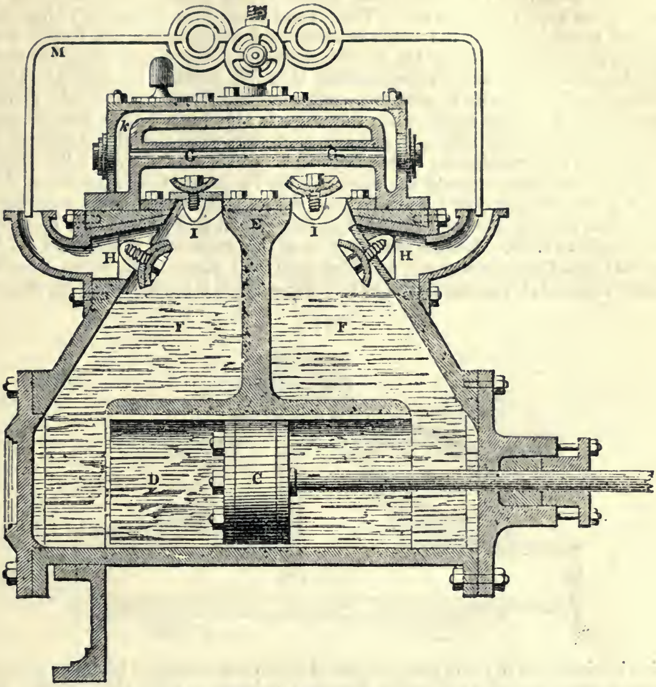
631



thence up through tubes (to prevent their being worn), to and over oscillating or swinging pulleys, placed in the plane of the centre of gravity of the nautilus, and thence to the points of affixment respectively (*fig.* 631). The object to be gained by having the swinging pulleys in the plane of the centre of gravity of the mass, is to hold the machine steady and to prevent oscillation. Within the machine, and directly over the above stuffing boxes, are windlasses for winding in the cables. By working these windlasses movement may be effected, and of course the number of these cables will depend on the variable character of the situation to be occupied. Having thus secured the means of descending, communicating with the bottom, and of movement, the next point is to ascend. Weight of water has caused a destruction of buoyancy at first, and consequent sinking; if then any portion of this water is removed, an upward effort will at once be exerted exactly proportionate to the weight of water thrown off. The air in the receiver at the surface being constantly maintained at a higher density than that of the water below, if we open the water cock on the top pipe, *c c*, throwing the condensed air from the receiver above directly on to the surface of the water in the chambers, movement and consequent expulsion of the water must take place, and an upward movement of the machine itself, which will rise to the surface.

It is evident that if, previously to the expulsion of the water, the nautilus be affixed to any object below, the power exerted on that object will be exactly proportionate to the weight of water expelled, and the power will continue increasing until, there being no farther weight to be thrown off, the maximum effect is produced. To apply this power to lifting masses of stone or rock, proper arrangements are affixed to the centre of the opening in the bottom, by which connection can be made with the weight, admitting, at the same time, the swinging around of the object suspended, so that it may be placed in any required position. In the construction of permanent work, or the movement of objects whose weight is known, or can be estimated, a water, or, so called, lifting tube is placed on the side of the water chamber, which indicates the lifting power exercised by the nautilus at any moment. The advantage of this gauge will be recognised, inasmuch as without it the closest attention of the operator, working very cautiously, would be necessary to determine when the weight was overcome: by its aid, however, the operator boldly throws open all the valves necessary to develop the power of the nautilus, watching only the gauge. The water, having reached the proper level indicating the required lifting power, he knows the weight must be overcome, or so nearly so that the valve or cocks may be at once closed, in order that the movement may take place horizontally. A moment's reflection will show that, if there were not an index of this character, carelessness or inattention on the part of the operator, by leaving the cocks open too long, might develope a power greater than required, and the nautilus would start suddenly upward. The expansive power of air, acting upon the incompressible fluid, water, through the opening in the bottom, gives a momentum which, by successive developments of expansion in the working chamber, is constantly increasing in velocity, until, in any considerable depth of water, the result would be undoubtedly of a very serious character. Take, for exemplification, the nautilus in thirty-three feet of water, and bottom covers removed, and an equilibrium, at fifteen pounds to the inch, existing between the air and the water at the level of the bottom of the machine. Upward movement is communicated the instant the machine rises in the slightest degree, the existing equilibrium is destroyed, and the highly elastic qualities of air assume preponderance, exerting, from the rigid surface of the water below, an impulsive effort upward in the direction of least resistance. At each successive moment of upward movement the impelling power increases, owing to the increasing disparity between the pressure of air within struggling for escape. The machine, thus situated, becomes a marine rocket (in reality), in which the propelling power is exhausted only when the surface is reached, and a new equilibrium is obtained. It will readily be seen that, were this difficulty not overcome, it would be impossible to govern the nautilus; for, rising with great velocity to the surface, the machine is carried above its ordinary flotation, or water line, a little more air escaping owing to the diminished resistance as that level is passed; the recoil, or surging downwards, causes a condensation of the air remaining in the chamber; a portion of the space previously occupied by air is assumed by water; the buoyant power becomes less, the machine settles slightly more by condensation of the air, a larger space is occupied by water, and the nautilus redescends to the bottom with a constantly accelerating movement, seriously inconveniencing the operator by filling more or less with water, according to depth. For many months the difficulties just enumerated baffled all attempts at control. A weight attached could be lifted, but the instant it was entirely suspended,—before the valves could be closed,—upward movement was communicated beyond control. This difficulty so fatal has been overcome by an arrangement at the bottom of the nautilus, with channels which radiate from the opening in an inclined direction, debouching at the sides of the machine. The moment then that the air, by its expansion from diminished resistance, or by the introduction from above of a greater volume than can be sustained by the water below, reaches, in its downward passage, the level of these chambers, following the direction of least resistance, it passes through these channels and escapes into the surrounding water, without of course affecting the movement of the machine in the least.

632



The pump for supplying air to the diving bell or other suitable vessel is represented in *figs.* 632 and 633, and is constructed as follows:—D is a cylinder, opening at the upper part into a chamber or chambers F F, separated by a partition E. On the side of each of these chambers there is a valve H H, opening inwards, and at the upper part of the same are two valves I I, opening outwards into the valve chamber G. Outside the opening for each of the valves H, H, there is a cup, into which the end of the water supply pipe M passes; by this means a small stream of water is supplied to the cup, and is drawn from it into the chamber F to supply the waste in the operation of pumping. The valve chamber G is covered with a jacket *k*, having a space between it and the valve chamber that is filled with water from the water-pipe M, which affords a stream of cold water to carry off the heat from the condensed air which is forced into the chamber. The water thus supplied circulates through the tubes in the chamber and round them in the jacket, and thus cools the air in these tubes; it is then conveyed so as to be

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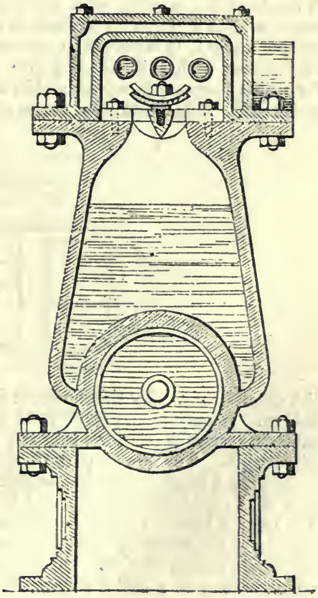

usefully employed in a steam-boiler, or is allowed to run off. The air and a small quantity of water is forced up from the cylinder D, by the stroke of the piston C, into the chamber F, which is thereby filled with water, and thus the air is expelled therefrom, a small quantity of the water passing with it and covering the valves, by which means they are kept tight and wet. The air and water thus discharged, after passing around the small tubes in the valve chamber and being cooled, are forced outward and conveyed to the condenser. On the return stroke of the piston, the other chamber F is filled, and air and water expelled from it in like manner through its valve into the valve chamber. There is always a sufficient quantity of water in the cylinder D and chamber F to fill the latter when the water is all expelled from the cylinder, by the piston C having been driven to one end of it, and when the piston returns to the opposite end of the cylinder the water flows in behind it, and draws in its equivalent in bulk of air and water through the valve H. On its return, this is forced out through the valve *k* into the chamber I, as mentioned above. The water being non-elastic, if the parts are kept cool enough to avoid raising steam, this process may be continued for any length of time. A transverse section of this apparatus is shown in *fig.* 633.

Figs. 634 and 635 represent the speaking tube and alarm bell above referred to. The construction of this mechanism is as follows:—There is a hollow casting, one portion of which is triangular in form, from one end of which a short tube *a* projects. This tube *a* has a screw cut on it, and a projecting flange at its junction with the triangle. This is screwed into the top of the diving vessel or armour from the inside, and projects through it to allow the coupling of a flexible or other hose to be attached to it. At the opposite angle, and in a line with *a*, there is a tubular projection *b*, provided with a screw to receive a cap *f*, to which is to be attached a piece of hose. Within the tube *f*, and at its junction with *b*, is placed a thin diaphragm of metal or other suitable material *c*, for which purpose, however, a thin silver plate that just fits the bore of the cap *f* is preferred. This diaphragm closes all communication between the diving vessel and the external air. By this means it is easy to converse through any required length of tubing. It may be desirable to fit a stop-cock into the tubular projection *b*, as a precautionary means of preventing the escape of air in the event of a rupture of the diaphragm. The upper part of the triangular enlargement of the speaking tube is tapped for a stuffing box at *g*, within which there is an axis *h*, which runs from side to side of the said enlargement, and through the stuffing box at one side. On this axis *h* is fixed a lever *i* within the said enlargement, which lever communicates with the surface of the water by means of a wire fixed at its reversed end, and running through the whole length of pipe. On the outer extremity of the axis *h* is affixed a hammer, which strikes on a bell *k* connected to the tube, as shown in the drawing. By this

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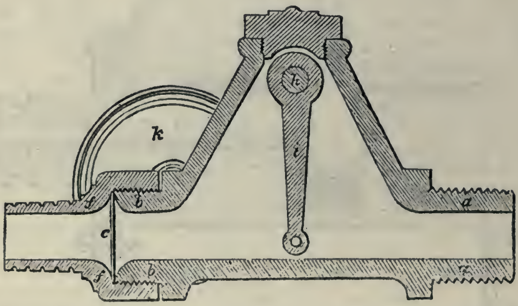

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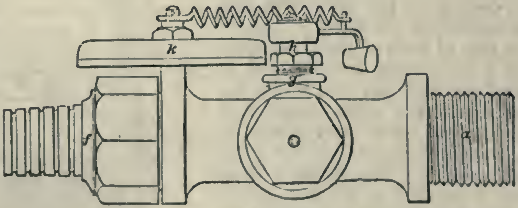

means the attention of the operator below may be drawn to the speaking tube when it is required to converse with him from the surface of the water, and the men whose duty it is to attend to the operator below can, by placing their ear at the end of the tube, hear the bell struck below as a signal for communication with them at the surface.

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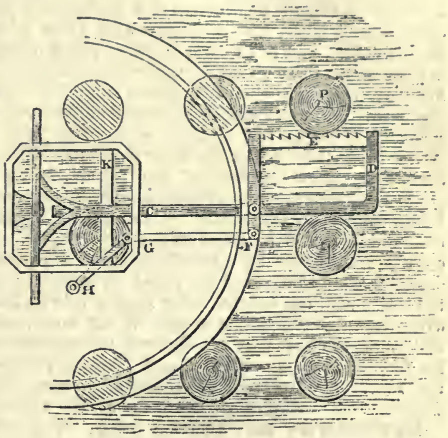
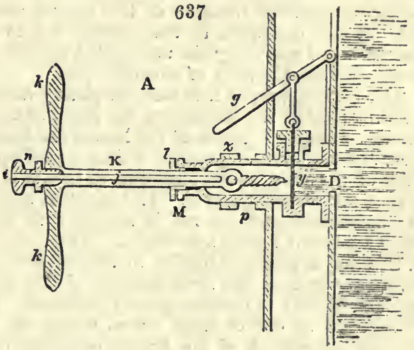


The only parts of the apparatus not yet described are the saw for cutting the tops of piles to an uniform level, the pump which enables the divers themselves to rise to the surface in the event of the flexible hose being detached or injured, and the contrivance for screwing an eye bolt into the side of the sunken vessels.

The arrangement of the saw-frame and connections are shown in *fig.* 636. Only as much of the bottom of the Nautilus is shown as will render the position of the saw understood. P is a pile which is required to be cut down to the same level as the others, E is the blade of the saw, D the framing by which it is stretched, C, D, the handle which rests on the cross bar K, to which is attached the upright part of the handle which is laid hold of by the workman inside when working the saw. H, G, F, a bent lever with two friction rollers at F, which guides the saw forwards while making the cut.

The pump for ascending in case of accident to the air hose is not shown in the drawing. It is a simple force pump placed in the working chamber, by which the ballast water in W W, *fig.* 630, can be pumped out so as to lighten the apparatus sufficiently to allow of its ascent.

637



The apparatus for fixing the eye bolts is shown in *fig.* 637. The operation of this apparatus is as follows:—It will be observed the chamber D opens outwards to the water, so that when the sliding partition or valve *y* is forced down by the lever *g*, the communication of the water with the chamber is cut off. The lid *z* being removed, a bolt *i* (or other operating tool or instrument) is placed within the chamber C; the rod K is forced through the stuffing box *l* until the recessed end of the rod contains the end of the bolt; the small rod *j* is then screwed through the stuffing box *n*, until the screw on the end of this rod has become affixed to the end of the bolt contained within the recess at *p*. The lid *z* of the chest is then fastened on, and the partition or valve *y* raised, the stuffing box M preventing the escape of air. Communication is thus opened between the chambers A and D, the latter being open outwards. The rod *i* is now pushed outwards by pressing on the handle *k* through the stuffing box *l*, until the vessel or object to be operated upon is reached, when the operation is performed as required. It will be observed that the stuffing box prevents the escape of air out of the bell or the admission of water into it, the stuffing box *n* having the same tendency. After the operation with the tool or instrument is complete, the rod *k* is disconnected by unscrewing the rod *j*, and is drawn into the chamber A by means of the handle *k*; the partition or valve *y* is again lowered, and the operations above described are repeated. It will hence be obvious that a number of eye bolts might in this manner be successfully inserted in the side of a sunken vessel from the diving bell, so that by hooking on the 'camels' the strain would be so distributed as to prevent injury by the process of lifting the said vessel.

DIVING DRESS, or **HELMET.** The diving helmet is, in principle, similar to the bell. In one case the head is enclosed in an air-tight metal covering, to which air is artificially supplied; in the other, the whole body is in a vessel fitted with pipes for the supply of fresh, and the removal of deteriorated, air.

The diving helmet is made of thin sheet-copper, which covers the head of the diver, large enough to admit of free motion, and pierced with three holes, which are covered with glass, and protected with brass wire. The diver wears a waterproof canvas jacket, and to this the helmet, which comes down over the breast and back, is fastened so tightly that no water can penetrate. Two weights, each about 40lbs., are suspended to a belt which passes round the diver, one in front, and the other at the back. This belt can be instantly unfastened in case of accident. Fresh air is supplied by means of a flexible waterproof pipe, which is attached to an air-pump in the barge from which the diver descends. This pipe passes under the diver's left arm, and enters the back of the helmet, being so contrived that the fresh air is made to impinge on the glasses, and thus prevents them in a great measure from being dimmed by the breath. From the back part of the helmet there is also led an eduction pipe, which carries off the breathed air. The attendants on the surface are communicated with by a signal line, which passes under the right arm. The diver descends from the side of the vessel by a rope or else by a wooden ladder, loaded at the lower end, the weight being kept at a little height above the ground. When the diver has descended, the weight is set down, and the rope slackened, so that the motion of the boat may not obstruct his movements. Heavy weights are attached to his feet to keep him steady; and he carries a line in his hand to guide him back to the rope. A waterproof dress entirely covers him, and thus he may remain under water five or six hours, perfectly dry all the while.

DIVINING; DIVINING ROD. The German miners who were brought over to this country at the instance of Queen Elizabeth, who was especially desirous of seeing the mineral treasures of this country developed, first introduced the divining rod. It has continued to the present day to be occasionally used in the mining districts—not merely by the uneducated miners, but by men of education and intelligence—for the discovery of mineral lodes.

The divining, or, as it is more frequently called in Cornwall, the 'dowsing' rod, is a forked twig of the blackthorn, the hazel, or the willow, of one year's growth. It is placed on the open palms of the hands, the fingers are closed upon each limb of the fork, and the point of junction is then turned up towards the operator, and then, by a twist of the arms, placed outwards, so that it is held with the muscles of the arm in a most constrained position. The operator, called 'a dowser,' walks over the ground to be examined, and the rod is supposed to turn downwards with irresistible force when a mineral lode is approached. There can be no question but the phenomenon in this case is precisely similar to that of table-turning. Fixedness of will operates involuntarily upon the rigid muscles of the arm, a movement is felt, and the slight impulse yielded to becomes greatly increased. Every fairly made experiment proves divining to be one of those errors which are born of ignorance, and perpetuated through the neglect of the proper education of the mind. Two or three well-established positions may serve to remove this superstition from those minds which can be brought to reflect on natural phenomena.

The divining rod is supposed to bend by virtue of some attractive power between the woody twig and the mineral lode.

1. Place the most approved divining rod over a mineral lode, so delicately poised that a breath will turn it. The metalliferous matter will exert no influence upon it.

2. Place the divining rod upon the open palms of the hands of the most approved 'dowser.' It will never move, however great may be the mass of metal.

Thus we have proofs that neither the metals, the twig, nor the man have any influence.

3. Close the hands tightly, keeping the arms still in an easy position. No change in the position of the rod will take place in passing over any number of mineral lodes.

4. Twist the arms in the way described, and then, and then only in the hands of a believer, will the rod bend; and it is a chance if it bends at the right time.

The divining rod is said to bend equally to water, hence it is used in some places to find that fluid; to blood, therefore it was used to track murderers; and to metals.

It is to be regretted that the human mind should cling, with so much obstinacy, to the errors of those days when everything was seen through the mists of superstition.

DOCIMACY. (*Docimasie*, Fr.) From the Greek Δοκιμάζω, I prove. See Assaying.

DOEGLING TRAIN OIL. The oil of the *Balæna rostrata*, or Bottle-nose whale,

DOG-TOOTH SPAR. Calcite, or carbonate of lime, crystallised in scalenohedra. Such crystals are common in the Mountain-limestone of Derbyshire.

DOG-WOOD. *Cornus sanguinea*, a small underwood known as the wild cornel, and as the common Dogwood. Little splinters of this wood are used by the watchmaker for cleaning out the pivot-holes of watches, and by the optician for cleaning deeply-seated small lenses. Its peculiarity is that it is remarkably free from silex. Toothpicks are also manufactured from dogwood.

DOG-WOOD BARK. The bark of the *Cornus florida*, a plant much used in the United States as a substitute for Peruvian bark in cases of fever.

DOLERITE. A variety of 'greenstone,' composed of augite and felspar. The difficulty of discriminating these minerals gives the name, from Δολερός, deceptive.

DOLLY; DOLLY-TUB. *A mining term* applied to a tub fitted with a perforated board, *the dolly*, to which a circular motion is given by a winch-handle, and thus imparts a similar motion to the ore. See Dressing of Ores.

DOLOMITE. (*Dolomie*, Fr.; *Dolomit* and *Bitterspath*, Ger.) A name applied to *Magnesian Limestone*, in honour of a distinguished French geologist and mineralogist of the last century, M. Deodatus Guy Silvanus Tancred de Gratet de Dolomieu. This mineral is essentially a double carbonate of lime and magnesia, containing, in the normal varieties: carbonate of lime, 54·35; carbonate of magnesia, 45·65; a percentage composition corresponding to the formula $CaO.CO^2 + MgO.CO^2$ (**$CaMg2CO^3$**). The relative proportion of the two carbonates is, however, subject to considerable variation, the species passing on the one hand into carbonate of lime, and on the other into carbonate of magnesia.

In its general characters, dolomite strongly resembles calcite or pure carbonate of lime, from which, however, it may be easily distinguished by its greater hardness and density, and by effervescing less briskly with acids. At the same time its crystalline forms are neither so varied nor so complex as those of calcite. It is notable that the crystals have a remarkable tendency to present curved faces, and from the nacreous lustre which they often possess, are commonly termed *pearl spar*. The presence of protoxide of iron replacing the isomorphous oxides, lime and magnesia, often causes the mineral to assume a brown colour after exposure to the atmosphere, whence such varieties are distinguished as *brown spar*. In this country, crystallised dolomite is common in the lead-mines of Derbyshire, Alston Moor, Leadhills, and the Isle of Man: the finest crystals, however, occur at Traversella, in Piedmont.

The massive and finely-granular forms of dolomite are very widely distributed, forming in certain districts rock-masses of considerable extent, and occasionally rising into mountains of characteristic boldness, well seen in the Dolomites of the Tyrol. In England, large deposits of magnesian limestone occur in the upper beds of the Permian system, or that group of rocks which immediately overlies the coal-measures, and of which the upper beds are commonly known as *Zechstein*, a name borrowed from their German equivalents. The principal deposits occur in the north-east of England, extending from the mouth of the Tyne in a south-westerly direction through Durham and Yorkshire, into the counties of Derby and Nottingham. In these beds the dolomite frequently assumes singular concretionary forms; whilst at Marsden, a few miles south of the Tyne, it presents a schistose structure, separating into thin layers of remarkable flexibility. A dolomitic limestone is also found in the so-called *Dolomitic Conglomerate* of Bristol, a rock which occurs locally at the base of the Trias, or New Red Sandstone, and contains fragments and pebbles of older rocks cemented together by a limestone more or less dolomitic. In addition to the recognised forms of dolomite, many limestone rocks, of various ages, are found, on chemical examination, to contain magnesia, and in some cases to pass into true dolomites. Dr. Sterry Hunt has shown, moreover, that the veins in certain marbles are dolomitic, whilst the base may be only an ordinary limestone; and also that the substance of some fossil shells is a dolomite, although the matrix is nothing more than limestone: this is notably the case with some of the fossils of the Trenton Limestone (Lower Silurian) of Ottawa, in Canada.

The origin of dolomite has long been a standing enigma to the geologist; but as the question is one of only theoretical interest, its discussion would be out of place in this article.

As building stones, the dolomites have been highly valued, those varieties being regarded as most durable which present a crystalline structure, and in which the carbonates of lime and magnesia exist in nearly atomic proportions. The quarries in the neighbourhood of Bolsover Moor, in Derbyshire, supplied the magnesian limestone employed in the construction of the new Houses of Parliament.

The dolomites of Durham are employed in the chemical works on the Tyne for the manufacture of sulphate of magnesia, or Epsom salts, although at present to a less extent than formerly.

Dolomite was employed first by the late Mr. Hugh Lee Pattison, for the manufacture of carbonate of magnesia, and it is still used for that purpose.

When dolomite is calcined, within certain limits of temperature, it is said to furnish an excellent hydraulic lime. M. H. Sainte-Claire Deville has called attention to the powerful hydraulic properties of caustic magnesia by its union with water to form a definite hydrate. It appears that if dolomite be calcined below a red heat, the carbonate of magnesia suffers decomposition, whilst the carbonate of lime remains almost intact; on slaking this calcined dolomite, the magnesia combines with water, and this hydrate cements the unaltered particles of carbonate of lime.—F.W.R.

DOMEYKITE. An arsenide of copper, occurring in Chili, in Bolivia, and at Lake Superior. Mr. D. Forbes found the domeykite of the Corocoro sandstone, in Bolivia, to contain copper 71·13; arsenic 28·41; silver 0·46. This has probably been formed *in situ* by the action of arsenical vapours on metallic copper disseminated through the sandstone. Faraday's *Condurrite* from Cornwall is closely allied to—if not identical with—domeykite.

DONARIUM. Bergmann supposed that he had detected, in a Norwegian mineral, a new metal, to which he gave the name of Donarium, from the Scandinavian god Donar. This metal is now proved to be identical with thorinum.

DONKEY ENGINE. A very small engine employed to pump water into boilers. If the use of the donkey engine were more usual than it is, we should hear less of steam-boiler explosions.

DONSHA. *Æschynomone Cannabina.* See Fibres.

DOOPARA RESIN. A resin obtained in considerable quantities in the East Indies from the *Vateria Indica*, which is used as a fragrant incense in the temples, makes an excellent varnish, and is sometimes called *East Indian Copal*, or *Gum Piney.*—*Simmonds.*

DORNOCK is a species of figured linen of stout fabric, which derives its name from a town in Scotland, where it was first manufactured for table-cloths. It is the most simple in pattern of all the varieties of the diaper or damask style, and therefore the goods are usually of coarse quality for common household wear. It receives the figure by reversing the flushing of the warp and woof at certain intervals, so as to form squares, or oblong rectangles upon the cloth. The most simple of these is a succession of alternate squares, forming an imitation of a checker board or mosaic work. The coarsest kinds are generally woven as tweels of three leaves, where every thread floats over two, and is intersected by the third in succession. Some of the finer are tweels of four or five leaves, but few of more; for the six and seven leaf tweels are seldom or never used, and the eight leaf twill is confined almost exclusively to damask.

DORSETSHIRE CLAY. Clay shipped from Poole in Dorsetshire. See Clay.

DOUK or **DOUKE.** Mr. Wallace, in his work on the mines of Alston Moor, expresses his belief that this term is derived from the Saxon *deagan*, to knead or mix with water. It is a soft substance, often found in veins, especially in crop veins, and where their walls or sides are formed of shale. It is evidently pounded or decomposed shale, though not unfrequently as compact as the rock from which it is derived, but differs from the latter in exhibiting no traces of bedding. Exposed to the atmosphere, it rapidly decomposes into a blue kind of clay.

DOWLAS. A coarse kind of linen.

DOWN. See Feathers.

DOWSING ROD. See Divining Rod.

DRAGON'S BLOOD (*Sang-dragon*, Fr.; *Drachenblut*, Ger.) is a resinous substance, which comes to us sometimes in small balls of the size of a pigeon's egg, sometimes in rods like the finger, and sometimes in irregular cakes. Its colour, in lump, is dark brown-red; in powder, bright red; friable; of a shining fracture; specific gravity 1·196. It contains a little benzoic acid, is insoluble in water, but dissolves readily in alcohol, ether, and oils. It is brought from the East Indies, Africa, and South America, as the produce of several trees, the *Dracæna draco*, the *Pterocarpus santolinus*, *Pterocarpus draco*, and the *Calamus rotang*.

Dragon's blood is used chiefly for tingeing spirit and turpentine varnishes, for preparing gold lacquer, for tooth tinctures and powders, for staining marble, &c. According to Herbenger, it consists of 9·07 parts of red resin called *Draconin*, 2 of fixed oil, 3 of benzoic acid, 1·6 of oxalate, and 3·7 of phosphate of lime. According to Johnstone, the resin of lump dragon's blood has the formula $C^{40}H^{21}O^{8}$ ($\mathbf{C^{20}H^{21}O^{4}}$), that of reed dragon's blood, $C^{40}H^{20}O^{9}$ ($\mathbf{C^{40}H^{40}O^{9}}$).

Pereira enumerates the following varieties of this substance found in commerce:—

1. *Dragon's blood in the reed; Dragon's blood in sticks* (*Sanguis Draconis in baculis*).

2. *Dragon's blood in oval masses; Dragon's blood in drops* (*Sanguis Draconis in lachrymis.*)

3. *Dragon's blood in powder.*
4. *Dragon's blood in the tear* (*Sanguis Draconis in granis*).
5. *Lump Dragon's blood* (*Sanguis Draconis in massis*).

Besides these, there are *Dragon's blood in cakes* and *False Dragon's blood in oval masses.*

DRAINING TILES. Burnt clay tiles, generally shaped in section like a horse-shoe, about one foot long, and two or three inches broad. These are much used in agricultural draining. See STONE-WARE.

DRAWING CHALKS. Chalks or crayons are frequently nothing more than the natural production reduced to a convenient form: they are, however, sometimes prepared artificially; a few of these manufactures are named.

The Brothers Joel, in Paris, employ as crayon cement the following composition: 6 parts of shellac, 4 parts of spirit of wine, 2 parts of turpentine, 12 parts of a colouring powder, such as Prussian-blue, orpiment, white lead, vermilion, &c., and 12 parts of blue clay. The clay being elutriated, passed through a hair sieve, and dried, is to be well incorporated by trituration with the solution of the shellac in the spirit of wine, the turpentine, and the pigment; and the doughy mass is to be pressed into proper moulds, so as to acquire the desired shape. They are then dried by a stove heat.

In order to make cylindrical crayons, a copper cylinder is employed, about 2 inches in diameter and 1½ inch long, open at one end, and closed at the other with a perforated plate, containing holes corresponding to the sizes of the crayons. The paste is introduced into the open end, and forced through the holes of the bottom by a piston moved by a strong press. The vermicular pieces that pass through are cut to the proper lengths, and dried. As the quality of the crayons depends entirely upon the fineness of the paste, mechanical means must be resorted to for effecting this object in the best manner. The following machine has been found to answer the purpose exceedingly well.

Fig. 638 is a vertical section through the centre of the crayon mill. *Fig.* 639 is a view of the mill from above. A, the mill tub, whose bottom B must be a hard flat plate of cast iron; the sides A being of wood or iron at pleasure. In the centre of the bottom there is a pivot C, screwed into a socket cast upon the bottom, and which may be strengthened by two cross bars D, made fast to the frame E. F, the millstone of cast iron, concave, whose diameter is considerably smaller than that of the vessel A; it is furnished within with a circular basin of wood G, which receives the materials to be ground, and directs them to the holes H, which allow them to pass down between the under part of the muller and the bottom of the tub, to undergo trituration.

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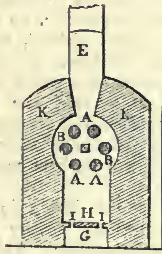

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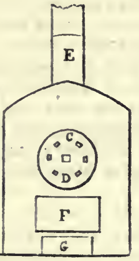

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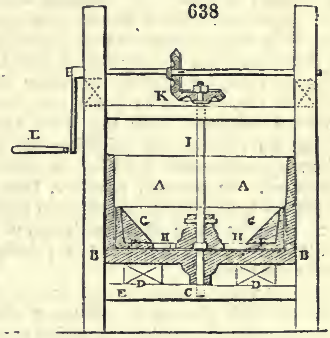

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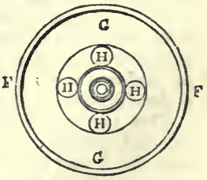

By the centrifugal motion, the paste is driven towards the sides of the vessel, rises over the sides of the muller, and comes again through the holes H, so as to be repeatedly subjected to the grinding operations. This millstone is mounted upon an upright shaft I, which receives a rotatory motion from the bevel-work K, driven by the winch L.

The furnace in which some kinds of crayons, and especially the factitious black-lead pencils, are baked, is represented in *fig.* 640, in a front elevation; and in *fig* 641, which is a vertical section through the middle of the chimney.

A A, six tubes of greater or less size, according as the substance of the crayons is a better or worse conductor of heat. These tubes, into which the crayons intended for baking are to be put, traverse horizontally the laboratory, B, of the furnace, and are supported by two plates C, pierced with six square holes for covering the axles of the tubes A. These two plates are hung upon a common axis D; one of them, with a ledge, shuts the cylindrical part of the furnace, as is shown in the figure. At the extremity of the bottom the axis D is supported by an iron fork fixed in the brick-work; at the front it crosses the plate C, and lets through an end about 4 inches square to receive a key, by means of which the axis D may be turned round at pleasure, and thereby the two plates C, and the six tubes A, are thus exposed in succession to the action of the fire in an equal manner upon each of their sides. At the two extremities of the furnaces are two chimneys E, for the purpose of diffusing the heat more equally over the body of the crayons. F, *fig.* 640, is the door of the fire-place, by which the fuel is introduced; G, *fig.* 641, the ash-pit; H, the fire-place; I, holes of the grate which separate the fire-place from the ash-pit; K, brick-work exterior to the furnace.

General Lomet proposes the following composition for red crayons. He takes the softest hematite, grinds it upon a porphyry slab, and then carefully elutriates it. He makes it into a plastic paste with gum arabic and a little white soap, which he forms by moulding, as above, through a syringe, and drying into crayons. The proportions of the ingredients require to be carefully studied.

Crayons or Chalks, *lithographic.* Various formulæ have been given for the formation of these crayons. One of these prescribes white wax, 4 parts; hard tallow-soap, and shellac, of each 2 parts; lamp-black, 1 part. Another is, dried tallow-soap and white wax, each 6 parts; lamp-black, 1 part. This mixture being fused with a gentle heat, is to be cast into moulds for forming crayons of a proper size. See Lithography.

DRESSING OF ORES. In metalliferous veins the deposits of ore are extremely irregular, and usually intermixed with gangue or vein-stone. In excavating the lode, it is usual for the miner to effect a partial separation of the valuable from the worthless portion; the former he temporarily stows away in some open place underground, whilst the latter is either employed to fill up useless excavations, or in due course sent to surface to be lodged on the waste heaps. From time to time the valuable part of the lode is drawn to the top of the shaft, and from thence conveyed to the dressing floors, where it has to be prepared for metallurgic treatment.

This process is known as Dressing, and in the majority of instances includes a series of operations. Hand labour, picking, washing, sizing, and reducing machinery, together with water-concentrating apparatus, comprise the usual resources of the dresser, but sometimes he may find it useful to have recourse to the furnace, since it may happen that, by slightly changing the chemical state of the substances that compose the ore, the earthy parts may become more easily separable, as also the other foreign matters. With this view, the ores of tin are often calcined, which, by separating the arsenic and oxidising the iron and copper, furnishes the means of obtaining, by subsequent washing, an oxide of tin much purer than could be otherwise procured. In general, however, these are rare cases; so that the washing almost always immediately succeeds the picking, crushing, or stamping processes.

Before entering upon the description of machinery employed in the concentration of ores, it is important to notice the principles upon which the various mechanical operations are based.

If bodies of various sizes, forms, and densities be allowed to fall into a liquid, in a state of rest, the amount of resistance which they experience will be very unequal, and consequently they will not arrive at the bottom at the same time. This necessarily produces a sort of classification of the fragments, which becomes apparent on examining the order in which they have been deposited.

If it be supposed that the substances have similar *forms* and dimensions, and *differ* from each other in *density* only, and it is known that the resistance which a body will experience in moving through a liquid medium depends solely on its form and extent of surfaces, and not on its specific gravity, it follows that all substances will lose under similar circumstances an equal amount of moving force.

This loss is proportionally greater on light bodies than in those having more considerable density. The former for this reason fall through the liquid which less rapidity than the denser fragments, and must therefore arrive later at the bottom, so that the deposit will be constituted of different strata, arranged in direct relation to their various densities, the heaviest being at the bottom, and the lightest at the top of the series.

Supposing, on the contrary, that all the bodies which fall through the water possess similar forms and equal specific gravities, and that they only differ from each other in point of volume, it is evident that the rapidity of motion will be in proportion to their *sizes,* and the larger fragments will be deposited at the bottom of the vessel.

As the bodies on starting are supposed to have the same forms and densities, it follows that the resistance they experience whilst descending through water will be in proportion to the surface exposed, and as the volumes of bodies vary according to the cubes of their corresponding dimensions, whilst the surfaces only vary in accordance with the squares of the same measurements, it will be seen that the force of movement animating them is *regulated by their cubes*, whilst their *resistance* is in proportion to their *squares*.

If, lastly, it be imagined that all the fragments have the same volume and density, but are of various forms, it follows that those possessing the largest amount of surface will arrive at the bottom last, and consequently the upper part of the deposit will consist of the thinnest pieces.

It is evidently then of the greatest importance that the grains of ore which are to be concentrated by washing should be as nearly as possible of the *same size*, or otherwise the smaller surface of one fragment, in proportion to its weight, will in a measure compensate for the greater density of another, and thus cause it to assume a position in the series to which by its constitution it is not entitled.

This difficulty is constantly found to occur in practice, and, in order as much as possible to obviate it, care is taken to separate by the use of sieves and trommels into distinct parcels, the fragments which have respectively nearly the same size. Although by this means the grains of ore may, to a certain extent, be classified according to their regular dimensions, it is impossible by any mechanical contrivance to regulate their forms, which must greatly depend on the natural cleavages of the substances operated on, and hence this circumstance must always in some degree affect the results obtained.

Each of the broken fragments of ore must necessarily belong to one of the three following classes:—the *first* class consists of those which are composed of the mineral sought without admixture of earthy matter; the *second* will comprehend the fragments which are made up of a mixture of mineral ore and earthy substances; whilst the *third* division may be wholly composed of earthy gangue without the presence of metallic ore. By a successful washing these three classes should be separated from each other.

The most difficult and expensive vein-stuff for the dressing floors is that in which the constituents have nearly an uniform aggregation, and where the specific gravities of the several substances approximate closely to each other. In such cases the ore is only separated from the waste after much care and labour, and often at the loss of a considerable portion of the ore itself. When, however, the ore is massive and distinct from the gangue, and the specific gravity of the latter much less than the former, then the operation of cleaning is usually very simple, effected cheaply, and with but little loss on the ore originally present.

Some of the more friable ores, when simply exposed to the influence of water, exhibit a large mechanical loss, so much so, that it is considered oftentimes more profitable to sell them without attempting their enrichment. Now it may be laid down as an axiom that water will always steal ore, and the longer it is exposed to its influence, and the more complicated the manipulation, the greater will be the loss incurred. In addition, the constitution of certain ores is so peculiar and delicate, that any attempt to concentrate them beyond a given standard, by varying the treatment, is seen to lead to an enormous loss, as will be apparent by inspecting the following memoranda of practical results:—

(A.)—The ore operated upon was sulphide of lead, associated with finely-disseminated iron pyrites, oxide of iron, quartz, and a small portion of clay slate. In each case the vein-stuff assayed 17 per cent. of metal.

	Quantity by weight		Quantity by weight[1]		
Assayed 17 per cent.	1	washed and concentrated to	·25	The loss on metal originally present in the ore by varying the mechanical treatment was .	61 per cent.
	1	,,	·40		39 ,,
	1	burnt, roasted, and do.	·20		57 ,,
	2·4	washed and do.	·43		37½ ,,
	1·56				
	20	loss by roasting			
	——1·36	washed and concentrated to	·40		50 ,,
	·8	roasted, washed, do.	·42		33 ,,
	·8	,, ,,	·69		16¾ ,,

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[1] The quantity of ore by weight is, in the first instance, 1: this unit 1—which might have been a ton—was washed and dressed; then weighed, when it was found that 75 parts had disappeared as tailings. The dressed ore, 25 parts, was then assayed, when it appeared that the metallic loss was 61 per cent. In other words, say 1 ton afforded 17 units of metal, the dressed ore only contained $6\frac{6}{10}$ units. ($17 \times 61 = 10{\cdot}37$. Then 17 units $- 10{\cdot}37 = 6\frac{6}{10}$).

(B.)—Took two parcels of argentiferous lead ore, associated with carbonate of iron, a little quartz, and blende. Weight $34\frac{6}{20}$ tons, which assayed $42\frac{1}{2}$ per cent. for lead, and 29 ozs. of silver per ton of metal. Crushed and carefully elaborated the same through jigging and buddle apparatus, obtained $14\frac{13}{20}$ tons of ore, giving $54\frac{1}{2}$ per cent. for lead, and 22 ozs. of silver per ton of metal. The produce for lead was therefore raised 12 units at a loss of 49 per cent. of the initial quantity of metal and 95 ozs. of silver. The commercial loss attending this operation, after making the several charges and allowances incident to the metallurgic reduction, was 91*l.* 14*s.*, or equal to 2*l.* 14*s.* per ton on the original weight.

Numerous instances of heavy losses incurred in the concentrating processes could be adduced if space permitted. But it may be observed that excessive loss of ore will always occur from an excessive reduction of the stuff; that in the stamping or crushing of complex ores the softer ores will suffer a greater loss than the harder ore; that the proportion of loss in water dressing is generally in proportion to the fineness of the grains; that a maximum loss will occur when the stuff is so treated as to detach, instead of shattering the ore; and that the loss of silver associated with lead ore, frequently increases with every separate reduction and washing of the grains.

In order to determine the loss of metal which may arise in enriching ores, accurate assays and notations should be made of the quantity of vein-stuff lodged on the floors, which should be compared with the metallic contents rendered merchantable, and the differences estimated.

It is not possible to ascertain the value of an improvement which would secure an additional one per cent. from the quantity of orey stuff annually sent to surface from the several mines in the United Kingdom; but if it be reckoned only upon the sale value it would be scarcely less than 40,000*l.* per annum.

In determining the site for a dressing floor, and in making the mechanical arrangements, various points suggest themselves; since, if they are overlooked, much loss will ensue to the undertaking, or otherwise it is evident that they can only be corrected by involving the proprietary in an increased outlay as well as a greater current expenditure. The first consideration should be to secure an ample supply of water, with a good fall, and an extensive area of ground. With advantages of this nature the machinery will be worked cheaply, the stuff gravitate through the various processes without returning to create double carriage expenses, whilst the castaways may be sent to the waste heaps at a minimum cost. The second point to be settled, is the class of machinery to be employed. This must obviously be based upon the character which the ores may present. If massive, and associated with light waste, simple apparatus will suffice; but if the ore be sparsely diffused through heavy vein-stone, it is probable that the various apparatus will have to be constructed with great nicety, varied in their principles of action, and that much precaution will have to be observed in order to create as little slime as possible, as well as to secure the initial quantity of ore against undue loss. In the disposition of the machinery there is also considerable scope for practical intelligence: it is not enough to wash, crush, jig, and buddle the ores, mixing the resulting smalls incongruously together; but a judicious sorting should be commenced at the wash kilns, and upon this basis the various sizes kept distinct whilst passing through the washing floors. The dresser should also take care to keep the several ranges of mineral produces and degrees of fineness together.

With the view of assisting the judgment in deciding upon the machinery to be employed, the following Table of Specific Gravities is given:—

TABLE OF SPECIFIC GRAVITIES.

Metals.

	Specific gravity
Gold	19·25
Mercury	13·26
Lead	11·35
Silver	10·47
Copper	8·89
Iron	7·78
Tin	7·30
Zinc	7·00

Ores.

		Hard ness	Specific gravity
Lead:	Sulphide (galena)	2·5 to 2·75	7·5 to 7·6
	Sulphate	2·3 „ 2·7	6·25 „ 6·29
	Carbonate (white)	3·0 „ 3·5	6·46 „ 6·48

		Hardness	Specific Gravity
	Phosphate (green and brown)	3·5 „ 4·0	6·58 „ 7·04
	Chromate (bright red)	2·5 „ 3·0	6·0 „ 6·04
	Molybdate	2·7 „ 3·0	6·7 „ 6·8
Tin:	Oxide of tin	6·0 „ 7·0	6·5 „ 7·1
	Tin pyrites	3·0 „ 4·0	4·79 „ 5·1
Copper:	Sulphide	2·5 „ 3·0	5·5 „ 5·8
	Oxide	3·5 „ 4·0	5·9 „ 6·0
	Carbonate	3·5 „ 4·0	4·0 „ 4·1
	Pyrites	3·5 „ 4·0	4·15 „ 4·16
	Sulphate	2·2	2·21
	Silico-carbonate	2·0 „ 3·0	2·0 „ 2·2
Zinc:	Red oxide	4·0 „ 4·5	5·43 „ 5·52
	Sulphide	3·5 „ 4·0	4·02 „ 4·07
	Carbonate	5·0	4·33 „ 4·44
	Silicate		3·43
Antimony:	Sulphide	2·0	4·51 „ 4·62
	Jamesonite	2·0 „ 2·5	5·5 „ 5·8

Minerals associated with Ores.

	Hardness	Specific gravity
Wolfram	5·0 to 5·5	7·1 to 7·4
Iron pyrites (white)	6·0 „ 6·5	4·67 „ 4·84
Mundic	6·0 „ 6·5	4·83 „ 5·01
Sulphate of baryta	2·5 „ 3·5	4·3 „ 4·8
Carbonate of baryta	3·0 „ 3·75	4·29 „ 4·3
Carbonate of iron	3·0 „ 4·5	3·73 „ 3·82
Fluor-spar	4·0	3·0 „ 3·33
Quartz or silica	7·0	2·6 „ 2·7
Carbonate of lime	2·5 „ 3·5	2·5 „ 3·8

Ore-bearing Rocks.

	Specific gravity
Hornblende rock	2·8 to 3·2
Syenite	2·7 „ 3·0
Trap or basalt	2·8 „ 3·2
Grauwacke	2·5 „ 2·9
Porphyry, trachyte, and felspar	2·3 „ 2·7
Granite and gneiss	2·4 „ 2·7
Mica slate	2·6 „ 2·9
Clay slate	2·6
Limestone and dolomite	2·5 „ 2·9
Sandstone	2·4 „ 2·7

The following general deductions will also be found serviceable:—

First.—Absolute perfection in separation according to specific gravity cannot be arrived at, chiefly on account of the irregularity of form of the various grains to be operated upon.

Second.—The more finely divided the stuff to be treated, the greater is the amount of labour and care required, and the more imperfect will be the separation.

Third.—That reducing machine may be considered the most perfect which produces the least quantity of stuff finer than that which it is intended to produce.

Fourth.—It is necessary in determining the degree of fineness to which a mineral should be reduced, to consider the metallurgic value of the ore contained in it, and to set against this the value of the loss which will probably be incurred, together with the labour and expense attendant upon the manipulation.

Fifth.—The vein-stuff should be reduced to such a degree of fineness that the largest proportion of deads and clean ore should be obtained by the first operation, thus saving the labour and preventing the loss incident to a finer subdivision of the ore and more extended treatment.

Sixth.—That apparatus or plan of dressing may be considered the most efficient which, with stuff of a given size, allows at an equal cost of the most perfect separation, and of the proper separation of stuff of nearly equal specific gravity.

The average percentage to which the crop is to be brought, and the highest percentage to be allowed in the castaways being determined, it is evident that the more perfect the degree of separation the greater will be the amount of crop and castaways obtained at each operation, and the quantity of middles or stuff to be re-worked will be diminished.

Seventh.—We may further consider as a great improvement in dressing operations such apparatus or plan of working as will allow, without a disproportionate increase in the cost, of the equally perfect separation of fine and coarse stuff. This will be of especial benefit in the case of finely-disseminated ore, which is necessarily obliged to be reduced to a great degree of fineness.

Washing and Separating Ores.

The vein-stuff on arriving at the surface, is not only associated with a large amount of gangue, but is frequently much intermixed with clay, rock, and siliceous matter.

In order to get rid of the latter substances, it is usually washed and picked. The washing apparatus ought to be so contrived as to allow the cleansing to be effected both cheaply and expeditiously, and for this purpose a good volume and fall of water is always desirable. In accordance with the character of the ore the apparatus will have to be varied, but for lead, certain varieties of copper ore, as well as iron, or other abundant ores, the kiln is well adapted. In many mines rectangular grates are fitted to the bottom of the kilns, but a perforated plate would be found to furnish better results, since the former allows of the passage of flat irregular masses of stone, rendering the treatment in the jigging sieves less successful. The holes in the perforated plate should be conical, the largest diameter underneath, so that the stones may have unobstructed passage. In connection with the kiln-plate a sizing trommel should be used, and in order to economise both time and expenditure it would be judicious to introduce the vein-stuff and discharge the castaways by means of railways.

The picking of the stuff is a highly important operation. As a rule all picked ore should be selected, and the dradge deprived of the largest possible amount of waste before it is sent to the crusher. It is fallacious to suppose, because machinery will deal with large quantities expeditiously, that it is cheaper to subject the mass to its action; on the contrary, if correct calculations are made of the losses which will ensue on the initial quantity of ore before the residue is ready for the pile, the cost of the several intricate manipulations requisite to get rid of the castaways, the wear, tear, and maintenance of machinery, it will appear in the majority of cases that the most profitable method is to incur an extra first charge in order to reject the sterile portions by means of hand labour. The ragging hammer should therefore be brought into free requisition, and all worthless stones at once rejected; then in spalling such portions as have been ragged, an additional quantity of refuse should be excluded; whilst in the process of cobbing, either ragged or spalled work, the greatest care and attention should be given in order to bring the dradge to a maximum degree of richness.

Among the siftings and washings which ores are made to undergo, we would notice those practised on the Continent, *grilles anglaises,* and *step-washings* of Austria, *laveries à gradins.* These methods of freeing the ores from pulverulent matters, consist in placing them, at their out-put from the mine, upon gratings, and bringing over them a stream of water, which merely takes down through the bars the small fragments, but carries off the finer portions. The latter are received in cisterns, where they are allowed to rest long enough to settle to the bottom. The washing by steps is an extension of the preceding plan. To form an idea of this, let us imagine a series of grates placed successively at different levels, so that the water, arriving on the highest, where the ore for washing lies, carries off a portion of it, through this first grate upon a second closer in its bars, thence to a third, &c., and finally into labyrinths or cisterns of deposition.

The *grilles anglaises* are similar to the *sleeping tables* used at Idria. The system of these *gradins* is represented in *fig.* 642. Such system is resorted to for the purpose of sorting the small fragments of quicksilver ore intended for the stamping mill.


642

These fragments are but moderately rich in metal, and are picked up at random, of various sizes, from that of the fist to a grain of dust.

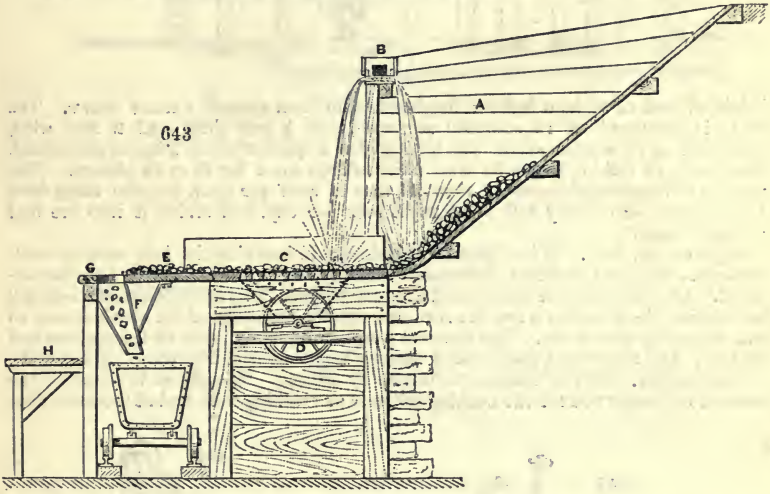
The ores are placed in the chest *a*, below the level of which 7 grates are distributed, so that the fragments which pass through the first, *b*, proceed by an inclined conduit on to the second grate *c*, and so in succession. (See the conduits *l*, *o*, *p*.) In front, and on a level with each of the grates *b*, *c*, *d*, &c., a child is stationed on one of the floors, fixed opposite to them.

A current of water which falls into the chest *a*, carries the fragments of ore upon the grates. The pieces which remain upon the two grates *b* and *c*, are thrown on the adjoining table *v*, where they undergo a sorting by hand; there the pieces are classified, 1, into gangue to be thrown away; 2, into ore for stamping mill; 3, into ore to be sent directly to the furnace. The pieces which remain on each of the succeeding grates, *d*, *e*, *f*, *g*, *h*, are deposited on those of the floors 3 to 7, in front of each. Before every one of these shelves a deposit-sieve is established (see *t*, *u*), and the workmen in charge of it stand in one of the corresponding boxes, marked 8 to 12. The sieve is represented only in front of the chest *h*, for the sake of clearness.

Each of the workmen placed in 8, 9, 10, 11, 12, operates on the heap before him; the upper layer of the deposit formed in his sieve is sent to the stamping-house, and the inferior layer directly to the furnace.

As to the grains which, after traversing the five grates, have arrived at the chest *x*, they are washed in the two chests *y*, which are analogous to the German chests. The upper layer of what is deposited in *y* is sent to the furnace; the rest is treated anew.

The kiln before adverted to is explained by *fig.* 643.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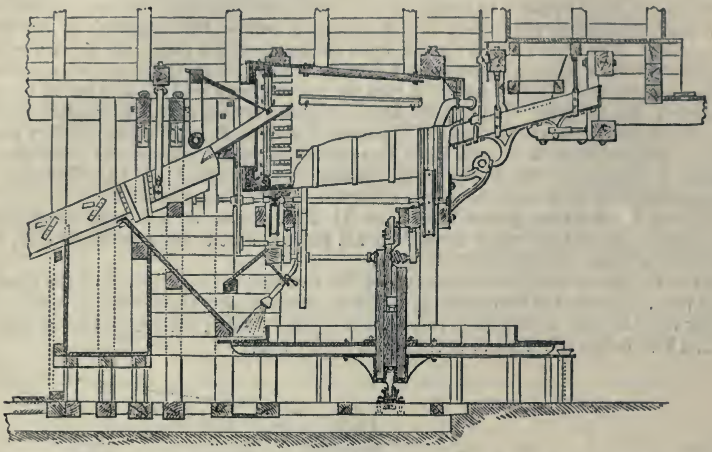
The vein-stuff is brought from the shaft by means of tram waggons, into the hopper A; water flows from the launder B, one portion distributing itself at the foot of the hopper, the other upon a cast-iron plate perforated with holes $1\frac{1}{4}$ inch diameter at top, $1\frac{1}{2}$ inch diameter at bottom, and 2 inches distant from centre to centre; the plate being 4 feet by 3 feet 6 inches. Between C and E, the washer stands. The fine stuff he rakes through the plate-holes, and that which is too coarse is drawn to E. Children standing on H, select the prill and dradge from the pile E, discharging such stones as are valueless through the shoot F, into the waggon beneath. The trommel D is constructed of perforated plates, having different degrees of fineness, in order to size the stuff which passes through into bins or compartments.

The washing arrangement shown in *fig.* 644 is in use at Przibram. The stuff is first introduced into a shoot, from whence it passes into a conical trommel, and is thence thrown upon a flat sieve, and divided into coarse and fine stuff, the former going to the rotative table, the latter to sizing sieves. The shoot at the entrance of the trommel is kept in movement by a cam shown underneath: the trommel rotates on carrier wheels, whilst circular motion is given to the picking table by means of a tangent wheel and screw. The inside of the trommel is fitted with ledges for lifting and dropping the stuff, water being continually introduced for washing and freeing it from slime and clay. A rose jet of water flows on the table for rendering the ore and waste more distinct to the eye. The small diameter of the trommel is 3 feet 9 inches; large diameter, 5 feet 4 inches; length of trommel, 9 feet. The diameter of the trommel carrier wheel is 2 feet 6 inches, outside diameter of picking table 14 feet, inside diameter 10 feet; height of back of table, 6 inches; height of table from ground, 2 feet 7 inches. The table is composed of 16 cast-iron segments, each ½ inch thick and 2 feet wide, supported on 16 wooden arms. The table makes a speed of about 2 inches per second. The length of picking line is 30 feet, which affords space for 15 or 16 pickers. This number of hands will dispose of about 15 tons of stuff per hour, the size being from 1 to 3 inches, or one boy will select say 4 tons per day, and divide it into ore and 'dradge' work.

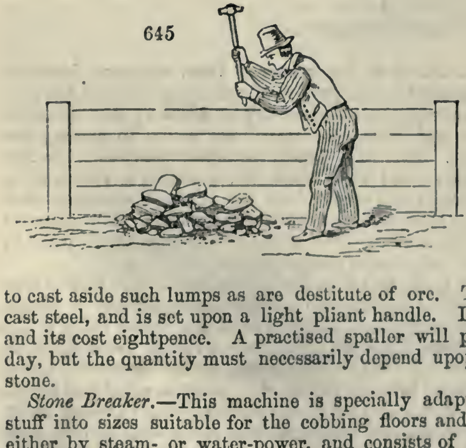
644



Ragging (*fig.* 645). It has been remarked that, in breaking the lode underground, numerous rocks are produced, throughout which valuable ore is more or less disseminated. After these stones are washed, they are ragged. This operation consists simply in reducing the stones to a smaller size, and rejecting as many of the sterile stones as can be readily picked out. The reserved heap is ultimately taken to the spallers and cobbers. The weight of a steel-headed ragging hammer varies from six to eight pounds.

Spalling (*fig.* 646), is usually performed by women. The object is to break the stones to a proper size for the bucking hammer or crushing mill, and at the same time to cast aside such lumps as are destitute of ore. The hammer employed is made of cast steel, and is set upon a light pliant handle. Its weight is about sixteen ounces, and its cost eightpence. A practised spaller will produce about one ton of stuff per day, but the quantity must necessarily depend upon the hardness and nature of the stone.

645



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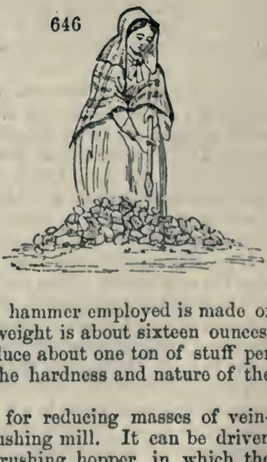
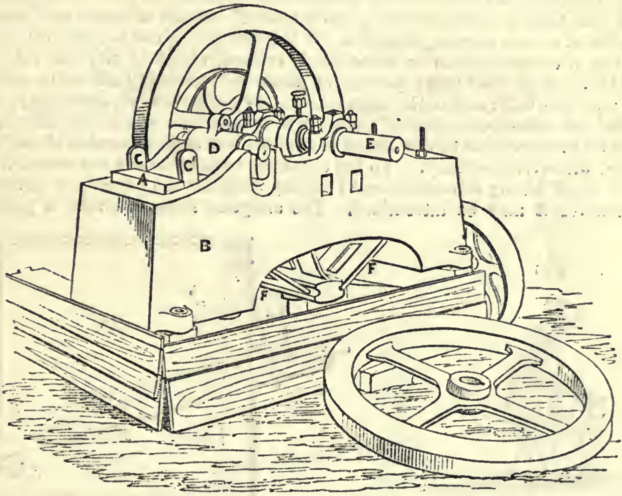


Stone Breaker.—This machine is specially adapted for reducing masses of veinstuff into sizes suitable for the cobbing floors and crushing mill. It can be driven either by steam- or water-power, and consists of a crushing hopper, in which the stone is broken between a pair of jaws, the one being fixed, the other actuated by knee-joint levers. The fixed jaw A, *fig.* 647, is a plate of cast iron, bedded in lead, and held in the frame B, by tapered cheek pieces C C′. The vibrating jaw plate D corresponds in this respect with the fellow plate A. The excentric shaft E gives motion to the toggles F F, which press forward the breaking jaw, D, about $\frac{3}{8}$ths of an inch. In the depression of the lever the jaw is drawn back by means of a strong India-rubber spring.

A stone dropped between the convergent jaws will be operated upon by a succession of bites, until it is crushed small enough to pass out at the bottom. The distance between the jaws at the bottom limits the size of the fragments. The frame of the machine is formed of one single casting, and although provided with bolt holes, yet is usually heavy enough to require nothing further than its own weight to retain it in working position, The apparatus should be fixed high enough either to allow a waggon to be placed under the jaws, or otherwise that the reduced stones may gravitate to the rollers of a crushing mill.

The width of the opening at the top of the jaws determines the size of the machines, and at the same time it represents the largest stone which can possibly be dealt with. The quantity of stone reducible in a given time must necessarily depend upon its degree of hardness, as well as upon its structure. In addition, the result is either lessened or increased, according to the minimum distance between the jaws, and the speed given to the excentric shaft.

647



The approximate duty rendered by stone-breakers of various size, at a speed of 200 revolutions per minute, is as follows:—

Length of jaw	Width between jaws at top	Power required	Produce per hour
inches	inches	horses	cubic yards
6	4	1½	1½
7½	4	1½	1¾
10	7	3	3
15	7	4	4½
20	9	5	6
18	12	8	8
24	12	10	10
24	15	15	13

At the Kirkless Hall Colliery, in Lancashire, it has been found that one ton of limestone falling through jaw pieces seven inches apart at the top is reduced into fragments which can be passed through a gauge one and three-quarters of an inch in diameter at a cost not exceeding threepence per ton, the coal for maintenance of engine being charged at three shillings and sixpence per ton. The various parts of the apparatus are of great strength, and the amount of wear and tear is comparatively small. In mines where it is requisite to reduce large quantities of vein-stuff, either for the cobbers, coarse sand jiggers, or crushing mill, this machine will prove an important and valuable auxiliary.

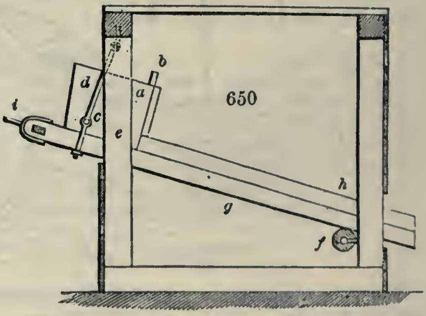
648

The jaw pieces of stone-breakers should be formed of double chilled iron: soft and badly-hardened iron is highly objectionable, since with the early inefficiency of the jaw pieces, together with cost and delay attending their replacement, the cost of reducing stone must be materially increased. A pair of hard jaws 12 inches by 9 inches will break from 2,000 to 3,000 tons of siliceous vein-stone. In large dressing establishments the stone-breaker is driven directly by a steam-engine. Small breakers, with jaws 7½ inches deep and 4 inches wide, are also frequently used for reducing orey vein-stone, derived from the 'coarse sand' jiggers.

Cobbing, fig. 648.—This work is generally performed by women, young girls, or boys. It consists of picking the best work from the dradge, and with a peculiarly shaped hammer, detaching from each piece the inferior portions, and thus forming either prill or best dradge ore. An expert cobber will manage to prepare about 10 cwts. of tolerably hard stuff per ten hours.

Sizing Apparatus.—In the various processes of dressing, no point is of greater importance than that of correctly sizing the vein-stuff, neither is there one demanding the exercise of a more correct judgment. If the particles of ore be reduced below their natural size a source of loss is immediately created, whilst if they are not brought within the limit of their size a portion of waste will probably adhere to each atom, forming a serious difference in the aggregate quantity of castaways, although such waste may afford but a low percentage of metal. The holes in the sieves or trommels should therefore be proportioned to the nature of the ore, but such apparatus should also be introduced wherever necessary. To the crushing mill, trommels are essential, whilst it will be found highly advantageous to employ them for the purpose of dividing the stuff whenever it may be intermixed. The simplest form of sizing is perhaps by the hand riddle, *fig*, 649, which is formed of a circular hoop of oak, ⅜ths of an inch thick and 6 inches deep. Its diameter ranges from 18 to 20 inches.

649

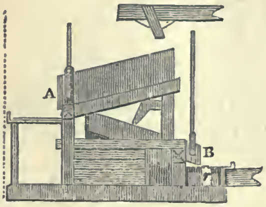

650

The bottom is made of a meshwork of copper or iron wire. The weight of an iron wire riddle is about seven pounds, and its cost 4*s.* 6*d.*

Fig. 650 represents a swing sieve employed in mines on the Continent. *a*, box into which the stuff to be sifted is introduced; *b*, regulating door; *c*, pendulating rod attaching the sieve frame to the frame *e*; *f*, friction roller carrying the sieve frame *g*. At *h* springs are fitted to each side of the frame, in order to give it a vibratory action; *i*, rod, giving motion to the apparatus, The width of the sieve frame is about one-third its length, but the sieve bottom only extends from the box, *a*, two-thirds of the length. The bottom of the sieve frame is subsequently contracted so as to form a shoot.

Fig. 651 is a swing sieve employed in the Hartz, for sifting the small fragments of the ores of argentiferous lead. Such an apparatus is usually set up on the outside of a stamps or washing mill. The two moveable chests or boxes A B, of the sieve, are connected together, at their lower ends, with an upright rod, which terminates at one of the arms of a small balance beam, mounted between the driving shaft of the stamps and the sieve, perpendicularly to the length of both. The opposite arm of this beam carries another upright rod, with cams,—placed so as to be pushed down by the driving shaft. During this movement the two lower ends A, B, are raised; and when the cam of the shaft quits the rod which it had depressed, the swing chests fall by their own weight. Thus they are made to vibrate alternately upon their axes. The small ore is put into the upper part of the chest A, over which a stream of water falls from an adjoining launder. The fragments which cannot pass through a cast-iron griddle in the bottom of the chest are sorted by hand upon a table in front of A, and are classed by the workman, either among the ores to be stamped, whether dry or wet, among the rubbish to be thrown away, or among the ores to be smelted by themselves. As to the small particles which fall through the griddle upon the chest B, supplied also with a stream of water, they descend successively upon two other brass wire sieves, and also through the iron wire *r*, in the bottom of B.

651



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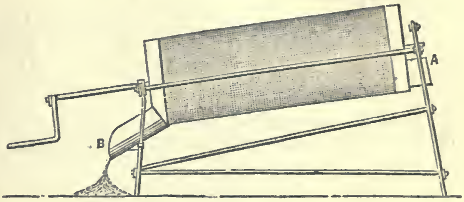
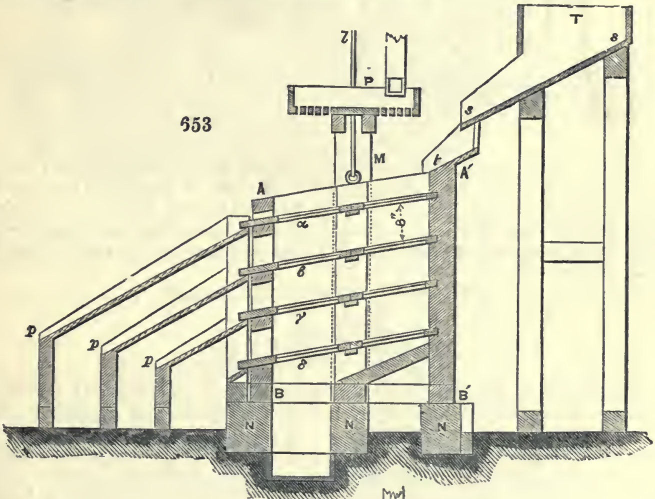


Fig. 652 shows the circular hand-riddle employed in the mines of Cornwall. Although this is in advance of hand riddling, yet it is by no means equal to the large sizing trommels employed in Germany.

The ore is thrown in it at A, the coarser pieces passing longitudinally through the riddle into the shoot B. The riddle is turned by a hookhandle, as shown in the illustration; the meshes of the sieve vary from $\frac{3}{4}$ths of an inch to 1 inch square, according to the character and quality of the vein-stuff to be operated upon.

653



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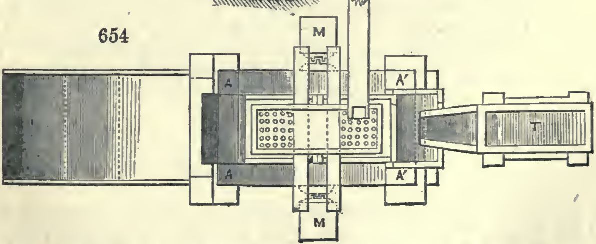
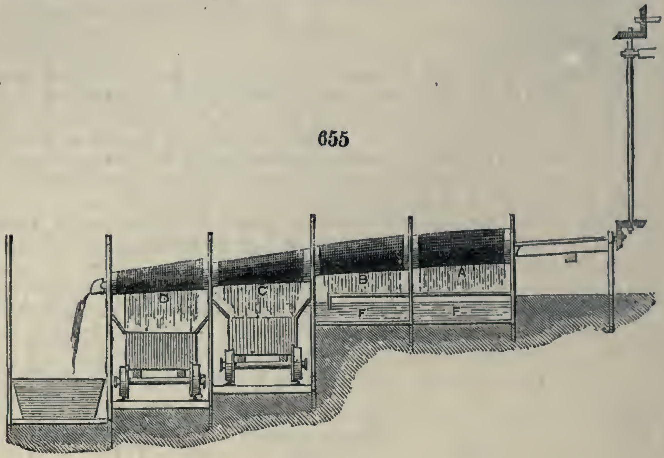


Figs. 653, 654 show an elevation and ground plan of a series of flat separating sieves. A A′, B B′ is a strong wooden frame. M M, guides for frame; N N N, basement upon which the sieve frame rests; P, cistern fitted with perforated plate through which clean water is distributed upon the sieves; T, hopper supplying the stuff to be sifted; *s s* bottom of ditto. The sieves are lifted by the rod *l* and make from 40 to 50 drops per minute. The sieves are set about 8 inches apart, and discharge the stuff upon the inclines *p p p*.

The holes in No. 1 sieve are ½ inch diameter.
" 2 $\frac{3}{8}$ "
" 3 $\frac{3}{16}$ "
" 4 $\frac{1}{12}$ "

Fig. 655 represents the trommel or sizing sieves formerly in operation at the Devon Great Consols. Although the yield of ore at these mines was extremely large, it may not be generally known that much of it was obtained from stuff yielding no more than from ¾ to 1½ per cent. of metal. The product of the lode on arriving at the surface was cobbed and divided into two classes, the first going to market without further elaboration, whilst the dradge or inferior portion was treated by various processes of washing. The whole was, however, crushed to such a degree of fineness as to pass through the following holes:—

655



Trommel A, holes $\frac{1}{20}$ inch diameter.
" B, " $\frac{1}{12}$ " "
" C, " $\frac{1}{10}$ " "
" D, " $\frac{1}{8}$ " "

The trommels were each 6 feet long, 24 inches diameter at the large end, and 18 inches diameter at the smaller, making 20 revolutions per minute, and altogether affording an area of 6,000 square inches.

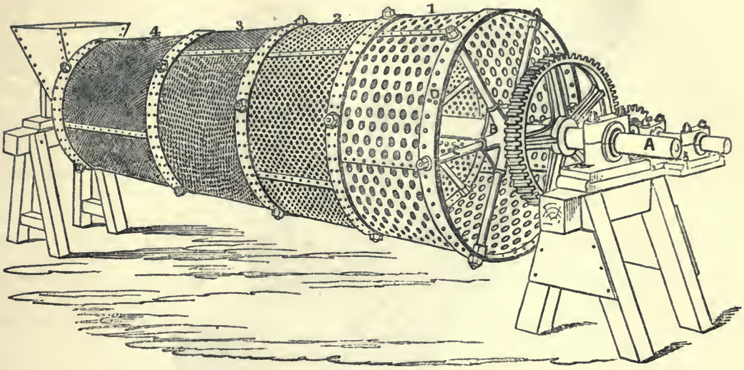
Continuous Trommels.—These are made of various diameters and lengths; the diameters of the perforated holes vary from two and a half inches to one-twentieth part of an inch. On a suitable wrought-iron shaft A, *fig.* 656, a cast-iron boss plate B, is fitted, the bosses receive six wrought-iron radial arms C, which pass through a thin but stiff wrought-iron ring D, governing the diameter of the trommel. The arms are fastened to the ring by means of outside and inside nuts, the perforated plates 1, 2, 3, and 4, are rivetted to the several rings, and in this way an excellent trommel is produced.

Conical Trommel.—The trommel *fig.* 657 may be used singly or in combination with others for sizing stuff coming from the wash grate clearing drum or crusher. The diameter as well as the length should be proportioned to the quantity of stuff to be treated within a given period.

The angle of the shell with the horizontal axis must also correspond to the diameter of the grains. The angle varies from three to five degrees, while the speed ranges from fifteen to twenty revolutions per minute.

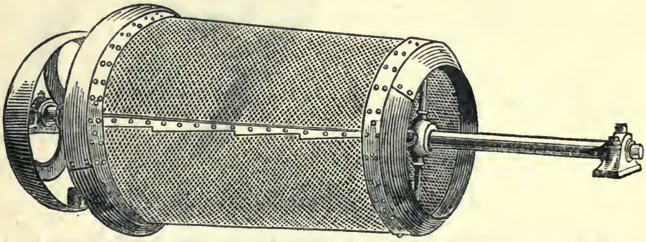
Double Conical Trommel, fig. 658.—For the purpose of obtaining three distinct sizes of stuff within the length almost of a single trommel and, without incurring much loss of fall, a double conical trommel is employed. Its use is, however, more for separating or dividing stuff for subsequent sizing, than for sizing directly to jiggers.

656



Cascade Trommels.—A system of six sizing trommels is shown in *Fig.* 659. Each trommel is 42 inches long, 21 inches diameter at the large end, and 18 inches diameter at the small end. At a speed of 20 revolutions per minute, the six trommels will dispose of from two to three tons per hour. The volume of water required per trommel to keep the holes clear is from two to three gallons per minute. The order of sizing is from great to small grains; that is, the first or uppermost trommel has the coarsest holes; each succeeding trommel having holes of lesser diameter. Through this arrangement the smallest holes and thinnest plates get only a minimum amount of wear. In order to convey the stuff from one trommel to another sheet-iron or wooden hoppers are employed.

657



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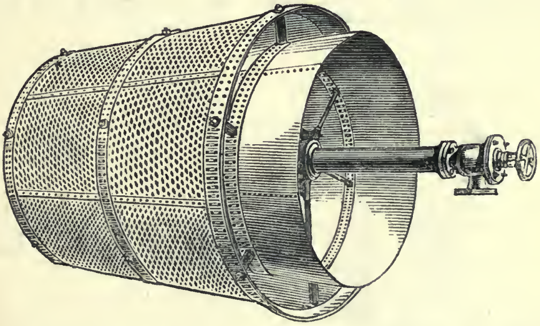
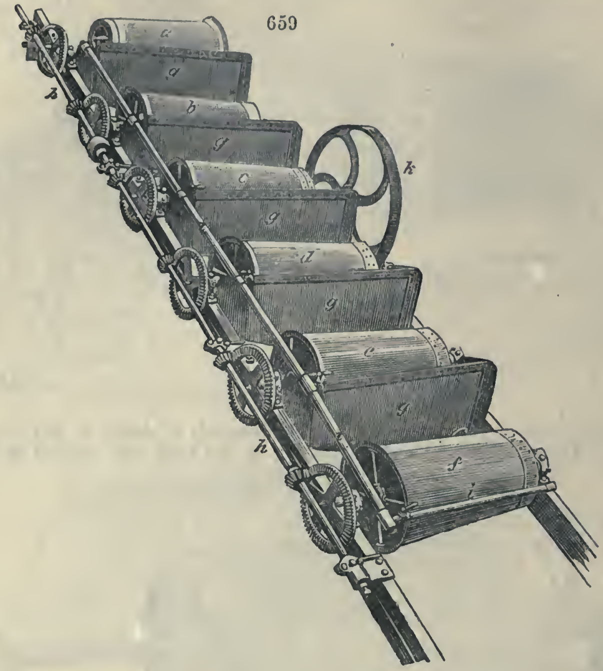


Each trommel is light, portable, and readily replaced. Instead of distributing the water by means of pipes, open launders are equally efficient. The trommels may be placed side by side, or run end-ways, and be driven by means of spur wheels or by a light chain crossed on the pulleys.

659



Grinding and Crushing Machinery.

In small mines, *Bucking*, *fig.* 660, is resorted to, instead of employing the crushing mill. This operation consists of pounding pieces of mixed ore on a slab of iron A, by means of a hammer or bucker B. The wall on which the plate A is placed, is about 3 feet high. The stuff to be pounded is placed behind the slab, and is drawn upon and swept off the plate by the left hand. In Cornwall it is customary to keep time with the blows and to stand to the bench · but in Derbyshire each operator works independently, and is usually seated.

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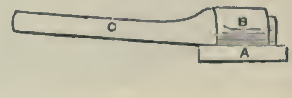


The bucker, *fig.* 661, is formed of a wrought-iron steel-faced plate A, 3 inches square, with a socket B, for receiving a wooden handle C. Its cost is about 1*s.* 4*d.*

The reduction of vein-stone to a suitable size, so as to extract a maximum quantity of ore is a matter of considerable importance. The class of machinery to be employed must depend upon the normal constituents of the stone.

If the ore is of a massive character and of little value it may be selected from the waste at the stone-breaker; but if much intermixed with other minerals, it will be necessary to submit it to the crushing, stamping, or grinding mill. In the employment of either apparatus the object should be to secure free and unbroken grains of ore so as to readily collect them in the subsequent dressing processes.

The general application of reduction machinery may be briefly stated:—Stone-breakers, for tin, ironstone, copper, and lead ore dradge; size of stuff, from 1 to 9 inches. Crushing mills; for copper, and lead ore; in pieces, from 2 to 50 millimeters diameter. Stamps, for tin, lead, and copper ore, in grains, and pieces, from ½ to 75 millimeters. Grinding apparatus, for tin, silver, and auriferous ore, in grains, from ½ to 2 millimeters size.

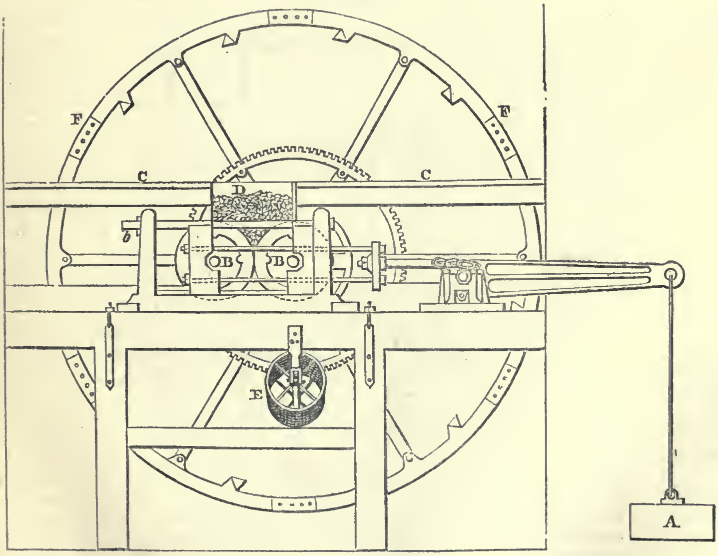
Crushing Mill. This machine was introduced by the late Mr. Taylor at Wheal Crowndale, near Tavistock, in the year 1804. In its simplest form it consists of two rollers mounted in a strong iron frame, and kept in contact by means of screws; motion is communicated to one of the rolls, either by a water-wheel or steam-engine, but the other is made to revolve by the friction generated between the moving roll and the stuff to be crushed. This mill is usually employed for reducing mineral substances which have already received some mechanical preparation, but machines have been contrived with a series of rolls, set below each other, into which the stuff is introduced as brought from the lode underground. In order to effect this operation, the upper rolls are fluted, and the lower ones have various speeds and diameters, but it may be remarked that although this arrangement has been somewhat extensively employed in the north of England, yet it has found few advocates either in Wales or Cornwall, or on the Continent.

The practice of keeping the rolls together by screws acting on the bearings is objectionable, since the entrance of a piece of steel, or other hard substance of greater width than the fixed opening between the rolls, immediately produces a stoppage and strains the apparatus, or otherwise causes serious breakages to some of the parts. In order to obviate these evils, the rolls are usually adjusted and kept in position by weighted levers pressing on their axis.

As the machines employed in Cornwall may be considered the most effective in operation, as well as complete in their construction, that type is selected for representation.

B B (*fig.* 662), are the crushing rollers fitted in a strong frame-work of cast iron, which is stayed by a wrought-iron bar *b*, and firmly bolted to longitudinal beams inserted in the walls of the crushing-house. The rollers revolve in bearings, which are so arranged as to slide in grooves, and therefore admit of the cylinders being brought

662



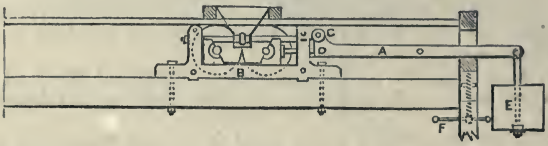
nearer to or separated farther from each other. To keep the rollers in contact and yet allow the action to take place, a weighted lever A is placed on each side, which by means of tension bars connected with one of the bearings, keep a constant pressure upon the rollers. The ore to be crushed is lodged upon a floor C, and introduced into a hopper D, from which it falls between the rolls; the requisite crushing pressure being attained by increasing or decreasing the weights applied to the end of the lever. The crushed ore passes from between the rollers B B into the higher extremity of an inclined cylinder E, made of coarse gauze, or perforated plate, which being set in motion by the same power as the rollers themselves, separates the pulverised material into two classes. That portion which passes through the sieve falls into a waggon placed on the floor of a house, whilst the other, which is too large to escape through the openings, is carried to the lower end of the cylinder from whence it passes into an inverted bucket-wheel F, by which it is again conveyed into the hopper to be re-crushed.

The modifications to the foregoing arrangement may be thus briefly noticed.

In some machines the feed-hopper is made of sufficient capacity to hold from 20 to 25 cwts. of stuff, which is introduced by means of a tram waggon, and renders hand feeding unnecessary. The shoot conveying the crushed ore to the rotating sieve, E, is sometimes divided at the bottom into two parts, one to deliver rough, and the other fine stuff, In connection with each division, is a cylindrical riddle revolving and separating the work according to the fineness or coarseness of the mesh employed.

A circular sieve divided midway into two parts, each of a different mesh, is in some instances advantageously substituted for two sets of seives; whilst, in other cases, circular sieves are omitted, the operation of sizing being performed by fixing perforated plates on the periphery of the inverted wheel.

663



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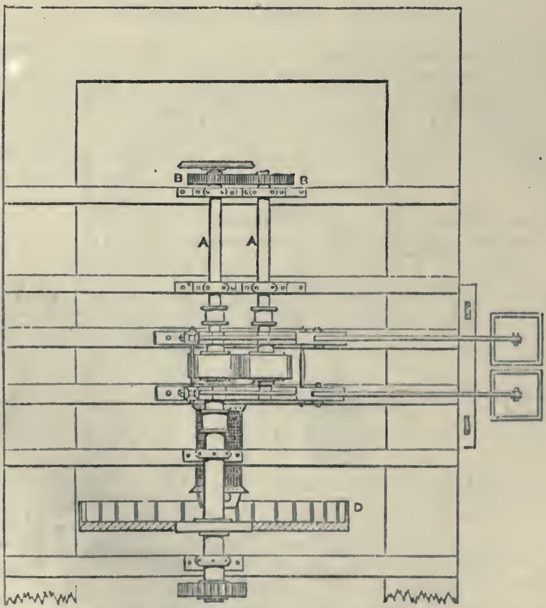
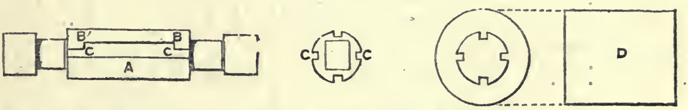


Instead of one roll being drawn towards the other, they are frequently kept in contact by direct pressure, which is effected as shown in *figs.* 663, 664.

A (*fig.* 663), lever hung to the cast-iron frame B at C, and pressing upon pin at D. When it is required to change the rollers, the pressure resulting from the lever A and weighted box E, is relieved by means of the screw tackle F.

The considerations which should be attended to in constructing a crushing mill, are, first, to make all the parts sufficiently strong to meet the varying resistances which continually occur in crushing. For this purpose, the framework to receive the rolls ought to be of good cast iron, the axles of the rollers of best wrought iron, and the cylinders of the hardest and most uniform metal. 2ndly. To design the machine, so that the matter to be crushed may be readily delivered into the hopper, sized by the circular sieves, for the dressing process; and such portions as are not properly crushed returned to the rollers without the intervention of manual labour. In order to effect this, the inverted, or raff wheel D, *fig.* 664, shown in section, ought to be made of sufficient diameter to allow the stuff, on being discharged, to descend by its own gravity, into the feed-hopper. 3rdly. To extend from the axis of the rollers, long tumbling shafts, A A, *fig.* 664, and fix on their ends the driving wheels B B, allowing a little play in the plummer blocks, so that any undue opening of the rolls may not vary the pitch line of the wheels B B, to such an extent as to endanger the safety of the teeth. 4thly. To construct the roll so that it may be readily changed, yet maintained on its axis without slipping when in motion. One of the most efficient plans for this purpose is shown in the following woodcut, in which A is the axis or arbor, and D the roll (*fig.* 665).

665



It will be seen that the cylinder roll is fitted with four internal projections; these are of the same length as the portion of the groove marked B B′, but no wider than the narrower part of the groove C C. When the cylinder is to be fixed on the axis, the studs are to be introduced into the recesses C, and the cylinder advanced into its working position, when it is turned until the studs fit into that portion of the recess between B B′, and which are then wedged to the roll by a close-fitting cutter.

5thly. The diameter of the rolls should be *decreased*, and the length *increased* in proportion to the fineness of the stuff to be crushed, since a fine material requires a longer line of contact, and not so large a grip as coarser substances.

In practice it has been found advantageous to make the roller placed on the driving shaft somewhat longer than that which is opposite, and to work the rolls by spur gearing rather than by friction, since the latter is proved to furnish less economical results than the former. It has also been found injudicious to harden the rolls by chilling; hence ordinary sand-cast rolls are most frequently employed.

The speed of the rolls varies from 45 to 60 feet per minute, but this necessarily differs with the character of the stuff to be crushed. Again, great variation is experienced in the quantities crushed within a given period, since a small amount of moisture in vein-stuff of a certain class, makes it cake, and will thus considerably reduce the produce of the mill. On the other hand, if the matter operated upon, be very dry, heavy, and brittle, as in the case of some varieties of lead ore, the produce may be much increased, since the mill can be driven at a great speed; a less bulk will have to pass for a given weight, and there will be a smaller quantity of material carried back by the raff wheel to be re-crushed.

Variable speeds have sometimes been tried in order to produce friction together with pressure at the line of contact, but it has been found that any departure from a uniform speed on the two surfaces absorbs a considerable additional amount of power, without materially augmenting the results.

The various dimensions and velocities of the rolls, crushing force and power employed, effective value of different mills, &c. now in use, may be gathered by referring to the Table at top of next page.

The *crushing machines* which are in general use at Alston Moor and the northern mines of this country, and where they have been employed for upwards of fifty years, differ in some respects from those described.

This machine is composed of one pair of fluted cylinders, *x x*, *fig.* 666, and of two pairs of smooth cylinders, z z, z′ z′, which serve altogether for crushing the ore. The two cylinders of each of the three pairs turn simultaneously in an inverse direction, by means of two toothed wheels upon the shaft of every cylinder, which work by pairs in one another. The motion is given by a single water wheel, of which the circle *a a a* represents the outer circumference. One of the fluted cylinders is

NAME OF MINE	ROLLERS				Total pressing Force on Rolls	SIFTER				Diameter of Raff Wheel	Horse Power	Quantity of Stuff Crushed in 10 hours	Cost of Crushing per Ton
	Diameter of Roller	Length of Roller	No. of Revolutions per Min.	Total Crushing Area per Min.		Diameter of Sifter	Length of Sifter	No. of Holes in Sifter	Revolutions per Minute				
	in	in.		sq. in.	cwt.	in.	in.	sq. in.				tons	pence
Grassington Mines .	27	12	5½	5593	91	21	48	6¼	37	14·0	..	80	
Minera . . .	14	14	8	4920	73⅓	24	42	9	48	10·6	6	20	2½
Cwmystwith, No. 1 .	27	14	4	4748	78	20	33	9	24	16·0	..	32	2½
„ No. 2 .	27	14	4½	5341	85	24	36	9	24	16·0	..	35	2¼
Goginan . . .	30	14	5½	7254	39	20	39	9	36	16·0	..	30	2¾
Cwm Erfin . . .	27	14	7½	8902	293	26	32	9	30	16·0	..	20	3
Lisburne, No. 1 . .	27	15	6	7632	180	22	36	12¼	30	16·0	..	42	2½
„ No. 2 . .	27	15	6	7632	224	22	36	12¼	30	16·0	..	42	2½
Derwent . . .	27	14	7	8309	227	22	60	16	..	15·0	..	60	2¾
Goldscope, (2 sets of rolls, 1 fluted, other plain) . . .	14	18	14	11060	6	No Sifter				..	..	25	2½
East Darren . .	30	18	6	9996	207	24	36	16	45	16·0	..	25	2¾
Cefn Cwm Brwyno .	20	13	5	4080	84	20	48	16	27½	14·0	..	20	2½
Lisburne, No. 3 . .	18	16	8	6432	169	22	36	25	30	16·0	..	42	2½
Llandudno . . .	18	15	15	12705	61	Flat Sifter, $\frac{1}{16}$ inch				Jacob's ladder	Steam power	30	11½
Wheal Friendship .	23	12	10	8670	123	24	36	36	30	13·0	10	20	2½
Pontgibaud . .	25	12	12½	12075	36	22	44	36	60	15·0	15	17	3¾
Devon Great Consols.	34	22	7	16443	458	2 { 24 lar. 12 sm.	84	64	21	..	..	65	2¼
Fabrica La Constante, Spain, No. 1 . .	24	15	10	11300	147	25	45	100	30	15·0	37	50	3¾
„ No. 2 . .	27	15	10	12720	110	25	53	100	30	16·0	26	50	3¾
„ No. 3 . .	24	12	16	14464	84	25	45	3600	48	Jacob's ladder, 192 ft. per m.	} 37	cwt. 13	19
„ No. 4 . .	27	15	15	19080	93	26	58	3600	45	Ditto.	..	13	19

placed in the prolongation of the shaft of this wheel, which carries besides a cast-iron toothed wheel, geared with the toothed wheels *e e*, fixed upon the ends of two of the smooth cylinders. Above the fluted cylinders there is a hopper s, which discharges down between them, by means of a particular mechanism, the ore brought forward by the waggons A. These waggons advance upon a railway, stop above the hopper, and

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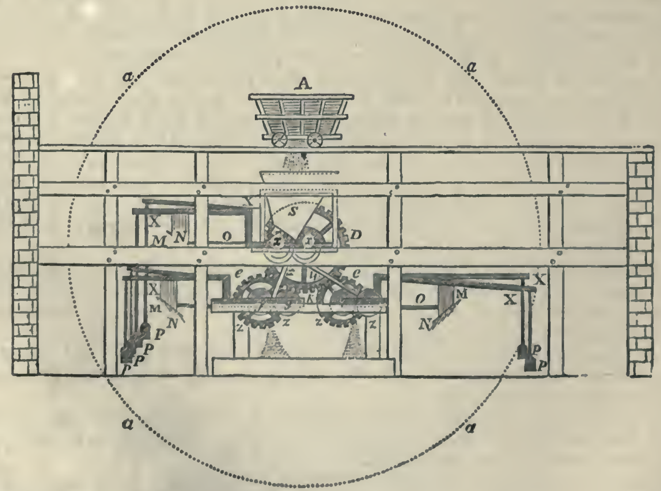


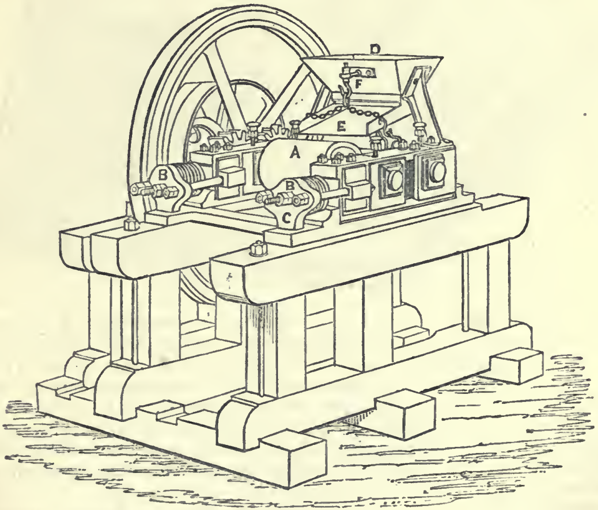
empty their contents into it through a trap-hole, which opens outwardly in the middle of their bottom. Below the hopper there is a small bucket called a shoe, into which the ore is shaken down, and which throws it without ceasing upon the cylinders, in consequence of the constant jolts given it by a crank-rod attached to it, and moved by the teeth of a wheel. The shoe is so regulated, that too much ore can never fall upon the cylinders and obstruct their movement. A small stream of water is likewise let into the shoe, which spreads over the cylinders, and prevents them from getting hot. The ore, after passing between the fluted rollers, falls upon the inclined planes N N, *fig.* 666, which turn it over to one or other of the pairs of smooth rolls.

These, the essential parts of this machine, are made of iron, and the smooth rolls are case-hardened, or *chilled*, by being cast in iron moulds. The gudgeons of both kinds move in brass bushes fixed upon iron supports *k*, made fast by bolts to the strong wood-work basis of the whole machine. Each of the horizontal bars has an oblong slot, at one of whose ends is solidly fixed one of the plummer-blocks or bearers of one of the cylinders *f*, and in the rest of the slot the plummer-block of the other cylinder *g* slides: a construction which permits the two cylinders to come into contact, or to recede to such a distance from each other as circumstances may require. The moveable cylinder is approximated to the fixed ones by means of the iron levers X X, which carry at their ends the weights P, and rest upon wedges M, which may be slidden upon the inclined plane N. These wedges then press the iron bar O, and make it approach the moveable cylinder by advancing the plummer-block which supports its axis. When matters are so arranged, should a very large or hard piece present itself to one of the pairs of cylinders, one of the rollers would move away, and let the piece pass without doing injury to the mechanism.

Besides the three pairs of cylinders which constitute essentially each crushing machine, there is sometimes a fourth, which serves to crush the ore when not in large fragments, for example, the *chats* and *cuttings* (the moderately rich and poorer pieces), produced by the first sifting with the brake sieve. The cylinders composing that accessory piece, which, on account of their ordinary use, are called *chats-rollers*, are smooth, and similar to the rollers Z Z and Z′ Z′. One of them is usually placed upon the prolongation of the shaft of the water-wheel, of the side opposite to the principal machine; and the other, which is placed alongside, receives its motion from the first, by means of spun wheel-work.

The general arrangement of a portable crushing mill may be gathered from *fig.* 667. The rollers A A are kept in close contact by means of the spring arrangement B B.

667



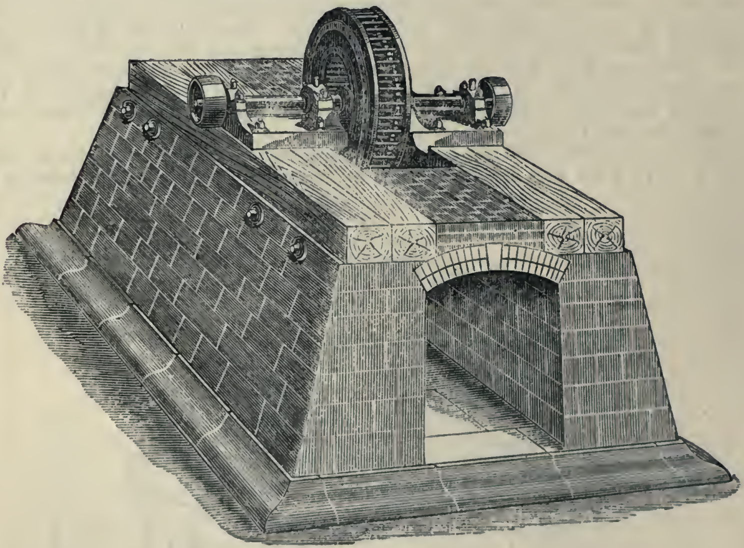
The spring itself is formed of discs of India-rubber alternating with discs of iron, both encircling an iron bar passing through and held firmly by the lug C. The stuff is thrown into the hopper D, and on motion being given to the rollers the inclined shoot E receives a percussive action by means of a horizontal lever or pallet attached to the shoot, and moved by one of the two cog wheels fixed on the ends of the rollers. The angle of the shoot is varied by lowering or raising the hook F.

Table of Crushing Mills for Hard Material.

Diameter of rolls	Length on face of roll	No. of revolutions of rolls per minute	Approximate weight of stuff reduced per hour	Horse-power required
inches	inches		cwts.	
36	10	20	100	10
27	10	25	80	8
21	10	30	60	6
15	10	40	40	4
12	10	60	20	2
10	10	80	10	1
		Hand Mills.		
10	10	30	5	4 men

Carr's Disintegrator.—This machine, the invention of Mr. Thomas Carr, has proved to be well adapted for the reduction of semi-elastic vein-stone, ores, and material requiring to be shattered rather than crushed or ground. The illustration, *fig.* 668, shows an improved 6 feet 3 inches machine, with two solid shafts, blocks, and bedplate, the disintegrating wheels being without the necessary hood or cover. The inventor in his description states:—The machine consists of a series of four strong cylindrical iron cages, of various sizes, formed of bars with open spaces of from three to four inches between them, arranged concentrically one within another, around, and parallel with the shafts or axles and rotated therewith with extreme rapidity in contrary directions to one another by means of an open and a crossed strap, the first and third cages rotating to the right, and the second and fourth to the left, so that while there are only two motions in reality, yet from the way in which the cages intersect one another there are relatively four.

668



'The material is thrown in at the central orifice, either by shovels or elevators, and after the lumps, if very large, are broken by a stationary knife (fixed so that its blade may extend into the interior of the innermost cage, but never used with very hard materials), they are thrown out by centrifugal force from the first cage at a tangent to its circle, precisely as stones are hurled from a sling, and at a speed equivalent to that at which the beaters of the said cage are rotating (which is usually 50 feet per second) when meeting the beaters of the next cage, moving in an opposite direction, usually at 60 feet per second, a collision ensues similar to that which takes place between a cricket-ball and bat; the shock thus produced being compounded from the aggregate speed of the beaters, and the speed and weight of the material meeting them The projectile impetus of the flying material is thereby arrested, and a fresh impulse given it in an opposite direction, to meet the beaters of the third cage travelling the reverse way, and so on in like manner with the fourth one, when, if the material is of a friable and non-fibrous nature, it is shattered by these successive blows into a fine granular state, usually like that of gunpowder.

'The disintegrating wheels are made of various sizes, from 3 feet 6 inches to 6 feet 3 inches, the capacity of the latter being nearly double that of a 4 feet 6 inches machine. For pulverizing ores and vein-stones a 6 feet 3 inches size, made extra strong with steel bars, shafts, and stout wrought-iron disc plates, is recommended. At a silver-mine in Norway a 6 feet 3 inches machine is found to reduce from seven to eight tons of ore per hour, to a size varying from 0 to 4 millimeters, seventy to eighty per cent. of the quantity being suitable for jiggers, the remainder for slime tables. As a general result, the cost of reduction is reported to be one-half less than that incidental to pans and edge-runners.

In the following tabular statement will be found particulars of stuff reduced and horse-power required:—

Stuff	Size of machine	No. of Revs. per minute	Quantity per hour	Horse-power required
	ft. in.		tons	
Superphosphate guano, sulphate of ammonia, and bone-ash . . .	4 6		10 to 12	10 to 12
Rock asphalte	4 6	500 to 600	5	12
Fire-clay and shale	6 3		10 to 30	12 to 25
Moist clay	6 3	400	20	15
Blende	6 3	600	8 to 10	20
Calamine	6 3	120	15 to 20	20
Copper, silver, and other ores . .	6 3	500	7 to 8	20

Dingey's Pulveriser.—In this machine, *fig.* 669, Mr. Dingey has produced an apparatus for the reduction of hard vein-stone and ore to a fine state.

The machine is on what may be called the slab and muller principle. The operative parts consist of four plates revolving within a pan that rotates in the opposite direction. The pan is made of iron, 6 feet in diameter, with a vertical rim in which are twelve openings, each 15 inches in length by 5 inches in depth, fitted with fine perforated copper plates or wire gauze. The inner or grinding surface of the pan is lined with a set of plates or shoes, made of the best white iron, which can be detached and replaced readily when worn out. The pan revolves from right to left, or in a direction contrary to the apparent motion of the sun, borne on four friction rollers fixed on the four horizontal cross-arms of the foundation frame, and it derives its rotatory movement from the first-motion shaft by spur pinion and gearing on the exterior of the pan.

The horizontal shaft also drives a central pair of bevel wheels actuating a central spur-wheel taking into four pinions on the vertical shafts of the revolving plates, by which these plates are rotated with the sun, in a direction contrary to the pan. The plates are provided with white-iron shoes, each 30 inches in diameter, and are driven at a speed of 200 revolutions per minute. Thus it will be seen that by the combined motions the grinding surfaces are preserved in good order from wearing in grooves.

The material to be pulverised is fed into a hopper, and thence transferred by an Archimedean screw-motion to a circular launder, wherein it is subjected to the action of a stream of water, entering therewith in the centre of the pan, whence it is immediately carried under the revolving plates, ground and rapidly passed through the external gratings by the centrifugal force of the stream, and there received into a launder that conveys it direct to the buddles.

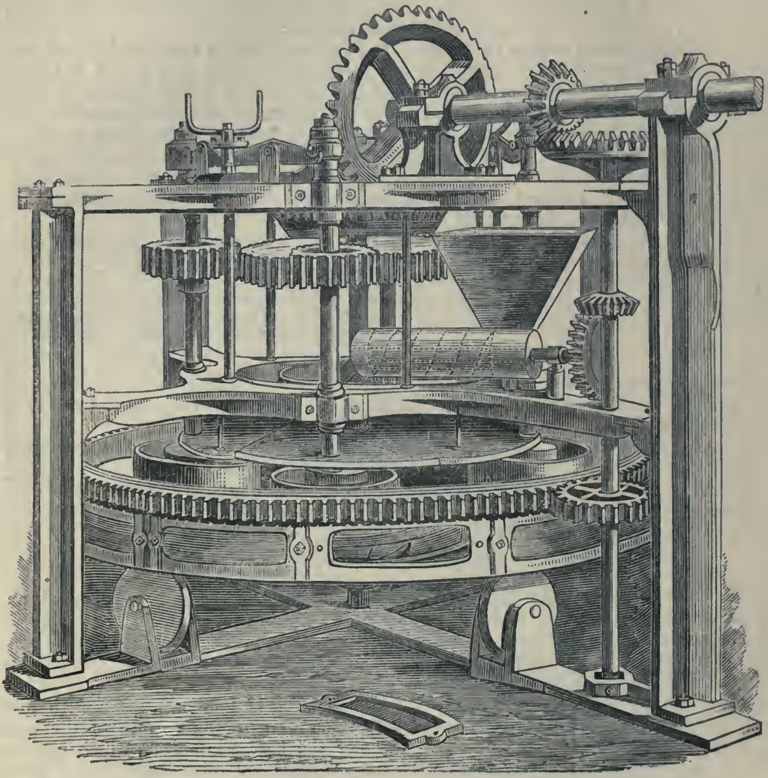
The whole machine is self-contained within four standards, with top, central, and bed plates and framing, so that it can be bolted down on a suitable foundation anywhere, for immediate work. It can be constructed in light parts, easily put together.

The motive power may be hydraulic or steam; a 10-inch single cylinder engine is sufficient for working it effectively.

This pulveriser is suited for the reduction of rough stamps'-work, and the grinding of gold and silver ores, tin roughs, skimpings, colours, clays, or earthy substances.

The work of one pulveriser is said to be equal to that of 24 Cornish heads of stamps, and the saving in working cost, in favour of the former, one-third less, the wear and tear in both cases being considered equal.

669

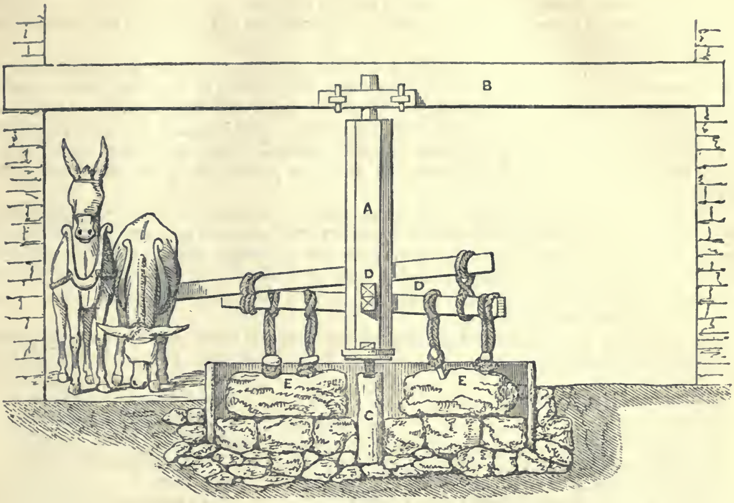


The first cost of 24 heads of stamps is about 200*l.*, of the pulveriser 150*l.* The grinding surfaces of the pulveriser lose 3 cwts. per month, whilst the stamps are said to lose 20 cwts. in the same time. At a comparative trial made at Wheal Jane, in Cornwall, on tin 'rows,' the cost of pulverising was 1*s.* 4½*d.* per ton; of stamping, 2*s.* 1¾*d.* per ton.

Arrastre or Tahona.—This machine is extensively employed in the mining districts of Mexico, for grinding silver ores previous to their amalgamation.

It consists of a strong wooden axle A (*fig.* 670), moving on a spindle in a beam B above it, and resting on an iron pivot beneath, turning in an iron bearing, which is inserted into a post of wood C, which rises about a foot above the ground in the centre of the arrastre. The shaft A is crossed at right angles by two stout spars D D, which form four arms, each about 5 feet long, one excepted, which is 9 feet long, to admit of two mules being attached to it; by this arm the machine is worked. The grinding is performed by four large porphyritic or basaltic stones, two of which are shown, E E. These are loosely attached by thongs of leather, or small sized rope, to the four arms, and are dragged over the ore, which is put in with water, until it is ground to a very fine slime or mud, called the *lama.* One of these machines, when in good working condition, will grind from 600 to 800 pounds weight of ore in twenty-four hours. In Guanaxuato, where the best and finest grinding is obtained in the arrastres, the lining or foundation and the grinding stones are, of coarse-grained porphyry, and form a rough surface. The cost of this apparatus in Mexico, including the paving of the bottom, and the four *metapiles* or stones, is on an average 7*l.* The original weight of a metapile is about 700 pounds, its dimensions are 2 feet 8 inches long, 18 inches broad, and 18 inches deep. Notwithstanding the hardness of the stones employed,

670



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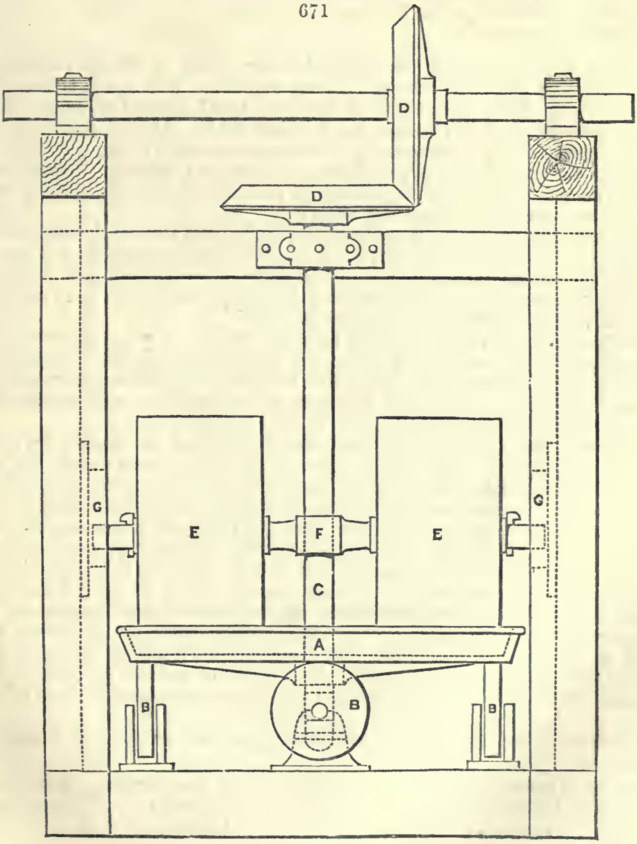


they are so worn as to become unserviceable in the course of ten or twelve weeks; the bottom, however, is only replaced once in twelve months.

This apparatus is well suited to patio amalgamation, but it affords bad results for the power expended.

Edge-mill.—This machine is employed for the purpose of reducing gold and silver ores to an impalpable powder. It is also used extensively in grinding flints, stones, slags, and a variety of other products. However much the details of this apparatus may vary, its principle is the same in all cases. Two vertical runners rotate on the outer circumference of a flat or slightly conical basin, and afford a frictional or grinding area *equal to the difference of distance performed by the inner and outer edges.*

The subjoined woodcut, *fig.* 671, represents a mill constructed at the Sandycroft Foundry, Flintshire. A, rotating pan, resting upon frictional wheels B; C, vertical shaft firmly keyed to pan A, to which motion is communicated by wheel gearing D. The runners E E revolve on arm F, and may be of cast iron or of stone bound with a ring of iron. These runners have no progressive motion, but have free play to rise or fall on the axis C, and in the stay slots G G.

The following dimensions and particulars are derived from one of the edge-mills recently working at the Fabrica La Constante, in the province of Guadalajara, Spain:

Diameter of edge-runner	6 feet.
Width of do. do.	centre 20 in. edge 16 in.
Weight of do. do.	3 tons 15 cwt.
Speed of runner	200 feet per minute.
Diameter of interior circle of runner	4 feet.
Gauge of stuff previous to its being ground	10 holes to the lineal inch.
Do. after it leaves the mill	60 " "
Quantity of stuff reduced per 10 hours	350 lbs.
Horse-power employed	7.

In some machines erected at the Real-del-Monte mines in Mexico the stones were 6 feet in diameter and 12 inches wide. They were fitted with a ring of wrought iron 3 inches thick. Each pair of runners revolved round a centre on its own axis, in a cast-iron basin of which the bottom was 7 inches thick. At first good results were obtained; each mill if kept constantly at work ground nearly 10 tons per week; but as their axles, and particularly the wrought-iron rings and cast-iron bottoms, began to wear hollow and to lose an even surface, the grinding rapidly diminished, and with one year's work they were completely worn out.

The chief advantage of this machine is its simplicity of construction and consequent small first cost; but all its parts require to be made of great strength, and therefore of proportionate weight: hence, in addition to the rapid wear to which it is liable, this apparatus becomes objectionable for countries where transit of heavy machinery is more than ordinarily difficult and expensive.

Horizontal mill.—For the purpose of reducing auriferous and argentiferous ores to an exceedingly fine powder, and where dry grinding is essential, no apparatus has been found more effectual than the horizontal mill. It affords the largest area of frictional surface for the least wear and tear, and accomplishes equal results at a cost not exceeding one-fourth of that incident to the edge-mill.

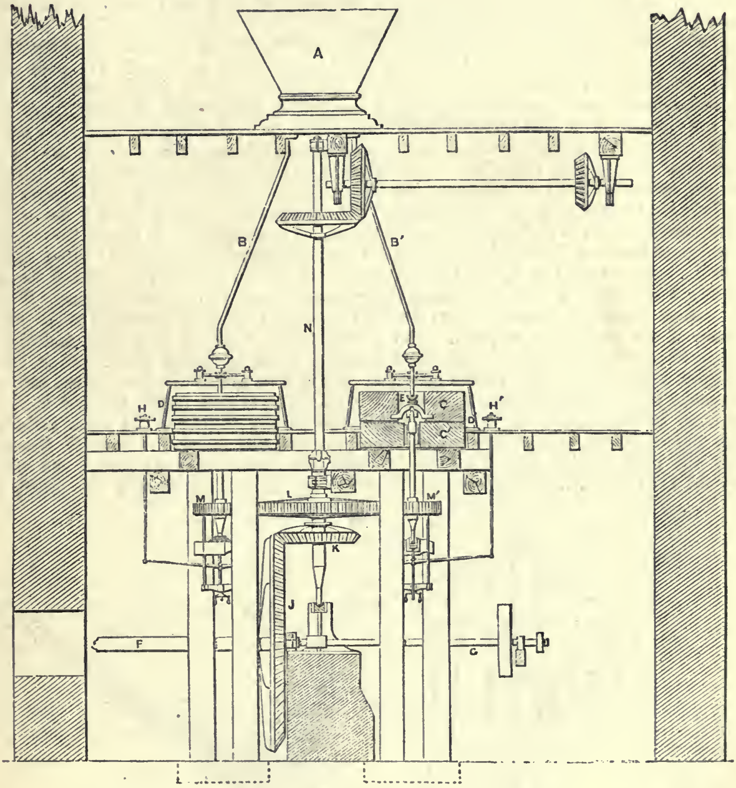
The construction of the horizontal mill will be rendered intelligible by the aid of the following illustration, *fig.* 672, in which one pair of stones is shown in section. A is a circular hopper, into which the stuff to be ground is introduced; B B, small pipes of sheet iron, for delivering the stuff between the surfaces of the runner C and bed-stone C′; D, casing enclosing the runner into which the ground material is delivered; E, hole in centre of runner; F, driving-shaft, with continuation shaft G, for giving motion to a Jacob's ladder if requisite; H H′, regulating screw for elevating runner C; J, driving-wheel; K, crown-wheel; L, wheel giving motion to pinions M M′; and N, vertical shaft, to drive any supplementary apparatus which may be required, such as sizing sieve, &c. Four pairs of stones are usually driven by the wheel L. The surface of the runner is in contact with the bed-stone, from the periphery to within one third of its diameter. The line of the runner then feathers upwards, in order to receive the stuff freely and to equalise the resistance throughout the area of the bed-stone.

The following particulars will convey much practical information relative to this machine:—

Diameter of stones	4 feet 2 inches.
Thickness of bed-stone	12 inches.
Ditto runner	14 inches.

No. of revolutions of stone per minute	108.
Gauge of stuff in hopper	100 holes to the square inch.
Ditto on delivery	3,600 ditto.
Quantity of stuff ground per 10 hours	1 ton per pair of stones.
Power employed in horses	About 5 per ditto.
Revolutions of sizing sieve	23 per minute.
Diameter of ditto	30 inches.
Length of ditto	108.
No. of holes per square inch in sizing sieve	3,600.
Character of runner	Coarse conglomerate.
Ditto bed-stone	Compact quartz, moderately hard.
Duration of runner	Average 18 weeks.
Ditto bed-stone	Ditto 22 ditto.
When dressed	Every third day.

672



From a series of practical experiments made on the same stuff by horizontal, crushing, and edge-mills, the following results have been obtained:—

	No. of Holes per sq. in. in Sizing Sieve	Quantity of Stuff ground in 10 Hours	Horse-power	Cost per Ton
		cwts.		s. d.
1. Horizontal mill	3600	20	5	2 3
2. Crushing mill	3600	13	5	1 7
3. Edge-mill	3600	13	7	6 10

Stamps.

Tin and some other of the more valuable ores are usually associated with and minutely disseminated in a hard crystalline gangue, requiring to be reduced to a fine powder before the valuable portions can be extracted.

Various contrivances have been employed for this purpose, but none of them seem to have entered into successful competition with the stamping mill. This apparatus essentially consists of a number of cast-iron pestles, each measuring about 20 inches high, and 6 by 10 inches in cross section. These are secured either to a wrought-iron or wooden lifter; a projecting arm is placed towards the top on each lifter, which may be slidden up and down so as to meet the wear of the pestle or any other irregularity. These lifters are retained in their vertical position by suitable metal or wooden supports. Motion is communicated by a revolving shaft in front, fitted with four or five projecting cams, each of which takes the arm, and lifting the pestle from 8 to 10 inches, lets it suddenly fall on the substances which may be underneath. The bottom on which the heads fall is formed by introducing hard stones or other suitable material, and pounding it until it becomes sufficiently solid. In most parts of the Continent of Europe, on the contrary, stamping mills are provided with solid cast-iron bottoms; these, however, require frequent renewal.

Around the pestles a wooden box or coffer is constructed, and covered in at the top; the back is partly open at the bottom in order to admit the vein-stuff. On each side one, and in front two openings are made, 7 or 8 inches square, which are fitted with wrought-iron frames, for the reception of perforated iron, copper, or brass plates, the bur of the punch or drill being towards the inside. As a precaution against the speedy destruction of the coffer from the constant scattering of fragments of stone, the inside is partially lined with sheet iron. The stuff to be stamped is supplied on an inclined plane, connected with a hopper at the back, in the front of which is a launder for affording a stream of water to the coffer. The stamped stuff passes through the grates into launders, and is thus directed to the floors. When water is the motive power, the number of heads is limited by the volume and fall of water available; three heads are the least number used, but a larger number is generally preferred. When steam-power is employed, a battery of heads sometimes includes 100 or more pestles. When in action these are elevated from 40 to 80 times per minute, according to the character of the stuff to be reduced. The pulverisation is said to be greatly facilitated by having four heads in the same chest or coffer, about 2½ inches apart. Each head is lifted separately, and the cams by which this is done are so disposed on the axle as to make the blows in regular succession. Great care is also taken whether it be in a large or small battery, to prevent any two pestles falling at the same instant; the object being to secure an equal load against the power. Practical dressers are not well decided as to the order in which the lifting of four heads in one coffer should take place, whether one of the inner pestles should precede the other, or whether a side pestle should be first lifted. A preference, however, seems to be given to the following method:—supposing a spectator to stand in front of a 4-head stamps, left side pestle first, right side second, right middle third, left middle last.

673

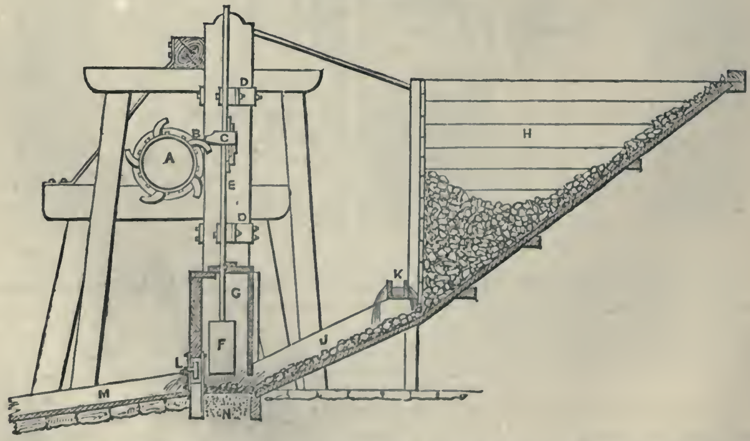


Fig. 673 represents the elevation of a steam stamps employed in Cornwall. A, axle; B, cams for lifting heads; C, tongue or projection on lifter; D D, guides for retaining lifter; E, the lifter; F, head of pestle; G, chest or coffer; H, hopper; J, pass connecting coffer and hopper; K, launder discharging water into the coffer; L, stamps grate; M, launder receiving the stuff which has been flushed through the grates; N, the bottom or bed of stamps.

The stamping process is not so simple as it may appear at first sight. Many of its particulars, such as the form of the coffer, mode of exit for the stuff, weight and rapidity of the pestles, and quantity of water employed, must be varied to suit the mode of dissemination and the structure and character of the ore, as well as of the matrix. Fineness of reduction is by no means always a desideratum, for if some kinds of stuff be reduced too low, much of the ore contained in it will be wasted, hence considerable judgment is necessary in selecting the grate best adapted to the stuff to be operated upon. Sometimes the grate is replaced by the 'flash,' which consists of a small hopper-shaped box, fitted to the front of the grate-hole. This box is provided with a shutter which is raised or lowered according as the ore is required in a fine or rough state. In dry stamping the fineness of the powder depends not on the grate, but on the weight of the pestles, the height of their fall, and the period of their action upon the substances beneath them. The following practical results are derived from the steam stamps at Polberro Tin Mines, Cornwall:—

Cylinder of engine, 36 inches diameter.
Diameter of the fly-wheels, 30 feet.
Weight of ditto, with cranks, shaft, and bolts, 42½ tons.
Power employed, 55 horses.
Reduced in 12 months, 30,201 tons of vein-stuff.
Average number of revolutions of stamp axles per minute, 8½.
Number of heads lifted per minute, 72, each 9 inches high.
Weight of each head, 600 lbs.
Average number of blows made per minute by each head, 45.
Weight of heads collectively, 19¼ tons.
Number of grates, 72.
Exposed area of front grates, 9 × 6 = 54 inches.
Ditto of end grates, 8 × 6 = 48 inches.
Number of holes to the square inch, 140.

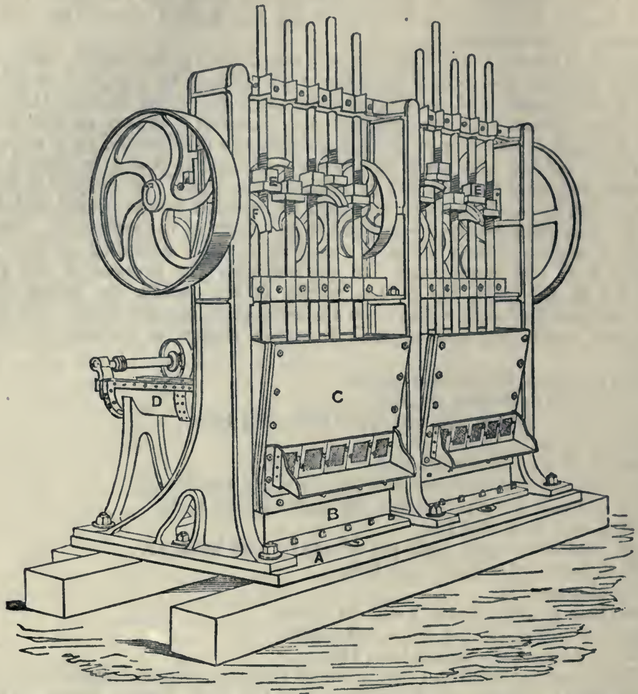
One of the most powerful and best arranged stamping engines in Cornwall, designed and constructed by Messrs. West and Sons, is at the West Phœnix Mines. Two vertical cylinders are employed, each 26 inches diameter, with 7-feet stroke. The weight of fly-wheel is 11 tons; speed of piston, 240 feet per minute. The length of stroke given by the cranks is 84 inches. The stamp axles, right and left of the engine, make 12 revolutions per minute, and drive at one and the same time 96 heads. The average weight of each stamp head is 600 lbs.; new, 800 lbs.; when worn out, 150 lbs.; dimensions of head, 20″ × 7″ × 11″, giving a sectional area of 77 inches. The number of drops per minute is 60; average drop, 10 inches. Number of heads in a battery, 4. Area of grate per battery box, 336 square inches, or 84 inches per head. Diameter of holes in grates, ½ millimeter. Weight of tin-stuff stamped per 24 hours, 18 cwts. per head. Average duration of head, 3 months. Weight of stuff stamped per head, 80 tons. Loss of iron per ton of stuff, from 9 to 10 lbs. Cost of stamp heads per cwt., 11*s.* Average weight of coal required to stamp 1 ton of stuff, 1 cwt.

The consumption of coal per 24 hours, is 4 tons, cost 7*l.* 4*s.* 0*d.* Engine driver's wages, 10*s.* Oil and grease, per month, 4*l.* The direct approximate cost of stamping, per ton of stuff, is therefore,

	s.	*d.*
Wear of stamp head	1	0
Coal	1	9½
Oil and grease		½
Total .	2	10

Fig. 674 represents a stamping mill arranged for the reduction of auriferous quartz, silver, and other valuable ores. The base consists of a cast-iron plate A, upon which is screwed a frame B, without end or side joints. A thick cast-iron bottom is dropped into this frame, upon which the stuff is pulverised. The coffer C, is made of cast-iron plates, bolted together at their edges. Each head is in connection with a grate or perforated plate. The feed is effected by means of an Archimedean screw, revolving in the trough D. The heads are solid cylinders of iron attached to wrought-iron lifters, and when in work are rotated by the action of the long cams F. The lift or rise of the head is varied by the blocks E E, which traverse a flat thread screw cut in the lifter. It will be seen that no stuff can be lost through the bottom of the coffer; whilst an economic advantage is secured by the use of a large area of perforated plate or grate. At a speed of 70 to 80 drops per minute one cwt. of stuff, is reduced to ½ millimeter size per hour, the quantity of water per head being about 4 gallons per minute.

674



German Stamping Mills.—To the German miners we are indebted for the general arrangement of the Stamping Mill. In a work, 'De Re Metallicâ,' by Agricola, edition 1621, many different mills are illustrated, showing clearly that all the essential features of the modern mill were then well known. In Rittinger's 'Lehrbuch der Aufbereitungskunde,' and other important works on Dressing, the subject of stamping mills is, generally, well and profoundly treated, and rendered clear by the aid of numerous illustrations. The following particulars of a practical character will, however, be interesting:—

Stamp Head.— Average weight, 300 lbs.
,, Minimum ,, 100 lbs.; maximum weight, 500 lbs.

Fall of Head.—Average 8 inches.
,, Maximum, 12 inches, for coarse stamping.
,, Minimum, 4 inches, for fine stamping.

Wear of Head.—Made of grey iron, after stamping 5 tons of stuff to a size of 1 millimeter.

,,	Hard tough stuff	11 to 13 lbs.
,,	Middling hard stuff	8 ,, 10 ,,
,,	Moderately ,, ...	5 ,, 7 ,,

Wear of Anvil or 'bottom' of cast iron 4 inches thick, per 5 tons of stamped stuff.

,,	Hard tough stuff	4 to 5 lbs.
,,	Middling ,, ...	3 ,, 4 ,,
,,	Moderately ,, ...	1 ,, 2 ,,

Order of fall.—Centre head first, then right and left.

Number of Heads in a Battery.—Three, at most five.

Stamping Results.—Weight of head, 250 lbs., fall 8 inches, making 60 drops per minute, will produce, in 24 hours,

,,	Stuff, 2 millimeters size	30 cubic feet
,,	,, 1 ,,	16 ,,
,,	,, ½ ,,	9 ,,

Cast-iron Bottoms—Will afford 3 per cent. higher result than can be obtained from a stone bottom.

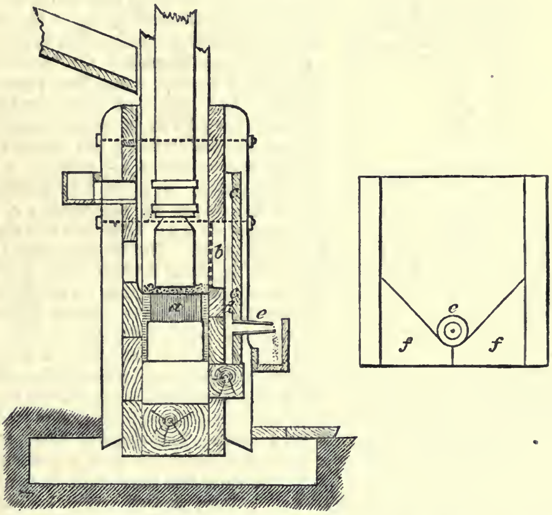
Water, per minute, per head:

	For direct discharge	3 to 5 gallons.
,,	Large stuff, 4 to 8 millimeters	12 gallons.
,,	Rough ,, 2 ,, 4 ,,	6 ,,
,,	Fine ,, 1 ,, 2 ,,	3 ,,

Space between head and inside of battery box 1 to 1½ inch, except at the side at which the stuff is introduced, where it is 2½ to 3 inches.

Some years ago the late P. Ritter von Rittinger contrived a battery box for stamping under water, *fig.* 675. *a*, cast-iron bottom wedged into the box; *b*, stamp screen set 1½ to 3 inches above the bottom; *c*, water-tight panel, made of strong boards fixed within a short distance from the front of battery box, the opening *d* extending several inches below the anvil of the battery; *e*, outlet-pipe, in the centre, and near to the lower edge of the panel. The bottom of the channel between the battery box and panel is inclined from both sides towards the outlet *e* by means of strips of timber inserted in the angles. The amount of discharge through the pipe *e* can be regulated, and the pipe is so fixed, that the water rises, and is kept at such a level above the stamp head, that the fall takes place entirely under water. At Schemnitz, the duty obtained by the use of this battery box is said to be nearly 50 per cent. greater than that obtained from the box previously in use.

675

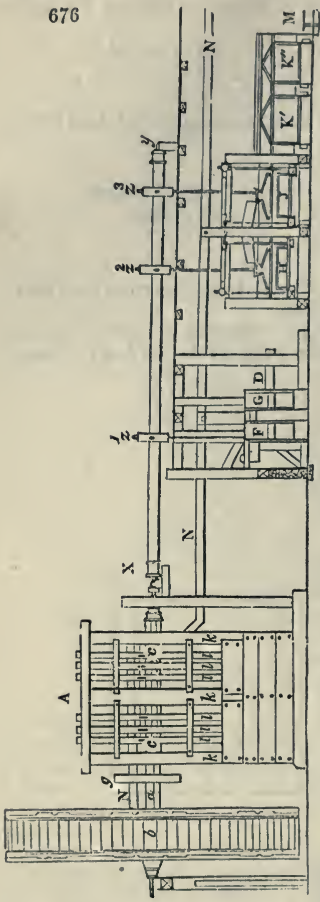


The feeding of the stamps is in some establishments effected by self-feeding hoppers, in others by manual labour; the batteries having, in the latter case, a small hopper attached, into which the stuff is thrown with shovels.

Fig. 676 is a set of stamping and washing works for the ores of argentiferous galena, as mounted at Bockwiese, in the district of Zellerfeld, in the Hartz.

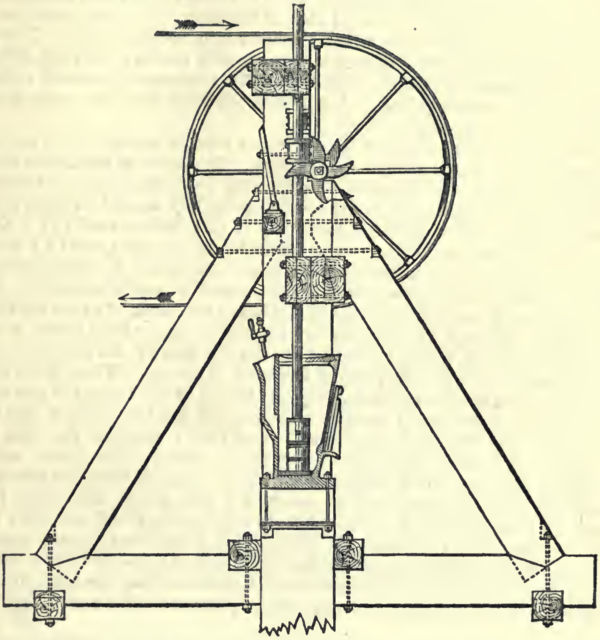
A is the stamp mill and its subsidiary parts: among which are *a*, the driving or main shaft; *b*, the overshot water-wheel; *c c*, six strong rings or hoops of cast iron for receiving each a cam or tappet; *g*, the brake of the machine; *k k k*, the three standards of the stamps; *l l*, &c., six pestles of pine wood, shod with lumps of cast iron. There are two chests, out of which the ore to be ground falls spontaneously into the two troughs of the stamps. Of late years, however, the ore is mostly supplied by hand; the watercourse terminates a short distance above the middle of the wheel *b*. There is a stream of water for the service of the stamps, and launders proceeding from it, to lead the water into the two stamp troughs; the launder of discharge is common to the two batteries or sets of stamps through which the water carries off the sand or stamped ore. There is a moveable table of separation, mounted with two sieves. The sands pass immediately into the launder placed upon a level with the floor, and separated into two compartments, the first of which empties its water into the second. There are two boards of separation, or tables, laid upon the ground, with a very slight slope of only 15 inches from their top to their bottom. Each of these boards is divided into four cases with edges; the whole being arranged so that it is possible, by means of a flood-gate or sluice, to cause the superfluous water of the case to pass into the following ones. Thus the work can go on without interruption, and alternately upon the two boards. There are winding canals in the labyrinth, N, N, N, in which are deposited the particles carried along by the water which has passed upon the boards. The depth of these canals gradually increases from 12 to 20 inches, to give a suitable descent for maintaining the water-flow. At D two percussion tables are placed. F, G, are two German chests. H, J, are two percussion tables, which are driven by the cams *z z*, fixed upon the main shaft X *y*. K′ K″ are two sloping sweep tables (*à balai*). The *German chests* are rectangular, being about 3 yards long, ½ a yard broad, with sides 18 inches high; and their inclination is such that the lower end is about 15 inches beneath the level of the upper. At their upper end, usually called the *bolster*, a kind of trough or box, without any edge at the side next the chest, is placed containing the ore to be washed. The water is allowed to fall upon the bolster in a thin sheet. The *sleeping tables* have upright edges; they are from 4 to 5 yards long, nearly 2 yards wide, and have fully a yard of inclination. The tables are sometimes covered with cloth, particularly in treating ores that contain gold, on a supposition that the woollen or linen fibres would better retain the metallic particles: but this method appears on trial to merit no confidence, for it produces a very impure *Schlich.*

676



Californian and Nevada Stamps.—The foundation is generally formed of vertical timbers, set close together, and firmly braced by means of cross timbers and bolts. Each piece of timber, 2 feet by 18 inches, is from 6 to 12 feet long, according to the nature of the ground, and height of the discharging grate. When the timbers are in position, the adjacent earth is firmly rammed together, and the foundation thoroughly consolidated. The sill, vertical, and diagonal timbers are strongly connected and laterally braced so as to render movement all but impossible. The stamps box is placed directly upon the vertical timber foundation, and is secured by bolts. The length of box shown in *fig.* 677, is 4 feet 6 inches, depth 4 feet, inside width 12 inches; and is so cast that bottom, sides, and ends, are in one piece. The feed opening is an aperture 4 inches wide and 3 feet 9 inches long. The discharge or grate opening is 45 inches long and 10 inches deep, the bottom edge being 4 inches above the top of the die. The grate is attached to a frame, secured by wedges in grooves cast in each end of the box, and by two lugs in front of the discharge opening. It is usually inclined at about 7½° with the view of facilitating the discharge of the stuff. For wet stamping, Russian sheet iron is employed, having holes varying from one half to one millimeter in diameter. The grate is attached to the frame by means of screws and to confine the 'flash' of the stuff, a piece of canvas hangs over the grate. The top of the cast-iron anvil, is of the same diameter as the shoe, and is from 4 to 6 inches high; the bottom is commonly square, large enough to extend from side to side of the battery box, the corners being removed, so that it may be withdrawn by the use of a pick point. The shoe is of the hardest white iron, 8 inches diameter and 6 inches high, with a shank tapering from 2 to 4½ inches. The shoe is attached to the head, by placing strips of pine wood, ¼ of an inch thick and ½ an inch wide around the shank. The strips of wood are tied by means of cord, and the head lifter gently driven home, the shoe striking a piece of timber until it is firmly fixed. When it is necessary to remove a shoe it is accomplished by driving a key into a key-way formed in the head for this purpose. The lifter is usually turned to a diameter of 3 inches, and is from 10 to 12 feet long; the head is of tough cast iron, 8 inches diameter and 15 inches high. At the top is a hole, slightly conical, about 7 inches deep, with a drift way for forcing the lifter from the head.

677



A stout wrought-iron hoop is put on hot at the top and bottom of each head so as to give it additional strength. To fix the lifter in the head a few blows of the hammer are first necessary, then a few beats in the ordinary way.

The gib tappet is 8 inches in diameter and 8 inches long, and made hollow so as to receive the lifter. The gib itself is two inches wide, nearly as long in the tappet, and with its inner face curved, to correspond to the circular hole, through which the lifter passes. The gib being fixed in place and the tappet put upon the lifter, is forced against the latter by means of two keys which are driven to such an extent as to maintain the tappet firmly in its position. This method is found to be in all respects satisfactory, and is superior to screw threads or key seatings. A partial revolution of the head is effected at each lift, and continues to some extent during the fall, causing, as it is alleged, a grinding as well as a stamping effect, and wearing the shoe more evenly than if no circular movement occurred. Guides of hard wood are preferred to iron. One set is placed below the tappet, about a foot above the battery box, a second set within 6 inches from the top. The width of guide is from 10 to 15 inches. Each cam piece has usually two arms, with faces 2 or 3 inches wide, the casting itself being of tough cast iron; the curve of the face is the involute of a circle the radius of which is equal to the distance between the centre of the cam axle and the centre of the lifter. The bottom of the cam is consequently perpendicular to the radius of the curve of the cam, and the stamp-head is uniformly lifted in a vertical line. In practice, the line of curvature necessary for the cam is obtained by taking—(1) a circular piece of board having a radius equal to the horizontal distance from the centre of the cam axle to the centre of the lifter; (2) a piece of thread with a pencil-point attached to the end; (3) measuring the desired lift of the head on the thread from such pencil-point, then attaching the end of the thread to the periphery of the circular piece of wood; (4) winding the thread on the periphery of the wood, laying the wood on a smooth board, unwinding the thread whilst being stretched to its utmost limit and at the same time tracing with the pencil-point the required curve. As it is desirable that the cam may be in contact with the tappet at the least practicable distance from the axle the curve is modified by giving to the cam a greater curvature near each of its ends. The cam point is also as near to the lifter as is practicable, without coming into actual contact. The axle is of round iron, from 4 to 6 inches diameter, turned, with two key-ways cut, for the purpose of securing the cams in their places. In some instances the shaft extends the entire length of the various batteries, but a separate light shaft for each battery of four or five stamps is preferred.

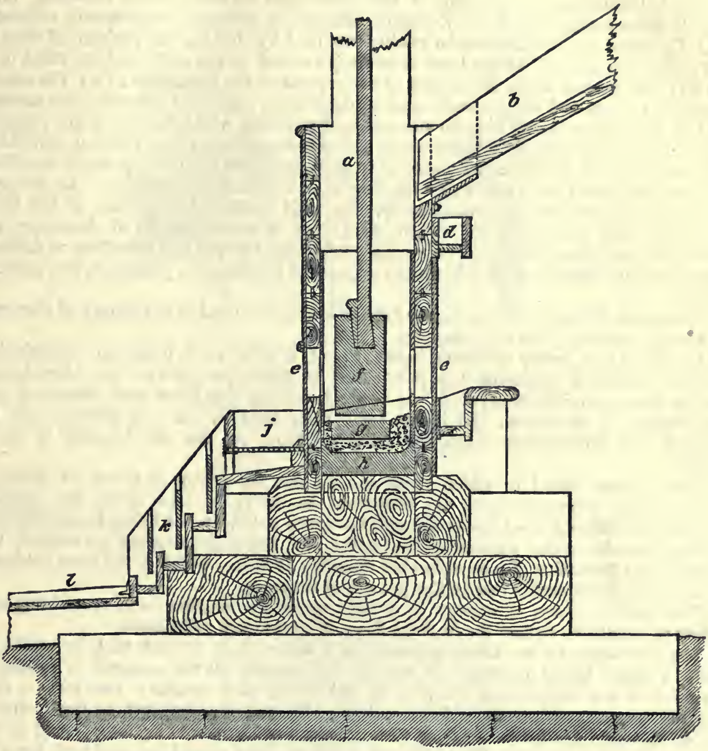
In such case each axle receives its motion from a counter shaft, the two shafts being connected together by means of belts and riggers. The order in which the heads fall varies in different mills, but the condition of having an uniform load on the engine at one and the same time, as well as a free and effective fall, should be observed. In a five-stamp battery the order of fall is commonly: (1.) Middle head; (2.) End right hand head; (3.) Second head on left; (4.) Second head on right; and (5.) End stamp head on left. The key-ways in the cams are cut so that when the latter are fixed, the heads are lifted in the order above stated. Occasionally quartz is crushed dry, but much more frequently water is admitted to the boxes by means of gas-pipes fitted with regulating cocks. When it is necessary to hang one or more of the heads a workman lays a smooth piece of board 1½ inch thick on the face of the cam as it is rising to the tappet, and holds the board whilst the head is lifting. When high enough a stud, articulated on a small shaft extending the length of the battery is put under the tappet, when the cam will freely revolve. To set the head in motion the board is again introduced and the stud withdrawn. The power required for each head of average weight, including friction, is about 1½ horse. The belts are manufactured out of a combination of canvas and India-rubber, and from the first motion to the intermediate shaft are sometimes as much as 2 feet wide. The belts from the second motion to the cam shaft are made of thinner material and are from 12 to 14 inches wide. The shafts are frequently provided with cast-iron driving riggers. In some cases, however, the riggers are constructed of either kiln-dried wood, with arms inserted in a cast-iron boss and then turned off in place, or they are built solid of well seasoned planks, on bored bosses and concentrically turned, after being keyed to the shaft.

In Colorado the stamp heads, are often, however, run more slowly, and have a greater fall than the heads employed in the Californian and Nevada mills. The average weight of head is from 500 to 600 lbs., minimum beats 15, maximum 40, average 30 per minute, with a fall of from 12 to 18 inches. The heads generally revolve and fall in an iron mortar, 4 or 5 feet long, 12 or 14 inches wide, the bottom being sometimes 9 or 10 inches thick. This casting is commonly laid on a block of timber, which rests on cross timbers. The mortar, is recessed for dies, having an octagonal base and a wearing cylindrical head of iron, commonly 8 inches in diameter. The battery box is entirely of wood and arranged so as to be readily removed. The 'grates' are of sheet iron, with very fine slot holes, about ⅛ of an inch long, and an equal distance apart.

The grate is usually from 9 to 10 inches wide, and the length of the box. It is fitted in a frame which is kept in position either by means of wedges or set screws. The lifter stem has usually a screw thread for adjusting the tappet, the latter being lightened by means of a key, driven in ways, cut in the tappet and stem. When the driving power is a steam-engine, power is frequently transmitted to a counter shaft by means of a belt and to the stamps axle by spur wheels. This axle, as in Cornwall, usually extends the length of the whole of the batteries. Water is introduced into each battery box, the quantity being sufficient to carry out the stuff as soon as it is reduced to the necessary degree of fineness. For the milling of gold ores, the ends of the battery box are lined with amalgamated copper plates, a third plate 10 or 12 inches wide, the length of the battery fixed in a frame, is secured in an inclined position behind the stamps, whilst a fourth but a narrower plate is placed on the front side of the box. The average weight of stuff stamped per day is believed to be less than a ton per head; the volume of water is, say 2,500 gallons per ton of rock. The tendency of improvements is in the direction of employing lighter heads, a lower fall, and an increased number of beats per minute.

Australian Stamps,—At the Port Phillip Company's Works, Clunes, Victoria, the battery box is set on a foundation of timber shown in *fig.* 678; the length of timbers in the under framing being 10 feet, depth 15 inches. On these transverse timbers are set running timbers 6 feet 6 inches wide, surmounted by logs having an aggregate width of 36 inches. On the latter rests the battery box. This is constructed partly of wood and partly of iron, with an internal iron casing. *a* lifter, *b* feeding shoot, *d* launder for supplying water, *e*, *e* back and front grate ways 9 inches wide, *f* stamp head, *g* cast-iron bed 3 inches thick and 10 inches wide, *j* perforated plate, *k* mercury boxes. The sectional width of head is 9 inches, depth 20 inches; width of internal casing 15 inches, width of battery box 18 inches, depth from feeding shoot to bottom of foot plate 4 feet 6 inches, depth from bottom edge of grate to surface of stamper plate 4½ inches. The weight of each head and lifter is 800 cwts.; number of blows, made per head per minute, 75; quartz reduced per head per 24 hours, and passed through screens having ten holes per lineal inch, 4 tons; quantity of water required per head per minute 8 gallons or 2880 per ton of quartz. The following statistical matter, compiled from R. Brough Smyth's most able and exhaustive work on the 'Gold-Fields and Mineral Districts of Victoria,' will indicate a variety of details connected with stamping machinery in that wealthy and thriving colony:—

678



Mineral District	Weight of Stamp head with shank and lifter	Fall of stamp head	No. of blows of stamp head per minute	Quartz crushed per head in 24 hours	No. of holes per square inch in grate	Horse-power per stamp head	Gallons of water per stamp head per hour	Loss of mercury per head per week
	Cwts. Cwts.	in.		Cwts. Cwts.				oz.
Ballarat . .	3¼ to 8	7 to 10	50 to 80	18 to 70	40 to 224	1 to 1½	220 to 600	nil to 8
Beechworth . .	4 „ 7¾	5 „ 16	45 „ 80	20 „ 80	65 „ 144	¾ „ 2	70 „ 480	nil „ 8
Sandhurst . .	5 „ 8	8½ „ 18	45 „ 72	15 „ 60	64 „ 130	¾ „ 1	211 „ 575	nil „ 4½
Maryborough .	4 „ 7½	8 „ 12	60 „ 80	30 „ 60	60 „ 140	¾ „ 1¾	200 „ 1116	½ „ 8
Castlemaine . .	2½ „ 7½	6 „ 15	35 „ 80	20 „ 80	64 „ 160	½ „ 2	27 „ 650	nil „ 8
Ararat . . .	5 „ 7	6 „ 10	60 „ 80	25 „ 30	100 „ 121	$\frac{6}{10}$ „ 1½	120 „ 480	1½ „ 8
Gippsland . .	3 „ 8	7 „ 11	70 „ 80	30 „ 41	70 „ 250	$\frac{8}{10}$ „ $1\frac{8}{10}$	120 „ 390	1 „ 5

In addition, Mr. Smyth gives the following particulars of cost of crushing quartz and extracting the gold :—

	Ballarat	Clunes	Sandhurst	Maryborough	Castlemaine	Maldon
Average cost of raising and delivering one ton of quartz at the mill .	5/10½	12/10 to 27/1	8/10½	21/8	7/8½	27/4
Stamping quartz and extracting gold	2/10	7/5	2/9½	8/	3/9	14/4½

The following are among some of the advantages afforded by the stamping mill: (1.) It gives a direct dead blow, highly effective in reducing semi-elastic minerals; (2.) The force of the blow can be readily modified by shifting the position of the tappet; (3.) The free fall of the head is entirely exerted on the stuff, and its effect is in no way transferred to the framework or other parts of the apparatus; (4.) The repairs required are few and simple, such as an ordinary mine smith and carpenter can execute; (5.) A battery of heads may be stopped and repaired while the others are running; (6.) Single heads may be thrown out of use without affecting the working conditions of the mill; (7.) The mineral under treatment receives the least possible handling, and can be flumed at once either to dressing or amalgamating apparatus; (8.) Minerals can be readily reduced to a condition of fine sand, provided the faces of the heads are good; (9.) Speed, lift, the weight, size, form of head, position of discharge, and extent of grate way, admit of numerous variations to suit the condition of different minerals, and afford a wide field for the exercise of intelligence, judgment, and practical skill.

Pneumatic Stamps.—The ordinary form of stamps, as used in the county of Cornwall, is a simple and very old type machine.

It consists of heavy cast-iron heads, about 6 cwts. each, fixed on wrought-iron square shanks, a projecting tappet attached to the upper part of the lifter, against which the revolving cams come into contact, raising the lifter and liberating it at the height of 10 inches; the heavy head then falls by its own gravity, and impinges with considerable force the crushing blow on the ore beneath it in the coffer.

The greatest speed to which these stamps can be driven is about 60 blows per minute; and consequently in tin stamping, the heavy particles of tin ore, although reduced to sufficient size to pass through the grate holes, by not being kept sufficiently agitated, settle to the bottom of the coffer, and there get further pulverised, thus causing the formation of a considerable quantity of slime, which is far from desirable, and entails considerable loss in the process of dressing.

This ancient form of stamps is a rude primitive machine, and something more effective should be looked for in these days of mechanical refinement.

If a man were to set about pulverising a stone, it is evident that he would not take a large heavy hammer, of say 25 lbs. employ all his strength in raising the hammer a few inches, and allow it to fall of its own weight; but with a much lighter hammer, with quicker blows, and using his muscular strength on the downward blow, he would get far better duty with the same expenditure of power. And so with the *machine* for obtaining the same end, a lighter head should be used and force employed in the downward blow.

To meet these discrepancies, evident and important as they are, the pneumatic stamps has been devised.

As early as 1856 the idea was conceived of employing an air-sponge or cushion in the working of steam-hammers, by Mr. Carr, an Englishman; since then, many patents have been taken out for various plans of employing springs, and air-cushions for hammers.

The same principle applied for stamping purposes is employed in the pneumatic stamps patented by Mr. W. Husband of Hayle, Cornwall.

These stamps, generally two heads to the coffer, consist essentially of a cast-iron crank, to which is attached by means of a forked connecting-rod, a pneumatic cylinder; the stamps' lifter is a hollow turned wrought-iron shank, fixed to head, with a metallic piston attached; the piston works in the air cylinder, with the lifter projecting through either end, and the head operating in a closed cast-iron coffer.

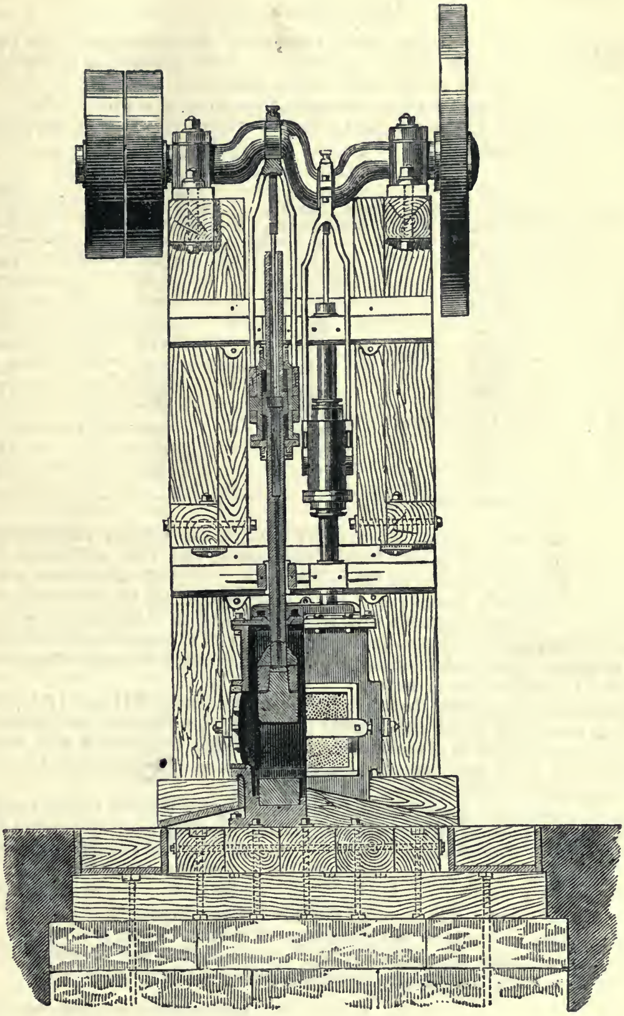
A rotatory motion being given to the crank, the cylinder is raised, the air it contains becomes compressed beneath the piston and the lifter with head attached, about 310 lbs. raised to the height of about 16 inches; as soon as the crank turns the centre, the compressed air yields back the force employed in its compression, and consequently a violent blow is given on the coffer.

A stream of water flows through the hollow lifter, discharging above the head into the coffer: this serves the double purpose of removing the heat generated through the compression of the air, and for providing the necessary water for stamping purposes.

Another object in making the lifter hollow, is to prevent crystallisation of the iron, from constant striking, and also to reduce its weight; the greater the weight of head, and the less in the lifter the better.

Arrangement is also made for giving the head a rotatory motion, so as to ensure an even wear on the face of the stamps' head.

679



These stamps are driven at about 150 blows per minute, and will reduce from *nine* to *eleven* tons of ore per head per day. At New Rosewarne Mine, Gwinear, 1¼ ton of stuff has been stamped with a consumption of 1 cwt. of coal, and from 6,000 to 7,000 tons of stuff with the loss of 5 tons of iron in the stamp heads. The stamps are exceedingly portable, which is a great advantage, and can be taken to pieces, carried to any part of the mine and erected with its portable engine in a few hours, requiring but little foundation.

A small battery may be used for prospecting purposes, and worked by horse or bullock power whenever it might be desirable to do so, the machine being made sufficiently portable for loading on a bullock dray.

In difficult or mountainous countries, where transport is expensive and dangerous, it is desirable that every part of a machine should be as light as possible, in order that it may be carried by mules or drawn by oxen; in the above machine this object is easily obtained, and several have been constructed for the gold-mines in Africa, Australia, and America, as well as for the mines of Cornwall and other parts of Europe.

Jigging Machinery.

In the jigging sieve only the initial velocity of the substances to be separated is obtained at each stroke. Were, however, the sieve plunged to a depth of, say 20 or 30 feet, the various grains would settle themselves according to their several velocities of fall, one over the other, assuming them to be of a uniform size.

The following Table shows the fall of various spheres of water in one second, the depth being in millimeters:—

Diameter Millimeters	Gold. Spec. Grav. 19·2 millimeters	Galena. Spec. Grav. 7·5 millimeters	Blende. Spec. Grav. 4 millimeters	Quartz. Spec. Grav. 2·6 millimeters
17·43	2614	1570	1066	780
11·32	2197	1320	898	653
8·71	1849	1110	750	550
6·16	1569	935	624	461
4·36	1307	785	514	385
3·08	1097	660	448	326
2·17	340	555	378	275
1·54	780	465	317	231
1·08	653	393	266	194
·77	548	327	210	163
·54	456	275	188	137

Let it be supposed that it is necessary to know the relative velocities of fall in water, of grains of gold, galena, blende and quartz, each 1·08 millimeter diameter. An inspection of the table shows the fall of gold to be 653 millimeters per second, galena 393, blende 266, quartz 194. Then, let it be assumed that the diameter of the grains vary; the foregoing table will show that gold of 6 millimeters would settle at bottom at the same instant as grains of galena 17·4 millimeters diameter, and that grains of galena 3 millimeters diameter would fall at about the same velocity as grains of quartz $11\frac{3}{10}$ millimeters diameter.

If, further, it be supposed that the grains varied between 8·71 and 17·4 millimeters diameters, some time would elapse after gold of 8·71 millimeters had settled before the galena would begin to deposit itself. With blende, however, of 8·71 millimeters, and quartz of 17·43 millimeters diameter, the grains of both would appear at the bottom almost at the same instant.

Two rules have been promulgated for determining the relative volumes of grains of different densities having the same velocity of fall in water, each rule giving a slightly different result. One in which the proportion between the maximum and minimum size of the grains is as the specific gravity of one to the other; the other in which the proportion is found by deducting 1, the equivalent of water, from the specific weight of the substance, and dividing the less into the greater.

Rule 1. Suppose a pile of stuff to consist of galena, blende, and quartz, and it is necessary to determine the maximum and minimum diameter of grains of each of these substances which shall have an equal velocity of fall in water. Then,

	Diameter of Grains having equal Velocity of Fall
Galena and Blende 4·0 : 7·5 :: 1 = 1·87 or	Galena 1 diam. Blende 1·87 diam.
Blende and Quartz 2·6 : 4·0 :: 1 = 1·53 „	Blende 1 „ Quartz 1·53 „
Galena and Quartz 2·6 : 7·5 :: 1 = 2·88 „	Galena 1 „ Quartz 2·88 „

Rule 2. If a pile of stuff consists of galena, blende, copper pyrites, and quartz, what will be the maximum and minimum diameter of the grain having an equal velocity of fall in water?

Diameter of Grains having equal Velocity of Fall

$$\left.\begin{array}{ll}\text{Galena} \;.\; & .\; 7{\cdot}5-1=6{\cdot}5 \\ \text{Blende} \;.\; & .\; 4{\cdot}0-1=3{\cdot}0\end{array}\right\} \text{ Then } \frac{6{\cdot}5}{3{\cdot}0}=2{\cdot}1 \text{ or } \quad \text{Galena 1 diam. Blende 2·1 diam.}$$

		Diameter of Grains having equal Velocity of Fall	
Copper Pyrites 4·1 − 1 = 3·1 Blende . . 4·0 − 1 = 3·0	Then $\frac{3{\cdot}1}{3{\cdot}0} = 1{\cdot}03$ „	Copper Pyrites 1 diam.	Blende 1·03 diam.
Copper Pyrites 4·1 − 1 = 3·1 Quartz . . 2·6 − 1 = 1·6	„ $\frac{3{\cdot}1}{1{\cdot}6} = 1{\cdot}9$ „	Copper Pyrites 1 „	Quartz 1·9 „
Galena . . 7·5 − 1 = 6·5 Quartz . . 2·6 − 1 = 1·6	„ $\frac{6{\cdot}5}{1{\cdot}6} = 2$ „	Galena 1 „	Quartz 4·0 „

As the latter rule will allow of a wider difference between the minimum and maximum diameter of the grains to be treated than the former, and is used by many practical engineers, it will, perhaps, be best to employ it, particularly in connection with ores and gangue, of a simple character; but apart from the rule itself, it will be desirable to bear in mind the following observations: (1) It will be impossible to separate by any hydraulic jigger a mixture composed of grains having an *equal* velocity of fall. (2) Separation of grains can only be effected by bringing the diameter of one set within such limits that the other will pass it within the descending range of the process. (3) If galena of 1 diameter and blende of 3 diameters are treated, the blende will be found at the bottom; galena of 1 diameter and blende of 2 diameters will be associated more or less together; whilst galena and blende of 1 diameter will fall with such a wide difference in their respective velocities as to leave each other at a very early period. The necessity of sizing stuff into equal volumes, so as to take advantage of the difference of fall due to their respective densities is therefore evident, as well as the fact that the nearer grains of stuff of equal volume approximate to each other in density, the greater length of fall will be requisite for their absolute solution.

Hand Sieve.—This apparatus, *fig.* 680, is formed of a circular hoop of oak, ⅜ths of an inch thick and 6 inches deep. Its diameter ranges from 18 to 20 inches. The bottom is made of copper or iron wire meshes, of various sizes. Sometimes perforated copper plate is employed, when the sieve is termed a copper bottom. The sieve is shaken with the two hands in a cistern or tub of water, an *ore vat* is, however, sometimes employed, and either fixed horizontally or in an inclined position. In using this sieve the workman (*fig.* 680) shakes it in the vat with much rapidity and a dexterous toss till he has separated the totally sterile portions from the mingled as well as from the pure ore. He then removes these several qualities with a sheet-iron scraper, called a *limp*, and finds beneath them a certain portion of enriched ore.

680

Deluing Sieve.—This sieve A, *fig.* 681, is either constructed with a hair or canvas bottom; the former is more expensive. but more durable. Its peculiar application is chiefly for the final treatment of ores previous to being put to pile, such ores having first passed through the finest jigging sieves, yet still maintaining a certain degree of coarseness and bearing a high specific gravity.

In the separation of ores from light waste, or such minerals as approach one another somewhat closely in their densities, this form of sieve is both good and effective, but to use it properly a considerable amount of dexterity and practice is requisite.

681

There are two principal methods of using it; by one a motion is given, whereby the waste is being constantly projected and carried over the rim into the kieve by a current of water forced through its bottom. This mode of treatment is adapted for poor ores. In the second case, when the ore is nearly pure, but still associated with a heavy gangue, a motion is given to the sieve whereby the water is forced through the ore, and made to traverse the surface of the mineral in concentric circles. This motion collects the waste into the middle of the clean result. By the first method about six tons per day may be passed through by each workman and enriched for the second operation. The weight of the sieve varies from four to five pounds, its diameter is twenty-six inches, depth four inches, and cost from 2*s.* 3*d.* to 2*s.* 6*d.*

A jigging sieve, constructed as shown in *fig.* 682, is sometimes employed on the Continent. A represents the table on which the mineral is placed; B is a large kieve of water, in which the sieve is suspended by the iron rod D, set in motion by means of the arrangement F, G, H, suspended at I, and having at the extremity H a box for the reception of small stones, to be used for the purpose of counterpoising the weight of the sieve and several fittings. By moving the rod F, sliding in K, the workman gives the required motion to the sieve, and when its contents have been sufficiently washed, he removes them by the same means as when the hand sieve is employed.

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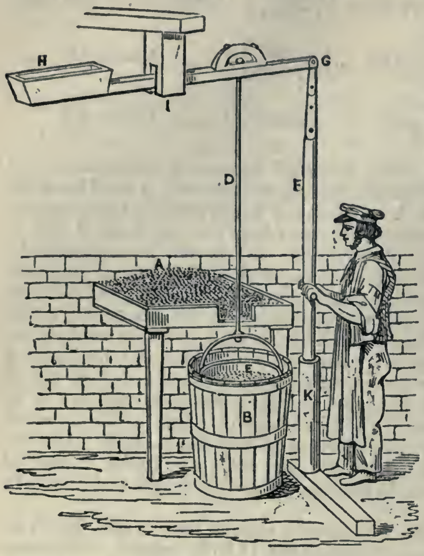
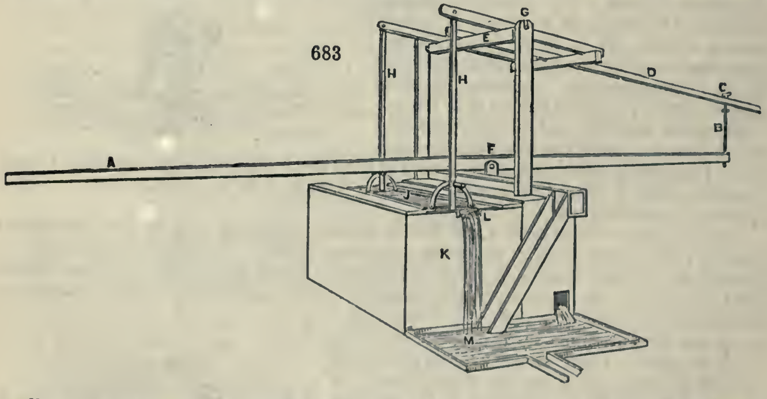


Hand Jigging or Brake Sieve.—The brake sieve, *fig.* 683, is of rectangular shape as well as the cistern in which it is agitated. A, wooden lever, having its axis at F; B, piece of wrought-iron bolted to the end of lever A, whilst its upper end passes freely through a slot opening in lever D, and having two shoulder projections C; E, axis of lever D; G, bars connected with lever D, supported on axle E, and from which the iron rods H H depend; J, rectangular sieve; K, within the hutch; L, shoot for overflow of water; M, receptacle for retaining any fine ore which may escape with the water from L, as well as for receiving the hutchwork. A boy placed near the end of lever A, by the action of leaping, jerks it smartly up and down, so as to shake effectually the sieve J. Each jolt not only makes the fine part pass through the meshes, but changes the relative position of those which remain in the sieve, bringing the purer and heavier pieces eventually to the bottom. The mingled fragments of ore and stony substances lie above them, while the poor and light pieces are at the top: those are first scraped off by the *limp*, then the mixed portion, and lastly the ore, which is usually carried to the ore heap. The sieve frame may be made 2 × 4 feet inside, and 8 to 9 inches deep. The hutch should then be 5 feet long, 3½ feet wide and 4½ feet deep, constructed of good deal boards 2 inches thick. The quantity of stuff which a boy can jig in ten hours will depend upon several circumstances. With a sieve six holes to the square inch and a tolerably light waste, from five to six tons can be operated on.

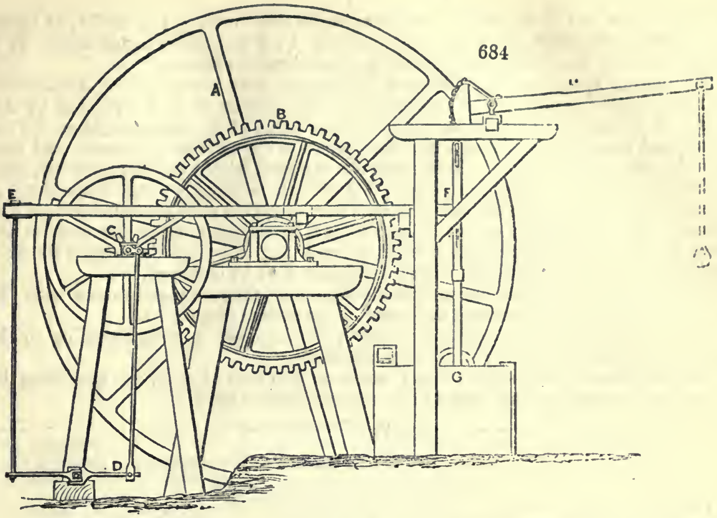
683



Machine Jigging.—The machine jigger. represented in *fig.* 684, is constructed on the same principle as the hand apparatus. The hutches are, however, somewhat larger, being 6 feet long, 4 feet wide, and 4 feet deep. A, fly-wheel; B, driving wheel; C, cog wheel receiving motion from B, and giving motion to a crank from which depends a rod attached to a lever D. The vertical rod E passes through a slot opening in the wooden lever F, and by these several combinations a vertical movement and jerk is given to the sieve contained in the cistern G.

When it is required to discharge the sieve, the lever H is depressed, and the pin

684



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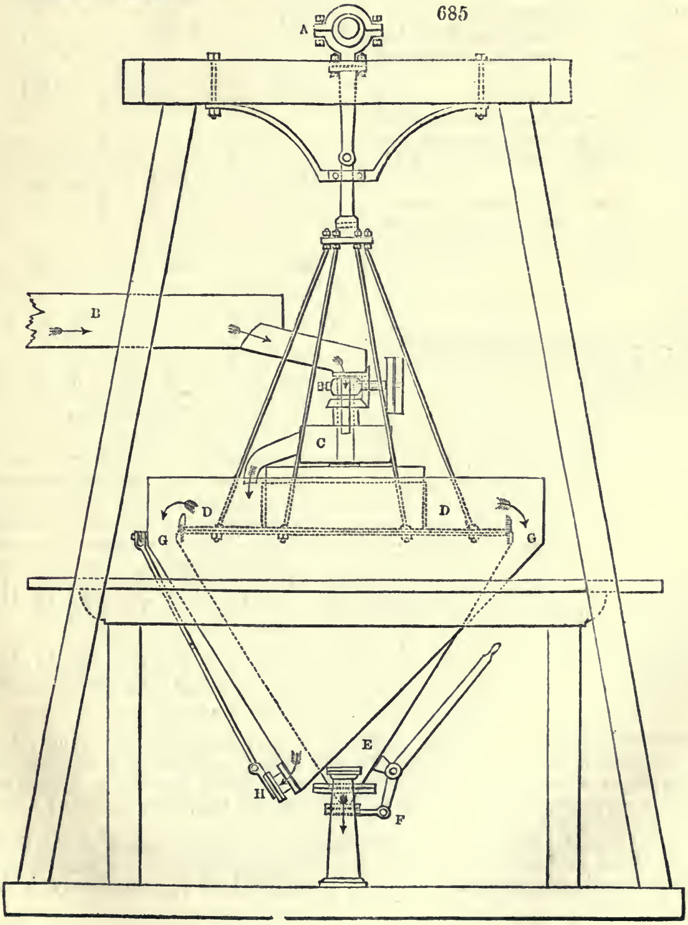


not seen in the end of the lever F, traverses in the slot shown in the bridle rod immediately below the bracket. The sieve measures 4 × 2 feet and 9 inches deep. It is strengthened by iron bands and numerous slips across the bottom.

The jigging apparatus, *fig.* 685, was introduced some years since at Allenheads, with satisfactory results. The larger and denser portion of stuff separated by this apparatus is conveyed by suitable launders to a series of sieves, arranged on the top of a conical reservoir, furnished with a feed pipe for the admission of water, and with an outlet pipe at the bottom. This reservoir is placed within another reservoir, also, in the form of an inverted cone, and provided with an outlet pipe at the lower part. A, excentric giving motion to the sieve; B, launder conveying stuff to such sieves; C, distributor, either stationary or revolving as may be required, delivering stuff to the sieves arranged on the top of the conical reservoir; F, valve for discharging the finer portion of the ore; G G, internal cistern furnished with an outlet valve H.

The sieves have a slight outward inclination, and the refuse substances with the waste water are carried over and deposited in the conical cistern G G.

The sieves should make from 150 to 200 pulsations per minute, according to the quantity and character of the stuff under treatment.

The following is the result of trials made on 160 tons of stuff, one half being delivered to this machine, the other to the common jigging hutch:—

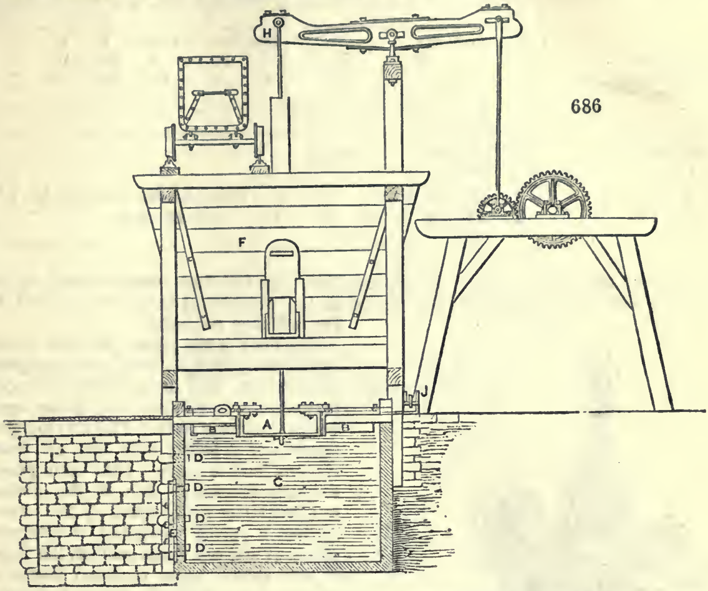
	Machine	Hutchers	Difference in favour of Machine
Time:—	Hours	Hours	Hours
Occupied hutching cuttings . .	50¾	58¼	7½
Ditto smiddum from do..	5	10½	5½
Sludge machine, washing sludge and smiddum	21½	61½	10½
Dressing the ore in a trunk . .	29½		
Aggregate number of hours occupied by the lads in doing the work, viz. feeding cuttings and hutching smiddum.	111½	195¾	84¼
Aggregate number of hours occupied by the lads in washing sludge and smiddum, including the final cleaning in a trunk	102	123	21
Cost:—	£ s. d.	£ s. d.	£ s. d.
Of boys attending machine, wheeling away waste, and preparing ore for the bing-stead	1 15 9	2 8 9½	0 13 0½

Produce.

	Sieve and Smiddum Ore				Sludge Ore				Total Ore		Total Lead	
	st.	lbs.	Assay	Lead	st.	lbs.	Assay	Lead	st.	lbs.	st.	lbs.
			p. cent.	lbs.			p. cent.	lbs.				
Machine . .	19	10	60	165·6	32	5¾	70	317·6	52	1¾	34	7¼
Hutchers . .	17	6½	60	146·7	13		64	116·5	30	6½	18	11¼
Difference in total produce in favour of machine .	...		...	...	...		...	...	21	9¼	15	10
Ditto ditto . .	...		...	...	...		...	...	71 p. cent.		84 p. cent.	

Petherick's Separator.—Figs. 686 and 687. A, the plunger or force-pump; B, receptacles fitted with sieves; C, hutch filled with water; D, discharge holes fitted with wooden plugs; E, moveable plate to admit of withdrawing the ore; F, hopper with shoots for supplying sieves; H, beam for giving motion to plunger piston A; J, launder for delivering water to hutch.

About the year 1831, Mr. Petherick introduced the above machine at the Fowey Consols Mines, in Cornwall. It was described in the 'Quarterly Mining Review,' January 1832: from which the following is extracted:—'This machinery is particularly intended to supersede the operation of *jigging* in separating ores from their refuse or waste. . . . In the separators, the sieves containing the ores to be cleaned are placed in suitable apertures in the fixed coffer of a vessel filled with water, connected with which is a plunger or piston working in a cylinder. The motion of the plunger causes the water to rise and fall alternately in the sieves, and effects the required separation in a more complete manner than can be performed by jigging. The variety in the extent and quickness of the motion required for the treatment of different descriptions of ores is easily produced by a simple arrangement of the machinery.



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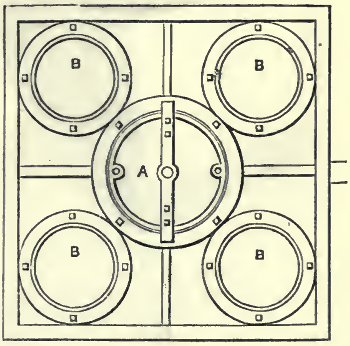


A principal advantage in this separator is derived from *the sieves being stationary* (in jigging, the sieve itself is moved) during the process; thereby avoiding the indiscriminate or premature passing of the contents through the meshes, which necessarily attends the operation of jigging, whether by the brake or hand sieve. Greater uniformity of motion in the action of the water, in producing the required separation, is also obtained; and superior facility afforded to the deposit in the water vessel (especially in dressing *crop* ores) of the finer and richer particles, which in jigging are principally carried off in the waste water.

The superiority of the patent separators over the ordinary means of cleaning ores will perhaps be best shown by reference to their actual performance. At the Fowey Consols and Lanescot Mines in Cornwall, where they were extensively used, seventeen distinct experiments were made on copper ores of various qualities from different parts of the mines, to ascertain the extent of the advantage of this mode of separation over the operation of jigging. Seventeen lots of ores, amounting together to about 300 tons, were accurately divided, one half was jigged, and the other half cleaned by the separator. A decided advantage was obtained by the latter in every experiment; the aggregate results being shown in Tables at top of next page.

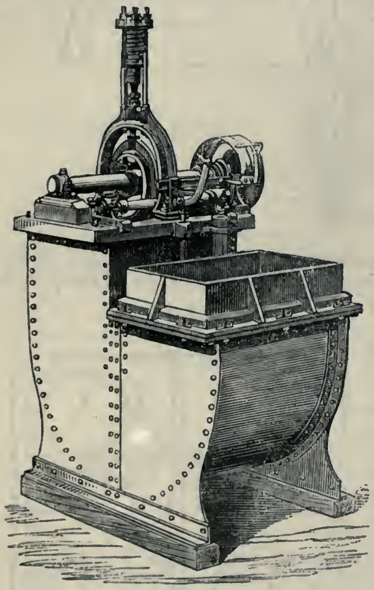
It must be obvious to those who are practically acquainted with the subject, that the poorer the stuff containing the ores, the greater must be the relative value of any improvement in the process of cleaning it. This was satisfactorily demonstrated by the trials made in the mines before mentioned, in dressing the *tailings*, which are

	Quantity of Marketable Ores returned			Percentage of Metal	Quantity of Metal				Value of Ores		
	Tons	cwts.	qrs.		Tons	cwts.	qrs.	lbs.	£	s.	d.
By jigging . .	76	19	0	$7\frac{3}{4}$	5	19	2	3	362	15	7
By the separators .	74	19	0	$8\frac{5}{8}$	6	9	0	18	396	6	7

Difference in the Value of Ores			In the Labour of Cleaning			Total			
£	s.	d.	£	s.	d.	£	s.	d.	
33	11	0	2	11	4	36	2	4	Being 9*s.* 8*d.* per ton, on 74 tons 19 cwts.

the refuse of the inferior ores. It appears that these tailings were dressed by the separators with more than triple the profit to the proprietors than that realised by the ordinary methods.

688



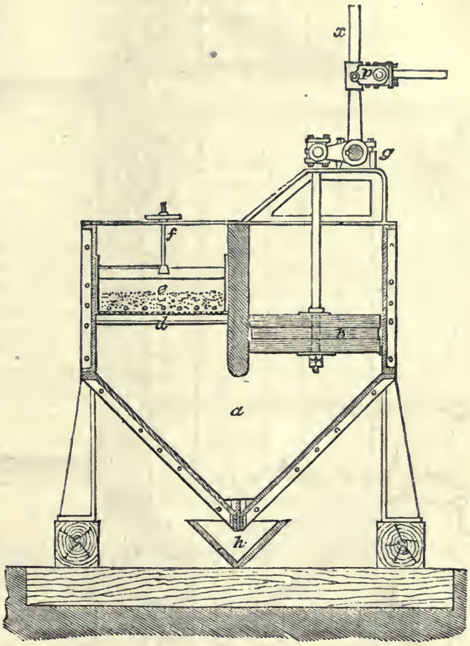
The body of the jigger, *fig.* 688, is constructed of wrought iron, the head-piece of cast iron. The sieve bottom is clipped between the head-piece and flange upon which the latter rests. The driving gear consists of a shaft, with fast and loose riggers, and a cam. This cam passes through the centre line of the piston-rod, the latter being lifted by the former against a spring composed of alternate plates of iron and India-rubber, the throw of the spring being rendered longer or shorter by means of screws and nuts. The valve for clearing the hutch is shown between the piston and sieve compartment. The sized sand when thrown upon the sieve is jigged; and on the completion of this operation, the skimming of the worthless portion is effected by hand.

Triple Sieve Jigger.—The three-sieve jigger is sometimes used for effecting a separation of lead and blende ore, associated with carbonate of iron, or heavy spar. The transverse section, *fig.* 689, shows hutch *a*, piston *b*, bridge *c*, regulating screw *f*, rocking shaft and gear *g*, and discharge launder *h*. The longitudinal section, *fig.* 690, exhibits three sieve plates *k*, three bridges *l*, each bridge enclosing an ore regulator, three discharge valves *m*, ore pipes *n*, furnished with stop valves *o*, ore trays *p*, fitted with perforated bottoms; and ore tray launders *r*. Sand suitably sized introduced at *s*, passes under the slide *t*, when it is progressed across the perforated plate to the first bridge; the ore flows into the receptacle *u*, while sand and ore, carried over the bridge, fall on the second sieve, and after treatment, pass to the third sieve. From the second sieve, mixed ore is obtained, from the third, a sand sparingly mixed with ore, and from the discharge shoot *r*, impoverished sand. The stuff lodged in the pipes *n*, is from time to time drawn into trays fitted with perforated bottoms, or otherwise, into boxes set in the ground. The ore regulators are formed so as to allow of the passage of large or fine grains, and of the enrichment of rich or poor stuff. Three or four of these jiggers may be combined together, so as to treat the sand as it comes from the trommels. Any necessary adjustment of stroke for jigging the stuff successfully is readily effected by shifting the cheek on the driving lever. Water may be supplied to the hutches, either by a wrought-iron pipe, furnished with a stop-cock, or by means of an ordinary launder.

For jigging sand from two to ten millimeters in diameter, the pistons should make from seventy to eighty strokes per minute.

Hancock's Percussion Jigger.—This continuous jigger, *figs.* 691, 692, consists of a V-shaped hutch contained within a frame, a suspended sieve, foot gear, side rods, and cross-heads. *a*, sieve, the wooden frame strengthened by means of side and end plates of iron; *b*, side rods supporting cross-head; *c*, side levers, combined together by means of short links; *d*, cam wheel for lifting the levers and sieve; *e*, point of lever in contact

689



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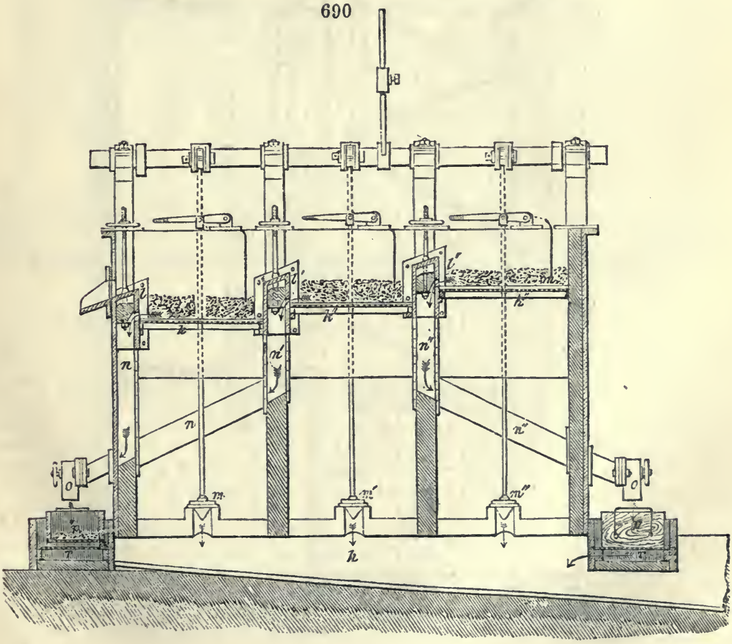
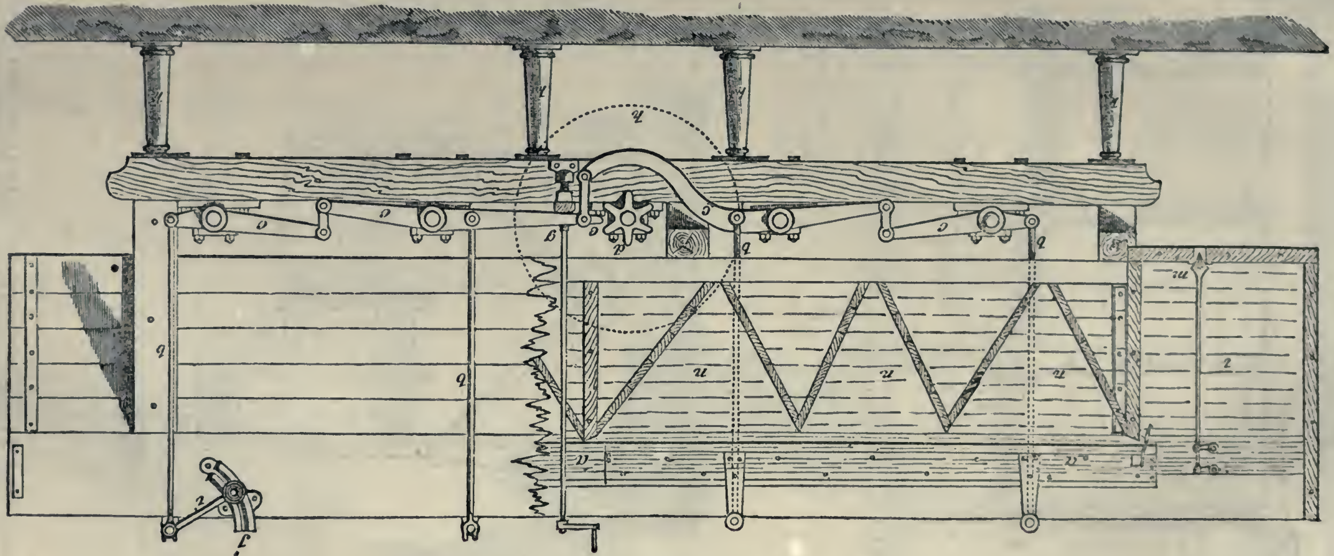


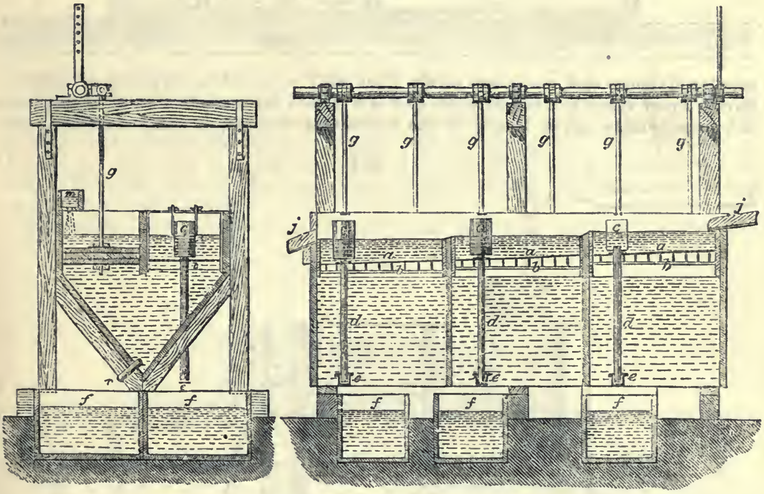


169

with the cam wheel; *g*, rod for regulating length of stroke and lifting side levers when necessary above the periphery of the cam wheel; *h*, driving rigger; *i*, radius bar for throwing the sieve horizontally; *j*, sliding block for lengthening or shortening the throw of the sieve; *k*, columns for carrying the hutch; *l*, waste compartment; *m*, valve for passage of water and castaways; *n*, ore compartments; *p*, pipe 2 inches diameter, one to each compartment for discharging the latter. The dimensions of the sieve are as follow: width 32 inches, depth 6 inches, length 20 feet. The sieve for dressing 1 to 3 millimeter stuff, has holes for the first 6 feet, 4 millimeters square; then, holes 3 millimeters square, until within 6 inches of the end, when it has holes 6 millimeters square. The wire bottom has a fall of ¾ of an inch in the total length. The ragging bars are 2½ inches deep, and are supported by a ¾ of an inch square bar of iron.

The stuff is introduced to the hutch by a 3-inch pipe, and is jigged from the head to the foot of the sieve, the ore falling between the ragging bars and thence into the V-shaped receptacles. The speed of sieve is 150 strokes per minute. The passage of water between the sieve frame and hutch is in a great measure prevented, as in Hugo Preuss's machine, by nailing on the bottom edge of the sieve frame a strip of leather about three inches deep. The total length of hutch is 22 feet. In Preuss's machine referred to and which was erected at Przibram in 1866, 3 sieves were employed, each slightly stepped one below the other; these were worked by means of shifting excentrics, and without any radius bars to effect a forward throw. At the Moonta Mines, South Australia, under the able direction of Mr. Hancock, the percussion jigger is found to despatch a large quantity of stuff in a given period. The ore consists of rich carbonates, sulphide of copper, and copper pyrites associated with a free light vein-stone.

692

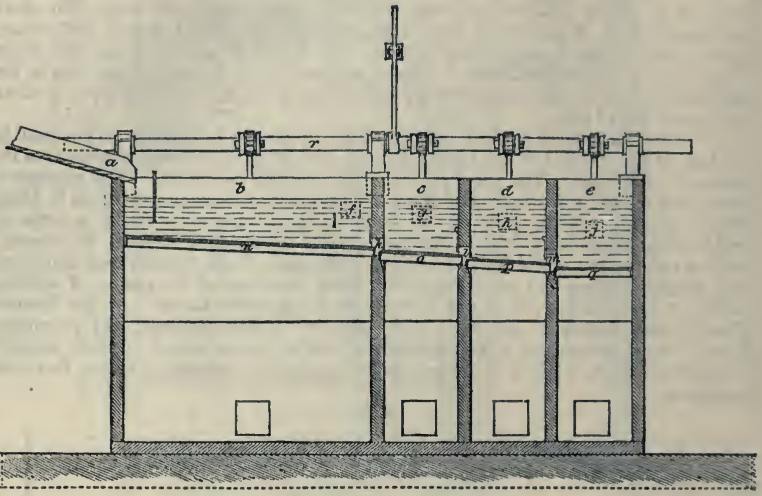


The jigger shown in *fig.* 693, is suitable for enriching coarse sand, that is, stuff composed of coarse grains from 2 to 7 millimeters diameter. In the longitudinal section, *a a a* the sieves are set so as to drop 1 inch in 36; *b*, grids supporting sieves; *c*, wrought-iron cylinders for regulating the outflow of ore and orey stuff; *d*, discharge pipes; *e*, regulators attached to pipes by means of set screws; *f*, ore boxes; *g*, piston-rods, two to each piston; *h*, driving lever; *j*, launder for admitting stuff to jigger; *k*, shoot for getting rid of castaways. In the transverse section *g* is the piston; *m*, launder for supplying water to piston boxes; *n*, draw-off plug; *y*, ore boxes.

The width of sieve may vary from 20 to 30 inches, and the length increased to such extent as may be found desirable.

Utsch's Patent Jigger.—This machine, introduced by Messrs. Kember and Co. of London, is so constructed that the grains or particles of the material with which it is supplied are properly balanced, and subjected to an unvarying pressure, whilst a continuous self-acting delivery of the minerals is obtained. *Fig.* 694 is a longitudinal vertical section of the apparatus, and *fig.* 695 is a transverse section. *a*, supply launder; *b*, jigging compartment; *c*, *d*, and *e*, separating compartments; *f*, *g*, *h*, *j*, discharge holes, which may be fitted with regulators; *n*, *o*, *p*, inclined sieves; *q*, horizontal sieve; *r*, driving gear; *v*, discharge shoot from main sieve; *w*, waste waggon; *x*, drip receptacle; *y*, door through which stuff is withdrawn from hutch; *z*, launder for receiving contents of hutch. When using the jigger, the smaller divisions *c*, *d*, and *e*, are partly filled with equivalents, or grains of mineral having equal velocity of fall in water, and of a certain determinate size, observing that the proportionate size or density of the equivalents contained in every successive sieve must be increased. Further, as a preliminary to the effective separation of stuff, it is expedient that it should be sorted or classified according to the varying size of its constituents, or, if necessary reduced to a specified size. At the zinc-mines at Iserlohn, where the stuff consists of galena, blende, calamine, and carbonate of lime, a sieve 24

693



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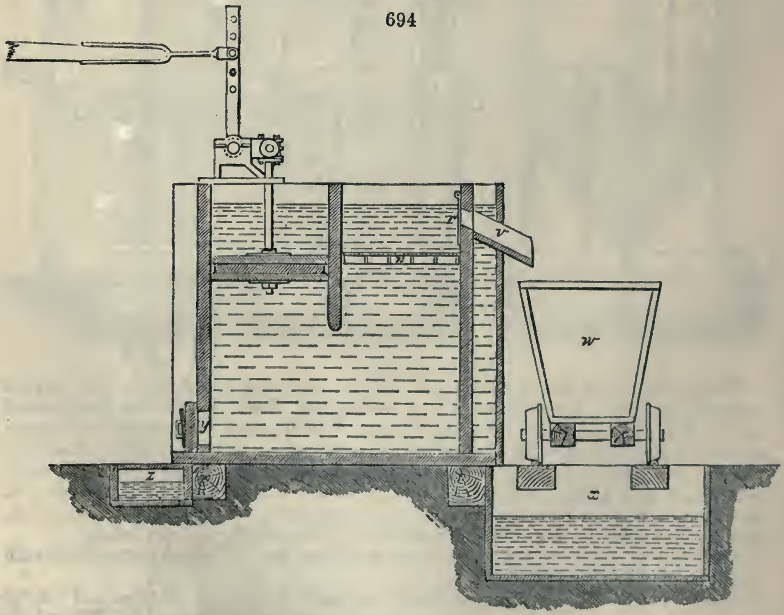

inches wide despatches 4 tons per hour, the grains varying in size from 2 to 4 millimeters. The size of stuff which can be treated per machine is 1 to 2, 2 to 4, 4 to 8, and 8 to 11 millimeters.

The fine sand jigger shown in *figs.* 695 and 696 is designed for the enrichment of sand from $\frac{1}{4}$ to 1 millimeter in diameter. The hutch is divided for 2 pistons, and a corresponding number of sieves. Compartments are formed underneath the sieves for receiving ore and orey stuff. The overhead gear consists of a shaft, driving wheels, and discs, the latter slotted for piston rod-pins. The pistons are hung so as to balance each other, and when 2 jiggers are employed the pistons of each are worked back to back. The discharged launders are not shown, but these deliver into a main launder set between the two hutches.

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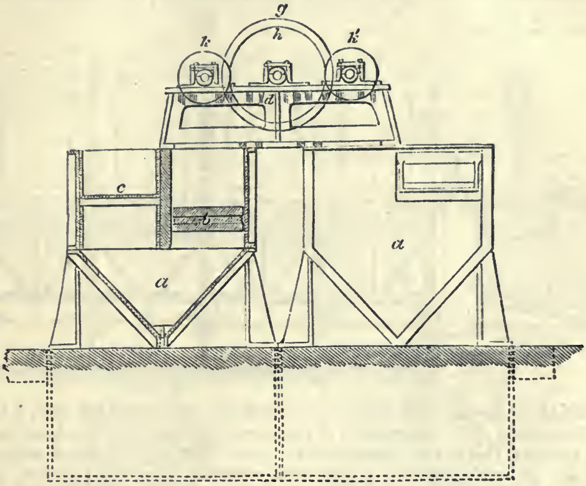
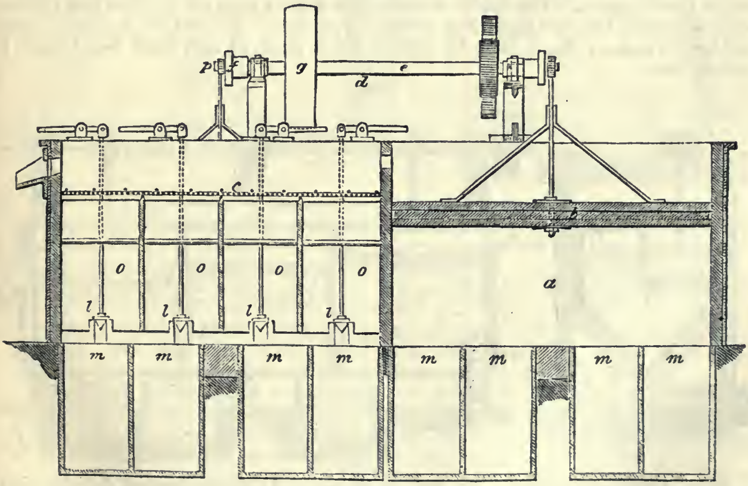


Fig. 696 is a section through the first piston and second sieve; *fig.* 695, a front elevation, cross section of hutch, and elevation of driving gear. *a*, hutch, 10 feet long, and $2\frac{3}{4}$ feet wide; *b*, piston, 5 feet long and 15 inches wide; *c*, sieve bottom of iron wire, supported on a wrought-iron grid, and held down by wrought-iron cross-bars; *d*, cast-iron head gear frame; *e*, jigger shaft; *p*, discs; *g*, driving rigger; *h*, driving wheel;

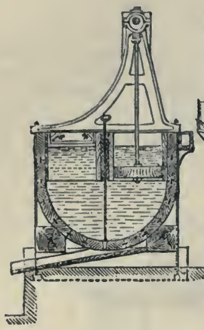
696



k k′, wheels on jigger shafts; *l*, discharge valves, 3 inches diameter; *m*, collecting boxes, 12 inches wide; *o*, receptacles, 15 inches wide. The piston-stroke is either lengthened or shortened by shifting and fixing the pins in the slotted discs; and, if necessary, slides are fitted to the discharge ways, for the purpose of modifying the thickness of the separating beds.

Fine Sand Jigger.—The Jigging Machine shown in *figs.* 697 and 698 is employed at a great number of silver, lead, and blende mines in Germany, and elsewhere, for the purpose of treating sand, classified or sized, into suitable sets of grains from ½ to 2 millimeters in diameter. The construction is rendered apparent from the longitudinal and transverse sections, the sieve bottoms are 34 inches long and 15 inches wide, depth of sieve from top of hutch 10½ inches, and from discharging slot 3½ inches, piston 30 inches long, 15 inches wide, and 4 inches thick. The box for discharging rough sand is 3 inches wide and 9 inches deep. The plug-valve for regulating outflow of stuff, 1 inch diameter; launder 3 inches wide, for taking off fine sand; plug valves 1½ inch diameter, for discharging stuff from sieve boxes. The outside dimensions of hutch are as follow:—length, 12 feet, 9 inches; width, 3 feet, 9 inches; height, 3 feet. For treating grains, say, ¾ millimeter in diameter, the piston should make about 200 strokes per minute, with a length of stroke of from ¼ to ⅜ths of an inch. For enriching and separating blende and lead ore the first two separating beds should be of lead ore grain from 3 to 4 millimeters diameter, and the other separating beds of coarse blende grains. The depth of beds must depend upon the richness and volume of stuff flowing into the apparatus within a given time. For the No. 1 sieve, it may be about 3 inches; No. 2 sieve, 2½ inches; No. 3 sieve, 1½ inch; and No. 4 sieve, 1 inch or less.

697



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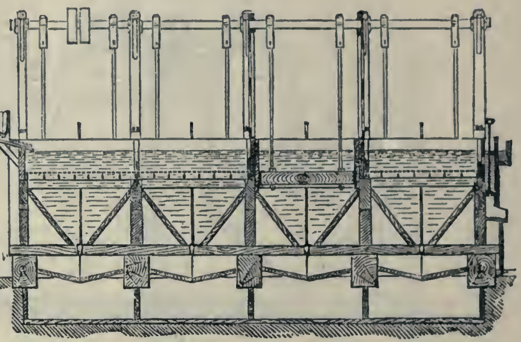

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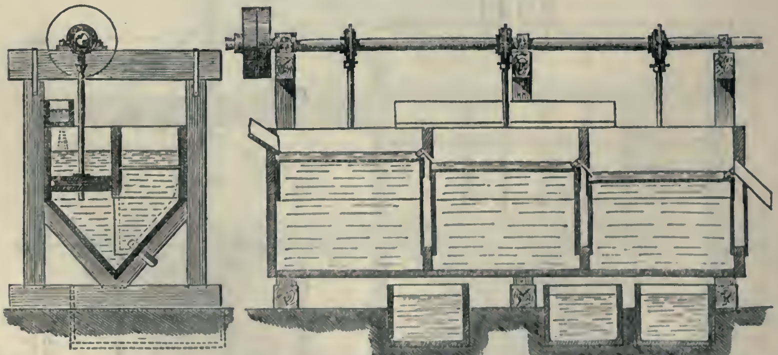


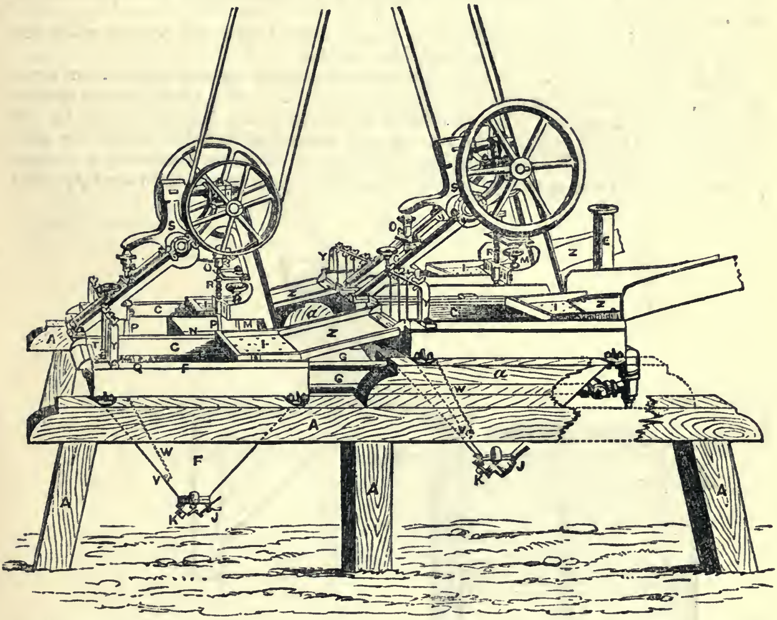
Slime Jigger.—This jigger, *fig.* 699, is in use at Iserlohn, Prussia, for enriching sand composed of clay, carbonate of lime, blende, and lead ore. The jigging is performed *on* the sieve; the ore and orey stuff being progressed into receptacles. In this respect it differs from those fine sand jiggers, where the orey products pass, through a coarse grain bed and sieve, into V-shaped boxes.

A *sheet of horse-hair* forming the sieve is placed between two sheets of wire or perforated places, having about eight holes to the lineal inch. The length of sieve is 30 inches; total length for 3 sieves, 7 feet, 6 inches; width of sieve, 12 inches. The depth from top of hutch to first sieve is 6½ inches; second sieve, 8½ inches; third sieve, 10½ inches; width of receiving chamber between the sieves, 2 inches. Each chamber is discharged at the side through a plug-hole into boxes set in the ground. The height of discharge openings into the several receptacles is about $\frac{3}{16}$ths of an inch, height of transverse plates above sieve bottom, ⅝″, ⅜″, and ¾ of an inch. The pistons make from 120 to 250 strokes per minute, according to the nature and fineness of the stuff treated. The quantity of water required per minute is from 1½ to 3 gallons per sieve.

Collom's Jigger.—The peculiar features of this jigger are its tappet piston gear, and the arrangement for discharging such grains of ragging as are too large to pass through the bed, and too heavy to flow from one sieve to another. The construction, as well as the mode of working the jigger, will be clearly understood from the following remarks:—

1. These machines should be firmly set upon a frame of square timber A (*fig.* 700).

700



2. The height of the vertical pipe E, supplying the clear water, through the regulating cocks to the hutches F, will be best determined by experience. Of the four regulating cocks, the sketch only shows one of the *lower* pair, viz, those through which the clear water passes before entering the pipes A, G.

3. The brass wire sieves H, on wood grids fastened with copper nails on the wood cross bars Q, should be set level *sideways*, about ¼ inch lower at the outlet than at the opposite end, and packed around the sides and ends with hemp or other suitable material. The side pieces C, and end pieces T, must be properly set in their places, and the whole secured by a wedge behind the outlet end of the side pieces.

4. The distributor I, and feed launders Z, should then be placed in position, and the regulating outlet arrangement J, applied. In this regulator there is a hole at both the front and the back. The holes that are found to be least convenient for discharging into the ore boxes should be fitted with wood-plugs K. To prevent an accumulation of stuff too light to pass through the 'bedding,' yet too heavy to be carried over the lips of the hutches, 'ragging-gear' is furnished. This consists of brass taper plugs, with wrought-iron stems, the stems being screwed and fitted with regulating thumb-screws, acting above and below the wrought-iron bridges Y. These plugs fit into bevelled brass seatings fixed in the sieving H. By regulating the height of these plugs, any undue accumulation of stuff is prevented.

The coarse raggings having passed through the seatings, falls into the portion of the hutch which is divided by thin wooden partitions W, and passes out through holes V.

5. Coarse ore should be placed upon the sieves, in grains twice the size of the sieve holes, and of the same ore, or mineral as that which is to be treated. The bed should be kept about $\frac{3}{4}$ inch thick; but in case of *rich* stuff, the thickness, should be less, varying to $\frac{1}{2}$ inch; and with *poor* stuff greater, extending to 1 inch, or even more if found necessary.

6. Clear water and a supply of stuff being furnished, and the machines started, the stop bolts, M, should be adjusted by turning them down until they are found to regulate the motion of the plunger N, so that each stroke shall be of *equal* length. *The speed should be about* 120 *strokes per minute.*

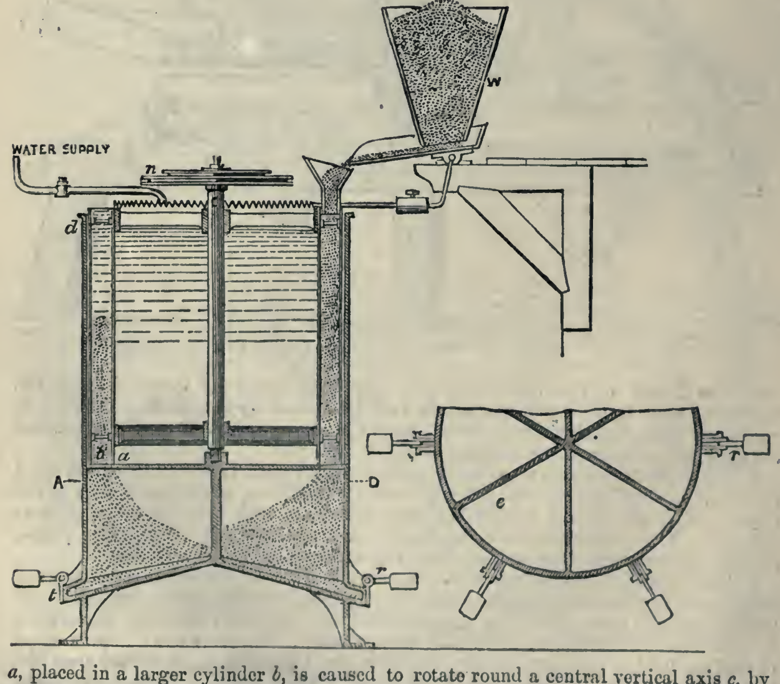
7. The degree of force operating upon the stuff may be increased by elevating nearer to the rocker S, the adjustible thimble O, on the top of the plunger, or stem P, or by increasing the supply of clear hutch water, or both. The stroke *should vary from* $\frac{1}{2}$ *inch to* 1 *inch.*

8. The spiral springs R should be just strong enough to strike the plunger against the stop bolts M, before the down stroke, but not stronger. Irregularity of stroke, viz., alternately long and short, may be remedied by attending to the adjustment in connection with the springs.

These jiggers have been introduced by Messrs. John Taylor and Sons, to whom the miner is indebted for the round and impeller buddles.

Hundt's Stream Separator.—This apparatus consists of an arrangement for separating, washing, or sorting ores and other substances according to the size or specific gravity of the particles. This is effected in a continuous manner by the agency of a body of water rotating in a horizontal direction, through which the substances are made to fall; and which are collected at distances increasing in inverse proportion to their size or specific gravity. For this purpose an annular vessel (*fig.* 701) *a*, placed in a larger cylinder *b*, is caused to rotate round a central vertical axis *c*, by means of a pulley or cone *n*. This annular vessel is open at top and bottom, and placed in the slightly larger and cylindrical vessel *d*, which is kept full of water during the action of the apparatus. The bottom of this vessel is divided into com-

701

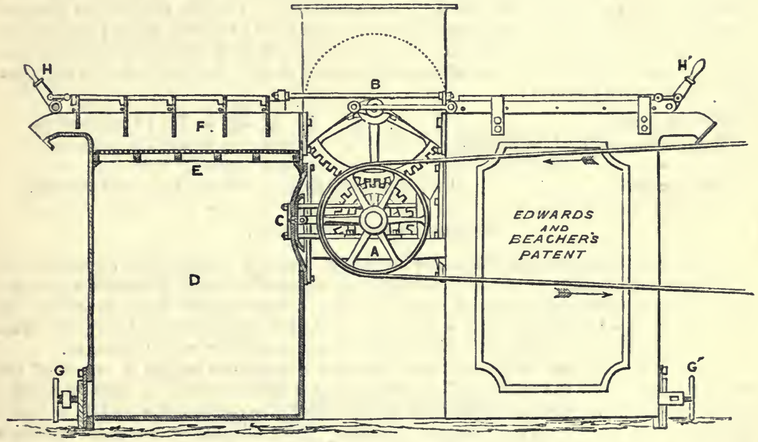


partments *e*, corresponding in number with the degrees of fineness into which it is desired to classify the ores. The vessel having been filled with water, the ore is caused to fall regularly through a spout into the body of water rotating with the vessel *a b*, round the axis *c*. In order to carry the water round with the vessel *a b*, a blade is fitted between the two cylinders *a* and *b*, which, if put in a suitable position does not interfere with the sorting.

The particles of ore having the greatest specific gravity will fall most rapidly through the water, and will consequently pass out at the bottom of the vessel *a b*, at a point nearest the stationary spout *t*, whilst the particles next in specific gravity will fall in the next compartment, and so on. The particles of ore to be classified according to their specific gravity must be as nearly as possible the same size, whilst any material in a granular state, and of the same specific gravity in all its particles, will be classed according to size. The action of the apparatus continues till the compartments *e* are full of ore. When full, the weighted levers *r*, are lifted up, and the ore allowed to escape with the water. In places where water is plentiful, the apparatus may be made to work continuously by giving to the opening *t*, such a size that no more water can escape with the ore than is continually supplied. The compartments *e*, may in this case be much smaller. Where water is scarce the quantity required may be reduced considerably by fixing a bottom to the inner cylinder *a*, and leaving this cylinder empty. The drum will thereby get a tendency to float, which may be overcome as far as necessary by putting ballast in it. By these means a quantity of water equal to the cubic contents of this cylinder will be saved; at the same time, by giving greater dimensions to the compartments *e*, the water will be made to do duty a longer time. The number of revolutions of the drum will be found in most cases to range between the limits of two to six per minute; the diameter of the drum from about four feet and upwards; the size of the ore grains, or particles, from one thirty-second to half an inch. The power required is extremely small, and one man can attend to a greater number of these machines.

Edwards and Beacher's Mineral and Coal Washing Machine, consists of two rectangular cisterns. Within a few inches of the top of these, perforated plates or screens, E *fig.* 702, are fixed, upon which the material to be washed is fed through a hopper, which also connects the two cisterns. On the inner sides of the cisterns are two apertures closed by flexible discs, or diaphragms of leather, C, which, when the machines are filled with water, cause it to rise and fall through a certain space, by means of a horizontal vibratory motion, which they receive from an excentric on a shaft, which is driven either by a steam-engine attached directly to it, or by a driving belt and pulley, A. See WASHING COAL.

702



The action of the flexible diaphragms is similar to that of cylinders and pistons, which are sometimes substituted for them. Above the driving shaft is a smaller one, B, which is driven at a slower rate by means of spur-wheels, and gives, by cranks or excentrics, a horizontal motion backwards and forwards to sets of scrapers F, above the cisterns. These are so arranged as to remove the upper stratum of the substance being acted upon, and discharge it into waggons or other convenient receptacles;

these upper strata are of course the lightest, the heavier part settling upon the perforated plates below.

When from the action of the machine a considerable quantity of material has accumulated upon these plates, the scrapers are thrown out of gear by means of apparatus attached, H H′, and the stuff raked off, the operation being then continued on fresh supplies. Doors, G G′, at the bottom of the machines, admit of any fine stuff which may pass through the perforated plates being removed from time to time as may be necessary.

These machines are in use for cleansing coal as well as other mineral substances.

In such cases the heavier stuff which remains upon the plates consists of shale and pyrites, very injurious substances in the manufacture of coke. One machine of two connected cisterns is capable of washing about thirty tons per diem of coal, but the quantity of mineral work will depend upon the amount of ore present in proportion to the waste. The size of the perforations in the screens is adapted to the quality of the material acted upon.

The introduction of water skimming jiggers into our British mines is probably due to Mr. John Hunt, late of Falmonth. This gentleman used an ore bed, two sieves divided by a low partition, two ore chambers, and a horizontal flow of water. Hunt's Specification, No. 707, is dated March 8, 1866.

In order to concentrate lead, zinc, copper, and other ores associated with vein-stone, coarse and fine sand jiggers should be employed, the former to receive the stuff from sizing trommels, the latter from trommels or classifiers. In the coarse sand jigger, stuff 10, 7½, 5, 3½ and 2 millimeters size is usually enriched *on* a plate, the holes in which are of *less* diameter than the grains, whilst in the fine sand jigger, sand 1¼, ¾ millimeter size is separated through the intervention of a bed of coarse grain ore, supported either on a perforated plate or wire work, the openings of which are *larger* than the grains to be collected.

For the purpose of effecting a good separation of ore from its gangue it is necessary to give great attention to the length of stroke, number per minute, and volume of flowing water. Every distinct class of vein-stuff will necessitate the observance of specific conditions, so that no absolute data can be offered; as, however, approximate figures may be useful, the following are given:—*Coarse sand jiggers*, speed from 60 to 75 strokes per minute; flowing or skimming water required, say ten to fifteen gallons each machine per minute. *Fine sand jiggers*, speed from 90 to 250 strokes per minute; piston and horizontal flow of water necessary, from fifteen to twenty gallons per minute.

The approximate length of stroke and piston speed for stuff ranging in size from one-third to ten millimeters, the area of the piston being that of the sieve, may be gathered from the following figures:—

Size of stuff	⅓,	½,	¾,	1¼,	2,	3¼,	5,	7½,	10	millimeters
Approximate length of stroke	¼,	⅜,	½,	1,	1¼,	1½,	2,	2¼,	2½	inches
Piston speed	150,	120,	110,	100,	60 to 75					per minute.

SEPARATORS OR CLASSIFIERS.

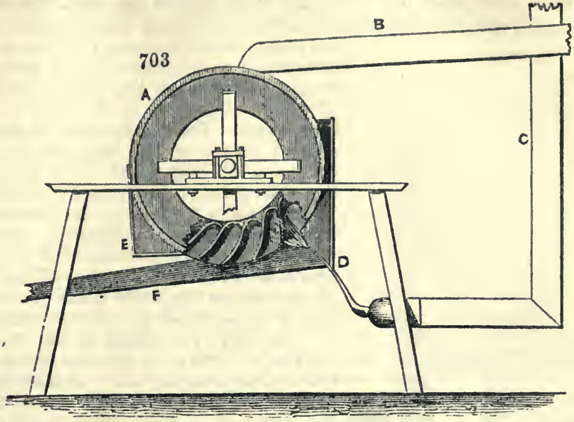
Of late years apparatus of this class have been steadily coming into operation, not only in lead and copper mines, but also in the dressing of tin ores. Unlike the trommel which groups together grains of equal volume irrespective of their densities, the classifier groups the grains into equivalents, that is to say, grains which differ from each other in their densities, but which have an equal velocity of fall in water.

To separate such grains in the after dressing process, advantage is taken of the resistance offered by the surface of a heavier over a lighter grain in passing upon a bed of ore as in the fine sand jigger, or in traversing the surface of a buddle or table. For the purpose of sizing stuff from x to grains of one millimeter diameter, trommels should be employed, but for dividing grains from 0 to 1 millimeter diameter, the cistern, cone, or expanding launder, will be found suitable.

Slime Separator.—This apparatus devised by Captain Isaac Richards, of Devon Great Consols, is employed for removing the slime from finely-divided ores which have passed through a series of sieves set in motion by the crusher. The finely-divided ores are for this purpose conveyed by means of a launder upon a small water-wheel, thereby imparting to it a slow rotatory motion. Whilst this is turning time is allowed for the particles to settle in accordance with their several densities; the result obtained, is, the heavier and coarser grains are found at the bottom of the buckets, whilst the lighter and finer matters held in suspension are poured out of the buckets and flow away through a launder provided for that purpose. The stuff remaining in the bottom of the buckets is washed out by means of jets of water obtained from a pressure-column 10 feet in height, and passes directly into the funnel, of a round buddle.

The wheel A, *fig.* 703, is 4 feet in diameter, 2 feet 6 inches in breadth; it has twenty-four buckets, and makes five revolutions per minute; B, launder for supplying the finely-pulverised ore; C, pressure-column; D, jet-piece; E, launder for conveying away the slime overflow of the wheel; F, launder for taking roughs to round buddle.

703



Sizing Cistern.—The tails from round buddles are sometimes passed through this apparatus. It consists, *fig.* 704, of a wooden box provided with an opening at the bottom, A, which is in communication with a pressure-pipe, B, an outlet, C, with a small regulating sluice, D. The stuff from the buddles enters at E, and the pressure in the column is so regulated as to allow the heavier particles of the stuff to descend, but at the same time to wash away at F the lighter matters that may be associated with the ore. This is done by having the outlet C of less area than the inlet, and fixing on the extremity D a convenient regulating sluice by which means a greater or less quantity of stuff may be passed over the weir F. Two cisterns of this kind are generally employed, the second being used to collect any rough particles that may have passed off from the first. The depth of a box may be 18 inches, its width 13 inches, and its length 3 feet 6 inches.

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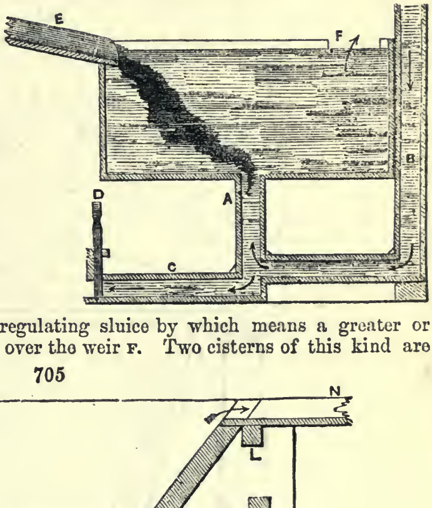

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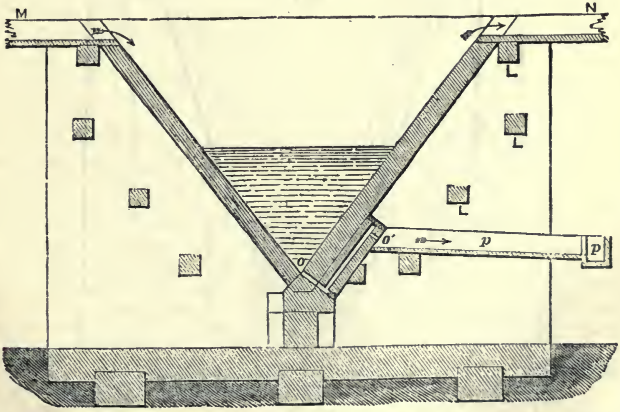
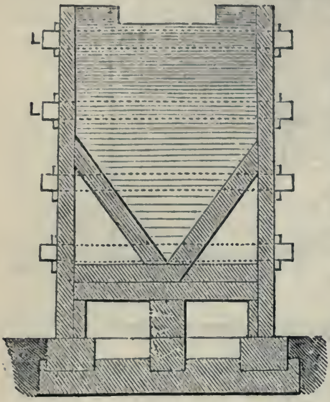


The arrangement of another separating box is shown in *figs.* 705 and 706. The slime water flows in at M; and water still holding a considerable portion of slime flows away from the opposite end. It is necessary that pieces of chip, small lumps, or other extraneous matter should be intercepted previous to entering this apparatus, also that the slime should be evenly sized by means of a trommel or sieve. The heaviest portion of the slime water in which the sand and ore are contained, is discharged at the hole *o*, about an inch square. The launders *p p*, are for the purpose of conveying the slime water either to buddles or shaking tables. The dimensions of the cistern No. 1 are: length, 6 feet; width, 1½ feet; depth 12 inches. But two other cisterns of similar form are attached. No. 1 cistern will work about 10 tons of stuff in 24 hours, and by widening the box from 18 to 27 inches it will get through 20 tons in 24 hours. Affixed to one side of the boxes are hammers so contrived as to give 30 blows per minute in the manner of a dolly tub. Care must be taken in the construction of these classifiers that the sides forming the pyramids be neither too steep nor too flat; if too flat, the sand is apt to settle until a quantity has accumulated, when it would suddenly sink and choke the discharge pipe *o′*; and if too steep the classifiers would become of inconveniently large dimensions. A gradient of 50° to the horizon is found to be the most suitable. The chief dimensions of two cisterns, viz. one working 10, and the other 20 tons, are given in the following Table:—

706



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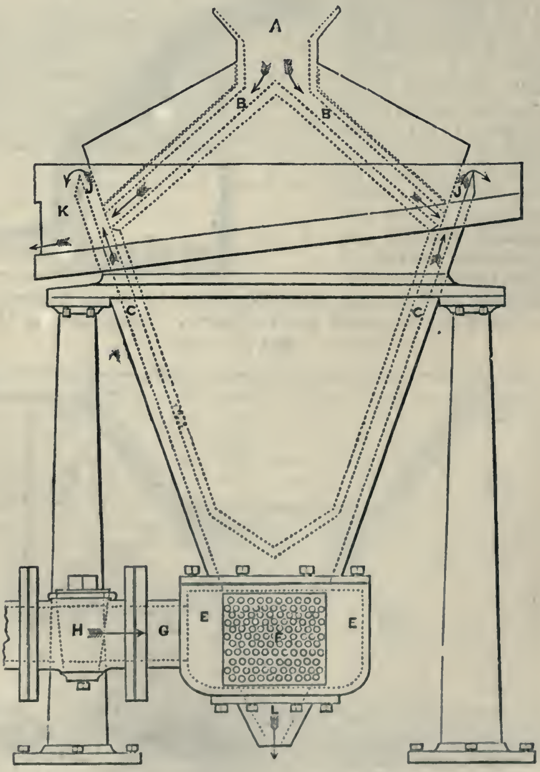

No. of Box	Ten tons			Twenty tons		
	Length of Box	Breadth of Box	Depth of Box	Length of Box	Breadth of Box	Depth of Box
	ft.	ft.	ft.	ft.	ft.	ft.
2	9	2	6	9	5	6
3	12	4	8	12	9	8
4	15	8	10	16	15	10

According to experiments made in the Stamping House of Schemnitz, where 12 tons are stamped in 24 hours, the 1st cistern separated from the slimes 40 per cent. of the ore; the 2nd cistern, 22 per cent.; the 3rd cistern, 20 per cent.; the 4th cistern, 12 per cent.; together, 94 per cent., leaving a loss of 6 per cent.

From No. 1 box every cubic foot of water flowing through gave 16 pounds of sandy matter. No. 2 afforded 13 pounds of finer stuff. No. 3, 16 pounds, and No. 4 yielded 12 pounds per cubic foot of water. It should be remarked that the outlet *o* is proportioned to the dimensions of the machine.

Cone Classifier, fig. 707. The ore and minerals, after passing through the crushing apparatus, are introduced at A, and flow through the spaces B B, passing into C C. At the bottom is a circular chamber E E, with a perforated cylindrical plate F. Water under pressure is supplied by the pipe G, and regulated by the cock H.

It will be seen that this apparatus consists of an external and internal cone with a space between them, and that a separation of the orey matter is effected by limiting the power of the water between the density of the stuff to be retained, and that which is to be discharged at J J into the shoot K.

At L the larger and denser portion of the mineral which has fallen through the ascending current of water, is conveyed either to a jigging machine or some other enriching apparatus.

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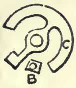

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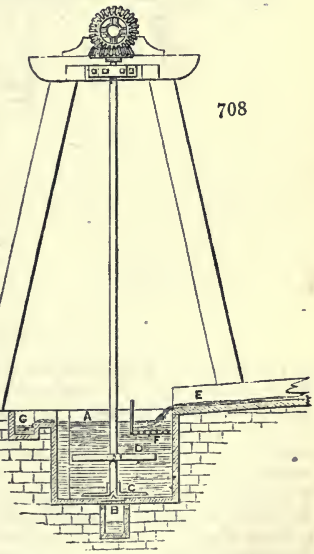
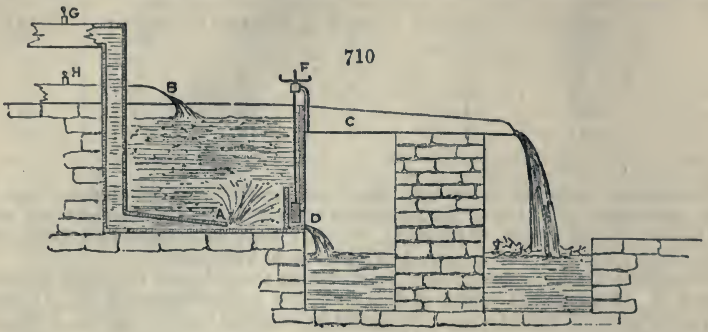


Fig. 708 represents a wooden cistern A, having an aperture B, at the bottom, about an inch diameter, which is alternately closed and opened by means of an iron plate C, fitted upon the vertical shaft, to which is also fixed an iron paddle D, which revolving horizontally keeps the ore and water in constant agitation. The tails from the various buddles, as well as the stuff from the coffers at the end of the strips, flow in at E, and pass through a perforated sizing plate F, into the cistern. The rougher and heavier portions escape through the hole B into a strip where it is continually stirred, in order that it may be evenly deposited, and at the same time freed from the lighter particles. The overflow containing fine ore passes in the launder G into catch pits, from which heads and middles are taken to be elaborated by means of buddles or other apparatus. When this separator is employed in tin dressing, it is usual to divide the stuff in the strip connected with the bottom of the box, into heads and tails. The first is taken direct to the stamps, and again pulverised with rough tin stuff; but before the tails can be so treated they are re-stripped in order to get rid of extraneous matter. A plan of the iron plate covering the discharge hole is shown on *fig.* 709. C, plate; B, discharge hole.

Wilkin's Separator.—This is a 'self-acting tossing machine, by which the rough particles are separated from the fine, and prepared for the inclined tables. The orey matter is carried into a small cistern by a stream of water which enters at the top and passes out at the opposite side, bearing the finer particles with it, whilst the rougher and heavier particles escape at the bottom through a rising jet of clean water, which prevents the fine and light particles from passing in the same direction.' A, *fig.* 710, inlet of clean water; B, launder delivering the orey matter; C outlet of fine and inferior stuff; D, discharge orifice for rough and heavy stuff. This operation must be regulated by a slide. A cistern, 10 feet square on the top and 18 inches deep, will pass through about 40 tons in 10 hours. When separating stamps work, a smaller cistern is employed, say about 14 inches square, 10 inches deep, this will despatch 6 tons in 10 hours.

710



A valuable form of classifier is shown in *fig.* 711, the peculiarity of which consists in the manner of introducing the water and slimes. Instead of the latter depending for separation upon the power of an ascending column of water, it here passes into a horizontal flow of greater or less volume and velocity, produced by altering the tap G. Compartments, viz. 1, 2, 3, and 4, are also fitted in the box, for the purpose of receiving mineral of different densities and size, which is discharged and washed in strips set underneath; A, inlet launder to trommel; C, trommel either of perforated plate, or wire gauze; D, shoot from trommel, serving to convey away the rougher portions. E, hopper for conveying stuff to shoot H, and from thence into the box; F, ascending column of water; G, tap for regulating the flow of water; K, L, M, N, outlet pipes for delivering the separated stuff to strips or buddles; O, launder for receiving overflow from cistern; P, Q, R, weirs regulating the length of the compartments, also for the purpose of effecting the disposition of the different minerals with which the ore may be associated.

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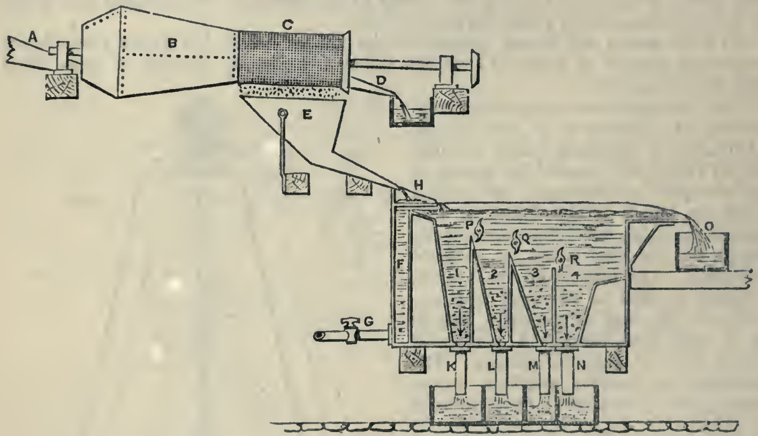

Horizontal Classifier.—This classifier, shown in longitudinal elevation *fig.* 712, plan *fig.* 713, and end elevation *fig.* 714, is frequently employed at lead and blende mines in Germany, and is known in some of the mines in this country. In many instances it is built of wrought and cast iron; but it may be equally well made in wood, and will cost much less. The slimey water is introduced at the narrow end; the heaviest equivalents fall into the first compartment, *a*; equivalents of the second degree into the second, *b*;

while the lightest collect into the third or largest one *c*; the result in each case being modified as may be desirable, by increasing or lessening the flow of water from the vertical pipes, *d*, *e*, *f*.

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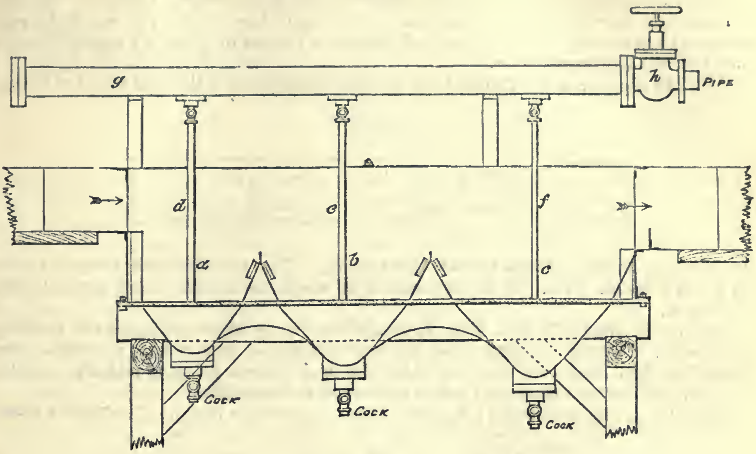

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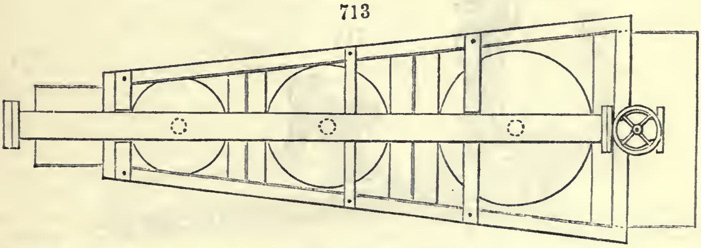

The length of the trough is six feet, greatest width 28½ inches, decreasing to 11½ inches, depth 18¾ inches, diameter of vertical pipes ¾ inch and of main pipe 3 inches; length of first receptacle 18 inches, second 24 inches, third 30 inches. The classified sand from first, second, and third compartments is in each case passed to suitably enriching machinery. The principle affecting the classification by the apparatus described is as follows:—

In a horizontal current of decreasing velocity, the larger equivalents introduced will be deposited first, decreasing in size in an equal ratio with the decreasing velocity, till with but a very slight flow even the finest slimes are deposited. A stream rising *vertically* with decreasing velocity, carries the smallest equivalents first away and only the larger ones remain, while in proportion to the decreasing velocity of the stream the fine and finest particles will eventually be deposited. In the construction of these classifiers, the following rules should be adhered to:—

The width of the first division should be $\frac{1}{10}$th of a foot for each cubic foot of slime water introduced per minute. The following divisions should increase in geometrical progression, thus, 1, 2, 4, &c. The length of the first division is usually taken at 6, the second, third, and fourth in arithmetical proportion, thus, 6, 9, 12, &c. The inclination of the sides of the box should be about 50°.

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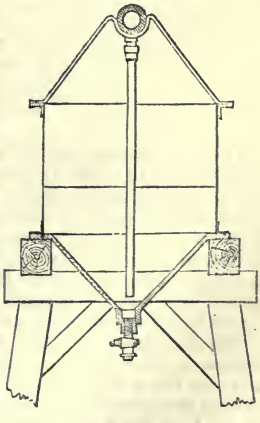

The Strake, Tye, and Strip.

These appliances may be considered modifications of each other. Instead of effecting a separation by relying upon subsidence according to the specific gravity of the substances, they are mechanically impelled against a volume of water so regulated as to carry off the lighter particles.

Fig. 715 represents the ground plan of a strake employed in the lead-mines of Wales.

715

Its extreme length is about 18 feet, width 3 feet. The top increases from 18 inches to 2 feet 9 inches wide. It is constructed of wood, the bottom being covered with sheet-iron.

The tye is usually 20 feet long, 2½ feet wide, and is often employed for cleaning hutchwork. In some instances when the ore or dradge is very rich, it is crushed, and then tyed into heads, middles, and tails, the first portion going to pile, the middles re-tyed, and the tails treated as refuse or washed in the buddle.

Fig. 716, A, inflow of water; B, head of tye; C, partition board. The stuff is introduced into the cistern D, flows over the inclined front E, and is broomed at F. Between E and G are the heads, from G to H middles, H to I tails. At K is an outlet launder, regulated with a shute. An outline plan of the tye is shown, *fig.* 717.

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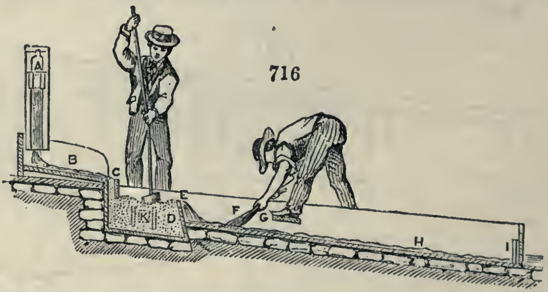

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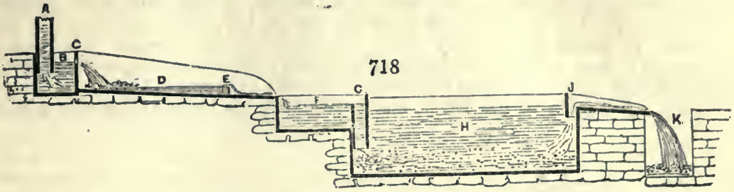
The strip also consists of a wooden box, with its bottom inclined at a greater or less angle, in order to suit the character of the stuff to be operated upon. The object of this apparatus is somewhat analogous to that of the separating box, viz. to deprive the ore of the fine particles with which it may be associated, and thereby to enrich it for subsequent treatment. A rather strong stream of water is employed, against which the mixed mineral is violently projected by means of a shovel. When ores are strong and clean in their grain, but little loss can occur from this process, provided proper care be exercised in conducting it; but if their structure be delicate, and the constituents intimately mixed, the wastage must necessarily by great.

The illustration, *fig.* 718, shows a strip, coffer, and settling cistern, with filtering apparatus contrived for lead ore. A, vertical launder 6 inches square, delivering water into the box B, 9 inches long by 26 inches wide at the point C; D, bottom of strip covered with sheet iron, 6 feet long and 16½ inches wide at E. At this point a ledge of wood is sometimes introduced for the purpose of modifying the velocity of the water and forming a kind of shallow reservoir, so as to allow the workman to stir the stuff. At the end of the strip a coffer, F, is fixed, 11 inches deep, 30 inches square; H, settling box, 6 feet long and 30 inches deep; K, outlet for waste water. At G is inserted a filtering launder, 13 inches deep, extending across the cistern. At J a similar launder is placed, about 9 inches deep. The water coming in at A, is lodged in cistern B, flows smoothly over the feather-edged board C, and falls into D; here the orey matter is exposed to its action, and a portion settles in F; the *florrin* and other light waste then descends through G, depositing itself in the box H; and to retain the valuable products as much as possible it is filtered at J, through a perforated plate covering the bottom of the launder. In stripping care must be taken to regulate the overflow of water at C; rough stuff must be subjected to a stronger current than finer matter, and the bottom of the strip should be constructed with a greater inclination. In some lead mines the buddles and hutchwork is stripped to be re-jigged, whilst the stuff resulting from the filtering box is hand-buddled until sufficiently enriched for the dolly. When ore is associated with a heavy matrix, and the grain breaks into a lesser size than the other particles, the stripping may be performed by inversion, that is to wash the orey product into the cover and filtering hutch, retaining the worthless portions at D.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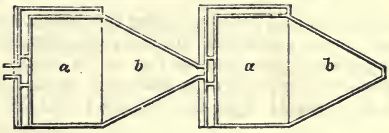
The flat buddle, *fig.* 719, is peculiar to the Welsh mines, and different from all others in its great proportional breadth as well as in its very trifling inclination.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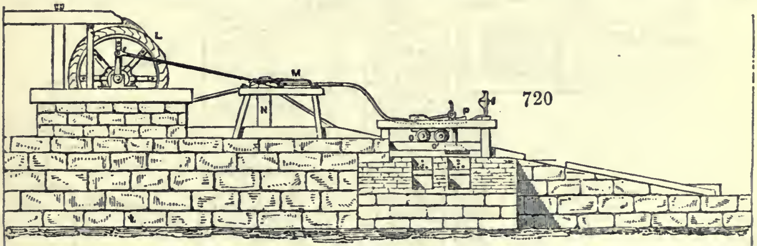
The stuff is placed in a small heap on one side of the supply of water, and drawn with a hoe partly against and partly across the stream to the other side of the buddle, losing in its passage all the lighter parts. A heap of ore treated in this manner may be deprived of a portion of blende and pyrites, minerals which from their high specific gravity may have resisted previous operations. *a*, platform of boards, inclined two and a half inches in seven feet. *b*, catch pit, two feet deep. The width of this buddle varies from ten to twelve feet.

Lisburne Buddle.—This apparatus has been successfully employed in separating blende from lead ores. *Fig.* 720 represents an elevation, and *fig.* 721 a ground plan of this machine.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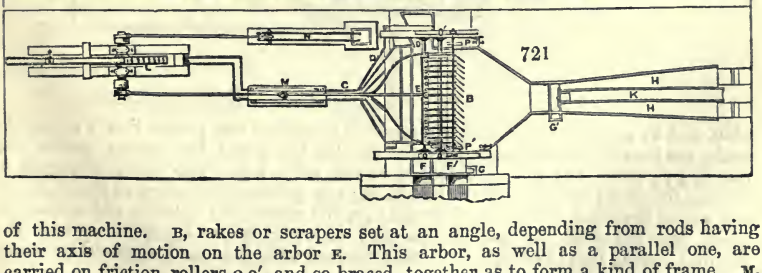
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B, rakes or scrapers set at an angle, depending from rods having their axis of motion on the arbor E. This arbor, as well as a parallel one, are carried on friction rollers O O′, and so braced together as to form a kind of frame. M, rod attached to frame, and connected with water-wheel L. N, balance beam, counterpoising the frame, and rendered necessary in order to equalise the motion. P P′, balance catches, serving to support the third arbor when elevated. This arbor is also parallel to the other two, but has its position on the top of the guide frame shown in the elevation. It passes immediately under the angle of the L-shaped rods, and is mounted on friction wheels. Its action is as follows: When the scrapers have nearly completed their ascending stroke this arbor is elevated by means of the wedge-shaped projection on the top of the frame, and immediately the balance catch acts so as to retain it in this position during the descending stroke, at the termination of which the catch comes in contact with the projecting screw shown in the elevation, thereby dropping the scrapers upon the face of the buddle. Consequently, in the ascending stroke these scrapers plough the vein-stuff against the flow of the stream. The orey matter to be operated upon is introduced into the compartment shown on the top of the plan, and by means of the diagonal scrapers it is washed and passed slowly across the table, the heavier portion being delivered into the bin F, and the lighter matter into the box F′, whilst the tails are lodged in the strips H H. The water employed in driving the wheel is also used for the buddle; one portion of it serves to introduce the ore, whilst the other is regularly diffused over the surface of the table, and washes the waste from the stuff. In case the quantity of water is too large for settling the residues flowing into the strips H H, and connected with the bins F F′, discharge launders are provided at G,

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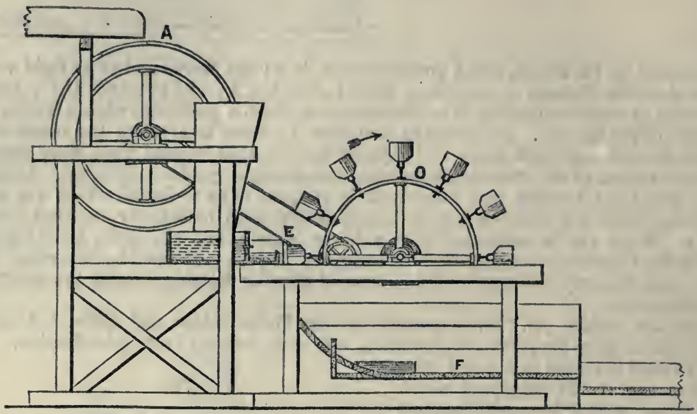

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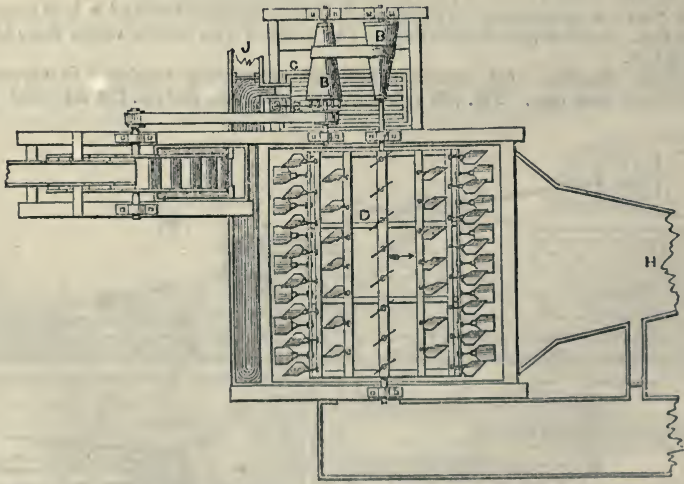


The table of the buddle has an inclination towards the bins F F′, and catch pits H H. This machine makes about 12 strokes per minute, and may be furnished with any number of rakes. With 22 rakes, 40 tons of stuff may be concentrated in 10 hours, so as to afford ore for the deluing sieve, whilst the blende will be sufficiently cleaned for the market. The cost of this apparatus complete is about 30*l*.

Figs. 722 and 723 represent plan and side elevation of the knife or impellor buddle. The water-wheel A, is 6 feet diameter, and is constructed of wood, with sheet-iron buckets. The speed of the trommel is carefully adjusted to the character of the stuff intended to be treated. This is effected by shifting the band on the driving cones B B. Straw, heath, and other extraneous substances are prevented from entering the separating table by means of an iron grating C, fixed near the top of the hopper. The trommel, D, is formed of 3 iron hoops braced together by flat lateral bars, 6 feet in length. Into these bars are inserted the scrapers, which are set spirally in the form of a screw. The hoops may be from 2 to 4 feet diameter, ⅝ths inch thick, by 1¼ inch wide. The scrapers are made of light sheet iron, and are 9 inches wide by 4 inches deep, with shanks 3 inches long. Twelve rows of scrapers are mounted on the periphery of the trommel. The first, fifth, and ninth rows contain nine, and the remaining rows are fitted with eight scrapers. Each scraper is adjusted by slightly rotating the stem, and tightening the nuts over and under the trommel-ring.

The trommel is rotated against the flow of water. From the vertical axis of the trommel, the table F is more or less inclined, according to the density of the minerals to be separated. The enriched stuff is collected in the side-bin, 2½ feet in width by 8 feet in length. From this receptacle the sand may be transferred to jigging sieves, round buddles, or other suitable dressing apparatus. The stuff deposited in the strake H is either subjected to additional mechanical treatment, or, if sufficiently free from ore, taken to the refuse heap.

The 'work' to be enriched enters at C, on one side of the table, and is propelled against the flowing water by the action of the scrapers. The heavier portion is progressed across the table, and passed into an ore bin, through an opening 18 inches long and 3 inches deep. The lighter materials are drifted into the strake, and in this way a separation is effected. Great care must be taken to distribute the stream of water equally upon the surface of the table, and to proportion its volume so as to divide the inferior from the more valuable minerals. The water flowing from the wheel may serve not only to supply the table, but a part of it may also be diverted into the feed-hopper C, and any excess discharged by the launder J. The quantity of stuff which can be passed through this apparatus in a period of 10 hours will vary with the densities of the minerals to be separated. The impellor buddle has recently been improved by Mr. Henry E. Taylor of Aberystwyth, and applied to the washing of coal and ores. See Specification 889, A.D. 1874. At Restronquet Mine in Cornwall, the Messrs. Taylor and Sons employ this buddle successfuly in the treatment of tin ores.

At Wildberg in Germany, the floor of the buddle was divided by moveable ledges, and the stuff diverted to enriching tables.

Sand and Slime Dressing Machinery.

In most mines a large proportion of the ore is composed of dradge, and has to be brought to a fine state of subdivision either by the crushing mill or stamps. In this condition the ore is freed from sterile matter, and rendered fit for metallurgic treatment. A variety of machines have been invented and applied to this division of dressing, in which the leading principle is to produce a separation by subsidence, according to the density of the substances. In connection with this principle, the stuff is not permitted to have a vertical fall, but is traversed by a flow of water, on a table or bed set at such an angle to the horizontal plane as may be found expedient. With extremely fine stuff, apparatus including both of these features are sometimes subjected to a mechanical jar or vibration, so as to loosen and eject, as it were, the worthless matter with which it may be charged. In concentrating crushed or stamped ore, a certain quantity will often exist in a very minute state of division, unable to withstand the currents and volume of water necessary for the separation of the larger particles.

The amount and richness must necessarily depend upon the united produce and character of the ore, as well as the mode of treatment observed. A good dresser will form as little slime as possible, since when the ore is brought to this condition it is usually associated with a large mass of worthless matter; and not only so, but the expense of extracting it is materially increased. The loss under the most favourable manipulation is very large, whilst the machinery requisite is probably more complicated and expensive than any other section of the dressing plant. Although several machines are illustrated under this head, and many more might have been added, it does not follow that they may be advantageously employed for every variety of ore.

Thus an apparatus which would enrich slimes by one operation from 1½ to 5 per cent. might be both economical and desirable for treating copper ore, but would not be so important in the case of lead ore of the same tenure; for after deducting the loss of metal incident to the enrichment, charging the manipulative cost on the full quantity of stuff, and estimating the relative value of the two products, it might be found that one would scarcely leave a margin of gain, whilst the other would yield a satisfactory profit.

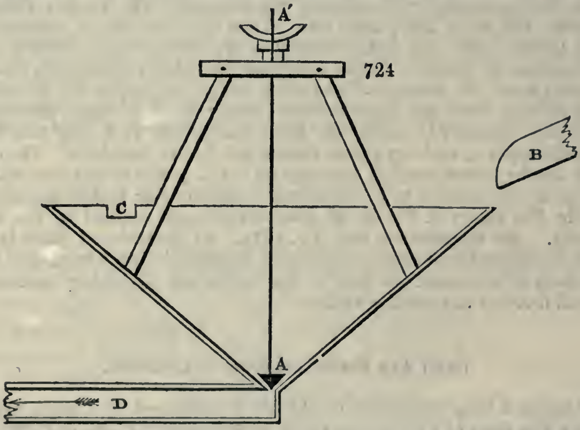
The proper sizing and subdivision of slime is as necessary as in the case of coarser work. In some of the German mines four or five distinct classes of slime are made, each class being treated on suitable enriching tables.

Richards' Slime Separator.—The water and stuff from the slime separated, is delivered through a launder into a pit, at the head of which is fixed a slightly inclined plank, divided into channels by slips of wood set in a radial direction from the aperture of the delivery launder. This pit has the form of an inverted cone, and since the water passes through it at a very slow rate, the more valuable and heavier matters will be deposited at the bottom. This apparatus thus becomes not only a slime pit, but also a slime separator.

The ordinary slime pit has usually vertical sides and a flat bottom; the slime and water enter it at one of its ends by a narrow channel, and leave from the other by the same means.

A strong central current is thus produced through the pit, which not only carries with it a portion of valuable slime, but also produces eddies and counter-currents towards the sides, which have the effect of retaining matters which from their small density should have been rejected.

The improved pit, *fig.* 724, receives its slimes from the launder B, and lets off a portion of them at C, whilst the richer and heavier matters, which fall to the bottom, escape through the launder D, regulated by means of the plug A, and screw A′.



724

In many cases sand and slime stuff are much commingled with clay, and require to be broken and disintegrated before the ore can be extracted. A method for accomplishing this is shown in *fig.* 725. A is the circumferential line of a round buddle; B, launder, leading to such buddle; C, sifting trommel; D, rotating paddles; E, tormentor; F, driving shaft.

A modification of this method is found in the slime trommel, *fig.* 726. A, hopper, into which slimes are lodged; B, launder, delivering clean water into hopper A; C, trommel of sheet iron, fitted in the interior with spikes for the purpose of dividing the stuff; D, disc, perforated to prevent the passage of pieces of chips or bits of clay and stone; E, Archimedean pipes fitted into a disc of sheet iron, conveying water into gauze or perforated trommel F; G, slime cistern; H, cistern for receiving the rough stuff; J, slime outlet, communicating with round buddle, or other suitable apparatus; K, outlet for trommel raff, which may be delivered to a sizing cistern. The speed of the gauze trommel for fine slimes varies from 80 to 100 feet per minute.

Hand Buddle.—This apparatus (*fig.* 727), is somewhat extensively employed in lead-mines for the concentration of stuff which contains but a small proportion of ore, such as middles and tails resulting from the round buddle, or the tails from strips, &c. A rising column of water is shown at A. This flows into a trough B, and through peg-holes into C. Here the stuff to be treated is introduced, and continually agitated by the boy in attendance. The finer portion passes through the perforated plate at D, and is distributed by the fan-shaped incline E in an uniform sheet on the head of the buddles. A boy stands just below the line of the middles with a wooden rake; with this instrument he continually directs the descending current to the head of the buddle, and by this means succeeds in separating a larger proportion of the ore than would otherwise be done, Whether the rake or the broom be employed, it is found that some of the fine lead is *florrined* to the extreme tail of the buddle. In order to prevent this the frame G has been introduced. It is strained with canvas, and floats on the water. This canvas retains the fine lead, which is from time to time washed off in a cistern. The section to the first dotted line shows the heads of the buddle; from this to the second dotted line will be the middles, and from the second dotted line the tails commence. It must, however, be remarked that the exact line of heads, tails, and middles must depend upon their relative richness. The wooden rake is undoubtedly preferable to the broom, as will appear from the following experiment, everything being equal in both trials:—

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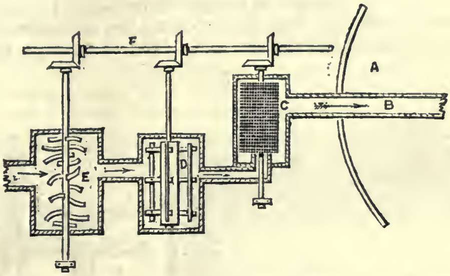

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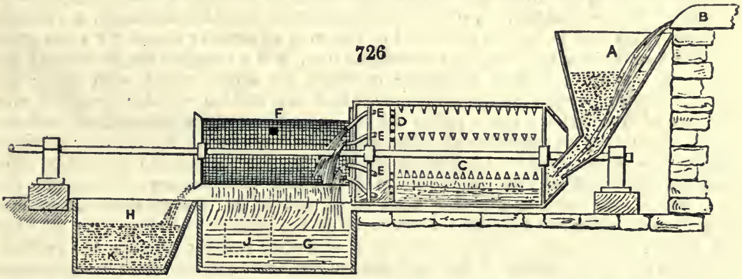

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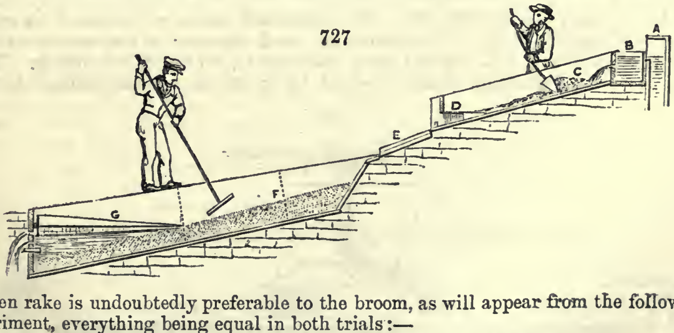


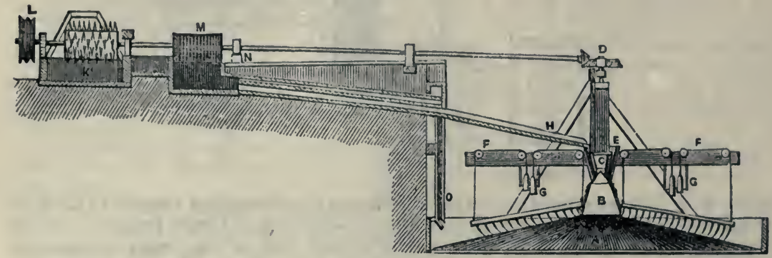
Stuff operated upon; tails from washing strips assayed 13 per cent.

	With broom	With rake
No. 1. Heads, assayed . .	16 per cent. . .	20 per cent.
„ 2. Middles, „ . .	$4\frac{3}{4}$ „ . .	$5\frac{3}{4}$ „
„ 3. Tails, „ . .	$4\frac{1}{4}$ „ . .	$1\frac{1}{2}$ „

It would be found a great improvement if these buddles were arranged so as to have their bottoms elevated when it might be necessary. As they are fitted at present the angle at the head is a constantly increasing one. The result is, the heads become poorer and the tails richer, as the operation proceeds, provided the fixed inclination of the buddle is correct at starting. In proportion to the poorness of the stuff the buddle should have its width increased, as well as be made shallower. If the stuff be also passed through a trommel before entering the buddle, the result will be found much improved.

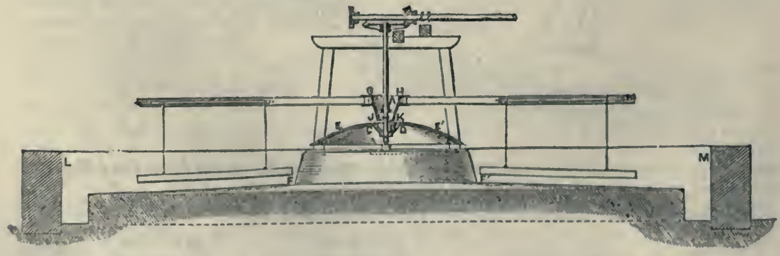
Round Buddle.—This machine serves to separate particles of unequal specific gravity in a circular space inclined from the centre towards the circumference. Its construction will be best understood by reference to *fig.* 728; in which A is the conical floor, formed of wood, and about 18 feet in diameter, on which the stuff is distributed; B is a cone, supporting the upper part of the apparatus, and serving to effect the equal distribution of the orey matter. D, wheel for giving motion to the arrangement; E, a funnel, perforated with four holes and furnished at top with an annular trough; F F are arms, carrying two brushes balanced by the weights G G; H is a launder, for conducting the stuff from the pit I; K is a receptacle in which the slimes mixed with water are worked up in suspension by the tormentor, which is a wooden cylinder provided with a number of iron spikes; L is a pulley taking its motion from a water-wheel, and M a circular sieve fixed on the arbor N. The stuff at K is gradually worked over a bridge forming one of the sides of a catch pit between the sieve M and the tormentor, from whence it passes off into the sieve by which the finer particles are strained into the pit I, whilst the coarser, together with chips and other like substances, are discharged on the inclined floor in connection with the launder O. From the pit I the stuff flows by the launder H into the funnel E, and after passing through the perforations flows over the surface of the fixed cone B, and from thence towards the circumference, leaving in its progress the heavier portions of its constituents, whilst the surface is constantly swept smooth by means of the revolving brushes. By this means the particles of different densities will be found arranged in consecutive circles. The arms usually make from two and a half to four revolutions per minute, and a machine having a bed 18 feet in diameter will work up from 15 to 20 tons of stuff per day of 10 hours.

728



In the ordinary round buddle the stuff is somewhat unevenly distributed, as well as imperfectly separated. This arises from the small diameter of the cone at its base, and the large volume of water and slime discharged upon its limited surface. These objections are to a certain extent removed by an improved round buddle, *fig.* 729.

729



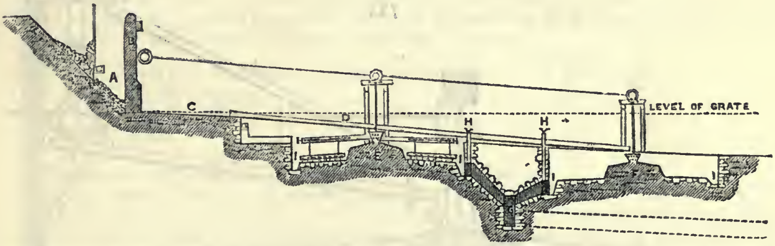
After the stuff has passed through a revolving trommel or grating connected with the apparatus, and to a certain extent sized, it is conveyed, by means of a launder, into a hopper A, and falls into the basin B. The slime from this basin flows freely over the convex plate E E′. It will appear that this arrangement secures an uniform distribution of the stuff, and at the same time the heavier portion is concentrated with greater rapidity than can be accomplished by means of the common rotating buddle.

The diameter of the hopper from G to H is 12 inches, from J to K 6 inches; the basin from C to D is 9 inches diameter, and the conical centre from F to F′ is 7 feet diameter. The buddle bottom is covered with plank in the usual way. Its diameter is 25 feet, with an annular ditch or gullet 12 inches wide. Into this gullet the sterile sand is scraped; and if the nature of the ground will admit, the bottom of the gullet may be sufficiently inclined to scour away the stuff, by the action of a stream of water. Captain Josiah Thomas states that the inclination of the buddle floor at Dolcoath varies from 1½ inch to ½ an inch in the foot; viz. for working 'roughs' 1½ inch, for slimes 1 inch, for treating stamps work, ½ an inch. The diameter of the wood centre F F′, also varies from 7 to 10 feet diameter. Mr. J. M. Pike, of Camborne, has furnished the following dimensions of a buddle erected at Tincroft:—

Floor of buddle, 20 feet diameter.
Inclination of floor of buddle, ¼ of an inch in a foot.
Wood cone, 9 feet diameter, depth 15 inches.
Number of arms in buddle, 6.
Height of arms from wood cone, 7 inches.
Speed of distributing plate, 2½ revolutions per minute.
Buddle, 21 feet diameter, filled in 24 hours to a depth of 13 inches. Contents 128 cubic feet, or 5⅓ cubic feet per hour, requiring 1,080 gallons of water, or 204 gallons per cubic foot of stuff treated.

The transverse section, *fig.* 730, shows the application of these buddles to the enrichment of tin ores. A, stamps pass; B, framework of stamps; C, stamps platform; D, launder for conveying stamp work to buddles E and F. Between the respective buddles runs a gullet, G, into which the waste flows, when the flushets, H H, are opened. The bed of each buddle is 20 feet in diameter, the annular spaces I I, one foot wide, making the distance from wall to wall 22 feet. It will be observed that the annular space is inclined towards the gullet, G. One buddle is sufficient to treat the stuff pulverised by a set of twelve or sixteen stamp-heads.

730

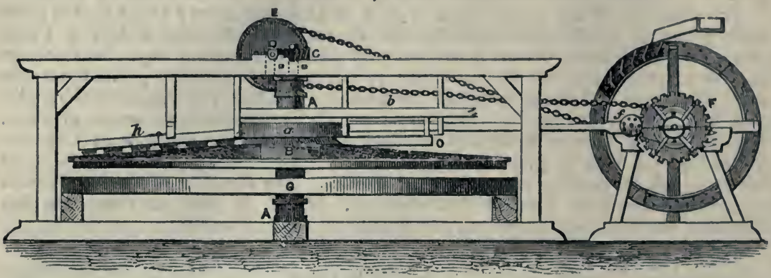


The inclination of the buddle bottom is ¼ of an inch per foot. Motion is given to the centre plate and arms by means of bevil gearing, moved by the stamping engine. The distributing plate of the buddle makes 2½ revolutions per minute. The stampwork, when passed through a perforated plate, having 36 holes to the lineal inch, can be concentrated at the rate of 5 cubic feet per hour.

Slime Buddle.—This machine, *fig.* 731, is said to effect the separation of the earthy matters from finely-divided ores more readily than the ordinary round buddle. For this purpose the pulverised ore is introduced near the centre of a large slightly conical rotating table, and flowing towards its periphery a portion of the upper part or head becomes at once freed from extraneous substances. Beyond this line of separation in the direction of the circumference, the stuff is subjected to the action of a series of brushes or rakes, and by means of a sheet of water flowing over the agitated slimes, clean ore is stated to be produced almost at a single operation.

The illustration, *fig.* 731, represents this machine at first erected at Clausthal, but it may be remarked that some of its mechanical details have been since judiciously modified by Mr. Zenner. A is an axis supporting and giving motion to the table B, 16 feet in diameter, and rising towards the centre 1 inch per foot; C, cast-iron wheel, 15 inches in diameter, operated on by the screw D. The tooth-wheel F drives the pinion *f*, the axis of which is provided with a crank giving motion to a rod fitted with brushes; G is an annular receiving box, 4½ inches wide and 6 inches deep; *a*, circular trough of sheet iron supported on the axis of the table an inch or two above its surface, and so divided that one quarter of it serves for the reception and equal distribution of the slime, whilst the other three quarters supply clear

731



water; *b*, launder for supplying slime ore, behind which is another not shown, for bringing in clear water. o, trough supplying additional water to the stuff agitated by the brushes. One end of this water-trough is fixed about the middle of the table, whilst the other advances in a curved direction nearly to the circumference.

Concave Buddle.—The object of this apparatus, *fig.* 732, is to concentrate on the

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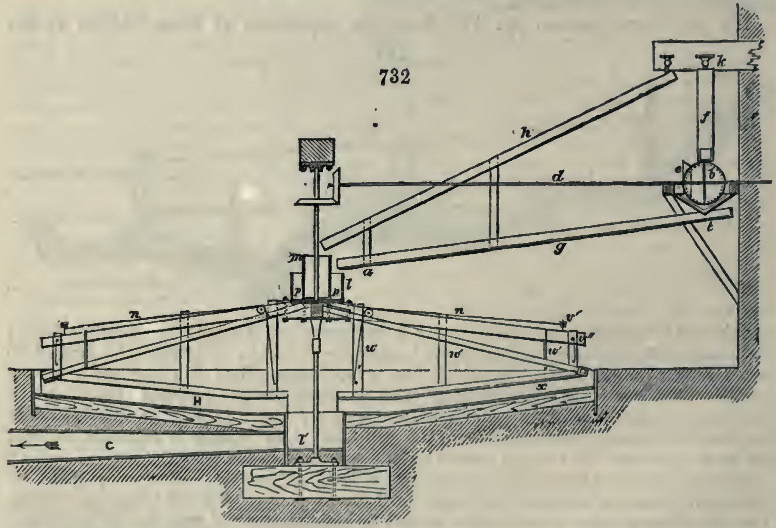


periphery of the floor, instead of the centre. This arrangement gives an immense working area for the heads, and at the same time admits of the separation of a greater portion of the waste than can be effected by the ordinary round buddle. After the slimy water has been discharged on the edge, the area over which it has to be distributed is gradually contracting, thereby increasing the velocity of the flow, and enabling it to sweep off a proportionate quantity of the lighter matter associated with the ore. *a* represents the inflow slime launder; *b*, a separating trommel, through which the slimes pass previous to their entrance into the launder *a*. c, outlet launder, for taking off castaways; *d*, arbor giving motion to the buddle arms and diagonal distributing launders attached thereto, held by the braces *w w'*; *e*, bevel wheel on driving arbor; *f*, downwright launder, to which is affixed a regulating cock, *k*, for supplying slimes to trommel; *h*, launder for delivering clean water to circular box *m*, and which water passes through slot openings at *p p*, uniting with and thinning the slimy matter previous to its passing into the diagonal delivery launders; *l'*, circular pit for receiving tailings. Attached to the wooden bar *x* is a piece of canvas with corresponding pieces depending in a similar manner from each arm, and which serve to give an even surface to the stuff in their rotation. The slimes flow from four diagonal launders, each having its upper end in communication with the box *l*. The speed of the arms and diagonal launders must vary with the nature of the stuff to be operated upon; for rough sands eight revolutions per minute have been found sufficient, but for fine slimes from fourteen to sixteen revolutions in the same time are necessary. The inflow of slime and water should also be proportioned to the speed and density of the stuff to be treated. No precise instructions can be offered on this head, but an experienced dresser would easily determine the proportions after a few trials. The bed is 18 feet diameter, and has a declination of about 6 inches from the edge to the point where it unites with the horizontal portion of the floor.

Experiment on slime ore, very fine and much intermixed with carbonate of iron:—

	Per cent.
Produce before entering buddle . .	6
Heads of buddle averaging 3 inches deep and 22 inches wide	12½ and 30 oz. of silver per ton of lead.
Middles of buddle averaging 1¾ inch. deep and 18 inches wide . . .	6½ and 42 oz. ,, ,,
Tails of buddle averaging ¾ inch deep.	3 and 55⅔ oz. ,, ,,
Castaways	½

Time required to fill buddle, 3 hours; number of arms in buddle, 4; number of revolutions of arms per minute, 8.

Experiment on fine slimes, much associated with carbonate of iron:—

Produce before entering the buddle . . .	3 per cent.
Heads 3 inches deep, 16 inches wide . . .	7½ ,,
Middles 1½ do. 12 do. . . .	1 ,,
Tails	traces.

Number of revolutions of arms per minute 14; time required to fill buddle 5 hours.

In working this buddle one month upon the fine and rough slimes, indicated in the two foregoing experiments, the results obtained were:—

	Mean
Assay of stuff before entering the buddle . .	5·0 per cent.
Heads afforded	12·5 ,,
Middles	5·0 ,,
Tails	0·77 ,,

Experiment on slime ore containing 7½ per cent. of lead:

In 12 hours 4 tons were washed, and gave 14 cwts. of crop, 28 cwts. middles, 12 cwts. tails, and 26 cwts. of waste. The 14 cwts. of crop were washed in 3 hours, and afforded 3½ cwts. dressed slime ore, 5½ cwts. of middles, 4 cwts. of tails, and 1 cwt. of castaways. The middles resulting from both operations, viz. 33½ cwts. were washed in 8 hours, and gave crop 4 cwts., middles 12 cwts., tails 4 cwts. and waste 13½ cwts. The tails were now washed in 3 hours, and afforded 4 cwts. of middles and 12 cwts. of castaways. 16 cwts. of middles were also washed in 3 hours, and furnished 2 cwts. crop, 6 cwts. middles, and 8 cwts. of castaways. In addition, 10 cwts. of crop ore were washed during 3 hours, and gave 1$\frac{8}{10}$ cwt. of slime ore, crop 1 cwt., middles, 6 cwt., castaways 1 cwt.

The results, therefore, show that 4 tons of rough slimes were washed in 32 hours, and afforded 5½ cwts. slime ore at 43½ per cent., leaving 1 cwt. of crop at 31 per cent., and 12 cwts. of middles yielding 4¼ per cent. A comparison was also made with the shaking table; 5 tons of the same slimes were washed in 48 hours, and gave 7 cwts. of dressed ore, 1 cwt. of heads, and 8 cwts. of middles.

The Table at top of following page shows the results of an experiment made between the concave buddle and the ordinary round buddle; time occupied, 24 hours.

The tails lying upon the horizontal part of the concave buddle contained 27½ per cent. of zinc and 2½ per cent. of lead.

It will be perceived that the much larger crop from the concave buddle was more than twice as rich for lead, whilst it was only 2 per cent. richer for zinc.

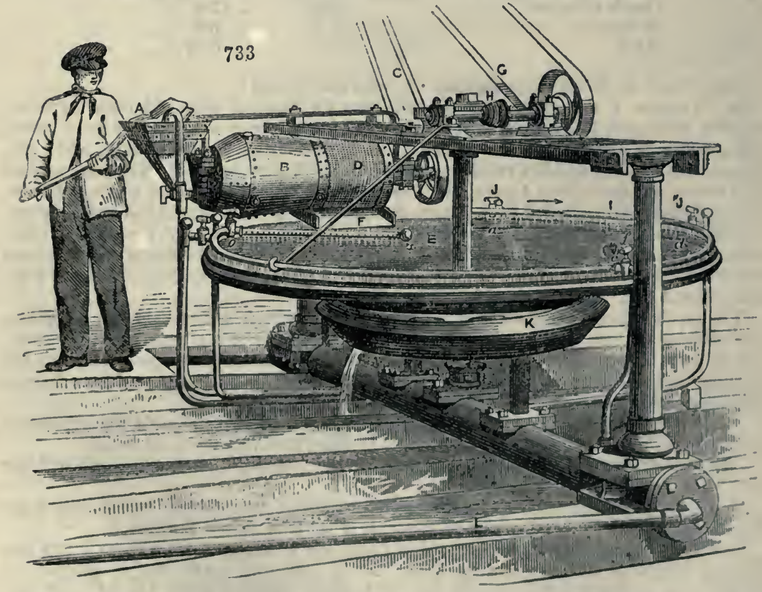
Quartzose ore without blende was then tried, and a similar weight gave 1,570 lbs. of crop, affording 56½ per cent. or 888½ lbs. of lead, and 3,450 lbs. of middles of 14 per cent. produce, equal to 483 lbs. of lead, or together 5,020 lbs. of stuff containing 1,372 lbs. of lead. The round buddle, on the contrary, gave 455 lbs. of crop ore, of 63½ per cent., equal to 290 lbs. of lead, 2,900 pounds of middles, of 18½ per cent., representing 541 lbs. of lead, or a total of 3,365 lbs. of stuff, containing 831 lbs. of lead.

Fig. 733 represents a buddle arranged for the treatment of fine slimes. It is entirely constructed of metal, and every part is carefully fitted in order to secure an even and delicate action. The stuff is introduced into the hopper A, from whence it passes into

	Pounds	Water. Weight per cent.	Dry Weight	Lead		Blende	
				Assay per cent.	Total	Assay per cent.	Total
Quantity of slimes to each buddle .	4262	23½	3268	8·7	284·5	34·33	1121·5
Obtained from concave buddle:—							
Crops . . .	505	15·4	427	23·6	100·8	36·65	155·6
Middles . .	1350	25·7	1003	7·6	77·7	37·0	371·0
Total . .			1430		178·5		526·6
Obtained from round buddle:—							
Crops . . .	510	24·8	383·5	10·2	39·	34·64	133·4
Middles . .	2530	39·9	1521·0	7·86	119·5	27·59	419·6
Total . .			1904·5		158·5		553·0
Loss by concave buddle					106·	. .	594·0
,, round ,, ...					125·9	. .	568·5

the trommel B, turned by the band C. The fine stuff passing through the perforated cylinder D, falls upon the shoot F, and flows upon the concave table E. This table revolves in the direction of the arrow and acquires its motion by means of the strap G driving the tangent wheel and screw shown at H. Concentric with the table a wrought-iron pipe I is fixed, which is pierced with numerous small holes. The quantity of water to this pipe is adjusted by the regulating cocks J J′ J″. Beneath the table is a circular receptacle or bottom K, having three compartments for receiving the washed stuff. From *a* to *d* the jets of water are comparatively light; from *d* to *c* the force of water is increased, and still further augmented in that portion of the circle extending from *c* to *o*, whilst from *o* to *x* it is sufficiently powerful to clean the buddle. In each of the sections a

733



portion of waste along with a little light ore is washed into the receptacles underneath, from whence it may flow into strips or buddles for further separation, or is otherwise manipulated upon a second buddle. The water is supplied to the machine under pressure by the pipe L. This apparatus will wash from 80 to 100 cubic feet of free slimes in 10 hours, or from 60 to 80 cubic feet of tough slimes in the same period. Lead stuff affording 4 per cent. with a light waste has been enriched to 40 per cent. in a second revolution, and in a third and fourth rotation 40 per cent. slime has been enriched so as to yield 60 per cent. of ore. The buddle table makes two revolutions per minute; its diameter varies from 8 to 10 feet, and the power required is about one-tenth of a horse-power. One boy can serve four buddles.

Rittinger's Rotating Buddle.—This apparatus is employed at Schemnitz, and is applicable to the treatment of fine slimes containing but a small proportion of metallic substances. The accompanying sketch (*fig.* 734) will serve to explain its construction and action. The machine may be said to consist of four principal parts:—

1st. The vertical axle *a*, which carries the buddle.

2nd. The surface of the buddle *b*.

3rd. The concentric launders *c c′*, for supplying the diluted slimes, as well as clean water to wash the mineral.

4th. The concentric launders *d d*, beneath the buddle for receiving the concentrated minerals and waste.

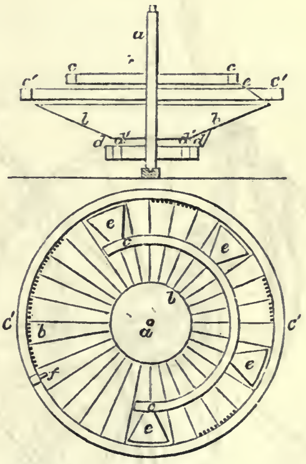
The vertical axle *a*, is fitted with a cast-iron centre-piece, which receives 16 wooden arms; these support the same number of segments, and form a circle 16 feet in diameter. Each segment is divided into two parts, by radial strips of wood, so that the whole surface of the buddle is divided into thirty-two parts, each being 5½ feet long, and having a fall of about 6 inches towards the centre.

Motion is given by a tangent wheel and screw geared at the upper end of the axle, one revolution in ten minutes being the required speed. Above the buddle are two concentric launders, the one *c′*, at the periphery, being for clean water, the other *c*, nearest the centre, for the contents of the sizing apparatus. The stuff is introduced by means of feeding boards on the outer circumference of the buddle.

Between each feeding board a fine sheet of water flows to the buddle from the launder *c*.

After the last feeding board, the launder forms a curve towards the centre of the buddle, and supplies along its length a thin fine stream of water, which washes the deposited stuff from top to bottom, carrying away all the lighter particles, and leaving only the heaviest minerals on the surface of the buddle. The buddle, after passing this point in the course of its rotation, comes under a strong jet of water flowing from a pipe *f*, supplied from a cistern about 12 feet above. This water flows with sufficient force to drive the concentrated mineral into the launders *d d*, which is divided into different compartments, for receiving the middles and waste from the buddle during its revolution. These are thrown away, unless it be found that the middles are worth repassing over the buddle. The finer the slimes, the more perfect is the result. The slimes from the sizing apparatus should be thin, from 2¼ to 4¼ lbs. of sand to a cubic foot of water being sufficient.

734



The water required for cleansing is from eight to nine-tenths of a cubic foot per minute.

The water for driving off the clean product is from one and a half to one and six-tenths of a cubic foot per minute.

Altogether, the quantity of water required per minute is about 2¼ cubic feet.

The buddle, if properly constructed, extracts about 80 per cent. of the ore contained in the slimes, and will treat about 1 cwt. per hour. One-twentieth of a horse-power is sufficient for rotating the buddle.

A valuable set of buddles for enriching palpable slimes, has been in use for many years at the lead and silver ore dressing establishment near Ems, Prussia.

The apparatus is shown in elevation *fig.* 735 and plan *fig.* 736, and consists of a

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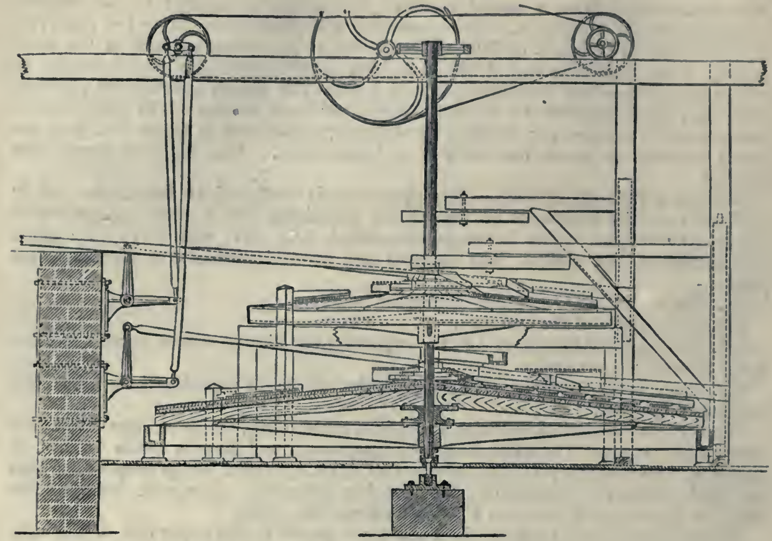

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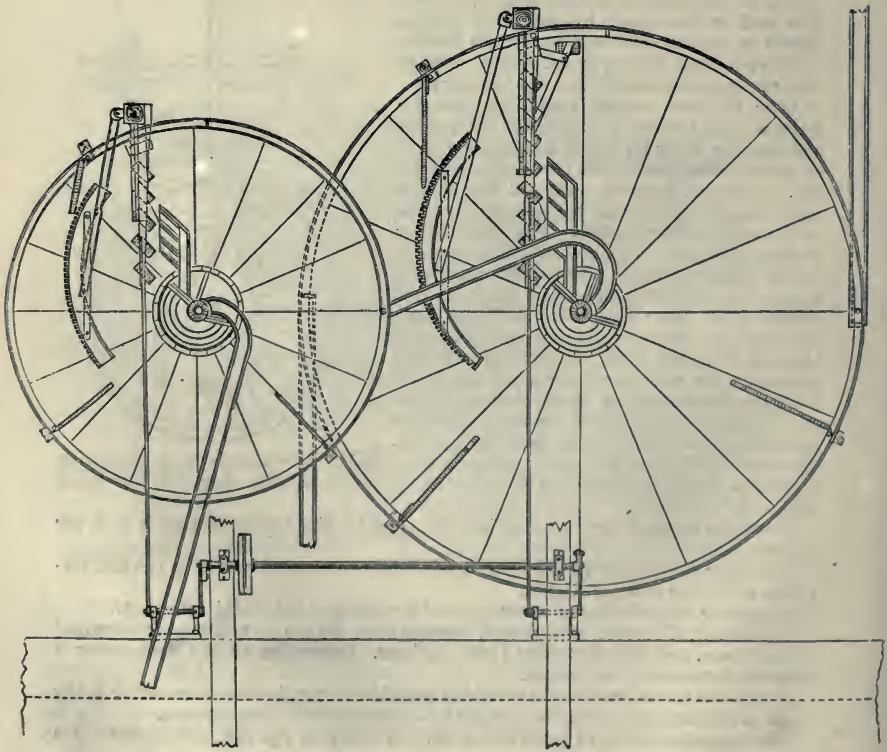
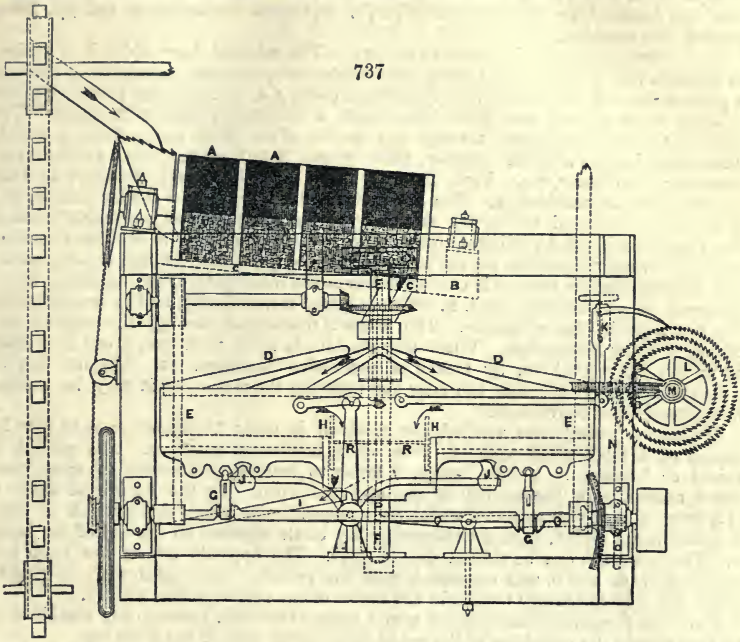


small and a large circular table, each rotated by means of a tangent wheel and screw. Slime of the fourth class, exceedingly fine, passes first to the small table 10 feet diameter, and after being deprived of the greater portion of its ore, flows to the larger table 18 feet diameter, where it is divided into a weakly-enriched product and waste. The fall of the table is 5°, and one revolution is performed in four minutes: the washing water is distributed by means of 3 short wrought-iron pipes, through a line of perforated holes, and a segmental launder; sufficient water being supplied to effect the desired separation, the brushes making 100 strokes per minute serving to clean the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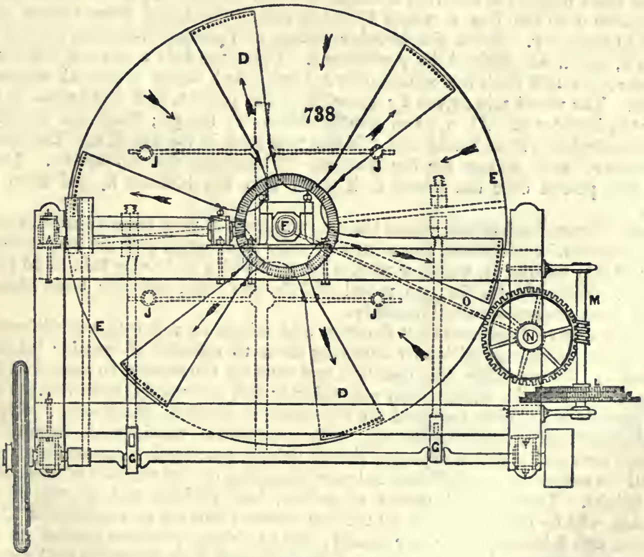

738

table. A fixed launder or trough coincident with the periphery of the table is divided so as to receive the ore and orey stuff.

In addition to the machines already described, a slime or sludge dressing apparatus has been designed by Mr. Borlase. *Fig.* 737 represents an elevation, and *fig.* 738 a plan of this machine.

It is described by the inventor as follows:—The mineral from which it is desired to separate the metallic ore having been crushed or pulverised, is conducted through a pipe or channel into a revolving cylindrical sieve, A A. The larger parts pass into a shoot or launder B, and from thence into a self-acting jigging machine. The slime or fine portion passes through the meshes of the sieve into a shoot, C, and is discharged into an annular launder, from whence it falls either into a stationary or revolving distributor, D D. From thence it flows through suitable channels into the outer part of the machine, E. The apparatus is fixed on a perpendicular axis, F, and is kept in a continual oscillatory motion by means of cranks and connecting rods, G, the speed of the cranks being adjusted so as to keep the slime in continual motion, and at the same time cause the ore to descend and deposit itself at the bottom, whilst the waste or lighter portion is carried towards the inner part of the machine, where it passes over a moveable ring, H, which is raised mechanically, and in proportion as the ore rises in the apparatus. The waste is discharged through the outlet I, and conveyed away in launders. When the machine is filled with ore, it can be settled, as in the dolly machine, by means of percussive hammers, J J. The ore can be collected either by reversing the gear and lowering the ring H, or it may be washed into a receiver as convenient.

Motion is given to the vertical bar K, which is made to vibrate so as to turn by means of a ratchet the wheel L, fitted on a horizontal shaft, M. The ratchet is raised or lowered by a worm screw, in order to increase or decrease the speed rendered necessary by the quality of ore operated upon. On the horizontal shaft M is a worm pinion, that works a wheel on a perpendicular shaft, N, on which is fixed a second worm pinion, raising or lowering the tooth segment on the end of the beam O. This segment can be shifted out of gear. The opposite end of the beam O is attached to the rod P, and connected with the crossbar R, as also with the ring H, which has a reciprocatory motion in the centre of the perpendicular shaft F.

From the foregoing description it would appear that Mr. Borlase has combined in this apparatus the principles of the round buddle with that of the dolly tub.

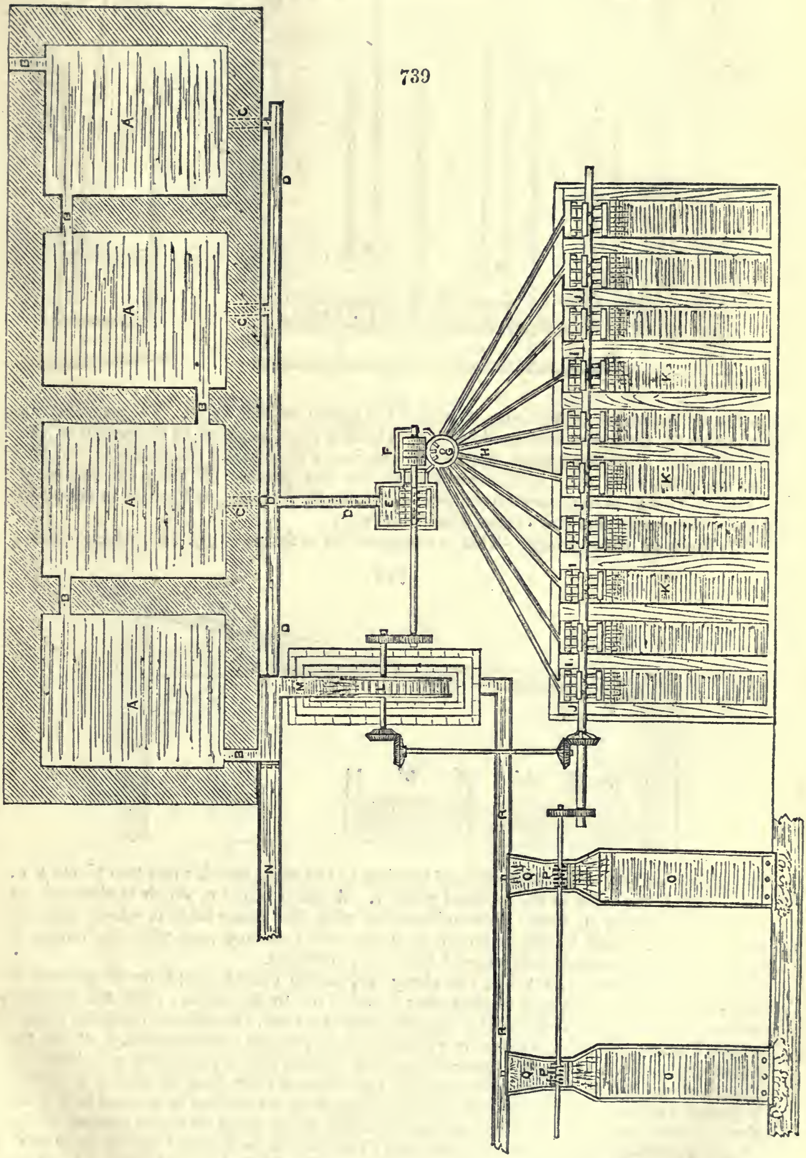
Slime Trunking Apparatus.—The illustration, *fig.* 739, shows the apparatus employed in some of the lead-mines of Cardiganshire. The slimes are lodged in the several settling pools marked A, and flow through the channels B. At C the slimes pass into the launder D to the box E, where they are comminuted, and from thence progress into the trommel F. From the circular cistern G, V-shaped launders diverge to the trunks K, which are divided by partitions I. Upon the axis J in each buddle head, paddles rotate, and flush the slimes over a head board, where a partial separation is effected. The wheel L is driven by water from the pools A, and any excess is carried off by the launder N. At O O two hand-buddles are shown; these are intended for the concentration of the heads and middles produced in the trunk K. The axis at P is furnished with spikes for the purpose of breaking up the slimes. After the water has passed over the wheel L, it flows into the launder R, and from thence into Q.

At the Minera lead-mines, where the ore produced is very massive and capable of a high degree of enrichment, the slimes average 9 per cent., and are concentrated by means of this apparatus, together with a round buddle and dolly tub, to 75 per cent. of metal. With six trunks, one round buddle, one man, and four boys, about nine tons of clean ore are obtained monthly.

Attempts have been made by Brunton and others to separate metalliferous ores of different specific gravities by allowing them to descend at regular intervals in still water. By reversing the operation and causing the current to ascend uniformly, the particles may be much more conveniently and accurately classified. This has been done in a machine designed by the late Mr. Herbert Mackworth. Suppose a funnel-shaped tube, larger at the top; with a current of considerable velocity flowing upwards through it, grains of equal size of galena, pyrites, and quartz, when thrown in, will be suspended at different heights depending on the velocity of the current at each height. Thus cubical grains of galena, iron pyrites, and quartz, of $\frac{1}{12}$ inch diameter, will be just suspended by vertical currents moving at velocities of 12 inches, 7 inches, and 5 inches linear per second; flat or oblong particles require rather less velocities to support them, inasmuch as they descend more slowly in still water than the cubical or spherical particles.

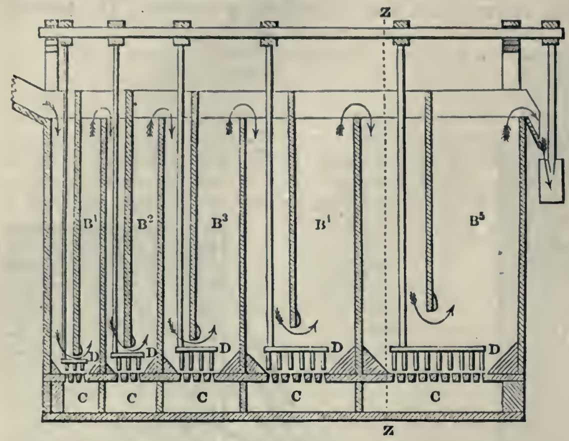
A simple form of applying this principle is presented by the vertical trunks shown in *figs.* 740 and 741. Metalliferous ore, after being classified by sifting, or tin ore as it comes from the stamps, may be allowed to flow mixed with water down the shoot A. The supply of water should be taken from a head so as to be perfectly uniform in quantity. The water mixed with the ore flows in the direction of the arrows down and then up the divisions B^1, B^2, B^3, B^4, B^5, each of which increasing in area, the velocity of the ascending current diminishes in the same proportion. The particles

739



of greatest specific gravity will be deposited in the bottom of B^1. In the bottom of B^2 will be found small particles of great specific gravity and large particles of small specific gravity. The same relation will exist in B^3, B^4 and B^5, only the particles of each will be smaller in succession. The plugs in the holes C C C being opened as is found necessary, allow the accumulations in the bottom of each trunk to discharge themselves into separate troughs. The rocking frame and rakes D D constantly stir up the sediment so as to bring it under the action of the water. To produce the oscillation of the rakes, two spade-shaped plates E E are exposed to the action of the falling water discharged from the end of the box which rocks the frame to and fro. The ore in the first trunk is fit for smelting; the ore passing off from the bottom of the other trunks is in a very favourable condition for framing, or it may be sifted to remove the larger particles of less specific gravity.

740



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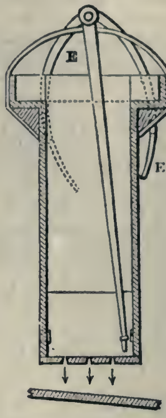
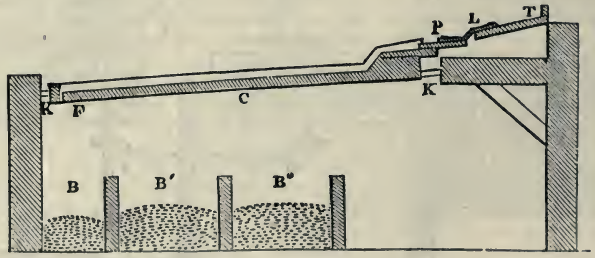


The Rack or Hand-frame.—This is composed of a frame C, *fig.* 742, which carries a sloping board or table susceptible of turning to the right or left upon two pivots K K. The head of the table is the inclined plane T. A small board P, which is attached by a strip of leather L, forms a communication with the lower table C, whose slope is generally 5 inches in its whole length of 9 feet, but this may vary with the nature of the ore, being somewhat less when it is finely pulverised.

742



In operating with the table, the slimy ore, to the extent of 15 or 20 pounds, is placed on the head T, and washed over L and P on to the table; then the operator with a toothless rake distributes it equally over the head, the richest particles remain on the highest part of the table by virtue of their greater specific gravity, whilst the muddy water falls through a cross slit at the bottom into a receptacle B. When the charge of ore has been thoroughly racked, the table is turned on its axes K K until it is brought into a vertical position, and the deposit on its surface is washed into boxes B′ B″. The box B′ will contain an impure slime, which must be again framed, whilst B″ will probably contain a slime sufficiently enriched to be finished by the dolly tub.

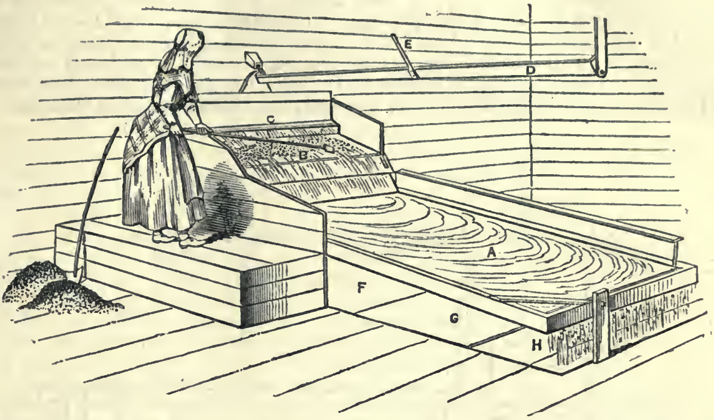
The slope of the rack table for washing tin stuff is 7¾ inches in 9 feet. The width is about 4 feet.

The average quantity of lead slime which can be washed per day of ten hours, is about 30 cwts., and the water necessary, say 600 gallons.

The general appearance of the rack is shown in the illustration, *fig.* 743. A, table;

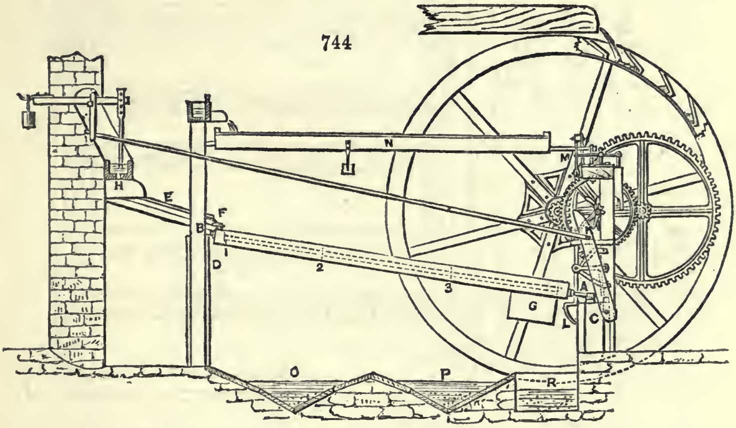
B, inclined plane upon which the stuff is lodged. Clean water flows over the ledge C. When the table A is turned in a vertical position, the racking girl washes it by depressing the lever E attached to the V-shaped launder D, thereby discharging the water which it may contain. The heads, middles, and tails are lodged in the compartments F, G, and H, respectively.

743



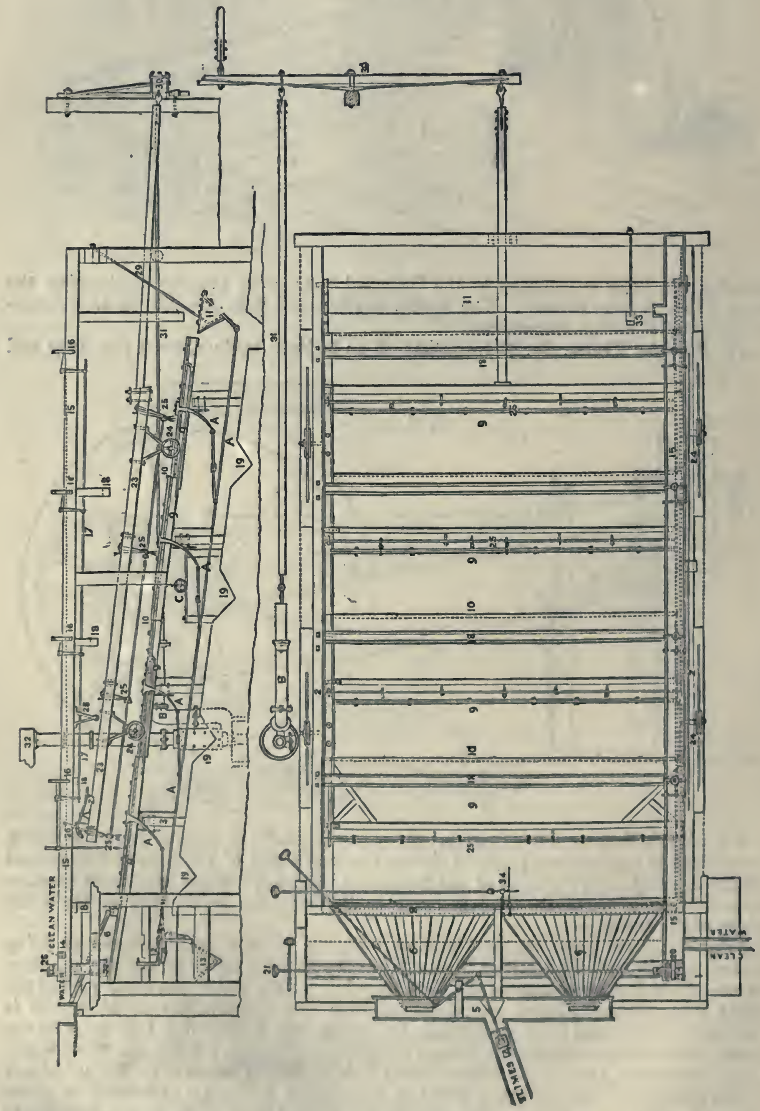
The Machine Frame, fig. 744, consists of an inclined table, about 8 feet long and 5 feet wide, with sides 5 inches high. At each end are fixed axles of iron, A B, which are centred in two vertical pieces of timber C D, and admit of the frame being turned perpendicularly. At the head of the frame is a ledge E, on which numerous lozenge-shaped pieces of wood are fixed in order to distribute the liquid stuff on the entire width of the frame.

744



From the frame head, the stuff falls on a sloping board F, which admits of being turned, as it is hung by leathern hinges, when the frame assumes an upright position. At one of the bottom corners of the frame is a box G, into which the chief part of the water from the table flows. In operating with this machine, the liquid matter is admitted to the frame head E, through the hole H, and flowing in a thin sheet on the table I, deposits the vein-stuff according to its varying specific gravity, the best quality being heads from 1 to 2, the middles from 2 to 3, whilst the tails are lodged at the end of the apparatus. To the water wheel is attached a horizontal axle fitted at given distances with cams, which disengage at the proper time parts of the machinery connected with the frame. The first cam acts on the rod K, and stops the flow of tin stuff; the second cam disengages a catch beneath the displacing box G, containing the frame water, and immediately the frame assumes a vertical position striking in its movement a catch at M, which upsets the V-shaped launder N, containing pure water, in such a way as to wash the ore on the table into two coffers O and P. The frame then returns to its horizontal position, and the orey matter is again admitted through H. One boy can manage twenty of these frames. When employed in cleaning tin stuff, the two coffers O and P are discharged into separate pits about 15 feet long, 6 feet wide, and 12 or 15 inches deep. The refuse from the end of the frames as well as the slimy water from the displacing box, is either thrown away or subjected to further treatment; the coffer O is usually taken to the hand frames, after which it is tossed and packed, whilst the stuff from coffer P is again submitted to machine framing.

745



Hancock's Slime Frame.—The ores and accompanying waste are brought into a state of suspension by water, and are then by adjustment made to pass over a slight fall, so as to produce the greatest regularity in its flow over tables fixed upon a given incline, each table having a sufficient drop from the table above. When the tables are sufficiently charged, clean water is introduced to pass over the table. The surfaces of the tables are subject to the action of brushes or brooms during a part or the whole time of both operations until the ore is sufficiently cleaned. In some cases the use of such brushes or brooms are dispensed with. The ore (on the tables) thus cleaned is washed off into cisterns by the action of water passing over the surfaces of the tables after they are raised to nearly perpendicular positions.

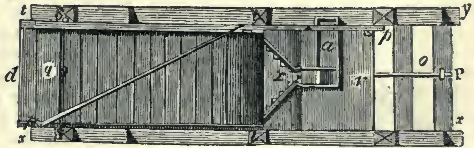
Fig. 745 represents, 1, framework to carry the gear on each side of the machine; 2, the stretcher or pivot piece on which all the tables are resting; 3, centre bearings of the tables, to which is attached an adjusting screw for raising or lowering them; 4, a slide valve, which admits or shuts off, as required, the ores, which are previously brought into a thin consistency with water; 5, launder through which the ores, pass to the heads, which are divided into sections and numbered; 6, the ores, &c., dropping from the heads into a launder, 7, the working edge of which is made level by an adjusting screw at each end for the ores to pass over; 8 is a stretcher, passing over the heads in both ends, bolted to 1, from which 6 and 7 are supported by three adjusting screws; 9 are four tables over which the ores have to pass, first receiving the deposit of the cleanest or best ores, and the rest in gradation; 10, the drop or fall from one table to another; 11, the balance cistern, into which the refuse from the tables passes, and when full, by lifting the catch 12 it forms a balance for turning up the tables to be washed down, each table being connected with rods and lever A; this done, such catch is lifted up, and 13 forms a returning balance for the tables; at 14 a stream of water is introduced, passing into 15 as a receiver; on the turning up of the tables, valves 16 are lifted by lever and rod 17, and admit the water into perforated launders 18 to wash off the ores into receivers 19, through which it passes out into deposit hutches. The slide valve 4 having admitted a sufficient quantity of ore, which has been deposited on the tables, is now closed, and the valve 20 is opened by the dresser at rod handle 21, through which a supply of water passes into launder 22, and flows over the tables for the purpose of cleaning the ores. The framework for the brushes 23 is carred on four wheels 24, each table being supplied with a brush 25, which brushes its respective table upwards, and on arriving at the heads of the tables, the brushes being all connected, are lifted by lever and 26 slips into the catch 27, and the brushes pass back over the tables without touching until the lever of the catch is struck out by 28, and the brushes drop again on the tables. Each brush is adjusted by screws and carried on arbors running across the frame. This frame with its appendages is propelled by a rod 29, attached to a beam 30, that can be worked by any sufficient power that may be applied.

The ores passing from the third and fourth tables through the two lower receivers 19 into a cistern, are lifted by a plunger B, attached to beam 30, by a rod 31, and passes back by launder 32 to be readmitted into slide valve 4, and repass the tables. In 11 balance cistern is a valve 33, which on the dropping of the table lets out the contents. 34 is a catch for holding the frame and brushes during the time of turning down and washing the tables. The machine is to be worked with or without brushes, as the character of the ores may require. It may be extended or diminished to any number of tables, and their size may vary as may be found necessary on the same principle. C is a wheel acting as a parallel motion for the plunger pole and running on a bar of iron.

This machine was in constant use at the Great Polgooth Mine for some time, and it is said effected a saving of 30 per cent. in the dressing of slime ore. It is not so well adapted for rough as for the treatment of fine slimes.

Percussion Table.— The diagrams, *figs.* 746, 747, 748, exhibit a plan, vertical section, and elevation of one of these tables. The *arbor* or shaft, is shown in section perpendicularly to its axis, at A. The *cams* are shown round its circumference, one of them having just acted on *n*.

746



These cams, by the revolution of the arbor, cause the alternating movements of a horizontal bar of wood, *o*, *u*, which strikes at the point *u* against a table *d*, *b*, *c*, *u*. This table is suspended by two chains *t*, at its superior end, and by two rods at its lower end. After having been pushed by the piece, *o*, *u*, it rebounds to strike against a block or bracket B. A lever *p*, *q*, serves to adjust the inclination of the moveable table, the pivots *q* being points of suspension.

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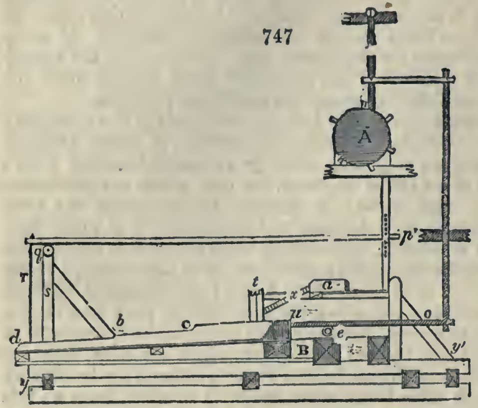

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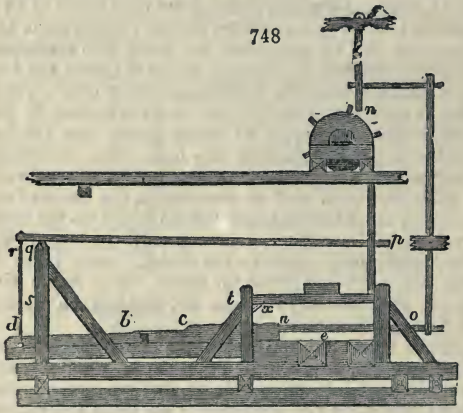


The stuff to be washed is placed in the chest *a*, into which a current of water runs. The ore, floated onwards by the water, is carried through a sieve on a small sloping table *x*, under which is concealed the higher end of the moveable table *d b c u*; and it thence falls on this table, diffusing itself uniformly over its surface. The particles deposited on this table form an oblong slope upon it; the successive percussions that it receives determine the weightier matters, and consequently those richest in metal, to accumulate towards its upper end at *u*. Now the workman by means of the lever *p*, raises the lower end *d* a little in order to preserve the same degree of inclination to the surface on which the deposit is strewed. According as the substances are swept along by the water, he is careful to remove them from the middle of the table towards the top, by means of a wooden rake. With this intent, he walks on the table *d b c u*, where the sandy sediment has sufficient consistence to bear him. When the table is abundantly charged with the washed ore, the deposit is divided into three bands or segments *d b*, *b c*, *c u*. Each of these bands is removed separately and thrown into the particular heap assigned to it. Every one of the heaps thus formed becomes afterwards the object of a separate manipulation on a percussion table, but always according to the same procedure. It is sufficient in general to pass twice over this table the matters contained in the heap, proceeding from the superior band *c u*, in order to obtain a pure slime; but the heap proceeding from the intermediate belt *b c*, requires always a greater number of manipulations, and the lower band *d b* still more. These successive manipulations are so associated that eventually each heap furnishes pure slime, which is obtained from the superior band *c u*. As to the lightest particles which the water sweeps away beyond the lower end of the percussion table, they fall into launders, whence they are removed to undergo a new manipulation.

749

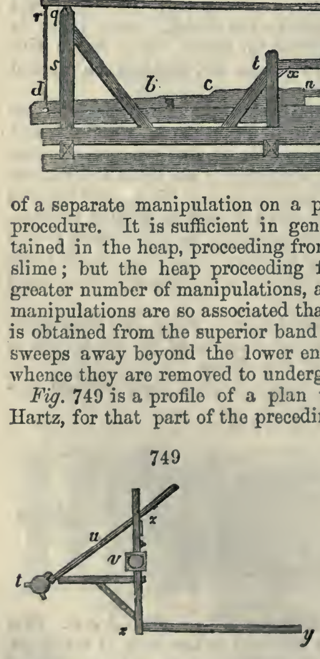


Fig. 749 is a profile of a plan which has been advantageously substituted, in the Hartz, for that part of the preceding apparatus which causes the jolt of the piece *o u* against the table *d b c u*. By means of this plan, it is easy to vary, according to the circumstances of a manipulation always delicate, the force of percussion which a bar *x y*, ought to communicate by its extremity *y*. With this view a slender piece of wood *u* is made to slide in an upright piece, *v x*, adjusted upon an axis at *v*. To the piece *u* a rod of iron is connected, by means of a hinge *z*; this rod is capable of entering more or less into a case or sheath in the middle of the piece *v x*, and of being stopped at the proper point, by a setscrew which presses against this piece. If it be wished to increase the force of percussion, we must lower the point *z*; if to diminish it, we must raise it. In the first case, the extremity of the piece *u*, advances so much further under the cam of the driving shaft t; in the second, it goes so much less forwards; thus the adjustment is produced.

The water for washing the ores is sometimes spread in slender streamlets, sometimes in a full body, so as to let two cubic feet escape per minute. The number of shocks communicated per minute, varies from 15 to 36; and the table may be pushed out of its settled position at one time three quarters of an inch, at another nearly 8 inches. The coarse ore sand requires in general more water, and greater slope of table, than the fine and pasty sand.

The following remarks on the Freiberg *Shaking Table*, are by Mr. Upfield Green, formerly of the Wildberg Mines, Prussia. The bed of the table is about fourteen feet long, by six feet wide, and is formed of double one-inch boards, fastened to a stout frame. The table is hung by four chains, the two hindermost are generally two feet long with an inclination of 2 to 4 inches. The two front ones, which are attached to a roller for the purpose of altering the inclination of the table, are five feet six inches long, and hang perpendicularly when the table is at rest.

The tables receives its action from cams inserted in the axle of a water wheel, acting on the knee of a bent lever. The slimes after being thoroughly stirred up by a tormentor, are conveyed by a launder in a box, where they are still further diluted with clean water, and passing through a sieve with apertures corresponding to the size of the grain to be dressed, flow upon an inclined plane furnished with diffusing buttons, and from thence drip on to the shaking table.

In treating rough slimes the two hindermost chains are set at an inclination of 5 to 6 inches, and the table with an inclination of 4 to 6 inches on its length, makes 36 to 39 pulsations of 5 to 6 inches in length per minute. About 2½ cubic feet of diluted slimes, twelve of clean to one of slime-water, enter the table per minute.

Before commencing the percussive action, the table is covered with a thin layer of rough slimes, and during the first few minutes only clean water is admitted. In consequence of the quantity of water and violent motion employed, the smaller and lighter particles of ore are likely to drift down the table, and a rake is therefore employed at intervals to reconvey such particles towards the head of the table. Care must, however, be taken not to allow the water to wear furrows in the deposit. From two to three hours are usually required for the roughest sand-slimes to deposit four to five inches on the head of the table. The crops are twice more passed over the shaking table, and afterwards dollyed. The rapidity of movement and quantity of clean water increase with each operation. The tails of the first operation, which are considerably poorer than the original stuff, may be either thrown away, or once more passed over the table, when the crop will be fit for treatment along with a fresh quantity of original slime. The treatment of fine slimes is similar to that of the rough, with the exception that the inclination of the table, quantity of slime-water, proportion of clean water, and length of stroke, constantly decrease with the degree of fineness of the slime; and the number of strokes increase in proportion. In fact, for the finest slimes, the table has no greater inclination than one inch on its whole length, while the stroke, of which 35 to 45 per minute are made, is no longer than ¼ to ½ an inch. The time required for dressing varies with the nature of the slime operated on, five tons of rough slimes occupies sixty-eight hours, whilst the same quantity of very fine slimes requires no less than four times that period.

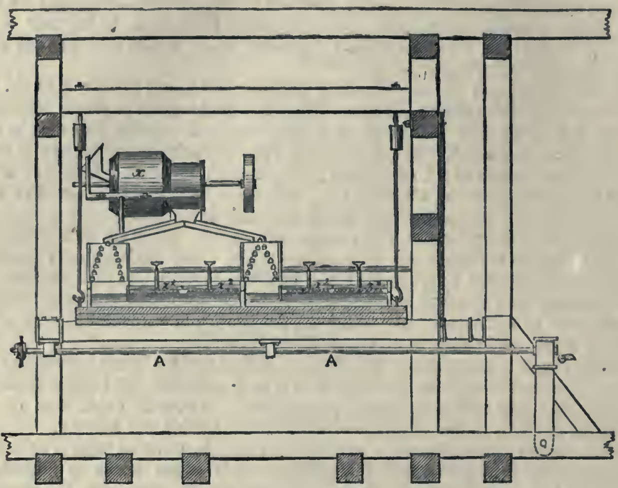
Rittenger's Percussion Tables.—The primary object intended to be accomplished by these tables, is the extraction of gold, silver, and other valuable ores from the veinstuff with which they may be associated.

Figs. 750, 751, represent front elevation and plan of two tables in one frame, divided by the strip S; these tables are suspended by rods from the points O, in such manner that they represent an inclined plane, the upper or higher end being at M N.

The sand and water, after passing through the sizing trommel x, is supplied to the tables at l l, the other places z^1 and z^2 being for the admission of water only. As the tables are suspended from four points, they are free to oscillate in one direction, that is, at right angles to the direction of their inclination. The oscillation is produced by a cam wheel acting upon the end of the beam A, upon which the table is mounted, the cam pushing it in one direction, and a spring bringing it back with a sharp blow, when the cam catches it, and a quick succession of blows is the result. It will thus be seen that the stuff under treatment is subjected to two forces, the one being the stream of water tending to wash the particles to the bottom of the table, the other being the blow, to bring the ores over to the ridges s s'. The effect of these combined forces is to induce the heavier or metallic particles to describe in their descent curvilinear lines, the light materials suspended in the water reaching the bottom of the table much quicker, and being less acted upon by the side blows, describe the shorter line r r', and leave the table almost in a straight line from the feeding plane l and l.

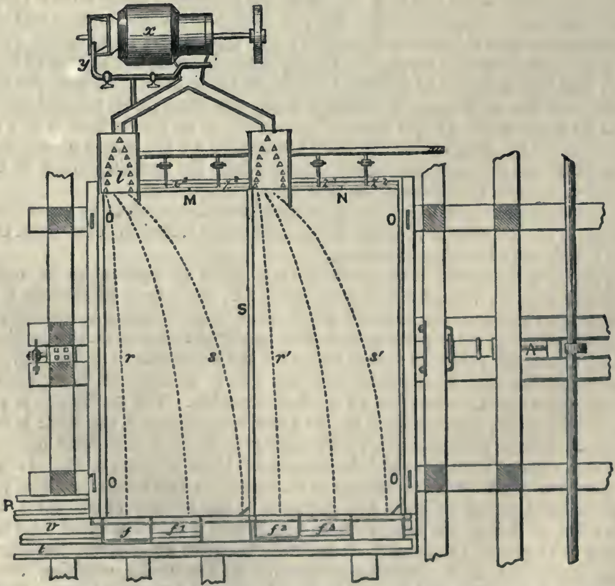
The tables are mounted on a rectangular frame, to which also is fixed the transverse beam which receives the blow. The surfaces of the table are planed as smooth as possible, and are framed in and divided by the strips s. Each table is about 8 feet long by 4 feet wide.

750



At the lower end of the tables are openings, f, f^1, f^2, f^3, under which are three parallel launders, which receive the stuff from the respective divisions of the table, the launder t receiving the clean mineral, the launder v a mixture of ore and waste, and the launder R the waste. To obtain successful results from these tables, care must be taken that the surfaces are perfectly smooth, and that in the direction of the blows they are set so as to be quite horizontal.

751

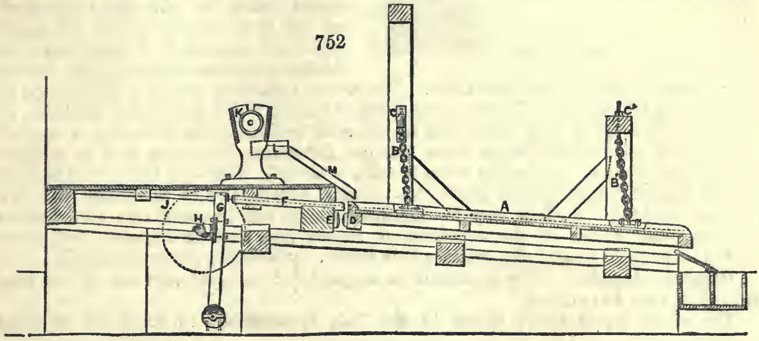


The stamp work must not flow on a feeding board above a foot in width.

The length of stroke and number of blows vary according to the stuff to be treated; the coarser the material, the longer, stronger, and fewer blows are necessary. The quantity of water containing mineral in suspension, to be fed on a single table, is of coarse stuff 1·2 gallon, containing 4 pounds of sand and of slimes, three-quarters of a gallon of water, containing about 13 ounces of sand in suspension. The action of these tables is precisely that of the vanning shovel; and any ore which can be cleaned upon the shovel can be dressed in a superior manner upon the table.

Two tables, making 120 blows per minute, require to be driven by a 15-feet water-wheel, and 50 gallons of water per minute. Each additional table will take 30 gallons of water per minute to drive it.

752

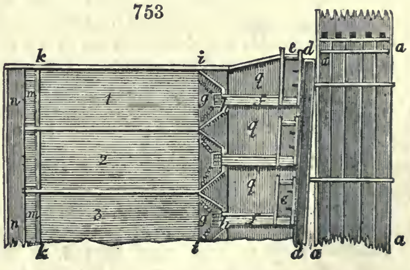


The shaking table shown in *fig.* 752 has the merit of being extremely light, requiring little power, and of performing its work in a highly satisfactory manner. A, table swung by chains, B B', its width being 3 feet and length 12 feet. A greater or less inclination is given to the table by raising or lowering the screws C C'. At the upper end of the table is a buffer, D, which acts against a counter-buffer, E. A sliding bar, F, is also fitted between the table and percussion lever G. This lever is struck by cams fitted on the axis H, driven by the runner J. The slimes to be treated flow into the cistern K, 30 inches long, 13 inches wide, and 18 inches deep. Into this box a tormentor is introduced for the purpose of breaking up the slimes. The bottom is fitted with a launder L, 7 inches long and 5 inches wide. From this launder proceeds a head-board M, expanded to the width of the table, and fitted with buttons, for the purpose of dispersing the slimes equally on the head of the table.

About five tons of rough slime are enriched per day on four tables, whilst from nine to ten tons of enriched slime are despatched in a similar period.

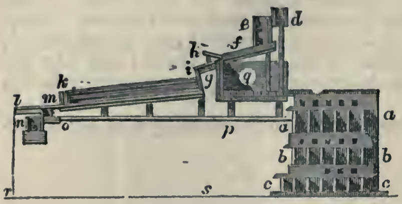
Sleeping Tables.—Figs. 753, 754 represent a set of *sleeping tables. Fig.* 753 is the plan, and *fig.* 754 a vertical section. The ores, reduced to a sand by stamps, pass into a series of launders, *a a*, *b b*, *c c*, which form three successive runs below the level of the floor of the works. The sand taken out of these launders is thrown into the cells *q*; whence they are transferred into the trough *e*, and water is run upon them by turning two stop-cocks for each trough. The sand thus diffused upon each table, runs off with the water by a groove *f*, comes upon a sieve *h*, and spreads itself upon the board *q*, and thence falls upon the sleeping table *i k*. The under surface *k* of this chest, is pierced with holes, which may be stopped at pleasure with wooden plugs. There is a launder *m*, at the lower end of each table to catch the light particles carried off by the water out of the chest *i k*, through the holes properly opened, while the denser parts are deposited upon the bottom of the chest. A general launder *n*, passes across at the foot of the tables *i k*, and receives the refuse of the washing operations.

753



In certain mines of the Hartz, *sweeping tables* are employed. The whole of the process consists in letting flow, over the sloping table, in successive currents, water charged with the ore, which is deposited at a less or greater distance, as also pure water for the purpose of washing the deposited ore, afterwards carried off by means of this operation.

754

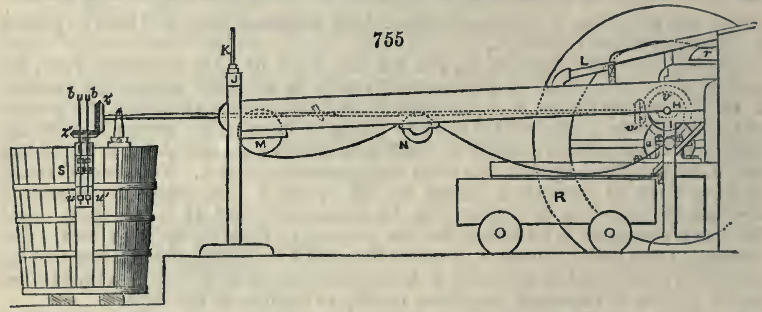


At the upper end of these *sweeping tables*, the matters for washing are agitated in a chest, by a small wheel with vanes, or flap-boards. The launder of the muddy waters opens above a little table or shelf; the launder of pure water, which adjoins the preceding, opens below it. At the lower part of each of these tables, there is a transverse slit, covered by a small flap with hinges, opening outwardly; by falling back towards the foot of the table. The water spreading over the table, may at pleasure be let into this slit, by raising a bit of leather which is nailed to the table, so as to cover the small flap when it is in the shut position; but when this is opened, the piece of leather then hangs down into it. Otherwise the water may be allowed to pass freely above the leather when the flap is closed. The same thing may be done with a similar opening placed above the launder. By means of these two slits, two distinct qualities of slime may be obtained, which are deposited into two distinct canals. The refuse of the operation is turned into another launder, and afterwards into ulterior reservoirs, whence it is lifted out to undergo a new washing.

Brunton's Machine.—This apparatus is adapted for the concentration of ore contained in very fine slimes.

The small water-wheel, shown in *fig.* 755, is sufficient to drive six of these machines, viz. three on each side. Before the stuff is permitted to enter upon the rotating cloth, it is disintegrated, and passed through a sizing trommel; it then flows over the head or dispersing board L, on to the cloth. This cloth rotates towards the stream on two axles, H and M, and is supported by a third roller N. It is also stiffened in its width by numerous laths of wood. Clean water is introduced behind the entrance of the slime, in order to give it the proper consistency. Different degrees of inclination are given to the cloth by raising or lowering the roller M, by means of the screw K. The heavier particles lodged on the cloth are caught in the waggon R, whilst the light matter is floated over the roller M.

755



One revolution of the cloth is made in 4½ minutes; its length is about 29½ feet, so that the speed is 6½ feet per minute. The width of the cloth is 4 feet 2 inches.

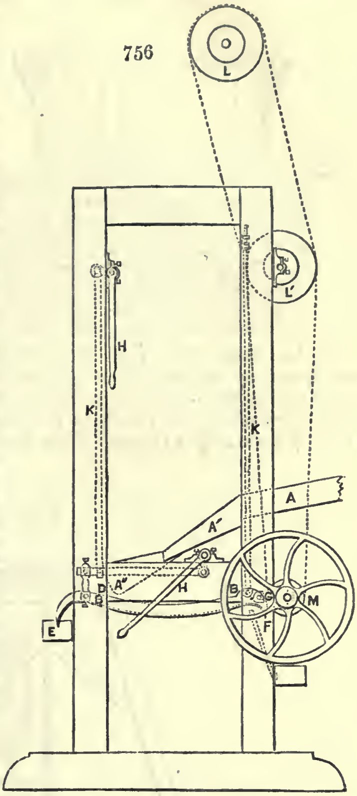
Before the slime comes upon the cloth, it is reduced to a size of $\frac{1}{60}$th of an inch, and yields an average of 1½ per cent. of copper; but by means of this machine the stuff is concentrated so as to afford 5 per cent. In ten hours it will clean 1½ ton. The speed of the cloth must, however, be varied with the condition of the stuff; if it be very poor, the cloth must travel very much slower, since the enrichment requires a longer period of time.

At the end of the machine, and worked by the same water-wheel, is a dolly tub: but the dimensions and mode of working this apparatus are fully stated at page 154.

Bradford's Slime Apparatus, fig. 756, is intended to imitate that of the vanning shovel. The slime enters by the launder A, about 5 inches wide, and descends on the inclined head A′, which expands from the width of the launder to within a few inches of the width of the table frame B. The slime box A″ is perforated at D with numerous holes, each of which is fitted with small regulating pins.

The table B B is 2 feet 2 inches wide, and 2 feet 10 inches long, with bottom formed of sheet copper. It is suspended by the vertical rods K, K, and varying degrees of inclination are given to the table by altering the levers H H. For he purpose of quickening or decreasing the action of the table two cones are employed L L′, upon which the driving band is shifted as may be necessary. A band from a runner, fitted on the axis of the cone L, communicates motion to a pulley wheel M, upon the shaft of which are cranks attached to connecting rods G, giving motion to the table.

756



When the machine is in operation, the ore flows over at F, into the launder baneath it, whilst the waste is carried over the opposite end into the trough E.

Professor B. Silliman and Mr. J. D. Whitney give the following particulars of results results realised by this machine :—

The total weight of ore stuff dressed during 122 days was 11,948,900 lbs. of rock stamped and crushed, or 5,080 tons miners' weight.

The total ore sold from this quantity of stuff was 128 gross tons (2,352 lbs.), or $2\frac{51}{100}$ per cent. of the stuff worked over. By the Captain's vans the average richness of the stamp work (forming much the larger part of what goes to the separators) for 22 weeks was 2·32 per cent. The humid assay of the average work from the stamps for five weeks in July and August gave for the richness of the stuff dressed on the separators 3·28 per cent. of ore, or 0·984 per cent. of metallic copper. There is, therefore, an apparent loss in the tailings of $\frac{77}{100}$ per cent. of 30 per cent. ore, or $\frac{23}{100}$ of copper. The amount of ore, however, lost in the tailings does not exceed $\frac{5}{10}$ to $\frac{6}{10}$ per cent., or about $\frac{15}{100}$ per cent. of copper. The actual products of working, therefore, as may be seen, exceed for the machines the average richness of the Captain's vans.

Of the total ore produced in this time, 181,126 lbs. came from the separators, and 160,858 lbs. from the jiggers. The whole amount of stuff, therefore, required to produced this amount of ore, estimated from the above ratio (1·15 : 1) is 768,680 lbs. This may be taken approximately as the actual quantity which passed over the separators, and if calculated on the Captain's vans, it should have produced 177,961 lbs. of ore, while in fact it did produce 181,126 lbs., or a variation in excess for the machines of only 3,210 lbs. Each of the separators, therefore, dresses about $1\frac{1}{2}$ ton of rock daily, of stuff yielding an average of 2·5 per cent. of 30 per cent. ore.

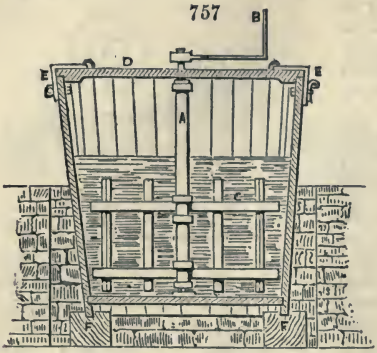
Dolly Tub or Packing Kieve.—This apparatus is employed for the purpose of excluding fine refuse from slime ore, which has been rendered nearly pure by previous mechanical treatment. In using it the workmen proceed thus :—

The kieve *fig.* 757, is filled to a certain height with water, and the dolly A introduced. A couple of men then take hold of the handle B, and turning it rapidly, cause the water to assume a circular motion. The tossing is then commenced by shovelling in the slime until the water is rendered somewhat thick. After continuing the stirring for a short period, the hasps E E are loosed, and the bar D with the dolly are suddenly withdrawn. The tub is then packed by striking its outside with heavy wooden mallets. When this operation is terminated, the water is drawn off through plug-holes in the side of the tub.

The object of the rotatory motion created by the dolly is to scour off clayey or other matter adhering to the ore, whilst the packing hastens the subsidence of the denser portions. In one portion of this kind four distinct strata may be procured, as indicated by the lines *a b*, *c d*, *e f g*, *h* c *k*, in *fig.* 758.

The upper portion, viz., from A to B, will probably have to be set aside for further washing, whilst the slime C should be fit for market. The conical nucleus in the centre of the tub generally consists of coarse sand, and is usually further enriched on a copper bottom sieve, or else submitted to the action of a tye, or other suitable apparatus.

757



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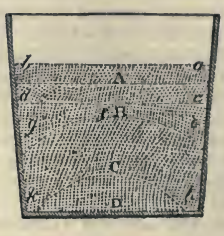
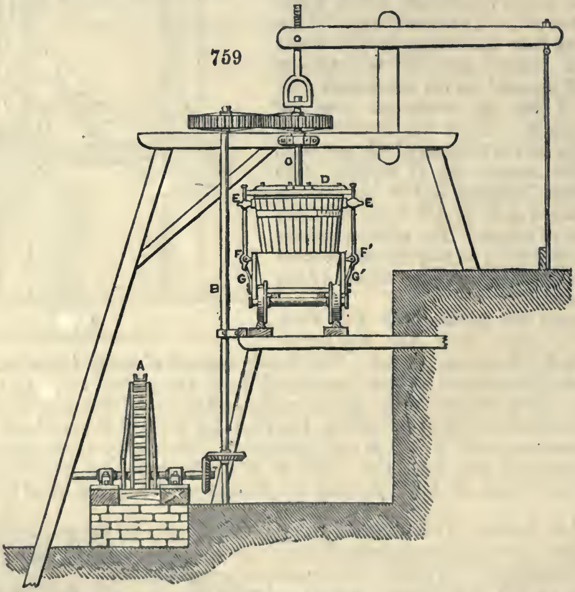


Machine Dolly Tub.—This tub, *fig.* 759, is packed by machinery represented in the accompanying woodcut, in which A is a small water-wheel, working a vertical shaft B, and driving another shaft O. At the bottom of this is fixed a notched wheel D, which presses outwardly the hammers E E; these are mounted upon iron bars F F′, and violently driven upon the side of the kieve by means of springs G G′.

759



The degree to which ore can be concentrated by dollying must evidently depend upon several conditions:—1st. The initial percentage of the ore. 2nd. The condition to which it is reduced. 3rd. The matrix with which it is associated. 4th. The proportion of water employed. And lastly, if the rotation and packing have been judiciously performed. An experiment upon some sand slime lead ore, much intermixed with fine carbonate of iron, gave the following results:—

Introduced into dolly tub, 17 cwts., assayed, 48 per cent.

Time required to introduce stuff	6	minutes.
Dolly rotated	5	,,
Dolly withdrawn—		
Tub packed	5	,,
Running off water	6	,,
Skimming and cleaning out tub	20	,,
Total	42	,,

Top skimmings	4 cwts., assayed	20 per cent.
Second	1¼ „	45 „
Clean ore, middles	5½ „	65 „
„ bottom	4½ „	67½ „
	15¼	
Fine Slime	1¾	
Total	17	

It may be remarked, that none of the various processes of dressing is more satisfactory than that of dollying, since, if carefully conducted, little or no loss of the total quantity of ore can occur.

Vanning is a method commonly practised by the tin-dressers of Cornwall and Devonshire, by which they ascertain approximately the richness and properties of the ore to be treated. If the object be to determine the value of a pile of stuff, it is carefully divided, then sampled, and a portion, say a couple of ounces, given to the vanner. If the stuff thus given should be rough, it is reduced to the tenure of fine sand, and in this state put upon the vanning shovel. The operator now resorts to a cistern or stream of water, and by frequently dipping the shovel into it, and imparting to the shovel when withdrawn a kind of irregular circular motion, he succeeds in getting rid of a greater or less portion of the waste: that which remains on the shovel is then considered equal to dressed work and assayed. So accurately is this operation performed by many of the tinners, that parcels containing only fifteen pounds of tin ore per ton of stuff, are sold by it to the mutual satisfaction of both buyer and seller.

The vanning process is also well adapted for determining the properties of an ore. If, by this method, vein-stuff should withstand concentration, no machinery is likely to dress it. If also the loss of ore is found great, then the apparatus to be employed for effecting the enrichment will have to be carefully considered and constructed.

760

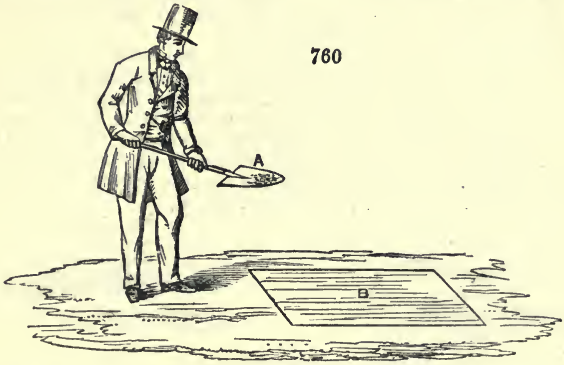


Fig. 760. The vanning shovel A, is 14 inches long, and 13 inches wide at the top, the edge of which is slightly turned up. The shovel is also formed with a hollow or depression. The handle is about 4 feet long. The vanning cistern is shown at B.

Hushing.—It often occurs, that the water employed on the dressing floors makes its escape below the refuse or waste heaps. This may be used for the purpose of hushing, which operation is performed in the following manner. The husher diverts the escape water into a rivulet and introduces a given quantity of waste. He then builds a dam or reservoir, with a door or trap valve at the high end, in order to collect the necessary water for hushing, and puts aside all the large stones lying in the middle of the hush gutter in order to form them into a wall. After this, he starts his hush by lifting the door of the dam, which slides in a wooden frame adapted for that purpose.

This allows the water to rush out, and displaces the waste to a certain depth, at the same time driving it forward.

If the hush has bared or uncovered a further quantity of large stones in the middle of the gutter, they are again removed to one side, since they would retard the force and action of the water. When these impediments are removed, the water is repeatedly discharged from the reservoir until the waste is hushed off the ore, which is found lying in holes, and around earth and fast stones, in the bed of the rivulet. A clay bottom is found to be most favourable for hushing, and the velocity and power of the stream should be proportioned to the size and density of the waste to be treated.

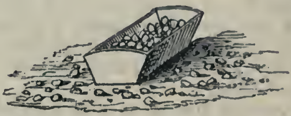
FORWARDING AND LIFTING APPARATUS.

Besides the machinery required for the enrichment of ores, it is a matter of great importance to introduce such auxiliary arrangements as shall not only facilitate actual dressing, but also be in themselves somewhat inexpensive. In this division, as in every other, the means should be strictly adapted to the end, and ought not to bear a cost disproportionate either to the circumstances or prospective advantages of an undertaking.

The shovel, *fig.* 761, usually employed in British mines is of triangular shape, and made of good hammered iron pointed with steel. The dimensions vary, but one of an average size is about 11 inches wide at the top, and 13 inches from the point to the shank, weight 4 pounds, and costs one shilling; to which must be added, five pence for the hilt, or handle. The hilt should be of ash, free from knots and slightly curved.

761

762

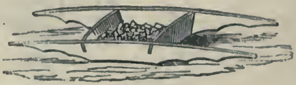


Picking Boxes, fig. 762, are employed for the purpose of collecting the prill and dradge ore from the stuff with which it may be mechanically intermixed. These boxes or trays are handled by children. They are made of deal, 1 inch thick, of the following dimensions: Length, 16 inches; depth, 7 inches; width at bottom, 7 inches; width at top, 10 inches; and cost about 1*s.* 3*d.* each. A ledge of wood to serve as a handle is sometimes nailed to the ends of the box.

Wheel-barrow.—The sides, ends, and bottom, are composed of deal 1¼ inch thick. The ends are mortised to the sides, whilst the bottom is generally fastened by means of nails, and bound with slips of hoop iron at the angles. Hoop iron is also employed to protect the upper edges of the barrow. The wheel is often made of wrought iron, (⅝ round) and 14 inches diameter. Its axes rotate in wrought-iron ears. The extreme length of the sides of a well-proportioned barrow is 60 inches, depth at centre 9 inches; the ends are inclined as shown in the *fig.* 763. The cost of a barrow with wrought-iron wheel complete, will vary from 6*s.* 6*d.* to 7*s.*

763

764



Hand Barrow.—When large quantities of stuff have to be removed from place to place on the surface, and where it would be inconvenient to use the wheel-barrow, a barrow having handles at both ends is employed (*fig.* 764). It is made of deal plank 1¼ inch thick; the length of the sides is 5 feet 6 inches; depth in centre, 9 inches; width, 18 inches at top and 10 inches at bottom; length, 24 inches at top and 18 inches at bottom; cost complete about 4*s.* 6*d.*

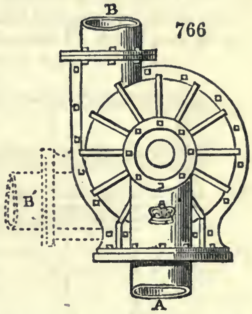
765

Railroads.—The gauge of surface roads varies from 15 inches to 2 feet 6 inches within the rails. Instead of manufactured rails, common flat wrought iron, 2½ inches wide and ½ inch thick, is oftentimes employed. An extremely serviceable rail is formed of a strip of timber 2 inches square, upon which is laid wrought-iron, 1¼ inch wide and ¼ inch thick, fastened by means of nails or screws.

Tram Waggon and Turn-table.—A tram waggon and turn-table is shown *fig.* 765. The waggon built of wrought iron, with cast-iron wheels. The latter are usually 12 inches diameter, with flanges 1 inch deep and tires from 2 to 3 inches wide. The turn table is of cast iron. It does not rotate, but the waggon is easily directed to either line of rail by means of the circular ring: the elliptical loops in advance serving to guide and place the wheels on the rails.

Lifting Apparatus.—It sometimes happens that the surface is nearly level, and affords very little natural fall. In such case the enrichment of ores becomes more expensive from the necessity of shifting some of the various products by manual labour, and of introducing lifting appliances in order to procure the requisite elevations for carrying out the various elaborative processes. It is, moreover, scarcely practicable from the conformation of the ground to form useful reservoirs of water within a reasonable distance; neither does it commonly occur in such cases that a free supply can be obtained for washing.

The pumping engine is therefore required to furnish the requisite quantity of water. This is generally conveyed over the floors by wood launders, often interfering with each other and obstructing the direct circulation of carts, railways, &c. Now if a stand-pipe or pressure column were erected at the engine, and a main judiciously laid throughout the floors, it is obvious that it would not only remedy this evil, but also afford water for the several washing purposes, as well as motive power for common, dash, or other wheels, together with turbines, flap jacks, &c.


766

When an inconsiderable proportion of water has only to be raised to a higher level the common shoe or chain-pump will be found to render effective service; but when a larger stream is requisite it would be better to employ the rotatory pump. This pump, *fig.* 766, has been brought to great perfection by Messrs. Gwynne. A is the suction-pipe, and B the discharge, the dotted lines showing the discharge B, horizontal when required.

Pumps of the following dimensions are stated to raise and discharge per minute for medium lifts, say from 10 to 30 feet high:—

Diameter of discharge-pipe.	Diameter of suction-pipe.	Gallons of water per minute.
1½ inch.	2 inches.	25
3 inches.	4 "	70
4 "	5 "	150
5 "	6 "	300
6 "	7 "	500
7 "	8 "	1400

Stuff consisting of slimes and sand may be readily elevated by means of a Jacob's ladder or the Archimedean screw. For short elevations, combined water and raff wheels may be advantageously employed.

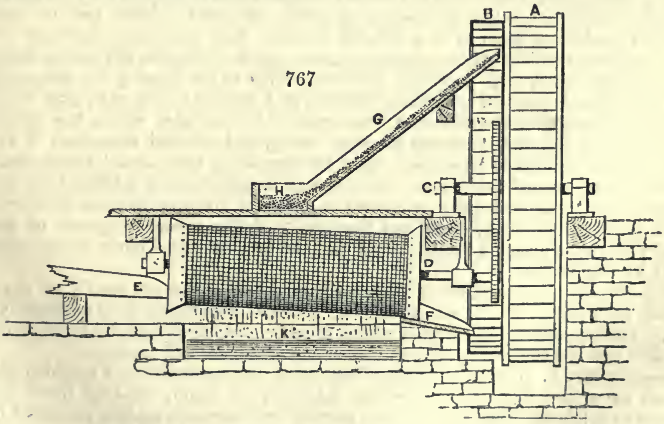
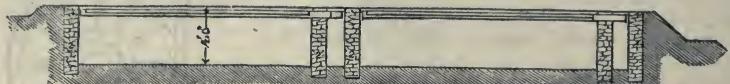

767

Fig. 767, A, water-wheel; B, raff or inverted wheel; C, axis of both raff and water wheels, carrying a tooth driving wheel; D, sizing trommel; E, launder for inlet of stuff; F, discharge launder; G, shoot delivering water and raff to launder H; K, cistern receiving slime from trommel.

Slime Pits.—In the several operations of cleansing ores from mud, in grinding, and washing, where a stream of water is used it is impossible to prevent some of the finely divided portions floating in the water from being carried off with it. *Slime pits* or *labyrinths*, called *buddle holes* in Derbyshire, are employed to collect fine sand and slime at a little distance from the place of agitation.

Settling Pits.—The slime pits shown in section *fig.* 768 and plan *fig.* 769 are constructed on the principle of the Classifier. The viscid water from the jiggers and buddles, takes the direction of the arrows. The stuff deposited in such a system of pits, will gradually vary from a maximum degree of coarseness at the head of the first pit, to the least degree of fineness at the end of the fourth pit. Should the water flowing into the pits be moderately charged with ore, the latter will be found mostly at the narrow ends, and may therefore be readily collected for mechanical enrichment. For the purpose of running off the pits, a side gullet is constructed which is in communication by means of iron slides, one to each pit. The aggregate length of the pits is 40 feet, width 31 feet, width of dividing walls 2 feet, depth of pit 4 feet. The content of each pit is about 400 cubic feet. Settling pits may also be constructed on the principle of the long classifier; the object in this, as well as in the case illustrated, being to effect an uniform distribution and classification of the slimes.

768



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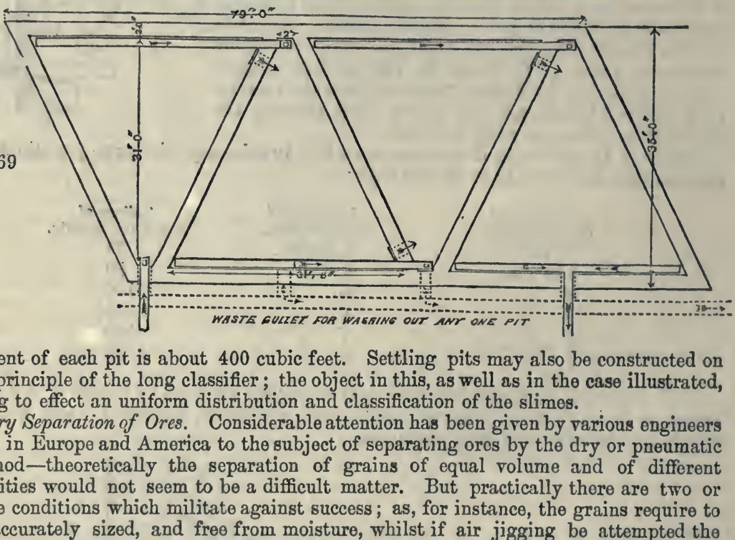

Dry Separation of Ores. Considerable attention has been given by various engineers both in Europe and America to the subject of separating ores by the dry or pneumatic method—theoretically the separation of grains of equal volume and of different densities would not seem to be a difficult matter. But practically there are two or three conditions which militate against success; as, for instance, the grains require to be accurately sized, and free from moisture, whilst if air jigging be attempted the feed to the sieve must be altogether uniform, and the bed such as to offer an equal resistance throughout the whole of its surface. In countries where the climate is both dry and hot, water scarce, carriage heavy, and mineral abundant, it is just probable that pneumatic separation might be resorted to with partial satisfaction. If the ores were crushed and sized, then exposed to the effects of a current of air, the lighter grains would naturally be ejected to a greater distance than the heavier ones; but it may be assumed beforehand that most of the grains composed of gangue and ore would be grouped together, and that the loss on such a mode of concentration would be very heavy.

Magnetic Separation of Ores. When ores and vein-stones are nearly of the same density, their separation by water dressing is almost impracticable or necessarily very slow. Further, the value of such ores is greatly diminished both by the cost of enrichment and the comparatively low percentage of the dressed product.

Recently Mr. F. J. King of London has found that carbonate and sulphide of iron, as well as copper pyrites are rendered magnetic by simply heating these ores in a retort or calciner. Carbonate of iron, parting with carbonic acid, is converted into a magnetic oxide of iron, whilst iron and copper pyrites, each yielding up one atom of sulphur becomes magnetic pyrites. In order to apply this important fact to the treatment of ores, Mr. King has designed a suitable retort and magnetic machine, and separates blende from carbonate of iron, copper pyrites from blende, and any mixture of ores in which one portion can be rendered magnetic, first getting rid of the lighter gangues by water dressing.

Calcining Ores. In Taylor's 'Records of Mining' published in 1829, a description and drawing of Brunton's continuous calciner is given. This apparatus has long been used at various mines in Cornwall for getting rid of arsenic, sulphur and other impurities with which tin-stuff is sometimes associated. The table is about 12 feet diameter, and makes from six to eight revolutions per hour, the stuff being introduced at the centre, and discharged at a point on the periphery of the table. Oxland and Hocking's calciner is now adopted at several mines, and consists of a trommel mounted on carrier wheels, about three feet inside diameter and 32 feet long, with a fall of 1 in 16 or 1 in 24, according to the size and nature of the stuff to be treated. The inside of this trommel is lined with fire-brick, the fire-place being at one end, and a feed-screw at the other. The calcination is performed by the heat generated in the fire-place passing through the cylinder. The cylinder makes from six to eight revolutions per hour. Inside of the cylinder, for about two-thirds of its length from the fire-place, are four longitudinal ledges, as in a mortar mill, for the purpose of turning over the stuff.

The time necessary for passing a charge from the entrance to the exit point in the trommel varies from three to six hours.

From the calciners the stuff is taken to various dressing machines, and sufficiently concentrated for the smelting furnace.

Other continuous calciners are in use, some for the purpose of producing sulphurous vapours to form sulphuric acid, such as Gerstenhöfer and Hasenclever, and which doubtless admit of ready application to the treatment of tin ores.

The machinery requisite for the enrichment of distinct classes of ore cannot well be grouped within the limits of a specification. The quantity of stuff to be disposed of within a given period, the value of the ore, the character of the vein-stone, the difference of density between one substance and another, the price of labour, together with any other direct or collateral feature, must carefully be considered. But in most cases, the machines enumerated in the following list may be successfully applied for the purposes stated:—

Reducing Machinery.

1. Stone-breakers	For reducing to fragments all hard and *non-elastic* stuff, for the cobbing process, crusher, stamps, and disintegrator.
2. Crushing mill	For reducing to grains stuff for the hand-pickers, jiggers, and buddles.
3. Disintegrators	For producing sand for jiggers or buddles.
4. Edge runners, horizontal mills, and pulverizers	For reducing dradge grains for treatment on buddles and tables.
5. Stamps	For reducing stuff for treatment in fine sand jiggers, buddles, or tables.

Washing Apparatus.

1. Kilns	For disintegrating and freeing vein-stone, in order to render it suitable for hand picking, cobbing, stone-breaker and crusher, also partly for the sizing trommels and jiggers.
2. Wash Trommels	Ditto.

Sizing and Classifying Apparatus.

1. Trommels	For sizing stuff, sometimes for hand picking, but chiefly for coarse and fine sand jiggers.
2. Single and divisional classifiers, ascending columns, dividing cones, and pyramidal boxes	For classifying stuff for fine sand jiggers, buddles and tables.

Concentrators.

1. Rotatory separator	For freeing sand from slime, and partly classifying the sand for jiggers or buddles.

2. Jiggers . . .	For getting rid of worthless vein-stuff and increasing the metallic percentage of the resulting product for subsequent treatment.

SEPARATING AND ENRICHING MACHINERY.

1. Rough jiggers . .	For dividing stuff into (1) castaways, (2) orey stuff, (3) ore, the stuff ranging in size from 10 mm. to x.
2. Coarse sand jiggers .	For separating grains from 2 mm. to 10 mm. into (1) waste, (2) orey stuff, (3) ore.
3. Fine sand jiggers .	For separating sand from ¾ mm. to 2 mm. into (1) waste, (2) orey stuff, (3) ore.
4. Slime sand jiggers .	For separating sand from 0 mm. to ¾ mm. into (1) waste, (2) orey stuff, (3) ore.
5. Convex and concave buddles . . .	For separating sand from ¾ mm. to 2 mm. into (1) waste, (2) orey stuff, (3) ore.
6. Side and end blow tables . . .	For separating sand from 0 mm. to ¾ mm. into (1) waste, (2) orey stuff, (3) ore.
7. Brunton and slime tables . . .	For separating sand from 0 mm. to ½ mm. into (1) waste, (2) orey stuff, (3) ore.

General Table relating to Ore Dressing Machines.

	Approximate quantity worked per 10 hours	Approximate horse-power required	Gallons of water required per minute
	cwts.		
Rotating picking table . . .	200	$\frac{1}{20}$	
,, ,, band . . .	150	$\frac{1}{20}$	
Common skimming jigger, coarse stuff	2½ per sectional inch	$\frac{1}{10}$	1½
,, ,, ,, fine ,,	2	$\frac{1}{10}$	1½
Kember's continuous jigger . .	20	$\frac{1}{4}$	15
Continuous coarse sand jigger . .	15	$\frac{1}{4}$	20
,, fine ,, ,, . .	8 to 10	$\frac{1}{4}$	18
,, sand slime ,, . .	5 ,, 6	$\frac{1}{4}$	15
Round buddle	variable	$\frac{1}{10}$	
Concave buddle	variable	$\frac{1}{10}$	
Side blow table	100	$\frac{1}{4}$	14
End ,, ,, ...	100	$\frac{1}{4}$	7
Dead frames			

In the year 1857, Herr Von Sparre, of Eisleben, Prussia, patented four machines for separating substances of different specific gravities, in all of which water is employed, either as a medium through which the said substances fall under the action of gravity, or as an agent for facilitating the motion of portions of the said substances along inclined surfaces. The particulars, together with illustrations, will be found in Patent No. 1405 for the year 1857.

The mechanical preparation of tin and copper ores has from time to time been noticed by several writers. In 1758 Borlase described the method employed in the west of Cornwall. Twenty years later, Price, in his *Mineralogia*, added to Borlase's description, and illustrated some of the apparatus then in use. Afterwards Dr. Boase published, in the second volume of the *Transactions of the Geological Society of Cornwall*, an article upon the dressing of tin in St. Just. In volume four, Mr. W. Jory Henwood inserted a paper on dressing; and some general remarks will be found on the subject in De la Beche's *Report on the Geology of Cornwall*. The enrichment of lead ores has been noticed by Forster, in his *Section of Mineral Strata*; also by Warington W. Smyth, in his memoir *On the Mines of Cardiganshire*, in the second volume of the *Memoirs of the Geological Survey of Great Britain*. In 1858, Mr. James Henderson presented a paper to the Institution of Civil Engineers 'on the Methods generally adopted in Cornwall in Dressing Tin and Copper Ores,' to which we are indebted for some of our illustrations. In the 'Proceedings of Mechanical Engineers, 1873,' will be found valuable papers on the 'Mechanical Appliances for Dressing Tin and Copper Ore,' by Mr. Henry T. Ferguson, and on the 'Tin Stream Works in Restronquet Creek,' by Mr. Charles D. Taylor.

In France, Dufrenoy, Elie de Beaumont, Coste, Perdonnet, Huet and Geyler, and Moissenet have treated on the mechanical enrichment of copper, tin, and lead ores. The latter gentleman has frequently visited this country, and given the results of his observations in a highly interesting memoir, entitled *Préparation du Minéral d'Etain dans le Cornwall*, and also in the *Annales des Mines*, tome ix. 1866. But it is to Germany we must look for an exhaustive literature on the Dressing of Ores, and machinery employed therein. In 1867, 1870, and 1873, Von Rittinger's *Lehrbuch der Aufbereitungskunde* appeared, with an atlas, containing forty-nine plates. In 1872 *Die Aufbereitung*, by M. F. Gaetzschmann, with an atlas of sixty-six plates, was published. In addition Hundt of Siegen, Neuerberg of Kalk, Cologne, Utsch of Iserlohn, Hoffmann of Lohmansfeld, Max Braun of Altenberg, and many others have promoted the science and art of Dressing. In England there are hopeful signs that the subject will be deemed worthy the attention of Mine Engineers. Continuous machinery is in operation at several mines, and its use somewhat extending. In South Australia Hancock has successfully applied himself to the subject of continuous Dressing; while in America the mechanical enrichment of minerals will necessarily command much consideration. Too much attention cannot be given to this section of mining economics; for with the increasing production of ores, especially of ores of low produce, and the ill-adapted machinery oftentimes employed, the loss in concentrating them is an item of most serious moment.

In this paper we have included those machines which have been long employed in our metalliferous mines,—many of them having been proved by experience to be most economical,—together with such of the modern introductions as appear to promise the most advantage, and some suggestions which cannot but be valuable, since the principles involved are founded upon the universal laws of gravitation, as applied to solids and fluids in motion.

It is not essential to describe the dressing routine observable in a particular mine, since it is scarcely possible to observe the same system in any two distinct concerns. In the various modes of treatment, however, it may be remarked that the two leading features will always be *reduction* to a proper size and *separation* of the ore from the refuse. Until the vein-stuff arrives at the crusher or stamps, the labour is chiefly one of picking and selecting; but from these machines usually commence a long series of divisions, subdivisions, selections, and rejections. To follow these out in their various ramifications would not only exceed the limits of this paper, but would perhaps be misunderstood by those not intimately acquainted with the subject.—J. D.

DRUGGET is a coarse, but rather slight, woollen fabric, used for covering carpets, and as an article of clothing by females of the poorer classes.

The manufacture of druggets of various kinds has been of late years considerably improved; and carpets, many of them handsomely figured, are now found in common use.

DRUID-STONES. Masses of quartzose rock scattered as loose blocks over the Chalk downs in the south of England, and known variously as Druid-stones, Sarsen-stones, and Greyweathers.

DRUSE. *A mineralogical term*, signifying a hollow space in veins of ore or in rocks, which is lined with crystals. A *drusy* cavity is one covered with crystals.

DRY BONE. A term sometimes applied by American miners to calamine or carbonate of zinc.

DRY GRINDING. The practice of employing dry stones has been long adopted for the purpose of quickening the processes of sharpening and polishing steel goods. The dry dust from the sand-stone, mixed with the fine particles of steel, being inhaled by the workmen, produces diseases of the pulmonary organs to such an extent, that needle and fork grinders are reported rarely to live beyond the ages of twenty-five or thirty.

Mr. Abraham, of Sheffield, first invented magnetic guards, which, being placed close to the grindstone, attracted the particles of steel, and thus protected the men from their influences. Still they suffered from the effects of the fine sand-dust, and the grinders heedlessly abandoned the use of them altogether.

Mr. Abraham devised another plan, which is employed, although only partially, in the Sheffield works. The grindstone is enclosed in a wooden case, which only exposes a portion of the edge of the stone; a horizontal tube proceeds at a tangent from the upper surface of the circle to the external atmosphere. The current of air generated by the stone in rapid revolution, escaping through the tube, carries off with it nearly all the dust arising from the process. It is curious to find so simple a contrivance frequently rejected by the workmen, notwithstanding that sad experience teaches them, that they are thereby exposing themselves to the influences of an atmosphere which produces slowly but surely their dissolution.

DRYING OILS. When oils, especially linseed and nut oils, are boiled with litharge or oxide of lead, they acquire the property of solidifying or *drying* quickly on exposure to the atmosphere. These are very useful to the painter, as without them the pigments with which they are mixed would remain soft. The oxide of lead appears to establish a state of more easy oxidation in the oils, so that they assume readily the conditions of a resin.

DRY ROT. This kind of decay in wood is ascribed to the attacks of fungi, especially to *Polyporus hybridus* and *Thelephora puteana.* There is no doubt that, by the formation of fungus, rot or decay may be commenced, and continued to a certain extent; but there are numerous cases where rot is due to an entirely different cause—a spontaneous decomposition.

Dry rot differs but little in the causes producing it, or in the result, from WET ROT. They are both alike the effect of the conversion of the carbon of wood into carbonic acid, and its hydrogen into water. The process is again the same as that by which wood is converted into humus, and into brown-coal. Mayer gives the analysis of oak wood, and of humus produced from it, as follows:—

	Oak wood.	Humus.
Carbon	52·53	48·32
Hydrogen	5·27	4·57
Oxygen	42·20	36·58

In this change, 7·73 per cent. of carbonic acid and 2·8 per cent. of carburetted hydrogen are disengaged.

The examination of the decay of wood, and its conversion into the brown powder (humus) which marks rottenness, shows that the change is almost entirely dependent on the absorption of oxygen. The decrease in the volume of wood during its decay is difficult to account for, unless we suppose, which is probable, that as much escapes in the form of carburetted hydrogen as there does of carbonic acid and water.

Hollow trees are sometimes met with, whose wood is entirely decayed away, nothing being left but the bark, and a quantity of pulverulent wood, which is altogether disproportionate to the hollow space. In most cases, likewise, the cavity extends so far below the lateral opening in the trunk that we cannot suppose the decayed wood to have been washed away by rain, at least, not during the last stages of the change. It is, therefore, very desirable that continued careful observations should be made with regard to this point. On the other hand, the slight loss of substance by the wood during the first stages of its decomposition, explains why the alteration of wooden piles under water appears to have taken place without any diminution of volume. If, indeed, besides this, inorganic substances—for instance, silica—should be introduced into the place of the organic constituents separated, it would not be difficult to account for the increased firmness and density presented by wood which has remained for some time under water. It has been seen that the conversion of ligneous fibre into a pulverulent substance, and into humus, admits of adequate explanation by means of the three cases mentioned above, and, what is especially important, that it may be supposed to take place independently of external oxygen. The formation of carbonic acid is, then, during the first stages of the decomposition, either extremely small or altogether wanting. The change commences with the separation of oxygen and hydrogen in the form of water, and the separation of oxygen and carbon, as carbonic acid, does not commence until a later period. It is, likewise, probable, that at a still later period carbon and hydrogen are separated in the form of carburetted hydrogen.

The remedy for dry rot is the use of such substances as will, when penetrating the wood, combine with its albuminous matter, and solidify it. Hence corrosive sublimate, sulphate of copper, and arsenic acid have been found to be excellent preservatives. Where they can be applied, nitric acid and sulphuric acid are very advantageous, especially where the growth of fungi is the cause of rot, or when vegetation has followed the decomposition, as it not unfrequently does. See WOOD PRESERVING.

DUALINE. A sawdust gunpowder impregnated with nitroglycerine. It resembles dynamite in most respects, but is not equal to it. See DYNAMITE; EXPLOSIVE COMPOUNDS.

DUCK. (*Duk*, a cloth, Swedish; *Tuch*, Ger.) A coarse cloth, a light sort of canvas. It is used for common articles of apparel, for small sails, and the like.

DUCTILITY (*Streckbarkeit*, Ger.) is the property of being drawn out in length without breaking, possessed in a pre-eminent degree by gold and silver, as also by many other metals, by glass in the liquid state, and by many semifluid, resinous, and gummy substances. The spider and the silkworm exhibit the finest natural exercise of ductility upon the peculiar viscid secretions from which they spin their threads. When a body can be readily extended in all directions under the hammer, it is said to be malleable, and when into fillets under the rolling press, it is said to be laminable.

There appears to be therefore a real difference between ductility and malleability; for the metals which draw into the finest wire are not those which afford the thinnest leaves under the hammer or in the rolling press. Of this fact iron affords a good illustration. Among the metals permanent in the air, 17 are ductile and 16 are brittle. But the most ductile cannot be wire-drawn or laminated to any considerable extent without being annealed from time to time during the progress of the extension, or rather the sliding of the particles alongside of each other, so as to loosen their lateral cohesion. See MALLEABILITY.

Table of the Ductility and Malleability of Metals.

Ductile and malleable metals in alphabetical order	Brittle metals in alphabetical order	Metals in the order of their wire-drawing ductility	Metals in the order of their laminable ductility
Cadmium	Antimony	Gold	Gold
Copper	Arsenic	Silver	Silver
Gold	Bismuth	Platinum	Copper
Iron	Cerium	Iron	Tin
Iridium	Chromium	Copper	Platinum
Lead	Cobalt	Zinc	Lead
Magnesium	Columbium	Tin	Zinc
Mercury	Iridium	Lead	Iron
Nickel	Manganese	Nickel	Nickel
Osmium	Molybdenum	Palladium	Palladium
Palladium	Osmium	Cadmium	Cadmium
Platinum	Rhodium		
Potassium	Tellurium		
Silver	Titanium		
Sodium	Tungsten		
Tin	Uranium		
Zinc			

DULSE. The *Rhodymenia palmata.* See ALGÆ.

DUNES. Low hills of blown sand, which are seen on the coasts of Cheshire and Cornwall, in this country, and also in many places skirting the shores of Holland and Spain.

DUNGING, in calico-printing, is the application of a bath of cow-dung, diffused through hot water, to cotton goods in a particular stage of the manufacture. Dunging and scouring are commonly alternated, and are two of the most important steps in the process. See CALICO-PRINTING.

DUNSTONE. Magnesian limestones of a dun colour, occurring near Matlock in Derbyshire.

DUTCH FOIL, LEAF, or **METAL.** A composition of copper and zinc, or of beaten bronze or of copper leaf. See ALLOYS; BRASS; and BRONZE POWDERS.

DUTCH LIQUID. A name given to an oily substance produced by the action of chlorine on olefiant gas. It was discovered at the close of the last century by an association of Dutch chemists.

DUTCH RUSH. *Equisetum hyemale.* This rush is known also as the *Large branchless Horse-tail.* The dried stems are much employed for polishing wood and metal. For this purpose they are generally imported from Holland.

DYEING (*Teinture,* Fr.; *Färberei,* Ger.) is the art of imparting to and fixing upon wool, silk, cotton, linen, hair, and skins any colour, with sufficient tenacity not to be removed by water or the ordinary usage to which these fibrous bodies are exposed when worked up into articles of raiment or furniture. We shall here consider the general principles of the art, referring, for the particular dyes and the manner of treating the stuffs to be dyed, to the different tinctorial substances in their alphabetical order.

Dyeing, although altogether a chemical process, and requiring for its correct explanation an acquaintance with the properties of the elementary bodies, and the laws which regulate their combination, has been practised from the most ancient times, long before any just views were entertained of the nature of the changes that took place; and it is still practised by many who know very little of chemical science: indeed, like many of the other chemical arts, its practice is often in advance of the science by which its principles are explainable. The art no doubt originated in that love of distinction inherent in the human mind, inducing man, for its gratification, to stain his dress or his skin with the gaudy colours of the vegetable kingdom. The earliest historical record speaks of coloured garments being worn as marks of distinction for offices both political and religious, and also as marks of favour. Jacob gave his favourite son Joseph a coat of many colours, and Moses speaks of a raiment dyed blue, and purple, and scarlet, and of sheepskins dyed red, circumstances which indicate no small degree of tinctorial skill. He enjoins purple stuff for the works of the Tabernacle and the vestments of the high priests.

In the article Calico-Printing it has been shown, from Pliny, that the ancient Egyptians cultivated the art of dyeing with some degree of scientific precision, since they knew the use of mordants, or those substances which, though they impart no colour themselves, yet enable white robes (*candida vela*) to absorb colouring drugs (*colorem sorbentibus medicamentis*).

Tyre, however, was the nation of antiquity which made dyeing one of its chief occupations and a staple of its commerce, and it is asserted by all writers upon the subject, that the invention of the celebrated purple dye, known as the Tyrian purple was made in that city, and the king of Phœnicia, being so captivated with the colour, it is stated that he made it one of his principal ornaments, and it became afterwards, and continued to be for many centuries, a badge of royalty.

The discovery of the purple dye is said to have been made 1,500 years before the Christian era. It must have met with a very early and general appreciation, and rapid commercial progress, as we find that, nine years after the above date, the Children of Israel, an enslaved people, on their leaving Egypt, had in their possession large quantities of this dye; it was extensively used by them, a short time after, for the furniture of the tabernacle and the vestments of the priests; and in after years this dye was always named amongst the valuable spoils of war. That it was the dress of royalty at a very early period, is indicated by the mention, amongst the spoils of the Midians collected by the Israelites, of the purple garments worn by their kings.

The juice employed for communicating this dye was obtained from two different kinds of shell-fish, described by Pliny under the names of *Purpura* and *Buccinum*; being extracted from a small vessel, or sac, in their throats, to the amount of only one drop from each animal. A darker and inferior colour was also procured by crushing the whole substance of the buccinum. A certain quantity of the juice collected from a vast number of shells being treated with sea-salt, was allowed to ripen for three days; after which it was diluted with five times its bulk of water, kept at a moderate heat for six days more, occasionally skimmed to separate the animal membranes, and when thus clarified was applied directly as a dye to white wool, previously prepared for this purpose by the action of lime-water, or of a species of lichen called *Fucus*. Two operations were requisite to communicate the finest Tyrian purple: the first consisted in plunging the wool into the juice of the purpura; the second, into that of the buccinum. Fifty drachms of wool required one hundred of the former liquor, and two hundred of the latter. Sometimes a preliminary tint was given with coccus, the 'kermes' of the present day, and the cloth received merely a finish from the precious animal juice. The colours, through probably not nearly so brilliant as those producible by our cochineal, seem to have been very durable, for Plutarch says, in his 'Life of Alexander' (chap. 36), that the Greeks found in the treasury of the king of Persia a large quantity of purple cloth, which was as beautiful as at first, though it was 190 years old.

The quantity of purple, said to be found by Alexander in the treasury of the king of Persia, is differently stated:—1st, as *amounting* to 5,000 talents; 2nd, as being of the *value* of 5,000 talents; 3rd, as weighing 5,000 quintals. Besides these discrepant statements, it is not clear whether these values or weights refer to cloth dyed or to the dye-drug, although it would be an important fact to know that the dye could be thus preserved for a length of time. Horace celebrates the Laconian dye in the following lines:—

> Nec Laconicas mihi
> Trahunt honestæ purpuras clientæ;

which have been translated as—

> 'No honourable lady dependents
> Spin Laconian purple for my use.'

Notwithstanding its almost universal use in more ancient times, it gradually declined, so that, either from the difficulty of collecting the dye, or the tedious complication of the dyeing process, so expensive was it that, about the commencement of the Christian era, one pound of the purple wool of Tyre cost, in Rome, about thirty pounds of our money.

Notwithstanding this enormous price, such was the wealth accumulated in that capital, that many of its leading citizens decorated themselves in purple attire, till the emperors arrogated to themselves the privilege of wearing purple, and prohibited its use to every other person. This prohibition operated so much to discourage this curious art as eventually to occasion its extinction, first in the Western and then in the

Eastern empire, where, however, it existed in certain imperial manufactories till the eleventh century.

Gage, Cole, Plumier, Réaumur, and Duhamel have severally made researches concerning the colouring juices of shell-fish caught on various shores of the ocean, and have succeeded in forming a purple dye, but they found it much inferior to that furnished by other means. The juice of the buccinum is at first white; it becomes by exposure to air of a yellowish green bordering on blue; it afterwards reddens, and finally changes to a deep purple of considerable vivacity. These circumstances coincide with the minute description of the manner of catching the purple-dye shell-fish which we possess in the work of an eye-witness, Eudocia Macrembolitissa, daughter of the Emperor Constantine VIII., who lived in the eleventh century.

The beautiful purple dye, which is now extracted from guano, is probably closely allied, both in property and appearance, to the Tyrian purple.

Dyeing seems to have been little cultivated in ancient Greece. The people of Athens generally wore woollen dresses of the natural colour: a circumstance forming a peculiarity in that nation, composed of a people who were such lovers of art.

The Romans appear to have bestowed some care upon the art of dyeing. In the games of the circus parties were distinguished by colours. Four of these are described by Pliny: the green, the orange, the grey, and the white. The following ingredients were used by their dyers:—A crude native alum mixed with copperas, copperas itself, blue vitriol, alkanet, lichen rocellus or archil, broom, madder, woad, nut-galls, the seeds of pomegranate and of an Egyptian acacia.

In Europe the progress of dyeing, as of all other arts, was completely stopped for a considerable time by war and invasion, and did not revive till about the beginning of the thirteenth century, and then so rapidly did its progress extend in some localities, that, towards the beginning of the fourteenth century, there were no less than two hundred dyeing establishments in Florence. At the same time the Italians and Venetians also prosecuted the art of dyeing to a large extent.

The art of printing proved for dyeing, as well as for other arts, its great pioneer and propagator. In the middle of the sixteenth century, Plictho's 'Art of Dyeing' was printed, which gave general instructions for dyeing all kinds of fabrics, and laid the foundation for that improvement of this art, which soon after followed throughout Germany, France, and England.

In the East, the art of dyeing did not experience that decline which passed over all the arts of Europe; hence the beautiful dyes of India maintained their high character: and, to this day these dyes are produced by processes differing little from those practised in the days of Pliny.[1]

The discovery and opening of America to commercial enterprise formed an era in the history of the art of dyeing, as from that country were introduced a variety of new dye-drugs, such as logwood, brazilwood, quercitron, cochineal, annotta, &c., which, with the discovery of the use of tin as a mordant about the same time, gave the dyer a facility and power of producing such a variety of tints, and of such a depth, durability, and lustre, that it is now difficult to conceive possible to have been produced in former times.

About the same time was discovered the art of using indigo as a dye, which it is believed the ancients only knew as a pigment. The introduction of this dye-drug into this country met with strong opposition; concerning which a writer in the 'Penny Cyclopædia' says:—

'Indigo, the innoxious and beautiful product of an interesting tribe of tropical plants, which is adapted to form the most useful and substantial of all dyes, was actually denounced as a dangerous drug, and forbidden to be used, by our Parliament in the reign of Queen Elizabeth. An act was passed authorising searchers to burn both it and logwood in every dye-house where they could be found. This act remained in full force till the time of Charles II., that is, for a great part of a century. A foreigner might have supposed that the legislators of England entertained such an affection for their native woad, with which their naked sires used to dye their skins in the old times, that they would allow no outlandish drug to come in competition with it. A most instructive book might be written illustrative of the evils inflicted upon arts, manufactures, and commerce, in consequence of the ignorance of the legislature.'

More recently another class of dye-drugs have been introduced, and have superseded some of those of the former century; these are bichromate of potash, red and yellow prussiate of potash, manganese, catechu, arsenic, &c.

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[1] In India was discovered the mode of dyeing Turkey red, which is the most durable dye known, as well as the richest tint that can be produced on cotton. It was introduced into France and England about the middle of last century, and is still carried on and practised with much perfection.

Colours are not, properly speaking, material; they are impressions which we receive from the rays of light reflected, in a decomposed state, by the surfaces of bodies. It is well known that a white sunbeam consists of an indeterminate number of differently-coloured rays, which, being separated by the refractive force of a glass prism, form the solar spectrum, an image divided by Newton into seven sorts of rays: the red, orange, yellow, green, blue, indigo, and violet. Hence, when an opaque body appears coloured, for example, red, we say that it reflects the red rays only, or in greatest abundance, mixed with more or less of the white beam, which has escaped decomposition. According to this manner of viewing the colouring principle, the art of dyeing consists in fixing upon stuffs, by means of corpuscular attraction, substances which act upon light in a different manner from the surfaces of the stuffs themselves. The dyer ought, therefore, to be familiar with two principles of optics; the first relatively to the mixture of colours, and the second to their simultaneous contrast.

Whenever the different coloured rays, which have been separated by the prism, are totally reunited, they reproduce white light. It is evident, that in this composition of light, if some rays were left out, or if the coloured rays be not in a certain proportion, we should not have white light, but light of a certain colour. For example: If we separate the red rays from the light decomposed by a prism, the remaining coloured rays will form by their combination a peculiar bluish green. If we separate in like manner the orange rays, the remaining coloured rays will form by their combination a blue colour. If we separate from the decomposed prismatic light the rays of greenish yellow, the remaining coloured rays will form a violet. And if we separate the rays of yellow bordering on orange, the remaining coloured rays will form by their union an indigo colour.

Thus we see that every coloured light has such a relation with another coloured light that, by uniting the first with the second, we reproduce white light; a relation which we express by saying that the one is the complement of the other. In this sense, red is the complementary colour of bluish green; orange, of blue; greenish yellow, of violet; and orange yellow, of indigo. If we mix the yellow ray with the red, we produce orange; the blue ray with the yellow, we produce a neutral tint; and the blue with the red, we produce violet or indigo, according as there is more or less red relatively to the blue. But these tints are distinguishable from the orange, green, indigo, and violet of the solar spectrum, because when viewed through the prism they are reduced to their elementary component colours.

If the dyer tries to realise the preceding results by the mixture of dyes, he will succeed only with a certain number of them. Thus, with red and yellow he can make orange; with blue and yellow, green; with blue and red, indigo or violet. These facts, the results of practice, have led him to the conclusion that there are only three primitive colours: the red, yellow, and blue. If he attempts to make a white, by applying red, yellow, and blue dyes in certain quantities to a white stuff, in imitation of the philosopher's experiment on the synthesis of the sunbeam, far from succeeding, he will deviate still further from his purpose, and the stuff will by these dyes become coloured of a depth varying according to the quality of the stuff used; until a full black is produced. Nevertheless, the principle is applicable, and in many cases adopted in practice by blending the yellow, red, and blue rays in order to produce or improve an otherwise imperfect white. When a little ultramarine, cobalt blue, prussian blue, or indigo is applied to bleached goods with the view of giving them the best possible white, if only a certain proportion be used, the goods will appear whiter after this addition than before it. In this case the violet blue forms with the brown yellow of the goods a mixture tending to white, or less coloured than the yellow of the goods and the blue separately were. For the same reason a mixture of prussian blue and cochineal pink, or archil and cudbear, is used for whitening of silks in preference to a pure blue, for on examining closely the colour of the silk to be neutralised, it was found by the relations of the complementary colours, that the violet was more suitable than the pure blue alone. The dyer should know, that when he applies several different colouring matters to stuff, as yellow and blue separately, they will appear green, not because the colouring matters have combined, but because the eye cannot distinguish the points which reflect the yellow from those which reflect the blue, and it is this want of distinction that produces the combined colour. With such a dye the colour will appear of different tints, the blue or yellow prevailing according to the position in which it is placed to the eye, whether seen by reflected or transmitted light, but when the dye applied to the stuff is in chemical union, producing a green, such as arsenite of copper, the yellow and blue rays cannot be thus distinguished. Other instances of mixed colours will be seen by examining certain grey substances, such as hairs, feathers, &c. with the microscope, by which it is seen grey colour results from black points disseminated over a colourless or slightly-coloured surface. The microscope may be thus usefully applied by the dyer to distinguish whether a colour be the result of a mixed or a combined dye.

The dyer should also be acquainted with the law of the simultaneous contrast of colours. When the eye views two colours close alongside of each other, it sees them differing most, in the height of their tone, when the two are not equally pale or full-bodied. They appear most different, when the complementary of the one of them is added to the colour of the other. Thus, put a green alongside of an orange, the red colour complementary of green being added to the orange, will make it appear redder. And in like manner, the blue complementary of orange being added to the green, will make it appear more intensely blue.

It is not sufficient to place complementary colours side by side to produce harmony of colour, the respective intensities having a most decided influence; thus, pink and light green agree, red and dark green also; but light green and dark red, pink and dark green do not; therefore, to obtain the maximum of effect and perfect harmony, the following colours must be placed side by side, taking into account their exact intensity and tint:—

Primitive Colours	Secondary Colours	
Red . . .	. Green	. Light blue; Yellow; Red
Blue . . .	. Orange	. Red; Yellow; Blue
Yellow orange .	. Indigo	. Blue; Red; Yellow
Greenish yellow	. Violet	. Red; Blue; Yellow
Black . . .	. White	. Yellow; Blue; Red

The mixed contrast gives the reason why a brilliant colour should never be looked at for any length of time, if its true tint or brilliancy is to be appreciated; for if a person looks, for example, at a piece of red cloth for a few minutes, green, its complementary colour is generated in the eye, and adding itself to a portion of the red, produces black, which tarnishes the beauty of the red. This contrast explains why the shade of a colour, may be modified, either favourably or otherwise, according to the colour which the eye has previously looked at. An example of the first instance is noticed, when the eye first looks to a yellow substance, and then to a purple one; and as exemplifying the second case looking at a blue and then at a purple.

The relations of dyeing with the principles of chemistry constitute the theory of the art, properly speaking; this theory has for its basis the knowledge—

1st. Of the nature and properties of the bodies which dyeing processes bring into contact.

2nd. Of the circumstances in which these bodies are brought together, facilitating or retarding their action.

3rd. The phenomena which appear during their action; and,

4th. Properties of the coloured combinations which are produced.

The first of these generalities embraces a knowledge of the preparations which stuff necessarily undergoes previous to dyeing, and also the preparations of the dye-drug before bringing it into contact with the stuff.

The operations to which stuffs are subjected before dyeing, are intended to separate from them any foreign matters which may have become attached, or are naturally inherent in the stuff. The former are such as have been added in the spinning, weaving, or other manipulations of the manufacture, and are all removed by steeping in an alkaline lye and washing. The second are the natural yellow colouring substances which coat some of the various fibres, both vegetable and animal; and the chlorophylle, or leaf-green of vegetables. The removal of these is generally effected by boiling in soap and alkaline lyes. A weak bath of soda, in which the stuff is allowed to steep for some time, and then washed in water, is generally the only preparation required for wool, in order that it may take on a uniform dye.

To remove the gummy or resinous matter from silk, it requires boiling in soap-lye; however, its removal is not essential to the stuff combining with the dye, as silk is often dyed while the gum remains in it, in which case it is only rinsed in soap-lye at a very moderate heat, to remove any foreign matters imbibed in the process of manufacture.

Vegetable fibre, as cotton, has such natural resinous matters that retard the reception of the dye removed by boiling, either with or without alkaline lyes; but the natural dun colour of the fibre is not removed, which from the laws of light and colour already referred to, would interfere with the production of bright light tints; under these circumstances, the natural colour of the fibre has to be previously removed by bleaching: for which see the article, Bleaching.

The necessary preparation of the dye-drugs within the province of the dyer, is to obtain the colour in a state of solution, so as to allow the fibre to absorb it, and to produce chemical combination, or to get the dye or colour in such a minute state of division as it will penetrate or enter into the fibre of the stuff. These preparations embrace the formation of decoctions, extracts, and solutions, and also in some cases of precipitation, previous to immersing the stuff into the bath. Stuffs, chemically considered, have but a feeble attraction for other matters, so as to combine with them chemically; still that they do possess certain attractions is evident from various phenomena observed in the dyeing processes, and that this attraction is possessed with different degrees of intensity by the different fibres, is also evident from the ease and permanence that woollen stuff will take up and retain dyes compared with cotton; and also, that certain dyes are retained and fixed within or upon one kind of fibre and not at all in another. This may be determined by plunging the dry stuff into solutions of the salts, and determining the density of the solution before the immersion and after withdrawing the stuff. Wool abstracts alum from its solution, but it gives it all out again to boiling water. The sulphates of iron, copper, and zinc resemble alum in this respect. Silk steeped for some time in a solution of protosulphate of iron, abstracts the oxide, and gets thereby dyed, and leaves the solution acidulous. Cotton in nitrate of iron produces the same effect. Wool put in contact with cream of tartar, decomposes a portion of it; it absorbs the acid within its pores, and leaves a neutral salt in solution in the liquor. Cotton produces no such effect with tartar, showing by these different effects that there are certain attractions between the stuff and dyes. This attraction, however, may be more what is termed a catalytic influence, the fibres of the stuff producing a chemical action with the salt or dye, with which it is in contact. This attraction or affinity of the fibre for the dye-drug, does not produce a very extensive effect in the processes of dyeing. More probably the power of imbibing and retaining colours possessed by the fibre is more dependent upon a mechanical than a chemical influence.

All dye-drugs must in the first instance be brought into a state of solution, in order that the dye may be imbibed by the fibre; but if the fibre exerts no attraction for the colour so as to retain it, it is evident that so long as it remains capable of dissolving in water, the stuffs being brought into contact with water, will soon lose their colour. A colour thus formed does not constitute a dye, however strongly stained the stuffs may appear to be, in or out of the dyeing solution; in order to form a dye, the colour must be fixed upon or within the stuff, in a condition insoluble in water. Hence the mere immersion of the stuff into a solution of a colour will not constitute a dye, except where the stuff really has an attraction for the colour and retains it, or causes a decomposition by which an insoluble compound is fixed upon it, such as is referred to by putting stuffs into solutions of iron. The abstraction of the colour from a solution by the immersion of the stuff, is often the result of a mechanical attraction possessed by porous substances, enabling them to absorb or imbibe certain colouring matters from solutions that are held by a weak attraction by their solvents. On this principle, a decoction of cochineal, logwood, brazil-wood, or a solution of sulphate of indigo, by digestion with powdered bone-black, lose their colour, in consequence of the colouring particles combining by a kind of capillary attraction with the porous carbon, without undergoing any change. The same thing happens when well-scoured wool is steeped in such coloured liquids; and the colour which the wool assumes by its attraction for the dye, is, with regard to most of the above coloured solutions, but feeble and fugitive, since the dye may be again abstracted by copious washing with simple water, whose attractive force therefore overcomes that of the wool. The aid of a high temperature, indeed, is requisite for the abstraction of the colour from the wool and the bone-black, probably by enlarging the size of the pores, and increasing the solvent power of the water.

Those dyes, whose colouring matter is of the nature of extractive, form a faster combination with stuffs. Thus the yellow, fawn, and brown dyes, which contain tannin and extractive, become oxygenated by contact of air, and insoluble in water; by which means they can impart a durable dye. When wool is impregnated with decoctions of that kind, its pores get charged by capillarity, and when the liquid becomes oxygenated, they remain filled with a colour now become insoluble in water. The fixation of iron oxide and several other bases also depends on the same change within the pores or fibre; hence all salts that have a tendency to pass readily into the basic state are peculiarly adapted to act as a medium for fixing dyes; however, this property is not essential.

In order to impart to the stuffs the power of fixing the colour in an insoluble form upon it, recourse is had to other substances, which will combine with the soluble and form with it an insoluble colour; and it is not necessary that this new substance should have an attraction for the stuff, or be capable of passing into a basic form, any more than the original colour, but it is necessary that it be rendered insoluble while in contact with the stuff.

Such substances, used to unite the colour with the stuff, have been termed *mordants*; it appeared that they had a mutual attraction for the stuff and colour, and combining with the stuff first, they afterwards took up the colour; but this is only so in some instances. A few examples will illustrate the action of these mordants. If a piece of cotton stuff is put into a decoction of logwood, it will get stained of a depth according to the colour of the solution, but this stain or colour may be washed from the cotton by putting it into pure water, the colour being soluble. If another piece of cotton stuff be put into a solution of protosulphate of iron, and then washed from this, a portion of the iron will have undergone oxidation, and left the acid, and become fixed upon the fibre and insoluble in water. Whether this oxidation is the result of an influence of the stuff, or the effect of the oxygen of the air and water in which the goods are exposed, it does not now matter; this fixed oxide, however, constitutes an example of a mordant, by its combining with the stuff. If this stuff is now put into a decoction of logwood, the colouring matter of the logwood will combine with the oxide of iron fixed upon the fibre, and form an insoluble colour, which after washing will not remove from the stuff. If, instead of washing the stuff from the sulphate-of-iron solution in water, it be passed through an alkaline lye of soda or potash, the acid holding the iron in solution is taken hold of by the alkali, and removed. The oxide of iron is thus left upon the stuff in a much larger quantity than in the former case, and as firmly fixed, although not by any attraction between it and the fibre, but simply by being left within it. And this stuff being now put into the logwood liquor, will form a dye of a depth according to the quantity of iron thus fixed upon the stuff, and equally permanent with that which had been fixed on the stuff by the oxidation in working.

Such then are the methods of fixing within the stuff insoluble colours from soluble compounds, and from these remarks the necessity of having the dye in solution will also be evident.

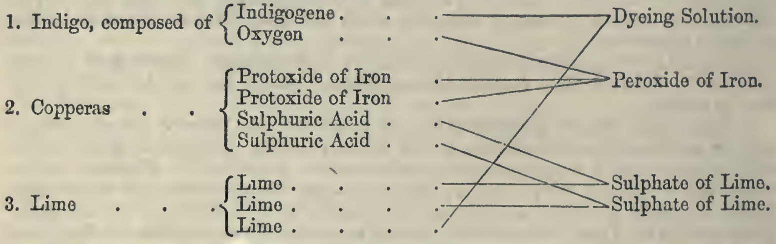
Suppose again that the sulphate of iron be mixed with the logwood decoction, there will be produced the same colour or dye as an insoluble precipitate: if the cotton stuff is put into this, no colour worthy of the name of a dye will be obtained, as the cotton will not imbibe within its fibre this precipitate. Place woollen stuff in the same liquid, and there is formed a very good dye, the woollen fibre having imbibed a great portion of the solid precipitate, probably owing to woollen fibres being much larger than those of cotton. Thus, with cotton and other stuff that will not imbibe freely solid precipitates, the mordant must be fixed within the fibre previously to applying the colouring substances, such as the vegetable decoctions. It will also be seen that the dye which is the product of combination between the mordant and colour is not that of the natural colour of the drug, but the colour of the compound. Hence the great variety of tints capable of being produced from one dye-drug, by varying either the kind or intensity of the mordant. So that in the above instances, it is not the colour of the hematoxylin fixed on the stuff, but its compound with iron, or tin, or alumina, as the case may be, all of which give different tints.

It is this principle of rendering bases insoluble while within the fibre, by chemical means, that has brought to the use of the dyer a great number of mineral dyes which in themselves, whether separate or combined, have no attraction whatever for the fibre; such as solutions of sulphate of copper, and yellow prussiate of potash, nitrate of lead, and bichromate of potash, &c. Suppose the stuff to be dyed a yellow by the two last-named salts were first put into the solution of lead and then washed previously to being put into the bichromate solution; the greater portion of the lead would be dissolved from the stuff, and a very weak colour would be obtained. If the stuff from the lead solution was put directly into the bichromate solution, a very good dye would be the result; but the portion of the solution remaining upon the surface of the stuff will combine with the chrome and form a precipitate which the fibre cannot imbibe, but it will form an external crust or pigment upon the surface, which blocks up the pores, and exhausts to no purpose the dye, causing great waste: hence the stuff from the solution of lead is put into water containing a little soda or lime, and the lead is thus reduced to an insoluble oxide within the fibre. The goods may now be washed from any loose oxide adhering, and then passed through the bichromate solution, when the chromic acid combines with the oxide of lead, forming a permanent yellow dye. Thus it will be seen that whether the combination of the colour with the stuff be chemical or mechanical, the production of the dye which is fixed upon the fibre is certainly a chemical question, and the dyer should be familiar with the nature and principles of these reactions.

There are a few instances where the dye produced does not come within the sphere of these principles, there being no mordants required, nor any combination of the colour formed within the stuff, but the dye-drug in its natural hue is fixed within the fibre. Such colours have been termed *substantive*, to distinguish them from those produced by means of mordants which are termed *adjective.* Amongst this class of dyes and dye-drugs stands pre-eminent indigo-blue. Indigo in its natural state is entirely insoluble in water, and is of a deep blue colour. The composition of this blue indigo is represented as—$C^{16}H^5NO^2$ ($\mathbf{C^8H^5NO}$). But it is found capable of parting with a portion of the oxygen, and by so doing, losing entirely its blue colour; and in this deoxidised condition it is soluble in alkaline lyes and lime-water; this colourless compound is termed *indigogene.* The opinión of Liebig upon the constitution of this substance was, that indigo contained a salt radical, which he termed *Anyle*, composed of $C^{16}H^5N$ ($\mathbf{C^8H^5N}$). He considered that indigogene or white indigo is the *hydrated* protoxide of this radical, and that blue indigo is the peroxide, represented thus—

Salt radical, anyle, $C^{16}H^5N$. Indigogene, $C^{16}H^5NO. HO$. Blue indigo, $C^{16}H^5NO^2$.

Advantage is taken of this property of indigo, of parting with its oxygen and becoming soluble, to apply it to dyeing, and it is effected by the following means, when for the purpose of dyeing vegetable stuff, as cotton; from the circumstance of these operations being done cold, the method is termed the cold vat, which is made up as follows:—The indigo is reduced to an impalpable pulp, by being ground in water to the consistence of thick cream. This is put into a suitable vessel filled with water, along with a quantity of copperas, and newly-slaked lime, and the whole well mixed by stirring. After a short time the indigo is deoxidised and rendered soluble by a portion of the lime which is added in excess, the reaction being represented thus:—



The peroxide of iron and sulphate of lime are precipitated to the bottom, and the indigogene and lime form a solution of a straw colour, with dark veins through it.

The operation of dyeing by this solution is simply immersion, technically, *dipping.* The stuff by immersion imbibes the solution, and when taken out and exposed to the air, the indigogene upon and within the fibre rapidly takes oxygen from the atmosphere, and becomes indigo-blue, thus forming a permanent dye, without any necessary attraction between the indigo and the stuff.

The indigo vat for wool and silk is made up with indigo pulp, potash, madder, and bran. In this vat the extracts of madder and bran perform the deoxidising functions of the copperas in the cold vat, by undergoing a species of fermentation.

Pastel and woad, either alone or with the addition of a little indigo, are also used for the dyeing of wool and silk stuff, the deoxidation being effected by the addition of bran, madder and weld. In dyeing with these vats, the liquor is made warm, and they require much skill and experience to manage, in consequence of their complexity, being always liable to go out of condition, as the dyeing goes on, by the extraction of the indigogene and the modification of the fermentable matter employed to deoxidise the indigo to supply that loss. The alkaline solvent also undergoes change, so there must be successive additions of indigo and alkali; the principal attention of the dyer is the maintaining the proper relation of these matters, as too much or too little of either is injurious.

Sulphate of indigo forms an intense blue solution, unaffected also by mordants. Vegetable stuffs dipped in this retain no dye, for the washing-off the acid in order to preserve the fibre removes the colour; but animal fibre, such as woollen and silk, becomes dyed; a portion of the blue remains upon the stuff after washing-off the acid, being retained by capillary attraction. This dye is termed *Saxon blue*, but it has very little of the permanence of indigo or *vat blue*, although it is also a substantive colour.

Another truly substantive colour is that dyed by *carthamus* or safflower, but the fixation of this dye upon the stuff differs from any of those referred to. Like indigo, it has no affinity for any base or substance capable of forming a mordant; its solvent is an alkali, but in this dissolved state it does not form a dye. The mode of proceeding in dyeing with carthamus is, first, to extract the dye from the vegetable in which it is found, by soda or potash, which is afterwards neutralised by an acid previous to dyeing, which renders the colour insoluble, but in so fine a state of division that no precipitation can be seen for some time and the stuff immersed in this imbibes the colour within its fibre, its lightness assisting this action, as the precipitate will remain suspended in water for days before it will subside. Vegetable fibre takes up this dye as easily as animal, but whether by an attraction for the stuff, or by a mechanical capillary attraction of the fibre is not so easily determined. A piece of stuff suspended in a vessel filled with water, having in it some insoluble carthamine, all the colouring particles will flow to and combine with the fibre from a considerable distance, giving a proof of the existence of some force drawing them together.

Such then are the various conditions and principles involved in the processes of fixing the dye within or upon the stuff.

During the operations of dyeing there are certain circumstances which have to be attended to, in order to facilitate and affect certain hues or tints of colour. Thus, with many of the colouring substances, heat not only favours but is necessary for the solution of the dye, and also its combination with the stuff or mordant. Decoctions of woods are always made by hot water, and the dyeing processes with decoctions are in hot liquor. When the colouring matter of quercitron bark is extracted by boiling water, the colour produced upon the stuff will be a rich amber yellow, but if the extract be made by water at 180° Fahr., a beautiful lemon yellow will be the dye produced by it, using the same mordant in each case. Colours dyed by madder and barwood must be done at a boiling heat during the whole process, or no dye is effected. Sumach, another astringent substance, is most advantageously applied at a boiling heat; and in order to have a large body of this dye fixed upon the stuff, it should be immersed in the liquor while hot and allowed to cool together, during which the tannin of the dye undergoes some remarkable change in contact with the stuff. Safflower dyes are kept cold, so are tin bases, Prussian blues, and chrome yellows: by applying heat to the last a similar result is effected to that with bark; instead of a lemon yellow, an amber yellow will be obtained. Almost all colours are affected less or more by the temperature at which they are produced. Some mordants are fixed upon the stuff by heat, such as acetate of alumina; the stuff being dried from a solution of this salt at a high temperature loses part of the acid by being volatilised, and there remains upon the fibre an insoluble suboxide, which fixes the dye. These remarks respecting the methods apply more particularly to vegetable stuffs, as cotton, and in many cases also to silk, but wool is always dyed at a high heat. Although wool seems to have a much greater absorbing power than cotton, the latter will absorb and become strongly dyed in a cold dye-bath, in which wool would not be affected; but apply heat and the wool will be deeply dyed, and the dye much more permanent than the cotton.

The permanence of colours is another property to be carefully studied by the practical dyer, as the colour must not be brought under circumstances that will destroy its permanency during any of the operations of the dye-house. The word 'permanent,' however, does not mean *fast*, which is a technical term applied to a colour that will resist all ordinary operations of destruction. For instance, a Prussian blue is a permanent colour, but not a fast colour, as any alkaline matter will destroy it; or a common black is permanent, although any acid matters will destroy it; while Turkey red is a fast colour and not affected by either acid or alkaline matters. A few of the circumstances affecting colours in the processes they are subjected to may be referred to in this place. If, for instance, the air in drying the dyed stuff in a hot chamber be moist, there is a great tendency to the colour being impaired in these circumstances. For example, a red colour dyed with safflower will pass into brown, a Prussian blue will pass into a grey lavender, whilst chrome yellows take an amber tint. Almost all colours are more or less affected by being subjected to strong heat and moisture; even some of those colours termed fast are affected under such circumstances. A dry heat has little or no effect upon any colour, and a few colours are made brighter in their tint by such a heat, as chrome orange, indigo-blue, on cotton, &c.

Some of these effects of heat and moisture differ with different stuffs; thus indigo-blue upon cotton is not so much affected as indigo-blue upon silk, while safflower-red upon cotton will be completely destroyed before the same colour upon silk will be perceptibly affected. The same colouring matter fixed by different mordants upon the same stuff is also differently affected under these conditions.

Light is another agent effecting a great influence upon the permanence of colours, which should be also considered by the dyer. Reds dyed by a Brazil wood and a tin mordant, exposed to the light, become brown; Prussian blue takes a purple tint; yellow becomes brownish; safflower-red yellowish, and these changes are facilitated by the presence of moisture; such as exposing them to strong light while drying from the dye-bath, either out or within doors. The direct rays of the sun destroy all dyed colours; even Turkey red yields before that agency.

Boiling was formerly prescribed in France as a test of fast dyes. It consisted in putting a sample of the dyed goods in boiling water, holding in solution a determinate quantity of alum, tartar, soap, and vinegar, &c. Dufay improved that barbarous test. He considered that fast-dyed cloth could be recognised by resisting an exposure of twelve hours to the sunshine of summer, and to the midnight dews, or of sixteen days in winter.

In trying the stability of dyes, we may offer the following rules:—

That every stuff should be exposed to the light and air; if it be intended to be worn abroad, it should be exposed also to the wind and rain; that carpets, moreover, should be subject to friction and pulling, to prove their tenacity; and that cloths to be washed should be exposed to the action of hot water and soap. However, such tests are not at all applicable to most of the colours dyed upon cotton stuff. Not many of them can stand the action of hot water and soap, or even such acids as the juice of fruits. Indigo-blue, one of the most permanent dyes on cotton, yields its intensity to every operation of washing, even in pure water.

Delaval's observations on the nature of dyes may be thus summed up. In transparent coloured substances, the colouring substance does not reflect any light; and when, by intercepting the light which was transmitted, it is hindered from passing through substances, they do not vary from their former colour to any other colour, but become entirely black; and he instances a considerable number of coloured liquors, none of them endued with reflective powers, which, when seen by transmitted light, appeared severally in their true colours; but all of them, when seen by incident light, appeared black; which is also the case with black cherries, black currants, black berries, &c., the juices of which appeared red when spread on a white ground, or otherwise viewed by transmitted instead of incident light; and he concludes, that bleached linen, &c. 'when dyed with vegetable colours, do not differ in their manner of acting on the rays of light, from natural vegetable bodies; both yielding their colours by transmitting, through the transparent coloured matter, the light which is reflected from the white ground:' it being apparent, from different experiments, 'that no reflecting power resides in any of their components, except in their white matter only,' and that 'transparent coloured substances, placed in situations by which transmission of light through them is intercepted, exhibit no colour, but become entirely black.'

The art of dyeing, therefore (according to Mr. Delaval), 'consists principally in covering white substances, from which light is strongly reflected, with transparent coloured media, which, according to their several colours, transmit more or less copiously the rays reflected from the white,' since 'the transparent media themselves reflect no light; and it is evident that if they yielded their colours by reflecting instead of transmitting the rays, the whiteness or colour of the ground on which they are applied would not in anywise alter or affect the colours which they exhibit.'

But when any opaque basis is interposed, the reflection is doubtless made by it rather than by the substance of the dyed wool, silk, &c., and more especially when such basis consists of the white earth of alum, or the white oxide of tin; which, by their strong reflective powers, greatly augment the lustre of colours. There are, moreover, some opaque colouring matters, particularly the acetous, and other solutions of iron, used to stain linen, cotton, &c., which must necessarily themselves reflect instead of transmit the light by which their colours are made perceptible.

The compound or mixed colours are such as result from the combination of two differently-coloured dye-stuffs, or from dyeing stuffs with one colour, and then with another. The simple colours of the dyer are red, yellow, blue, and black, with which, when skilfully blended, he can produce every variety of tint. Perhaps the dun or fawn colour might be added to the above, as it is directly obtained from a great many vegetable substances.

1. Red with yellow, produces orange; a colour, which upon wool is given usually with the spent scarlet bath. To this shade may be referred flame colour, pomegranate, capuchin, prawn, jonquil, *cassis*, chamois, *café au lait*, aurora, marigold, orange-peel, *mordorés*, cinnamon, gold, &c. Snuff, chestnut, musk, and other shades are produced by substituting walnut peels or sumach for bright yellow. If a little blue be added to orange, an olive is obtained. The only direct orange dyes are annotto, and subchromate of lead.

The latter is never used for dyeing orange upon silk and wool, while the former is now never used for cotton. An orange with annotto is very fugitive, even upon the animal fibre; but much more so upon cotton. Subchromate of lead is produced upon cotton by dyeing it first a deep chrome yellow by acetate of lead and bichromate of potash, as already noticed, and then passing the stuff so dyed through a hot solution of an alkali or lime, which changes the dye from the yellow chromate to the state of subchromate, which is deep orange. See SILK and WOOL DYEING.

2. Red with blue produces purple, violet, lilac, pigeon's neck, mallow, peach-blossom, *bleu de roi*, lint-blossom, amaranth, &c.

Thus a Prussian blue dyed over a safflower red, or *vice versâ*, will produce any of these tints by varying the depth of the red and blue according to the shade required; but the same shades can be produced direct by logwood and an aluminous or tin mordant; the stuff being steeped in sumach liquor previously to applying the tin mordant produces the reddish or purple tint when such is required.

3. Red with black; brown, chocolate, maroon, &c. These tints are produced by various processes. To dye a deep orange by annotto liquor, and then form over it a black by sumach and sulphate of iron, gives a brown; or dye the stuff first a rich yellow by quercitron and a tin mordant, and then over the yellow produce a purple by passing it through logwood; chocolates are thus produced. A little brazil-wood with the logwood gives more of the red element. When maroon is required, the red is made to prevail, and so by a judicious mixture, these various tints are produced. Brown, especially upon cotton fibre, is more often produced direct by means of catechu. Steep the stuff in a hot solution of catechu, in which the gummy principle has been destroyed by the addition of a salt of copper; then pass through a solution of bichromate of potash at boiling heat, when a rich brown is obtained.

4. Yellow with blue; green of a great variety of shades; such as nascent green, gay green, grass green, spring green, laurel green, sea green, celadon green, parrot green, cabbage green, apple green, duck green, &c.

Green is essentially a mixed dye, and produced by dyeing a blue over a yellow or a yellow over a blue. In almost all cases the blue is dyed first, and then the yellow, and according to the depth of each or any of these are the various tints of green produced. With silk and wool, one kind of green dye may be produced simultaneously by putting sulphate of indigo into the yellow dye-bath, and then working the previously-prepared or mordanted stuff in this. With cotton, an arsenite of copper (Scheele's green) may be produced by working the stuff in a solution of arsenite of potash or soda, and then in sulphate of copper, which produces a peculiar tint of green.

5. Mixtures of colours, three and three, and four and four, produce an indefinite diversity of tints: thus, red, yellow, and blue form brown olives and greenish greys; in which the blue dye ought always to be first given, lest the indigo vat should be soiled by other colours, or the other colours spoiled by the alkaline action on the vat. Red, yellow, and grey (which is a gradation of black) give the dead-leaf tint, as well as dark orange, snuff colour, &c. Red, blue and grey give a vast variety of shades; as lead-grey, slate-grey, wood-pigeon grey, and other colours too numerous to specify.

Care must be taken, however, in mixing these colours, to study the depth of the tint required; as, for instance, were we wishing to dye a slate-grey, and to proceed first by dyeing a blue, then a red, with a little of the grey, we should produce, instead of a slate grey, a purple or peach. The arrangement referred to, applies only to the elements of the colours that enter into the composition of the various tints, so that a slate-grey is a blue with a small portion of red, and a still smaller portion of the black element, that produces the grey tint. Thus, dye the stuff first a deep sky-blue by the vat, then by passing through a solution of sumach, with a small quantity of logwood, brazilwood, copperas, and alum, grey will be produced. The brazilwood gives the red tint, sumach and copperas the black tint, the logwood assisting in this, and with the aid of the alum throwing in the puce or dove-neck hue; and thus by the variation of these hues by such arrangements, any of the grey tints can be produced. See CALICO-PRINTING.

ANILINE DYES. Dyeing and printing have undergone a considerable change through the introduction of these dyes. The colours produced are more brilliant than formerly, and, since the use of mordants has been almost dispensed with, the processes are very much shorter. The styles and patterns have undergone a marked change.

These dyes, however, have not yet supplanted the use of dyewoods and the other colouring matters formerly in use. They are not so permanent, and at the same time they are much more expensive. But continued improvements in the modes of producing and applying these dyes will no doubt greatly advance and develope their commercial importance.

Reference to the article ANILINE, and also to CALICO-PRINTING, will show the simplicity of the applications of these tinctorial substances, and the great variety of decided colours and varying tints which are produced.

We have not only the true aniline colours available for the use of the dyer and calico-printer, but we have the Murexide Dyes, and others of an analogous description—especially such as belong to the Picric Acid series—which, by intercombination, produce an almost infinite variety.

In dyeing silk and wool with aniline colours no mordant is required. Solution in a suitable solvent (acetic acid or alcohol) is all that is necessary. In the case of the rosaniline salts, however, a neutral solution and a temperature not exceeding 180° F. are requisite.

In dyeing vegetable fibres, albumen, glutin, gelatine, casein, tannin or tannic acid, &c. are used as mordants.

In printing with these colours the process is the same as in the case of steam colours. Either the mordant is first printed on the fabric, which is then steamed and dyed, or the colouring matter is thickened with the mordant (albumen, &c.), the fabric dyed with this, and then steamed so as to fix it.

Aniline Black has been quite recently produced by the direct oxidation of aniline on cotton fibre. A mixture consisting of an aniline salt, perchloride of copper, and chlorate of potash, is printed on the cotton, which is then exposed to an atmosphere of steam. After some time a black is developed.

The following figures show the rapidity with which aniline and its derivatives have fallen in price during the last few years, and thus give an idea of their rapid industrial development:—

Aniline and Colours. Average Prices.

Colour	1860			1866			1872		
	£	s.	d.	£	s.	d.	£	s.	d.
Aniline . . . . per lb.	0	14	0	0	1	6	0	1	6
,, Violet paste . . . . ,,	2	0	0	0	10	0	0	7	0
,, ,, powder . . . . ,,				5	0	0	1	6	0
Violet or mauve, alcoholic solution, per gallon	6	0	0	2	5	0	0	16	0
Magenta, alcoholic solution . ,,	6	0	0	0	12	0	0	7	0
Aniline blue . . . . . . per lb.	11	0	0	2	0	0	1	17	0

DYER'S ALKANET, *Anchusa tinctoria.* See ALKANET.

DYER'S MADDER, *Rubia tinctorum.* See MADDER.

DYER'S OAK, *Quercus infectoria.* See GALLS and OAK.

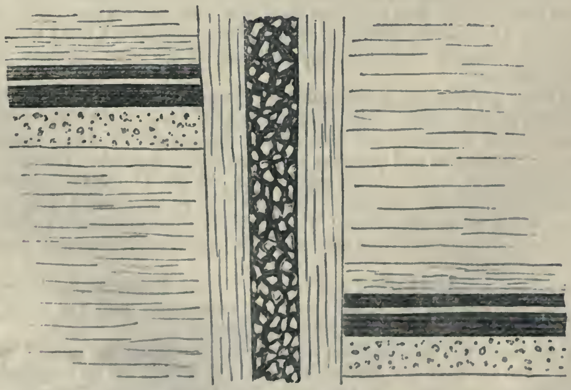
DYER'S ORCHELLA WEED, *Roccella tinctoria.* See ARCHIL; ORCHELLA.

DYER'S SAFFLOWER, or Bastard Saffron. The *Carthamus tinctorius.* The flowers are of a deep orange colour, but they are used for dyeing various shades of red. The flowers of the carthamus are employed in Spain for colouring dishes and confectionary. See CARTHAMUS.

DYER'S WOODROOF. *Asperula tinctoria.* The roots of this plant are used in some parts of Europe, particularly Dalmatia, instead of madder for dyeing wool and cloth of a reddish colour; but in bulk the crop obtained is inferior to that of the madder.—*Lawson.*

DYKE. (Scot. a *wall* or *fence.*) Applied to those wall-like intrusions of igneous rock which fill up rents and fissures in the stratified rocks. They may sometimes fill up pre-existing rents and fissures, but they usually burst through and displace the rocks through which they are forced. Dykes are generally understood to be connected with the volcanic rocks below, from which they have been forced, in a molten state,

770



through the superincumbent rocks—often overflowing the newer strata; filling fissures which may have been pre-existent, or may have been formed by the mechanical force of the fluid mass in its upward movement. The substances of which dykes are composed is basalt, in one or the other of its varieties—or trap in some of its many forms. Dyke-matter is of different degrees of fineness, some of it being coarse and granular, and some of it of a fine texture, like the cinder of iron furnaces. The Giant's Causeway is a good example of the lithological character of the rocks forming dykes, or they are like the 'whin-sill' of South Staffordshire or the greenstone rocks of Rowley and other places.

In the North of England the dykes have been very carefully examined. From the 'Practical Treatise on Mine Engineering,' by G. C. Greenwell, we extract the following notices of some of the principal dykes observed in the Newcastle coal-field:—

Name	Magnetic bearing	Width	Dislocation
		feet	fathoms
1. Hitchcroft dyke, near Alnwick .	N. 72° W.	69	
2. Acklington dyke	N. 80° W.		
3. Blyth dyke	N. 60° W.		
4. Mausoleum dyke, Hartley . .	N. 61° W.	9	8½
5. Swallow dyke, ,, . .	N. 65° W.	12	12
6. Coaley Hill dyke . . .	N. 45° W.	11	
7. Walbottle Hill dyke . .	N. 45° W.		
8. Tynemouth dyke	N. 63° W.	12	
9. Willington or Tudhoe dyke . .	N. 82° W.	8	
10. Cockfield dyke . . .	N. 45° W.	66	6

Many of these dykes passing through the coal, by dissipating the volatile bitumen, bring it into an anthracitic state, and in some instances the coal is actually coked by the heat of the intrusive mass.

The main dyke running from near Cullecoates, in a south-westerly direction to Hedley, is usually called the 90-fathom dyke, because it has a downthrow to the north from 90 to 180 fathoms.

The Mausoleum dyke (*fig.* 770) was discovered and passed through in the workings of the low main seam at the depth of 53 fathoms in the Old Hartley Colliery, its position being nearly underneath the mausoleum in the Seaton Delaval grounds; hence its name. It is frequently called the 'Hartley Whin Dyke.' By it the strata are thrown down to the north-east to the extent of 8½ fathoms. This dyke consists of two walls of basalt of the thickness respectively, of 9 feet and 4 feet 4 inches, separated from each other by a mass of the *débris* of other strata of the thickness of 8 feet 10 inches.

771

In the neighbourhood of Dudley, in South Staffordshire, these overflows of trap, upon the beds of coal, and in many cases through them, are strikingly exhibited. *Fig.* 771 shows the passage of a dyke through the coal, the portions of the coal near the trap being changed by its heat, or 'blacked,' as it is locally called, the coal losing all its brilliancy. The late Mr. Jukes thus describes these intrusive dykes in the coal of South Staffordshire:—

'All parts of these galleries, indeed, were riddled, as it were, with these trap veins running here and there in the coal, and also in the sandstone, altering the coal to a greater or less extent, according to the bulk of the trap, but producing very little apparent alteration in the sandstone.

'From the fine tortuous and branching veins which the rock forms, it seems hardly possible to suppose that at the time of its injection it was not in a fluid state and almost perfectly liquid. The distances to which these narrow veins run seem also to make it necessary to suppose that, at the time of injection, it had a temperature not merely just sufficient to melt it, but a much higher one; sufficiently high to allow of the loss of a considerable quantity of heat, and yet for the matter to remain still molten in its passage to very considerable distances from the volcanic focus.'

DYNAMITE. In 1867 Mr. Nobel, in his endeavours to lessen the dangers attending the use of nitroglycerine, made the important observation that the readiness or certainty with which it is exploded through the agency of a detonation is not reduced, but, on the contrary, somewhat favored by mixing the liquid with solid substances in themselves thoroughly inert. This discovery led at once to the production by Nobel of solid, or more or less pasty, preparations of nitroglycerine, which under the name of dynamite were first brought before the public in 1867. The form in which dynamite was first presented to the public was that of a soft, readily-moulded powder of a pink or buff colour, which consisted of about 75 parts of nitroglycerine held absorbed by 25 parts of a porous, infusorial, silicious earth known in Germany as 'Kieselguhr'. The moist appearance of this powder favored the opinion that the nitroglycerine would be liable to exude from it; and it undoubtedly was open to this objection. Dynamite has, however, been supplied for some time past in the form of small cylindrical cartridges consisting of the material in a compact condition, enclosed in a single wrapping of parchment-paper. These cartridges are consolidated by pressure whereby any excess of nitroglycerine which the porous earth will not hold absorbed, is expelled, and thus the separation of the nitroglycerine in dressing, handling, transport, or exposure to elevated temperatures appears effectually guarded against. The consistence of the dynamite charges is like that of dry putty. The Kieselguhr selected as the medium for the application of nitroglycerine appears the material best calculated to hold absorbed a large proportion of the liquid, and to retain it even when the mixture is submitted to considerable pressure. Mr. Abel, in his paper 'On Explosive Compounds,' published in the 'Proceedings of the Institution of Civil Engineers,' states that when dynamite factories were established in the outskirts of Paris during the siege, and this particular silicious earth could not be procured, a series of experiments was instituted for the purpose of discovering a good substitute. The most efficient absorbents next to this material were found to be precipitated silica, kaolin, tripoli, precipitated alumina and sugar, but none of these appeared thoroughly equal to Kieselguhr in their power of retaining a very large proportion of the oil. Eventually the ashes of Boghead coal were used for the production of dynamite during the siege of Paris. Mr. Nobel's No. 2 dynamite, which is sold as a cheaper blasting agent than the so-called No. 1, contains a much smaller proportion of nitroglycerine mixed with finely-powdered saltpetre, and resin or coal, but this cartridge can only be used when the violent crushing and rending action of the stronger dynamite is not required.

The danger, real or supposed, attending the use of dynamite has led to many restrictions, not only on its manufacture, but on its transmission: the following particulars contributed to one of our scientific periodicals in 1873 will be read with some surprise a few years hence:—

'Not very long ago a coasting screw steamer embarked a cargo of 42 tons of dynamite at the Dynamite Company's works, on the Aryshire coast, to be distributed along the west coast of England and Wales—at Whitehaven for the Cleator and Furness hæmatite ironstone districts; at Aberystwyth for Mid-Wales, at Cardiff for South Wales, at Sydney for the mining districts of the Forest of Dean, Gloucestershire, and the South Midland Counties; and at Hayle, in Cornwall, for the county, and the adjoining county of Devon. Soon afterwards another cargo of 25 or 30 tons was shipped and despatched to the north-east coast of England *viâ* the Forth of Clyde Canal, to be delivered in varying quantities at Newcastle; at Redcar, for the districts of Cleveland and North Yorkshire; and at Goole, for East and West Yorkshire. Since these arrangements have been put in train for establishing agencies in, and sending large quantities of dynamite into, the North of Scotland—Aberdeenshire, Caithness, &c., and various parts of Ireland. More recently additional large consignments have been forwarded to the principal agents in England, and at present arrangements are in progress for sending a very large cargo down along the west coast. The greatest proportion of the material yet despatched from the dynamite works seems to have been greedily absorbed into use in the districts that are reached with more or less ease from Whitehaven, and thither a number of consignments have found their way, both by railway and steamer.

'Great anxiety is being manifested to get large supplies of dynamite sent out to the Australian colonies, and it is not unlikely that a ship-load will accordingly soon be sent to the other side of the world. Shipowners, equally with railway companies, still 'boggle' at, and express great fear of, dynamite, otherwise considerable quantities of it might already have found their way to the antipodes.

'Besides being used in pit-sinking and coal-getting, in slate-quarrying and limestone-quarrying, in the ironstone mines and the metalliferous mines generally, in railway cutting, tunnelling, &c., dynamite is proving itself to be eminently serviceable in breaking up and removing the immense masses of mixed iron and slag which form the bottoms, or 'salamanders,' of blown-out blast furnaces. It is also about to be used extensively in subaqueous blasting on the Clyde for the removal of a large quantity of a whinstone dyke that occupies the bed of the river near Erskine Ferry; and we have recently learned that half a ton of it is to be employed in connection with the torpedo experiments that the naval authorities have at present in progress.'

The following particulars respecting the storing of dynamite cannot but prove interesting to those who are using this useful explosive agent:—

'The district store magazines are constructed in accordance with plans approved of by the Inspector of Gunpowder Factories and Magazines. At first they were intended to contain a maximum quantity of five tons, but there is some expectation that the license may be extended to twice that amount. The internal dimensions of these magazines are 12 feet 6 inches square, by 8 feet high from floor to top of side walls. In structure they are so simple that they may easily be erected by the ordinary tradesmen found in the mining districts. The walls may be of 9-inch brick and mortar work; but where stone walls, of hammer-dressed rubble set in mortar, can be more conveniently or economically used, it is recommended that they should be 15 inches thick.

They are arranged on what is technically known as the 'shelf system,' the internal fittings consisting simply of joists or battens set on edge, resting on the floor, and let half-way into the end walls for further security. Upon these as bearers, cross-spars, 3-inch by 1-inch, cut out of flooring boards, or similar materials, and kept an inch or so apart, are pegged down on the joist with wood tree-nails, and the vertical, 3-inch by-½ inch, wood strips are fastened on the walls in a similar manner; the latter being put four inches apart, so as to prevent the packing-boxes chafing on the rough walls. On the shelves thus described the boxes of dynamite are placed in rows, and the floor space within the doorway may be of earth, clay, or sand, and should be raised six or eight inches above the level of the ground outside. By this simple arrangement the use of special magazine shoes or slippers is dispensed with. The door in each case consists of red pine frame, 1½ inch thick, covered back and front with ⅞-inch flooring boards, grooved and feathered; the outside boards being put on vertically, the inside boards horizontally, and the spaces between being packed with dry sawdust or sifted engine ashes. It is fitted with strong double-tail hinges, and provided with a good, safe, and strong lock and key, all of brass by preference. It is insisted that the doors always open outwards, and that when closed they shall shut against a hardwood kerbstep. The roof, main, or corner principals are formed of sound red pine battens, 9-inch by 3-inch, having spars 6-inch by 2½-inch, spaced two-feet centres, and well secured to the principals and wall-plates in the usual manner; the spars being covered on the lower side with ⅝-inch close-jointed lining-boards, and the spaces between the spars being packed similarly to the doors, and then sacked over and slated. A square box ventilator, with cowl, is placed in the apex of the roof, and the whole is finished off with lead or zinc ridge-plates on skews and lead or zinc cover on the top of the ventilator, the air spaces for ventilation on the lower side of the cowl being covered with perforated zinc. A district store magazine of a different design, but of the same size, has been approved of by Major Majendie. It consists entirely of wood, the framework having a covering of 3-inch planking, which is carefully coated with tar outside and inside, to preserve the timber, and then felted over externally to render it watertight. Suitable provision is made for the ventilation, and then the magazine is covered over with sand or earth, to the depth of 1½ yard on the top, by 2½ to 3 yards at the sides, finished with turf sods, and provided with requisite drainage, &c.

'All exposed ironwork in the interior of these magazines is distinctly prohibited by Her Majesty's Inspector of Gunpowder Factories and Magazines, so that wood-pegs or tree-nails or zinc nails are preferred for all fastenings. If iron nails are anywhere used they must be punched in and puttied over. Where it is practicable, Major Majendie urges the desirability of a high fence being placed round the magazine with a locked door; such a fence as may be made with old railway sleepers has been strongly recommended.

'Consumers' store-magazines are arranged for, which are capable of containing one ton of dynamite. They are also arranged on the 'shelf system,' and are 6 feet 6 inches square internally, and 6 feet 6 inches from the floor line to the top of the side walls.

'Special licenses for storing dynamite in magazines of approved construction are granted by the Home Secretary: the quantity stored in any one magazine being never more than five tons, unless with the authorisation of the officer of state. Important conditions are laid down as regards the distance of the site of the proposed magazine from buildings of various kinds. For instance, a magazine licensed for five tons of dynamite may not be nearer to a royal palace, or the metropolis, as defined in the Local Management Act of 1855, than three miles. It may not be nearer than two miles to any magazine belonging to the Crown, and containing gunpowder or any other explosive. Then lesser distances, varying down to 200 yards, are stipulated for in the case of any borough or market town, church, hospital, other magazine or store for explosives, dwelling-house and factory, or workhouse (except with the consent in writing of the occupier), school or charitable institution, highway, river or sea-wall, canal or railway. But the limits as to distances may be lessened, however, in special cases, if, in the opinion of the Government Inspector, the natural features of the site selected admit of so doing without endangering the public safety. The authorities desire it to be distinctly and clearly understood that, where an applicant to have a magazine licensed is unable to comply with the conditions of the general license as to distances, construction, &c., it is open to apply for a special license, which is in all cases granted where the proposition appears to be one which can be safely acceded to. For example, a person desirous of using dynamite finds that he is unable to erect the necessary magazine at the required distance of 200 yards from a dwelling-house, factory, &c. In this case it would be for him to consider whether he should reduce the quantity, or whether he should so construct or protect his magazine as to render the full distances assigned in the general license unnecessary. It might happen that a quantity of, say, a quarter of a ton, would answer all his purposes, and, in this case, reduced distances would clearly be admissible. Again the full distances of the general license are not insisted upon when such protection is obtainable as is afforded by burrowing into the earth, or into the face of a colliery or mine waste heap, and protecting by mounds, or traverses, &c.'

See Explosive Compounds; Gun-Cotton; Nitroglycerine.

DYSODILE. A combustible mineral found in secondary limestone, at Melili, near Syracuse, in Sicily. It is laminated and fragile, and has an argillaceous odour when breathed on. It burns with a crackling noise, and considerable flame, with much smoke, giving out a fœtid smell, whence it has acquired the name of *Stercus Diaboli* or *Merda del Diavolo* in Sicily. It is also found in some parts of France—(Bristow, 'Glossary of Mineralogy.') A kind of dysodile has been brought from the Mersey river in Tasmania, and has been described by Prof. Church under the name of *Tasmanite.*

Tasmanite is a material of organic origin, found in Tasmania, described sometimes as resinferous or combustible shale; it is distinctly laminated, the organic matter, which occurs in scales, being disposed in planes parallel to the lamination, and probably causing it. These scales are of a reddish-brown colour, and form from 30 to 40 per cent. of the rock. The average diameter of the discs is about ·03 of an inch, while their thickness at the centre is sometimes as much as ·007. As none of the ordinary solvents of resinoids seemed capable of dissolving out the carbonaceous constituent of the mineral, the following plan of effecting the separation was adopted:—A large quantity of the mineral was crushed to a coarse powder, placed in a Phillip's precipitating glass, and strong hydrochloric acid poured upon it. A trace of carbonic anhydride was thus set free from the small quantity of carbonate of calcium present, while the alumina and ferric oxide of the mineral were partly dissolved. These actions break up the mineral, and the 'scales' mostly became disengaged and floating, owing to the high gravity of the hydrochloric solution, which had been further increased by the addition of chloride of calcium. The scales were collected by a strainer, and repeatedly washed by decantation, the inorganic matter being reduced to a minimum. The substance thus prepared presents such remarkable distinct chemical and physical characters as to lead to its receiving a distinct name. When tasmanite is heated in the air it burns readily, with a very smoky flame and offensive odour. Submitted to destructive distillation, it fuses partially, and yields oily and solid products of a disagreeable smell, resembling the odour of Canadian petroleum. Qualitative analysis of tasmanite showed it to contain a large quantity of carbon and hydrogen, and a considerable portion of sulphur. It was found impossible to free the specimens completely from mineral impurities, even with the most careful mechanical treatment. The sulphur detected was an integral part of the carbonaceous matter itself, and not owing to the presence of an inorganic sulphide or sulphate; this was proved in several ways, and was further confirmed by the observation that the more completely the mineral matter had been removed, the more sulphur was found in the specimen of tasmanite operated upon.

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EAGLE-STONE. A name applied to nodular concretions of iron-stone, which present a concentric structure, and are often hollow, containing loose materials, which rattle when the stone is shaken.

EAGLE-WOOD. (*Bois d'Aigle*, Fr.) The wood of the *Aquilaria Malaccensis* or *A. ovata.* This is the 'aloes-wood' of commerce; an exceedingly aromatic wood, much used in Hindostan and in all Mohammedan and Catholic countries for fumigation and incense. The trees, belonging to the *Aquilariaceæ*, are natives of tropical Asia. Eagle-wood, or aloes-wood, is also yielded by the *Aloexylon Agallochum.*

EARTH. Common *alluvial* deposit, or *agricultural soil.* Weight of a cubic foot varies from 95 to 125 pounds. Specific gravity from 1·5 to 2·0.

EARTH-COAL, or Earthy Brown Coal. A name sometimes given to Lignite or Brown Coal. See Brown Coal, Lignite.

EARTHENWARE. See Pottery.

EARTH-FLAX. Asbestos is sometimes so called. See Asbestos.

EARTH-NUT. The fruit of the *Arachis hypogæa*, a leguminous creeping plant, native of India, South Africa, and South America. It is cultivated in North America and Southern Europe. The legumes are ripened under ground, whence the name, and the seeds are edible.

EARTH-NUT OIL. (*Huile d'Arachide; Huile de pistache de terre*, Fr.; *Erdnussöl*, Ger.) The oil expressed from the earth-nut by cold pressure. It is nearly colourless, and has an agreeable odour. It is used for culinary purposes instead of olive oil, but it is liable to become rancid much sooner. The hot-pressed earth-oil is coloured, and has a disagreeable taste and smell. A soap made from the oil of earth-nuts is manufactured in France, and to some extent in Germany. Earth-nut oil is much used by watchmakers.

EARTHS. (*Terres*, Fr.; *Erden*, Ger.) It has been demonstrated that the substances called Earths, and which, prior to the electro-chemical discoveries of Davy, were deemed to be elementary bodies, are all compounds of certain metallic bases and oxygen. Five of the earths, when pure, possess decided alkaline properties, being more or less soluble in water, having (at least three of them) an acrid alkaline taste, changing the purple infusion of red cabbage to green, most readily saturating the acids, and affording thereby neutral salts; these are *baryta*, *strontia*, *lime*, (*calcia*), *magnesia*, and *lithia.* The earths proper are *alumina*, *glucina*, *yttria*, *zirconia*, and *thorina*; these do not change the colour of infusion of cabbage or tincture of litmus, do not readily neutralise acids, and are quite insoluble in water.

EARTHY BITUMEN. A bituminous schist found at Hurlet near Glasgow, and in the Binney quarries near Edinburgh. See Bitumen.

EARTHY COBALT. A manganese ore, containing oxide of cobalt sometimes to the amount of 33 per cent. See Wad.

EARTHY MANGANESE. See Wad and Manganese.

EAST-INDIA BLACK WOOD. The Sit Sâl of the natives of India; the *Dalbergia latifolia.* It is a wood of a greenish black colour, with light coloured veins. It takes a fine polish, and is very heavy. This wood is sometimes called East India Ebony.

EAU DE COLOGNE. See Perfumery.

EAU DE JAVELLE. A solution of 'chloride of potash,' occasionally used as a bleaching agent. See Chloride of Potash.

EAU DE LUCE. See Perfumery.

EBONITE. A name given to vulcanised India-rubber, or Vulcanite. The process of manufacture has been fully described under Caoutchouc. Ebonite has been applied almost to every kind of small ornamental manufacture. A large trade is done in imitations of jet ornaments made of it. It is also used for electrical machines and apparatus. In Poggendorf's 'Annalen,' 1873, F. Kohlrausch has a paper on the expansibility of ebonite by heat. He observed that ebonite lids stuck fast in glass vessels and even cracked them. Some experiments were therefore made, and ebonite was found to be three times as expansible as zinc.

The coefficient for 1° was found to be

0·0000770 measured between 16°·7 and 25°·3
0·0000842 „ „ 25°·3 and 35°·4

thus the increase with the temperature is very considerable. The linear coefficient of expansion for the temperature t can be put

$$0{\cdot}000061 + 0{\cdot}0000076\,t,$$

Two strips of ebonite and sheet zinc, when rivetted together, curve very materially with even a moderate heating. A thin strip of ivory, 20 centimes in length, cemented by means of isinglass to a similar one of ebonite, forms a delicate thermometer, seeing that its free end moves through several millimeters for one degree. The curvature in consequence of unequal expansion may be most simply demonstrated by the aid of a mere plate of ebonite, for, owing to its bad conductivity, it curves considerably when heated on one side. See CAOUTCHOUC.

EBONY. Of this black wood three kinds are imported:—

The *Mauritius Ebony*, which is the blackest and finest grained.

The *East-Indian Ebony*, which is not of so good a colour.

The *African Ebony*, which is porous and bad in point of colour.

The ebony of the Mauritius is yielded by the *Diospyros Ebenus.* Colonel Lloyd says, that this ebony when first cut is beautifully sound, but it splits, like all other woods, from neglectful exposure to the sun. The workmen who use it immerse it in water, as soon as it is felled, for from six to eighteen months; it is then taken out, and the two ends are secured from splitting by iron rings and wedges. Colonel Lloyd considers that next to the Mauritius, the ebony of Madagascar is the best, and next that of Ceylon.

The Mauritius ebony is imported in round sticks like scaffold poles, about fourteen inches in diameter. The East-Indian variety comes to us in logs as large as twenty-eight inches diameter, and also in planks. The Cape-of-Good-Hope ebony arrives in England in billets, and is called billet wood, from about three to six feet long and two to four inches thick.

The uses of ebony are well known.

White Ebony comes from the Isle of France, and is much like box wood. See GREEN EBONY.

EBULLIOSCOPE. See EBULLITION ALCOHOLOMETER.

EBULLITION. (Eng. and Fr.; *Kochen*, Ger.) *Boiling.* When the bottom of an open vessel containing water is exposed to heat, the lowest stratum of fluid immediately expands, becomes therefore specifically lighter, and rises through the colder and heavier particles. The heat is in this way diffused through the whole liquid mass, not by simple communication of that power from particle to particle as in solids—called the *conduction* of heat—but by a translation of the several particles from the bottom to the top, and the top to the bottom, in regular succession. This is denominated the *carrying* power of fluids, being common to both liquid and gaseous bodies. These internal movements may be rendered very conspicuous and instructive, by mingling a little powdered amber with water, contained in a tall glass cylinder, standing upon a sand-bath. That this molecular translation or locomotion is almost the sole mode in which fluids get heated, may be demonstrated by placing the middle of a pretty long glass tube, nearly filled with water, obliquely over an argand flame. The upper half of the liquid will soon boil, but the portion under the middle will continue cool, so that a lump of ice may remain for a considerable time at the bottom. When the heat is rapidly applied, the liquid is thrown into agitation, in consequence of elastic vapour being suddenly generated at the bottom of the vessel, and being as suddenly condensed at a little distance above it by the surrounding cold column. These alternate expansions and contractions of volume become more manifest as the liquid becomes hotter, and constitute the *simmering*, vibratory sound which is the prelude of ebullition. The whole mass being now heated to a pitch compatible with its permanent elasticity, becomes turbulent and explosive under the continued influence of fire, and emitting more or less copious volumes of vapour, is said to boil. The further elevation of temperature, by the influence of heat, becomes impossible in these circumstances with almost all liquids, because the vapour carries off from them as much heat in a latent state as they are capable of receiving from the fire.

The temperature at which liquids boil in the open air varies with the degree of atmospheric pressure, being higher as that is increased, and lower as it is diminished. Hence boiling-water is colder by some degrees in an elevated situation, with a depressed barometer, than at the bottom of a coal-pit in fine weather, or, when the barometer is elevated. A high column of liquid also, by resisting the discharge of the steam, raises the boiling point. As we ascend from the sea-level, the boiling point becomes lower; the table at the head of page 181 illustrates this.

In *vacuo* all liquids boil at a temperature about 124° F. lower than under the average atmospheric pressure. For a table of elasticities, see VAPOUR. Gay-Lussac has shown that liquids are converted into vapours more readily, or with less turbulence, when they are in contact with angular or irregular, than with smooth surfaces; that they therefore boil at a heat 2° F. lower in metallic than in glass vessels, probably owing to the greater polish of the latter. For example, if into water about to boil in a glass matrass, iron filings, ground glass, or any other insoluble powder, be

Places	Yards high	Inches of pressure	Boiling point
Farm of Antisana	4488	17·87	187·34
Quito	3170	20·74	194·18
Mexico	2490	22·52	198·14
St. Gothard	2302	23·02	199·22
Briançon	1423	25·39	203·9
Monte Doré	1136	26·26	205·7
Madrid	665	27·72	208·04
Moscow	328	28·82	210·2
Lyons	177	29·33	210·92
Paris	71	29·69	211·46

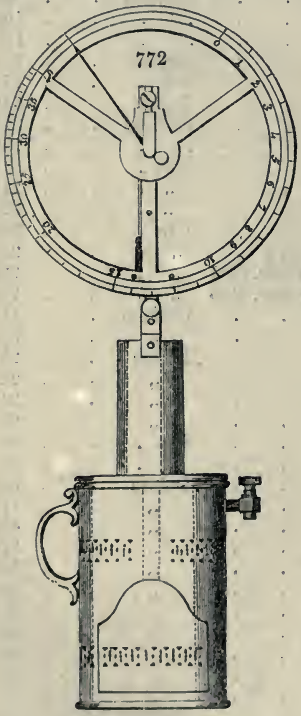
thrown, such a brisk ebullition will be instantly determined, as will sometimes throw the water out of the vessel; the temperature at the same time sinking 2° F.

The following table exhibits the boiling-heat, by Fahrenheit's scale, of the most important liquids:—

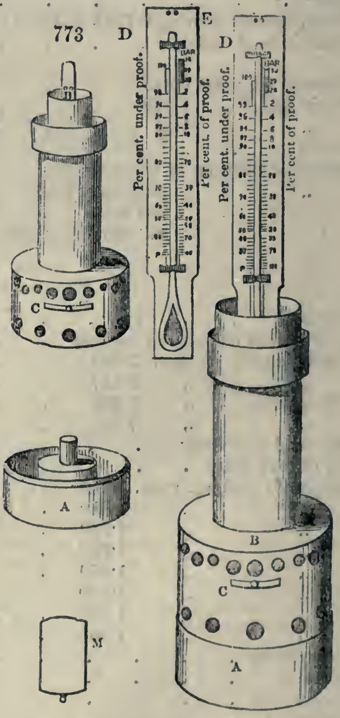
Ether		Graham	96°
Ether, specific gravity 0·7365 at 48°			100
Bisulphide of carbon			113
„		Graham	118
Alcohol, sp. grav. 0·813		Ure	173·5
Nitric acid, „ 1·500		Dalton	210
„ „ 1·42		Graham	248
Water			212
Saturated solution of Glauber salt		Biot	213⅓
„ „ acetate of lead		„	215⅔
„ „ sea salt		„	224⅓
„ „ chloride of calcium		Ure	285
„ „ „	1 + water, 2	„	230
„ „ „	35·5 + water, 64·5	„	235
„ „ „	40·5 + water, 59·5	„	240
Ammonia		Graham	140
Crystallised chloride of calcium		„	302
Muriatic acid, sp. grav. 1·094		Dalton	232
„ „ 1·127		„	222
Nitric acid, „ 1·420		„	248
„ „ 1·30		„	236
Rectified petroleum		Ure	306
Oil of turpentine		„	316
Sulphuric acid, sp. grav. 1·848		Dalton	600
„ „ 1·810		„	473
„ „ 1·780		„	435
„ „ 1·700		„	374
„ „ 1·650		„	350
„ „ 1·520		„	290
„ „ 1·408		„	260
„ „ 1·300		„	240
Phosphorus		„	554
Sulphur		„	570
Linseed oil		„	640
Whale oil		Graham	630
Mercury		Dulong	662
„		Crighton	656
Saturated solution of acetate soda, containing	60 per cent.	Griffiths	256
„ „ nitrate of soda,	60	„	246
„ „ Rochelle salt,	90	„	240
„ „ nitre	74	„	238
„ „ chloride of ammonium,	50	„	236
„ „ tartrate of potash,	68	„	234
„ „ chloride of sodium,	30	„	224
„ „ sulphate of magnesia,	57·5	„	222
„ „ borax,	52·5	„	222
„ „ phosphate of soda,	?	„	222

Saturated solution of carbonate of soda			Griffiths	220
,, ,, alum,	containing	52 per cent.	,,	220
,, ,, chlorate of potash,		40	,,	218
,, ,, sulphate of copper,		45	,,	216

EBULLITION ALCOHOLOMETER. That the boiling temperature of water is increased by holding neutro-saline and saccharine substances in solution has been long known, and has been the subject of many experiments, made partly with the view of ascertaining from that temperature the proportion of the salt or sugar, and partly with the view of obtaining a practical liquid bath. But it seems to have been reserved for the Abbé Brossard-Vidal of Toulon to have discovered that the boiling temperature of alcoholic liquors is, in most cases, proportional to the quantity of alcohol, irrespectively of the quantity of neutro-saline or saccharine matter dissolved in them. When, however, such a quantity of dry carbonate of potash, or sugar, is added to a spirituous liquor as to abstract or fix in the solid state a portion of the water present, then the boiling temperature of that mixture will be lowered in proportion to the concentration of the alcohol, instead of being raised, as would be the case with water so mixed. But, generally speaking, it may be assumed as a fact, that the boiling point of an alcoholic liquor is not altered by a moderate addition of saline, saccharine, or extractive matter. On this principle, M. Brossard-Vidal constructed the instrument represented in *fig.* 772, for determining by that temperature the proportion of alcohol present. His chief object was to furnish the revenue boards of France with a means of estimating directly the proportion of alcohol in wines, so as to detect the too common practice of introducing brandy into their cities and towns under the mask of wine, and thereby committing a fraud upon the *octroi*; as the duty on spirits is much higher than on wines.



772



773

The above instrument consists of a spirit-lamp, surmounted by a small boiler, into which a large cylindric glass bulb is plunged, having an upright stem of such calibre that the quicksilver contained may, by its expansion and ascent when heated, raise before it a little glass float in the stem, which is connected by a thread with a similar glass bead, that hangs in the air. The thread passes round a pulley, which turning with the motion of the beads causes the index to move along the graduated circular scale. The numbers on this scale represent percentages of absolute alcohol, so that the number opposite to which the index stops, when the liquor in the cylinder over the lamp boils briskly, denotes the percentage of alcohol in it.

Dr. Ure introduced another form of instrument (*fig.* 773). It is thus described by the inventor:—

It consists, 1, of a flat spirit-lamp A, surrounded by a saucer for containing cold water to keep the lamp cool, should many experiments require to be made in succession; 2, of the boiler B, which fits by its bottom cage C, upon the case of the lamp. At the point C, is seen the edge of the damper-plate for modifying the flame of the lamp, or extinguishing it when the experiment is completed. D is the thermometer, made with a very minute bore, in the manner of the Rev. Mr. Wollaston's instrument for measuring the height of a mountain by the boiling point of water on its summit. The bottom of the scale in the ebullition thermometer, is marked P for proof on the left side, and 100 (of proof spirit) on the right side. It corresponds to 178·6 Fahr. very nearly, or the boiling point of alcohol of 0·920 specific gravity. The following table gives the boiling points corresponding to the indicated densities:—

Temp. Fahr.	Specific Gravity		Temp. Fahr.	Specific Gravity	
178·6	0·9200	P.	185·6	0·3665	50 U. P.
179·75	0·9321	10 U. P.	189·0	0·9729	60 ,,
180·4	0·9420	20 ,,	191·8	0·9786	70 ,,
181·0	0·9516	30 ,,	196·4	0·9850	80 ,,
183·4	0·960	40 ,,	202·0	0·992	90 ,,

The above table is the mean of a great many experiments. When alcohol is stronger than 0·92, or the excise proof, its boiling point varies too little with its progressive increase of strength to render that test applicable in practice. In fact, even for proof spirits, or spirits approaching in strength to proof, a more exact indication may be obtained by diluting them with their own bulk of water, before ascertaining their strength and then doubling it.

The boiling point of any alcoholic liquor is apt to rise if the heat be long continued, and thereby to lead into error in using this instrument. This source of fallacy may be in a great measure avoided by adding to the liquor in the little boiler about a teaspoonful (thirty-five grains) of common culinary salt, which has the curious effect of arresting the mercury in the thermometer at the true boiling point of the spirit, wine, or beer, to enable a correct reading to be had. The small measure marked M holds the requisite quantity of salt.

The thermometer is at first adjusted to an atmospheric pressure of 29·5 inches. When that pressure is higher or lower, both water and alcohol boil at a somewhat higher or lower temperature. In order to correct the error which would hence arise in the indications of this instrument under different states of the weather, a barometrical equation is attached, by means of the subsidiary scale E, to the thermometer D.

Having stated the principles and the construction of the ebullition alcoholometer, I shall now describe the mode of its application.

First.—Light the spirit-lamp A.

Second.—Charge the boiling vessel B, with the liquid to be tested (to within an inch of the top), introducing at the same time a paper of the powder; then place the vessel B (the damper-plate being withdrawn) on to the lamp A.

Third.—Fix the thermometer D on the stem attached to B, with its bulb immersed in the liquid. The process will then be in operation.

The barometrical scale indicated on the thermometer is opposite the mean boiling point of water. Prior to commencing operations for the day, charge the boiler B with water only, and fix the instrument as directed; when the water boils freely, the mercury will become stationary in the stem of the thermometer, opposite to the true barometrical indication at the time. Should the mercury stand at the line 29·5 this will be the height of the barometer, and no correction will be required; but should it stand at any other line, above or below, then the various boiling points will bear reference to that boiling point.

In testing spirituous or fermented liquors of any kind, when the mercury begins to rise out of the bulb of the thermometer into the stem, push the damper-plate halfway in its groove to moderate the heat of the flame. When the liquor boils freely the mercury will become stationary in the stem; and opposite to its indication, on the left, the underproof percentage of spirit may be read off at once, if the barometer stand that day at 29·5 inches; while on the right-hand scale, the percentage of proof spirit is shown; being the difference of the former number from 100. The damper-plate is to be immediately pushed home to extinguish the flame.

The alcoholometer will by itself only indicate the percentage of alcohol contained in any wine; but, by the aid of the hydrometer, the proportionate quantity of saccharum in all wines may be readily and easily determined. The hydrometer will show the specific gravity of the liquid upon reference to table No. 1, annexed. In testing a sample of wine, first take the specific gravity, and suppose it to be 989, then charge the boiler of the alcoholometer with the wine, as directed, and at the boiling point it indicates the presence of alcohol at 69·6 per cent.$^{\text{u.p.}}$, whose specific gravity will be found to be 979; deduct that gravity from the gravity of the bulk, or 989, and 10 will remain, which 10 degrees of gravity, upon reference to the wine table, will be found to represent 25 lbs. of saccharine or extractive matter in every 100 gallons, combined with $30\frac{4}{10}$ths gallons of proof spirit.

Sikes's hydrometer will only show the specific gravity of liquids lighter than water (or 1,000), and for wines in general use, the gravities being lighter than that article, will answer every purpose; but there are wines whose gravities are heavier than water, such as mountain, tent, rich Malagas, lachrymæ Christi, &c., to embrace which additional weights to the hydrometer will be required, as for cordialised spirits, &c. In testing a sample of rich mountain, its specific gravity was found to be 1032, or 39° heavier than water; that wine at the boiling point indicated the alcohol 72·5 per cent.$^{\text{u.p.}}$; but 980 specific gravity deducted from 1039 leaves 39° of specific gravity; against 59 of the wine tables will be found 147·5 or 147½ lbs. of saccharine or extractive matter, combined with 27½ gallons of proof spirit to every 100 gallons.

Should the barometer for the day show any other indication above or below the standard of 29·5, the thermometer scale will then only show the apparent strength, and reference must be had to the small ivory indicator, E, it being the counterpart of the barometrical scale of the thermometer; thus, should the barometer indicate 30, place 30 of the indicator against the boiling point of the liquid, and opposite the line of 29·5 will be found the true strength.

Example 1.—Barometer at 30.—Suppose the mercury to stop at the boiling point 72$^{\text{u.p.}}$, place 30 of the indicator against 72 on the thermometer, and the line of 29·5 will cut 69·6$^{\text{u.p.}}$, the true strength.

Example 2.—Barometer at 29.—Suppose the mercury to stop at the same point, 72$^{\text{u.p.}}$, place 29 of the indicator against 72 on the thermometer, and the line of 29·5 will cut 74·3$^{\text{u.p.}}$, the true strength.

For malted liquors.—To all brewers and dealers in fermented liquors, this principle, by its application, will supply a great desideratum, as it will not only show the alcohol created in the wort by the attenuation, as well as the original weight of the wort prior to fermentation, but it will indicate the value of malt liquors in relation to their component parts. It will likewise be a ready means of testing the relative value of worts from sugar compared with grain, as well as being a guide to the condition of stock beers and ales.

To ascertain the strength of malt liquors and their respective values, the instrument has been supplied with a glass saccharometer, testing-glass, and slide-rule. Commence by charging the testing-glass with the liquid, then insert the saccharometer, to ascertain its present gravity or density per barrel, and at whatever number it floats, that will indicate the number of pounds per barrel heavier than water.

Example 1.—Suppose the saccharometer to float at the figure 8, that would indicate 8 lbs. per barrel; then submit the liquid to the boiling test, with the salt as before directed, and suppose it should show (the barometrical differences being accounted for) 90$^{\text{u.p.}}$, that would be equivalent to 10 per cent. of proof alcohol. Refer to the slide-rule, and place A on the slide against 10 on the upper line of figures, and facing B on the lower line will be 18, thus showing that 18 lbs. per barrel have been decomposed to constitute that percentage of spirit; then, by adding the 18 lbs. to the present 8 lbs. per barrel, the result will be 26 lbs., the original weight of the wort after leaving the copper.

Example 2.—The saccharometer marks 10 lbs. per barrel, and at the boiling point it indicates 88$^{\text{u.p.}}$, equivalent to 12 gallons of proof spirit per cent.; place A against 12, and opposite B will be 21½ lbs. per barrel, when, by adding that to the 10 lbs. present, 31½ lbs. will be the result.

To ascertain the relative value.—Suppose the price of the 26 lbs. of beer to be 36*s.* per barrel, and the 31½ lbs. beer to be 40*s.* per barrel, to ascertain which beer will be the cheapest, place 26 on the opposite side of the rule against 36, and opposite 31½ lbs. will be 43*s.* 7*d.*, showing that the latter beer is the cheapest by 3*s.* 7*d.* per barrel.

By taking an account of the malt liquors by this instrument prior to stocking, it may be ascertained at any time whether any alteration has taken place in their condition, either by an increase of spirit by after-fermentation and consequent loss of sugar, or whether, by an apparent loss of both, acetous fermentation has not been going on towards the ultimate loss of the whole.

This instrument will likewise truly indicate the quantity of spirit per cent. created

No. 1.

Table of Specific Gravities, by Sikes's Hydrometer, adapted to Field's Patent Alcoholometer for Cordialised Spirits.

TEMPERATURE 60°. SPECIFIC GRAVITY OF WATER 1000°.

60		70		80		90		100		110		120		130		140		150		160		170		180	
Wt.	S. G.	Wt.	S. G.	Wt.	S. G.	Wt.	S. G.	Wt.	S. G.	Wt.	S. G.	Wt.	S. G.	Wt.	S. G.	Wt.	S. G.	Wt.	S. G.	Wt.	S. G.	Wt.	S. G.	Wt.	S. G.
60	922	70	942	80	961	90	981	100	1000	110	1020	120	1041	130	1063	140	1085	150	1107	160	1129	170	1152	180	1175
1	924	1	943	1	963	1	983	1	1002	1	1022	1	1044	1	1065	1	1087	1	1109	1	1131	1	1155	1	1178
2	926	2	945	2	965	2	985	2	1004	2	1024	2	1046	2	1067	2	1089	2	1111	2	1134	2	1157	2	1180
3	928	3	947	3	967	3	987	3	1006	3	1026	3	1048	3	1069	3	1091	3	1113	3	1136	3	1159	3	1182
4	930	4	949	4	969	4	989	4	1008	4	1029	4	1050	4	1071	4	1093	4	1116	4	1139	4	1162	4	1185
5	932	5	951	5	971	5	991	5	1010	5	1031	5	1052	5	1074	5	1096	5	1118	5	1141	5	1164	5	1187
6	934	6	953	6	973	6	993	6	1012	6	1033	6	1054	6	1076	6	1098	6	1120	6	1143	6	1166	6	1189
7	936	7	955	7	975	7	995	7	1014	7	1935	7	1056	7	1078	7	1100	7	1123	7	1145	7	1168	7	1191
8	938	8	957	8	977	8	997	8	1016	8	1037	8	1058	8	1080	8	1102	8	1125	8	1148	8	1171	8	1194
9	940	9	959	9	979	9	999	9	1018	9	1039	9	1061	9	1082	9	1104	9	1127	9	1150	9	1173	9	1196
10	942	10	961	10	981	10	1000	10	1020	10	1041	10	1063	10	1085	10	1107	10	1129	10	1152	10	1175	10	1199

The foregoing Table, which shows the Specific Gravity on the bulk of the mixture, bears reference to the Table (No. 2) of the Alcoholometer following.

in distillers' worts, whether in process of fermentation or ready for the still; the only difference will be in the allowance on the slide-rule.

N.B.—The saccharometers applicable to the foregoing rules for beer, ales, &c., have been adjusted at the temperature of 60° Fahrenheit, and will be found correct for general purposes; but where extreme minuteness is required, the variation of temperature must be taken into account; therefore, for every 10° of temperature above 60, $\frac{3}{10}$ths of a pound must be added to the gross amount found by the slide-rule; on the contrary, for every 10° below 60, $\frac{3}{10}$ths of a pound must be deducted.

For cordialised Spirits.—The operation in this instance is somewhat different from that of beers, which have the alcohol created in the original worts; whereas, in cordialised spirits, gins, &c., the alcohol is the original, and the saccharine matter, or sugar, is an addendum.

No. 2.

Table showing the lbs. of Sugar per Gallon in Cordialised Spirits, with Per Centages to be added to the identical Strength, per the Alcoholometer.

Difference of Gravity Lbs. of Sugar per Gallon		10 4 oz. or 25 to 100	15 6 oz. 37⅛ to 100	20 8 oz. 50 to 100	25 10 oz. 62½ to 100	30 12 oz. 75 to 100	35 14 oz. 87½ to 100	40 1·0	45 oz. 1·2	50 oz. 1·4	Difference of Gravity Lbs. of Sugar per Gallon	
Sp. Grav. of Spirit	Per Cent. of Spirit										Per Cent. of Spirit	Sp. Grav. of Spirit
920	Pf.	1·6	2·5	3·4	4·4	5·3	6·2	7·1	8·1	9·0	Pf.	920
923	2·5	1·6	2·5	3·3	4·3	5·2	6·1	6·9	7·8	8·8	2·5	923
926	5·	1·5	2·4	3·2	4·2	5·0	5·9	6·8	7·7	8·6	5·	926
929	7·5	1·5	2·3	3·2	4·1	4·9	5·8	6·6	7·5	8·4	7·5	929
932	10·	1·4	2·2	3·1	4·0	4·8	5·7	6·5	7·4	8·2	10·	932
935	12·5	1·4	2·2	3·1	3·9	4·7	5·5	6·3	7·2	8·0	12·5	935
938	15·	1·4	2·1	3·0	3·8	4·6	5·4	6·2	7·0	7·8	15·	938
940	17·5	1·3	2·1	2·9	3·7	4·5	5·3	6·0	6·8	7·6	17·5	940
943	20·	1·3	2·0	2·8	3·6	4·4	5·2	5·9	6·7	7·5	20·	943
945	22·5	1·3	2·0	2·7	3·5	4·3	5·0	5·7	6·5	7·3	22·5	945
948	25·	1·2	1·9	2·6	3·4	4·1	4·8	5·5	6·3	7·0	25·	948
950	27·5	1·2	1·9	2·5	3·3	4·0	4·7	5·3	6·1	6·8	27·5	950
952	30·	1·1	1·8	2·4	3·1	3·8	4·5	5·1	5·8	6·5	30·	952
954	32·5	1·1	1·7	2·3	3·0	3·6	4·3	4·8	5·5	6·2	32·5	954
956	35·	1·0	1·6	2·2	2·9	3·5	4·1	4·6	5·3	6·0	35·	956
958	37·5	1·0	1·6	2·1	2·8	3·4	3·9	4·4	5·1	5·8	37·5	958
960	40·	·9	1·5	2·0	2·7	3·2	3·8	4·3	4·9	5·5	40·	960
962	42·5	·9	1·5	2·0	2·6	3·1	3·6	4·1	4·7	5·3	42·5	962
964	45·	·9	1·4	1·9	2·5	3·0	3·5	4·0	4·6	5·1	45·	964
965	47·5	·8	1·4	1·9	2·4	2·9	3·4	3·9	4·4	4·9	47·5	965
967	50·	·8	1·3	1·8	2·3	2·8	3·3	3·8	4·3	4·8	50·	967
969	52·5	·7	1·2	1·7	2·2	2·6	3·1	3·6	4·1	4·5	52·5	969
970	55·	·7	1·2	1·6	2·0	2·4	2·9	3·4	3·8	4·2	55·	970
972	57·5	·6	1·1	1·5	1·9	2·2	2·7	3·1	3·5	3·9	57·5	972
973	60·	·6	1·0	1·4	1·8	2·1	2·5	2·9	3·3	3·6	60·	973
974	62·5	·6	1·0	1·3	1·7	2·0	2·4	2·7	3·1	3·4	62·5	974
976	65·	·5	·9	1·2	1·5	1·8	2·2	2·5	2·8	3·1	65·	976
977	67·5	·5	·8	1·1	1·4	1·7	2·0	2·3	2·6	2·9	67·5	977
979	70·	·4	·7	1·0	1·3	1·5	1·8	2·1	2·4	2·6	70·	979
980	72·5	·4	·7	·9	1·1	1·3	1·6	1·9	2·1	2·3	72·5	980
982	75·	·3	·6	·8	1·0	1·2	1·4	1·6	1·8	2·0	75·	982
983	77·5	·3	·5	·7	·9	1·0	1·2	1·4	1·6	1·8	77·5	983
984	80·	·2	·4	·6	·8	·9	1·0	1·2	1·4	1·6	80·	984
986	82·5	·2	·3	·5	·7	·8	·9	1·0	1·2	1·4	82·5	986
988	85·	·2	·2	·4	·6	·7	·8	·9	1·0	1·2	85·	988
990	87·5	·1	·2	·3	·5	·6	·7	·8	·9	1·0	87·5	990
992	90·	·1	·1	·2	·4	·5	·6	·7	·8	·9	90·	992
994	92·5	...	·1	·2	·3	·4	·5	·6	·7	·8	92·5	994
996	95·	...	...	·1	·2	·3	·4	·5	·6	·7	95·	996
998	97·5	...	...	...	·1	·2	·3	·4	·5	·6	97·5	998

If 100 gallons of spirits are required at a given strength, say 50 per cent. under proof, 53 gallons of proof spirit, with the addition of 50 gallons of water, would effect that object, and upon testing it by the alcoholometer, it would be found as correct as by the hydrometer. But in cordialising spirits it is different, for to the 50 gallons of proof spirit 50 gallons of sugar and water would be added, thereby rendering the hydrometer useless, except for taking the specific gravity of the bulk, and according to the quantity of sugar present, so a relative quantity of water must have been displaced; and as the sugar has no reducing properties, the alcoholometer will only show the strength of the cordial in relation to the water contained in it, as the principle indicates, irrespectively of saccharine or extractive matter.

Suppose, in making 100 gallons of cordial at $50^{u.p.}$, 3 lbs. of sugar are put to the gallon, or 300 lbs. to the 100 gallons, that 300 lbs., displacing $18\frac{67}{100}$th gallons of water, only $31\frac{33}{100}$th gallons of water instead of 50 have been applied; the sugar, without reducing properties, making up the bulk of 100 gallons, which is meant to represent 50 per cent.$^{u.p.}$.

The alcoholometer will only show at the full point of ebullition the alcoholic strength in relation to the water in the 100 gallons of the mixture, or 35 per cent.$^{u.p.}$, leaving 15 per cent. to be accounted for on the bulk.

As the quantity of sugar present must be determined before that percentage can be arrived at, a double object will be effected by so doing, namely eliciting in all instances the quantity of sugar present, as well as the percentage of spirit to be accounted for.

Example 1.—In taking the specific gravity of a cordial, suppose it to be found 1076, then submit the liquid to the boiling point, and having ascertained the percentage of alcohol, and it proves to be $35^{u.p.}$, the specific gravity of alcohol at that strength will be found to be 956; deduct 956 from the specific gravity of the bulk, 1076, and 120 will remain; refer that to its amount on the head line of the table No. 1, namely, 120, under which will be found 3, representing 3 lbs. of sugar to the gallon; and by running the eye down the column table No. 2 to opposite the alcoholic strength indicated ($35^{u.p.}$), will be found 14·9, which represents the percentage of water displaced by the sugar, and which amount of 14·9, added to the 35 per cent. ascertained, makes the total upon the bulk 49·9 per cent.$^{u.p.}$, with 3 lbs. of sugar to the gallon.

For Gins, &c.—Example 2.—In taking the specific gravity, suppose it to be found 957; then submit to the boiling point, and it proves to be $14^{u.p.}$, whose specific gravity is 937, which, deducted from 957, leaves specific gravity 20; on the head-line of table No. 2, under 20, will be found 8 oz., or ½ lb. of sugar to the gallon, and on running the eye down to opposite $14^{u.p.}$, will be found 3·0, which, added to the 14, makes the total on the bulk 17 per cent.$^{u.p.}$, with 50 lbs. of sugar to the 100 gallons.

To chemists for their tinctures, &c., this instrument will be found essentially useful.

N.B.—Care must be taken that the mercury is entirely in the bulb of the thermometer before it is fixed on the stem for operation, and in all cases (except for water) the salt must be used.

ECLOGITE. See Eklogite.

EDDOES. A plant (*Arum esculentum*) which is found in most tropical climates, and cultivated for food. It contains 63 parts of matter soluble in water, and 37 parts insoluble. It ranks with the potato as an article of nutrition.

EDENITE. A variety of hornblende, occurring at Edenville, New York.

EDGE TOOLS; more properly *cutting tools*, of which the chisel may be regarded as the type. Holtzapffel, whose book on 'Mechanical Manipulation' is the best to be found in any language, divides cutting tools into three groups: namely, paring tools, scraping tools, and shearing tools.

First. Paring or splitting tools, with thin edges, the angles of which do not exceed sixty degrees, one plane of the edge being nearly coincident with the plane of the work produced (or with the tangent in circular work). These tools remove the fibres principally in the direction of their length, or longitudinally, and they produce large coarse chips, or shavings, by acting like the common wedge applied as a mechanical power.

Secondly. Scraping tools, with thick edges, that measure from sixty to one hundred and twenty degrees. The planes of the edges form nearly equal angles with the surface produced, or else the one plane is nearly or quite perpendicular to the face of the work (or becomes as a radius to the circle). These tools remove the fibres in all directions with nearly equal facility, and they produce fine dust-like shavings by acting superficially.

Thirdly. Shearing, or separating tools, with edges of from sixty to ninety degrees generally duplex, and then applied on opposite sides of the substances. One plane of each tool, or of the single tool, coincident with the plane produced.

Mr. James Bouydell introduced a process which professed to produce cheap edge tools of excellent quality, He welded iron and steel together in such a manner that when cut up to form edge tools, the steel constituted a thin layer to form the cutting edge. He piled a slab or plate of steel upon two or more similar plates of iron; heated it in a furnace to a good welding heat, and then passed it between grooved or other suitable rollers to convert it into bars; the steel being in a thin layer either on one of the outer surfaces of the bar, or between two surfaces of iron, according to the kind of tool to be made therefrom. The bars thus produced were cut up and manufactured into the shape of the desired articles by forging. If the cutting edge was to extend but a short distance, the steel was applied only near one edge of the pile. The compound bars which have the steel on one side are suitable for chisels and other tools, which have a cutting edge on one side, the iron being ground away when making or sharpening the tool. See CUTLERY; STEEL.

EDULCORATE (*Edulcorer*, Fr.; *Aussüssen*, Ger.) is a word introduced by the alchemists to signify the sweetening, or rather rendering insipid, of acrimonious pulverulent substances, by copious ablutions with water. It means, in modern language, the washing-away of all particles soluble in water, by agitation or trituration with this fluid, and subsequent decantation or filtration.

EFFERVESCENCE. (Eng. and Fr.; *Aufbrausen*, Ger.) When gaseous matter is suddenly extricated with a hissing sound during a chemical mixture, or by the application of a chemical solvent to a solid, the phenomenon, from its resemblance to that of simmering or boiling water, is called effervescence. The most familiar example is afforded in the solution of sodaic powders; in which the carbonic acid gas of bicarbonate of soda is extricated by the action of citric or tartaric acid.

EFFLORESCENCE (Eng. and Fr.; *Verwittern*, Ger.) is the spontaneous conversion of a solid, usually crystalline, into a powder, in consequence either of the abstraction of the combined water by the air, as happens to the crystals of sulphate and carbonate of soda; or by the absorption of oxygen and the formation of a saline compound, as in the case of alum schist, and iron pyrites. Saltpetre appears as an efflorescence upon the ground and walls in many situations.

EGGS. The eggs of birds become useful in many processes of manufacture. They consist of four parts:—

1. The *shell*, consisting of—

Carbonate of lime	89·6
Phosphate of lime and magnesia	5·7
Animal matter and sulphur	4·7

2. *A membrane* (*membrana putaminis*) which lines the shell, which analysis shows to be composed of—

Carbon	50·7
Hydrogen	6·6
Nitrogen	16·8
Oxygen and sulphur	26·0

3. *The white.* Albumen, a colourless liquid, enclosed in large cells formed of a thin membrane.

4. *The yolk*, or *vitellum.* Surrounded by the albumen; also enclosed in a membrane.

The albumen, or white-of-egg, is used for numerous purposes in the arts. It contains carbonates in variable quantity, albumen, a small quantity of fat, glucose, and extractive matter.

The yolk of birds' eggs consists mainly of fat and pigment. See Watts's 'Dictionary of Chemistry.'

Eggs, non-incubated, respire, giving off water and carbonic acid, and absorbing oxygen, so that the air confined at the broad end of the egg is richer in oxygen than the external air. This indicates the method to be adopted in the preservation of eggs, viz., to fill the pores of the shell, so as to prevent entirely the osmose force to which this process of respiration belongs. If the eggs are dipped into melted tallow or wax, or into a cream of freshly-slaked lime, this is effected. Dipping eggs into a strong brine is said to be effectual; the effects are similar in either case. The trade in eggs is large.

The *Importation* of eggs in the last five years was as follows:—

Year	Great hundreds	Computed value
		£
1868	3,199,742	1,009,285
1869	3,684,772	1,126,853
1870	3,590,352	1,102,080
1871	3,351,106	1,265,484
1872	4,650,676	1,837,886

EGGS, HATCHING. See Incubation, Artificial.

EGG-APPLES. The edible fruit of *Solanum ovigerum* and *S. Melongena.*

EGYPTIAN JASPER. Rolled pebbles of brown jasper from the Valley of the Nile. They are cut and polished as ornamental stones.

EHLITE. A hydrated phosphate of copper, occurring generally in reniform and botryoidal masses. It takes its name from one of its localities—Ehl, near Linz, on the Rhine. According to the analyses made by Bergemann, this mineral contains vanadium, and it has hence been sometimes called phosphovanadate of copper.

EHRENBERGITE. A mineral found as a deposit in trachyte in the Siebengebirge. It was examined by Ehrenberg, after whom it was named. It contains silica and alumina, and, according to Bischof and Schnabel, water extracts from it chlorine, sulphuric acid, and magnesia, while hydrochloric acid extracts both iron and manganese. Its composition is very variable.

EIDER-DOWN is so called because it is obtained from the *Eider*-duck.

EIDER-DUCK. *Sometaria.* There are two species of these ducks, abundant in the frozen regions of the North, especially in Iceland, Lapland, Greenland, Spitzbergen, Baffin's Bay, and Hudson's Bay. To the inhabitants of these countries these birds are exceedingly valuable. They build their nests among precipitous rocks, and the female lines them with fine down plucked from her breast, among which she lays her five eggs. The natives of the districts frequented by the eider-ducks let themselves down by cords among the dangerous cliffs, to collect the down from the nests. They also catch the hen bird while she is sitting, and pluck the down. When brought to market the down is in balls, weighing from three to four pounds, and not much larger than a man's fist. But the down is so fine and elastic that when opened and held near a fire to expand, one ball would fill a quilt five feet square. See Swan's Down.

EISENKIESEL. A German name for ferruginous quartz, sometimes used for convenience by English mineralogists.

EJOO. *Saguerus Rumphii.* A vegetable fibre possessing considerable strength. See Fibres.

EKLOGITE. A rock composed of green smaragdite, in which red garnets are embedded. When polished, it forms a beautiful stone for ornamental purposes. It is found in the Sau Alp, in Styria; and at Münchberg, in the Fichtelgebirge.

ELÆIS. A genus of palm-trees, containing one or two species which grow in tropical Africa and America. The oil-palm, or *Elæis guineensis*, is a native of the western coast of Africa.

The oil resides in the fleshy portion of the fruit, which is about the size of pigeons' eggs, ovate, somewhat angular, deep orange-yellow, collected in beads. They have a thin epicarp, a fibrous, oily, yellow sarcocarp, which covers and closely adheres to the hard stony putamen or endocarp, within which is the seed. The oil is obtained from the sarcocarp, and in this respect resembles that of the olive. It is obtained either by expression, or by boiling the fruit with water, when the oil separates and rises to the surface. It is imported principally from Cayenne and the coasts of Guinea. It is, when freshly imported, of the consistence of tallow, of an orange colour, possesses the smell of violets, and fuses at about 80° F. It speedily becomes rancid, and decomposes with liberation of glycerine and the fatty acids, and as this change progresses, its fusing-point gradually rises till it sometimes even reaches 97° F. It is composed principally of a peculiar fat, *palmitin*, and a little oleine and colouring-matter. It is used in the manufacture of soap and candles, and is imported in very large quantities. The following is a general outline of the treatment of palm-oil at Price's Candle Company's works. (See 'Pharmaceutical Journal,' vol. xv. p. 264.) The crude palm-oil is melted out of the casks in which it has been imported, and allowed to remain in a melted state in large tanks until the mechanical impurities have settled to the bottom. The clear oil is then pumped into close vessels, where it it is heated and exposed to the action of sulphuric acid. The glycerine and fatty acids are thereby separated, and the colouring-matter and impurities are carbonised and partly rendered insoluble. The mixture has now a greyish-brown colour, and is washed with water to remove the acid. From the washed product, distillation now separates the mixed fatty acids (palmitic and palm-oleic acids), as a white crystalline fat, while the residuum in the still is converted into a fine hard pitch. This pitch is fit for any of the purposes for which ordinary pitch is applicable. The mixed fatty acids may be made directly into candles, or they may be separated by hydraulic pressure, aided, if necessary, by heat. This effects the separation of the liquid part (oleic acid), which, after purification, is fit for burning in lamps and other purposes. The hard cake left in the presses is nearly pure palmitic acid; it is brilliantly white, not at all greasy, and has a melting point of 135° to 138°. It is fit for the manufacture of the finest candles, either alone or in admixture with the stearine of the cocoa-nut oil.

Palm-oil often requires to be bleached for its various uses, and there are several processes used to effect it, viz. chlorine, powerful acids, and the combined influence of air, heat, and light.

M. Bohl has bleached palm-oil by heating it quickly to 464° F., and keeping it at that temperature for a few minutes, without the aid of light or air. And he says this process has been carried on for some time in a factory. The heating of the palm-oil is effected as rapidly as possible in cast-iron pans; it is kept for ten minutes at the temperature of 464° F., and the bleaching is complete. Ten or twelve hundredweight of palm-oil may be conveniently heated in one pan, which, however, must only be two-thirds full, as the oil expands greatly by the heat. It must be covered with a well-fitted cover, which prevents inconvenience from the disagreeable vapours which arise. This answers better on the large scale than on the small. By this process it acquires an empyreumatic odour, which disappears after a little time, and the original odour of the palm-oil returns.

The yellow fat which is used to grease the axle-trees of the railway carriages is prepared with a mixture of palm-oil and tallow, with which is mixed a little soda-lye. (*Gerhardt.*)

For the properties of *palmitin* and *palmitic acid*, see PALMITIC ACID.

Of palm-oil our *Imports* have been :—

Places	1868		1869		1870		1871		1872	
	cwts.	Value	cwts.	Value	cwts.	Value	cwts.	Value	cwts.	Value
From		£		£		£		£		£
France .	..	..	..	..	14,546	26,145				
Portugal .	..	..	6,899	13,350	7,446	13,512	19,466	33,923	6,994	12,965
Fernando Po	4,478	8,776	3,854	7,518	11,029	19,999				
Portuguese Possessions in Western Africa .	30,993	61,472	23,310	45,298	22,026	39,876	..	..	7,702	14,286
Ditto, not designated	..	..	..	..	..	..	..	..	824,488	1,474,016
Western Coast of Africa .	791,548	1,557,554	653,268	1,270,308	711,509	1,298,194	872,678	1,518,487	7,129	13,260
Sierra Leone	20,947	41,673	6,249	12,084	10,882	19,783	22,056	35,582		
British Possessions on the Gold Coast .	102,629	203,861	109,709	213,388	77,512	141,835	118,847	208,574	139,057	252,932
Other parts	9,464	18,237	11,231	21,755	13,320	24,486	14,835	24,132	18,919	33,437
Total .	960,059	1,891,573	814,520	1,583,701	868,270	1,583,830	1,047,882	1,820,693	1,006,494	1,805,153

ELŒOMETER. A variety of hydrometer which is sometimes used for detecting adulterations in fixed oils by their specific gravity, and by their different rates of expansion by heat. The determinations by this instrument are not, however, to be strictly relied on.

ELAINE (called also OLEINE) is the name given by Chevreul to the thin oil, which may be expelled from tallow and other fats, solid or fluid, by pressure either in their natural state or after being saponified, so as to harden the *stearine.* It may be extracted also by digesting the fat in seven or eight times its weight of boiling alcohol, specific gravity 0·798, till it dissolves the whole. Upon cooling the solution the stearine falls to the bottom, while the elaine collects in a layer, like olive-oil, upon the surface of the supernatant solution, reduced by evaporation to one-eighth of its bulk. If this elaine be now exposed to a cold temperature, it will deposit its remaining stearine, and become pure. Braconnot obtained it by exposing olive-oil to a temperature of about 21° F. in order to cause the congelation of the margarine or stearine (?). The elaine was a greenish-yellow liquid; at 14° F. it deposited a little margarine. See OILS and STEARINE.

ELASTIC BANDS. (*Tissus élastiques*, Fr.; *Federharz-zeige*, Ger.) See CAOUTCHOUC and BRAIDING MACHINE.

ELASTIC BITUMEN, called also *mineral caoutchouc* and *elaterite*, was first observed in Derbyshire, in the forsaken lead-mine of Odin, by Dr. Lister, in 1673, who called it a subterranean fungus. It was afterwards described by Hatchett. The analysis of this variety, by Johnston, gave the following as its composition :—

Carbon 85·47 . . . . . . Hydrogen 13·28.

Two descriptions of elastic bitumen were analysed by M. Henry fils (‘*Ann. des Mines*’). He states the English to have been in brown masses, slightly translucid, of a greenish colour, soft, elastic, burning with a white flame, and giving off a bituminous odour, and of specific gravity 0·9 to 1·23, and obtained from Derbyshire.

The French elastic bitumen generally resembled the English, excepting that it was opaque, and floated on water. It was discovered at the coal-mines of Montrelais.

	English	French
Carbon	0·5225	0·5826
Hydrogen	0·0742	0·0489
Nitrogen	0·0015	0·0010
Oxygen	0·4011	0·3675
	1·0000	1·0000

Elastic bitumen is found in soft, flexible masses at Castleton in Derbyshire. See BITUMEN.

ELASTICITY. The property which bodies possess of occupying, and tending to occupy, portions of space of determinate volume, or determinate volume and figure, at given pressures and temperatures, and which, in a homogeneous body, manifests itself equally in every part of appreciable magnitude (*Nichol*). The examination of this important subject in Kinetics does not belong to this work. A few remarks, and some explanations, only are necessary.

Elastic Pressure is the force exerted between two bodies at their surface of contact.

Compression is measured by the diminution of volume which the compressible (elastic) body undergoes.

The *Modulus* or *Coefficient of Elasticity* of a liquid is the ratio of a pressure applied to, and exerted by, the liquid to the accompanying compression, and is therefore the reciprocal of the compressibility. The quantity to which the term *Modulus of Elasticity* was first applied by Dr. Young, is the reciprocal of the extensibility or longitudinal pliability. (See the Edinburgh Transactions, and those of the Royal Society, for the papers of *Barlow, Maxwell,* and *Rankine,* and the British Association Reports for those of *Fairbairn, Hodgkinson,* &c.)

Names of the woods	Density	Sound velocity			Coefficients of elasticity			Cohesion		
		L.	R.	T.	L.	R	T.	L.	R.	T.
Acacia	0·717	14·9	...	...	1216·9	...	...	7·93	...	...
Fir	0·493	13·96	8·05	4·72	1113·2	94·5	34·1	4·18	0·220	0·297
Hornbeam	0·756	11·80	10·28	7·20	1085·7	208·4	103·4	2·99	1·007	0·618
Birch	0·812	13·32	6·46	9·14	997·2	81·1	155·2	4·30	0·823	1·063
Beech	0·823	10·06	11·06	8·53	980·4	269·7	159·3	3·57	0·885	0·752
Oak	0·808	...	...	...	477·8	...	...	6·49	...	...
Holm-oak	0·872	11·58	9·24	7·76	921·3	188·7	129·8	5·66	0·582	0·406
Pine	0·559	10·00	8·53	4·78	564·1	97·7	28·6	2·48	0·256	0·196
Sycamore	0·692	13·43	9·02	6·85	1163·8	134·9	80·5	6·16	0·522	0·610
Ash	0·697	14·05	8·39	7·60	1121·4	111·3	102·0	6·78	0·218	0·408
Alder	0·601	13·95	8·25	6·28	1108·1	98·3	59·4	4·54	0·329	0·175
Aspen	0·602	15·30	9·72	5·48	1075·9	107·6	43·4	7·20	0·171	0·414
Maple	0·674	12·36	9·26	6·23	1021·4	157·1	72·7	3·58	0·716	0·371
Poplar	0·477	12·89	8·44	6·32	517·2	73·3	38·9	1·97	0·146	0·214
Elm	...	...	8·56	6·11	...	122·6	63·4	...	0·345	0·366

L refers to rods cut lengthwise with the grain,
R to those cut in a direction radial, and
T to those tangential to the annual rings.

Various tables, showing the elasticity of metals, glass, &c., have been constructed, and will be found in treatises on mechanics. The following notices of the mechanical properties of woods may prove of considerable interest. The experiments were by Chevandier and Wertheim.

Rods of square section 10 mm. in thickness and 2 m. in length were prepared, being cut in the direction of the fibres, and the *velocity of sound* in them was determined by the longitudinal vibrations, *their elasticity* from their increase in length, and *their cohesion* by loading them to the point of rupture. Small rods were cut in planes perpendicular to the fibre grain (in directions radial and tangential to the rings of growth) and their elasticity and sound velocity were measured by the lateral vibrations. It was thus again established, that the coefficients of elasticity, as deduced from the vibrations, come out higher than those derived from the elongation.

ELATERITE. See Elastic Bitumen.

ELATERIUM. A peculiar extract obtained from the juice of the wild cucumber. (*Mormordica elaterium.*) It owes its properties to a crystallisable principle called *Elaterin.*

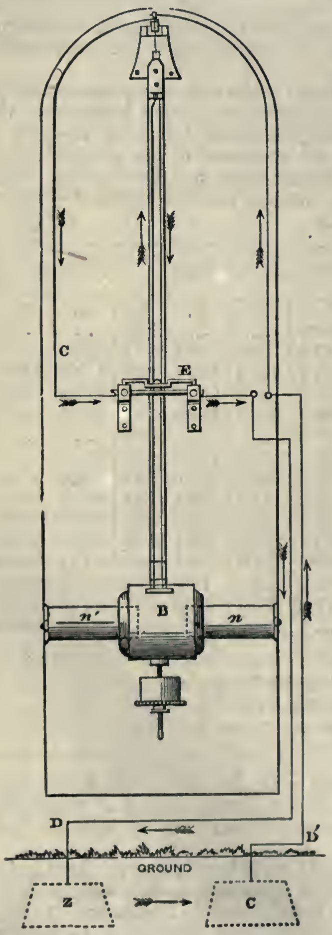
ELAYL. See Olefiant Gas.

ELDER. (*Sureau,* Fr.; *Holunder,* Ger.) *Sambucus nigra.* Pith-balls for electrical purposes are manufactured from the pith of the elder-tree, dried. The wood is employed for inferior turnery-work, for weavers' shuttles, netting-pins, and shoemakers' pegs. Its elasticity and strength render it peculiarly fitted for these latter purposes. The flowers of the elder are largely collected for distillation, yielding the well-known elder-flower water; 9 pounds of flowers distilled with 4 gallons of water give 3 gallons of the fragant distillate; they are also heated in lard for making elder-ointment. The berries or fruit of the elder are employed for making one of the truly British wines.

ELECTIVE AFFINITY. (*Wahlverwandtschaft,* Ger.) See Decomposition; Equivalents.

ELECTRIC CLOCKS. The application of electricity as a motive power to clocks, and as a means of transmitting synchronous signals or time, is naturally intimately connected with the attempts (not yet realised in an economic point) to apply it as a motive power to machinery, and with its application, so fully realised to telegraphy proper (see article Electro-Telegraphy); and it has grown up side by side with the latter. Prof. Wheatstone's attention was directed to it in the very early days of telegraphy. Without entering upon the history of electric clocks, it will suffice to describe two principles on which they have been constructed, and which are best known: Bain's and Shepherd's. In the former, electricity maintains the pendulum in motion, and the pendulum drives the clock-train; in the latter, the motion of the pendulum is maintained by electricity, but the clock-train is driven by distinct currents, sent to it by means of pendulum contacts.

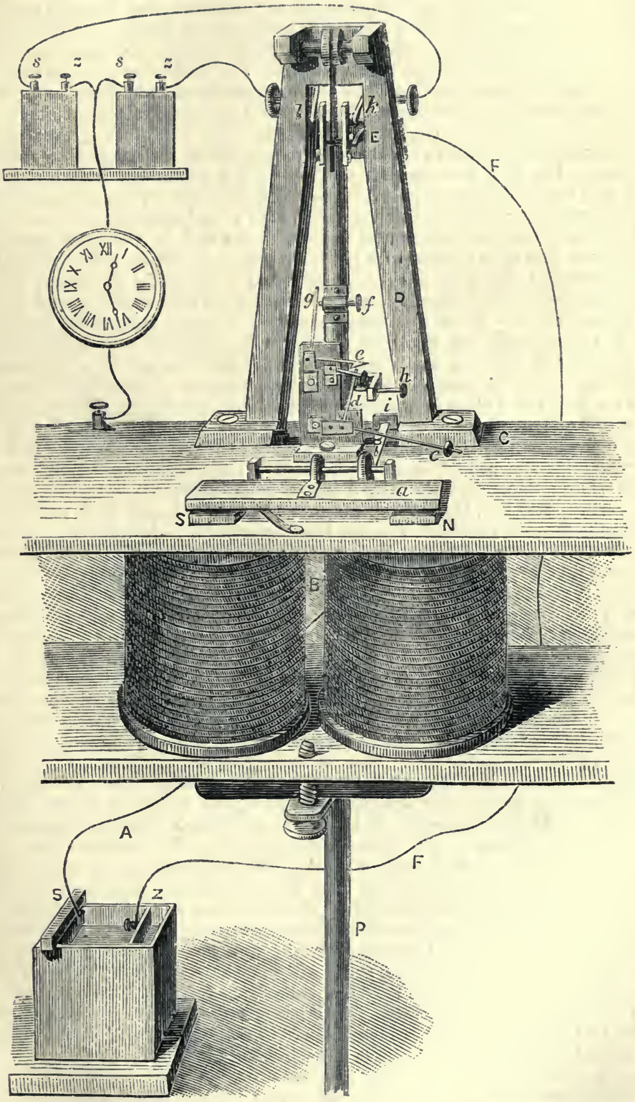
774



The bob of Bain's pendulum consists of a coil of wire, wound on a bobbin with a hollow centre. The axis of the bobbin is horizontal. Bar magnets, presenting similar poles, are fixed on each side of the coil, in such a position that, as the pendulum oscillates right and left, the poles on either side may enter the coil of wire. It is one of the laws of electric currents, when circulating in a helix, or spiral, or coil, or even in a single ring, that each face of the coil presents the characters of a magnetic pole; of a south pole, if the current circulates in the direction in which the hands of a watch move, of a north pole, if it circulates in the reverse direction. Things are so arranged in Bain's pendulum that a battery current is alternately circulating in and cut off from the coil. When the current is circulating, the coil has the character of a magnet, with a north end and a south end; if the permanent magnets present north poles, the north end of the coil-bob will be repelled from one of the magnets, while its south end will be attracted by the other magnet. This constitutes the impulse or maintaining power in one direction. Now the connections are such that, when the arc of vibration is complete and the pendulum ready for the return vibration, the pendulum rod pushes aside a golden slide, by which the electric circuit had been completed, and the current is cut off; the pendulum is thus able to make its return-vibration by mere gravity. It starts to repeat the above operations also by gravity; but, ere it completes the arc, the rod pushes back the slide, and again completes the electric circuit, and gives rise to a second impulse, and so on. A small amount of magnetic attraction is sufficient to supply the necessary amount of maintaining power. One pair of zinc-copper, buried in the moist earth, has been found ample.

In an ordinary clock, the train is carried by a weight or by a spring, and the time is regulated by the pendulum. In Bain's the time is regulated and the train is driven

775



by the pendulum. The rod hangs within a crutch in the usual way; the crutch carries pallets of a particular kind, acting in a scape-wheel; and, from the latter, the motion is transmitted to a train of the usual character, but much lighter. For large clocks, Mr. Bain proposes a modification of the slide, which shall invert the current at each oscillation, so as to have attraction as a maintaining power in both oscillations. The general arrangement of the pendulum is shown in *fig.* 774. B is the pendulum bob, with its coil of wire, the ends of which pass up on either side of the rod. Z and C are the battery plates, with their attached wires D and D′. The arrows show the course of the voltaic current from the plate C by the wire D′, thence down the pendulum rod by the right-hand wire, through the coil B, up by the wire on left side of rod, then by the wire C, along the slide at E, and by the wire D to the zinc plate Z. When the slide E is in position, the circuit is complete, and the bob is attracted by the *n* pole of one of the magnets, and repelled by the *n′* pole of the other. When the slide is displaced, the attraction ceases, and the pendulum is left to the mere action of gravity.

Shepherd's electric clock has a remontoir escapement. There is no direct connection between the electric force and the pendulum, or between the pendulum and the clock-train. The attractive power, derived from the electric current, is simply employed to raise the same small weight to the same height; and the clock-train is carried by the attractive force derived from electric currents, whose circuits are completed by the pendulum touching contact springs. The pendulum is thus protected from the influence of change in the force of the current, or from irregular resistances in the train. *Fig.* 775 is a perspective view of this pendulum, with batteries, S Z, attached, and the clock connections and those of its batteries, *s z*, *s z*, shown. The electricity leaves the pendulum battery by the wire A, and returns to it by the wire F. There is only one break in this circuit, namely, at E, which is a slender spring faced with platinum, that is in contact with platinum on the pendulum at the extreme of its right vibration, but at no other time. The wire A reaches the pendulum from the battery by the coils B, the plate C, and the frame D; the wire F goes direct from the spring E to the zinc Z. From this arrangement, it happens that every time the contact at E is completed, the iron core, of which the ends N S are visible, contained within the coils B, becomes a magnet, and when the contact at E is broken, the magnetism ceases. The poles N S have, therefore, a power alternately to attract and to release *a*, which is a plate or armature of soft iron, moving on an axis, as shown in the figure, and to which is attached a bar *b*, with a counterpoise *i*. We have said that the office here of the electric force is merely to raise a weight; the fall of the weight maintains the pendulum in motion. When the armature *a* is attracted, the lever *b* is raised; this raises the wire *c* into a horizontal position, and its other part *d* into a vertical position; the latter is caught and retained by the latch or detent *e*; so that when the magnetic attraction ceases, the counterpoise *i* descends with the lever *b*; and so the armature *a* leaves the electro-magnet N S. But the wire *d* remains vertical, and its other part with the small weight *c* remains horizontal. Now, when the pendulum makes its left-hand oscillation, the point of the screw *f* impinges upon the stem *g*, and carries it a little to the left; this raises the detent *e*, and liberates the piece *d c*, which descends into its original position by gravity; the small ball *c* adds to its weight. In descending, the vertical piece *c* strikes against the point of the screw *h*, and gives a small impulse to the pendulum P. The ball *c* is not larger than a pea, and its fall is not an eighth of an inch; but the impact is sufficient to keep the pendulum in motion; and it is constant, being this same body falling through the same space; and is independent of any variation in the battery power, which latter is only concerned in raising the ball. The arc of the pendulum's vibration is regulated by adjusting the small ball to a greater or less distance from the centre. Provision is thus made for maintaining the pendulum in motion, and giving it an impact of constant value. If this arrangement is in connection with a compensating mercurial pendulum, extreme accuracy of time-keeping is attained. The next step is to transfer the seconds thus secured to a dial or clock. The same movement of the keeper *a* with its counterpoise *i*, has sometimes been made to impart motion to the seconds wheel of a clock-train; but more commonly the clock train is distinct, as shown in the drawing, and is carried by a special electro-magnetic arrangement, in connection with separate batteries, *z s*, *z s*, the contacts of which are, however, under the control of the pendulum. Insulated springs, *k* and *l*, are fixed near the top of the rod; from *k* a wire leads to the silver *s*, of the left-hand battery; and from *l* another wire leads to the zinc *z*, of the right-hand battery. The other metals of the respective batteries are connected by a wire with an electro-magnet within the clock, the other end of the said electro-magnet being connected with the metal bed and frame of the pendulum. When, therefore, the pendulum oscillates to the right, the circuit is completed at *k*; and the current of the left-hand battery circulates from *s* through the wire *k*: and thence through the metal frame and by the wire to the clock, and so to the zinc *z*. When the oscillation is to the left, and *l* is in contact, the right-hand battery is in action, and the current circulates from *s*, through the clock, to the metal frame, and thence to *l* and to the zinc *z* of the battery. In one case, a voltaic current enters the clock by the wire shown below, and leaves it by the upper wire; and, in the other case, it enters by the upper and leaves by the lower wire. There is a double set of electro-magnets within the clock, showing four poles in all; there are also two magnetised steel bars, mounted see-saw fashion, with their poles alternate, and facing the four electro-magnetic poles. When the current enters the clock from below or in one direction, the bars oscillate this way; when it enters from above or in the reverse direction, they oscillate that way. They are both fixed at right angles to and upon the same axis; which axis carries a pair of driving pallets, that act on a scape-wheel. and so the clock-train is driven. It will be seen at a glance that two or more clocks may be connected in the same circuit, as readily as one; it being merely necessary in such case to modify the battery power, to correspond with the work to be done. For instance, three such clocks have been going for several years at Tonbridge by the same pendulum; several are actuated in like manner at the Royal Observatory, Greenwich. Nor is it necessary that the clocks should be in the same room with the pendulum, or in the same building, or even in the same parish. All the clocks above referred to, are variously distributed; and one of the Observatory clocks is six miles distant from its pendulum, being at the London Bridge Station of the South-Eastern Railway.

In cases where it has not been found convenient to drive the clock-train, especially in the case of a public one, the movement of which is heavy, great advantage has been derived for regulating the oscillations of the pendulum of the large clock, by means of electric currents, under the control of a standard pendulum. Mr. Jones has adopted this method, and it is likely to meet with much favour. The turret-clock, under this arrangement, is driven by weights in the usual way, and the time is regulated by a pendulum. The bob of the pendulum is placed under a condition analogous to that of Bain's (*fig.* 774), the permanent magnet, however, being attached to the pendulum, and the electro-magnet fixed facing it. If currents are made to circulate synchronously in the latter, by means of a standard pendulum, the oscillations of the pendulum of the turret-clock are constrained to accord with those of the standard, and a very perfect system of time-keeping is obtained. This is practised at Liverpool; and has been introduced at Greenwich.

Under the above arrangements the clock is controlled by the standard pendulum second by second, and the two keep time together throughout the day. There are cases in which it is sufficient, and also more convenient, to correct a clock once a day only by means of a telegraph-signal transmitted from a standard clock. This is managed in several ways. There is a clock at the Telegraph Office in the Strand; a good regulator, adjusted to gain a second or two during the twenty-four hours, and to stop at one P.M. A telegraph-signal is sent from the Royal Observatory precisely at one, that drops a time-ball at the Strand office, which, in falling, starts the clock. At Ashford, seventy-three miles from Greenwich, there is an electric clock which has a gaining rate, and which is so constructed that the battery circuit is opened at one o'clock by means of pins and springs attached to the movement, and the clock therefore stops. At one P.M., Greenwich mean time, a signal is sent through the Ashford clock from the Royal Observatory, which starts it at once at true time. At the Post Office, Lombard Street, there is a clock which, in the course of the twenty-four hours, raises a weight. At noon a telegraph signal is sent from Greenwich, which passes through an electro-magnet; the latter attracts an armature of soft iron and liberates the ball, which falls, and in falling it encounters a crutch or lever, attached to the seconds-hand, and thrusts it this way or that, as the case may be; but so as to bring it to sixty seconds on the dial, and thus to set the clock right.

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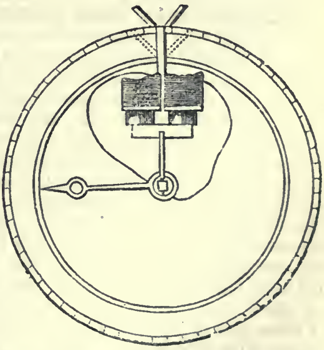

Intermediate between the one method of sending a signal every second to regulate a clock, and the other method of sending it once a day, we have the following arrangement of Bain's for sending it once an hour. *Fig.* 776 shows the arrangement, with part of the dial removed, to show the position of the electro-magnet. The armature is below; it carries a vertical stem terminating above in a fork. Its ordinary position is shown by the dotted lines. The minute hand (partly removed from the cut) carries a pin on its back surface. When the hand is near to sixty minutes, and an electric current is sent through the magnet, the armature is attracted upwards and the fork takes the position shown by the full lines at the top of the dial, and, in doing so, it encounters the pin and forces the hand into the vertical position, and sets the clock to true time, providing the signal comes from a standard clock, or is sent by hand at true time. A dial of moderate character keeps so near to time that once or twice a day would be, for all common purposes, often enough to correct it.

Fig. 777 is an arrangement of Bain's, by which a principal clock, showing seconds, sends electric currents at minute intervals to other clocks, and causes the hands to move minute by minute. A is a voltaic battery; B is the principal clock, which may be an electric clock or not at pleasure; G and H are two out of many subordinate clocks. The seconds hand of the principal clock completes a voltaic circuit twice (for the case of two clocks) during the minute; at the thirty seconds for the clock G, and at the sixty seconds for the clock H. The clock H shows time in leaps from one minute to the next; and the clock G from one half minute to the next half minute. As many more contacts per minute may be provided for the seconds-hand of the prime clock as there are subordinate clocks.

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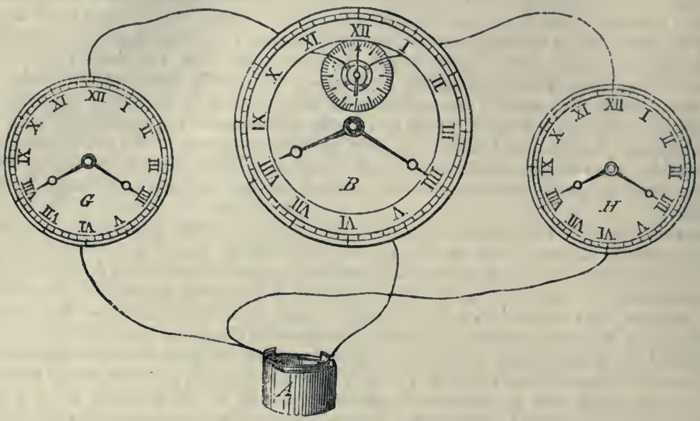

Next akin to the time signals above described, and which act automatically upon clocks, either to drive the clock-train or to correct the clock errors, are mere time signals, which are extensively distributed throughout the country by the ordinary telegraph wires, and are looked for at the various telegraph stations, in order to compare the office dials with Greenwich mean time, and to make the necessary correction; they are also re-distributed by hand the moment they appear, through sub-districts branching from junction-stations. Large black balls, hoisted in conspicuous stations, are also dropped daily by electric currents in various places, for the general information of the public, or of the captains of ships.—C. V. W.

ELECTRICITY FOR BLASTING *in Mines and Quarries.* Professor Hare was the first who entertained this idea, but Mr. Martin Roberts devised the following process. In order not to be called upon to make afresh a new apparatus for each explosion, Mr. Roberts invented cartridges, which may be constructed beforehand. With this view, two copper-wires are procured, about a tenth of an inch in diameter, and three yards in length, well covered with silk or cotton tarred, so that their insulation may be very good. They are twisted together (*fig.* 778) for a length of six inches, care being taken to leave their lower extremities free, for a length of about half an inch (separating them about half an inch), from which the insulating envelope is removed, in order to stretch between them a fine iron wire, after having taken the precaution of cleaning them well. The upper extremities of the two copper-wires are likewise separated, in order to allow of their being placed respectively in communication with the conductors, that abut upon the poles of a pile. The body of the cartridges is a tin tube, three inches long, and three quarters of an inch in diameter, the solderings of which are very well made, in order that it may be perfectly impermeable to water. A glass tube might equally well be employed, were it not for its fragility, which has caused a tin tube to be preferred. The system of copper-wires is introduced into the tube, fixing them by means of a stem that traverses it at such a height that the fine iron wire is situated in the middle of the tin tube, so arranged that the ends of the copper-wire do not anywhere touch the sides of the tube (*fig.* 779). The cork is firmly fixed at the upper extremity of the tube with a good cement. Mr. Roberts recommends for this operation, a cement composed of one part of bees'-wax and two parts of resin; the tube is then filled with powder by its other extremity, which is likewise stopped with a cork, which is cemented in the same manner. *Fig.* 780 indicates the manner in which the cartridge is placed in the hole, after having carefully expelled all dust and moisture; care must be taken that the cartridge is situated in the middle of the charge of powder that is introduced into the hole. Above the powder is placed a plug of straw or tow, so as to allow between it and the powder a small space filled with air; and above the plug is poured dry sand, until the hole is filled with it. The two ends of the copper-wires that come out of the cartridge are made to communicate with the poles of the pile, by means of conductors of sufficient length, that one may be protected from all dangers arising from the explosion of the mine.

M. Ruhmkorff, and after him M. Verdu, have successfully tried to substitute the induction-spark for the incandescence of a wire, in order to bring about the ignition of the powder. This process, besides the considerable economy that it presents—since instead of from fifteen to twenty Bunsen's pairs, necessary for causing the ignition of the wire, it requires but a single one for producing the induction-spark—possesses the advantages of being less susceptible of derangement. Only it was necessary to contrive a plan to bring about the ignition of the powder; in fact, it happens that when by the effect of the length of the conductors that abut upon the mine, the circuit presents too great a resistance, the induction-spark is able to pass through the powder without inflaming it. M. Ruhmkorff has conceived the happy idea of seeking for a medium, which, more easily inflammable by the spark, may bring about the ignition of the powder in all possible conditions. He found it in Statham's fuzes, which are prepared by taking two ends of copper-wire covered with ordinary gutta-percha; they are twisted (*fig.* 781), and the ends are bent so as to make them enter into an envelope of vulcanised (sulphured) gutta-percha, which has been cut and drawn off from a copper-wire that had been for a long time covered with it. Upon this envelope a sloping cut *a*, *b*, is formed; and after having maintained the extremities of the copper-wires at about the eighth of an inch from each other, their points are covered with fulminate of mercury, in order to render the ignition of the powder more easy. The cut is filled with powder, and the whole is wrapped round with a piece of caoutchouc tube *c*, *d*, or else it is placed in a cartridge filled with powder.

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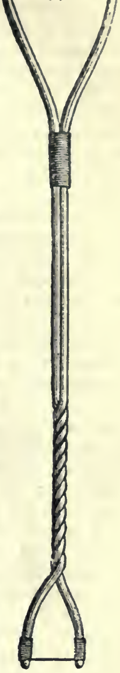

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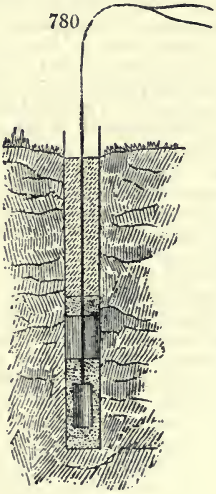

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In the Statham fuzes, it is the sulphide (sulphuret) of copper adhering to the wire, produced by the action of the vulcanised gutta-percha which is removed from the copper-wire that it covered, which by being inflamed under the action of the induction-spark brings about an explosion. But it is necessary to take care when the fusee has been prepared, as we have pointed out, to try it in order to regulate the extent of the solution of continuity. It might, in fact, happen that while still belonging to the same envelope of a copper-wire, the sheath of a vulcanised gutta-percha with which the fusee is furnished, may be more or less impregnated with sulphide of copper; now, if the sulphide of copper is in too great quantity, it becomes too good a conductor, and prevents the spark being produced; if, on the contrary, it is not in a sufficiently large quantity, it does not sufficiently facilitate the discharge.

The first trials on a large scale of the application of the process that we have just described were made with Ruhmkorff's induction apparatus, by the Spanish colonel, Verdu, in the workshops of M. Herkman, manufacturer of gutta-percha covered wire, at La Villette, near Paris. Experiments were made successively upon lengths of wire of 400, 600, 1,000, 5,000, and up to 26,000 mètres (of 3·28 feet each); and the success was always complete, whether with a circuit composed of two wires, or replacing one of the wires by the earth; two ordinary Bunsen's pairs were sufficient for producing the induction-spark with Ruhmkorff's apparatus. Since his first researches with M. Ruhmkorff, M. Verdu has applied himself to fresh researches in Spain; and he was satisfied, by many trials, that of all explosive substances, not any one was nearly so sensitive as fulminate of mercury; only, in order to avoid the danger that arises from the facility of explosion of this compound, he takes the precaution of introducing the extremity of the fusees into a small gutta-percha tube, closed at the end. After having filled with powder this species of little box, and having closed it hermetically, the fuzes may be carried about, may be handled, may be allowed to fall, and even squeezed rather hard, without danger. The elastic and leather-like nature of gutta-percha, which has been carefully softened a little at the fire, preserves the fulminate from all chance of accident. We may add, that with a simple Bunsen's pair, and by means of Ruhmkorff's induction apparatus, M. Verdu has succeeded in producing the simultaneous explosion of six small mines, interposed in the same circuit at 320 yards from the apparatus. He has not been beyond this limit; but he has sought for the means of acting indirectly upon a great number of mines, by distributing them into groups of five, and by interposing each of these groups in a special circuit. The fusees of each group are made to communicate by a single wire, one of the extremities of which is buried in the ground, and whose other extremity is near to the apparatus. On touching the induction apparatus successively with each of the free ends that are held in the hand, which requires scarcely a second of time, if there are four wires, that is to say, four groups and consequently twenty mines, twenty explosions are obtained simultaneously at considerable distances. There are no limits either to the distance at which the explosion may take place, or to the number of mines that may be thus made to explode.

The following account of experiments on the application of permanent magnets to the explosion of charges and to submarine operations, is from a memoir by Professor Abel, F.R.S. The ignition of gunpowder by the direct magneto-electric current, though well known to be practicable, has never yet been applied to military or industrial operations, and no satisfactory experiments appear to have been made, before those undertaken at Woolwich, showing its practical applicability to these purposes.

In the first experiments on this application of the magneto-electric current, a very large powerful magneto-electric machine was employed, which had been constructed by Mr. Henley (and had been exhibited by him at the Paris Exhibition in 1855). The principle of this instrument was precisely the same as that of the machine devised by Mr. Wheatstone, for ringing magneto-electric bells. Its armature, instead of being rotated, was suddenly detached from the magnet by means of a lever. It was soon established by a few experiments that, even with this instrument, gunpowder itself could not be ignited with any degree of certainty. Results obtained with Statham's and other fuzes, though superior to those furnished by gunpowder alone, were still far from satisfactory. The first efforts were therefore directed to the discovery of a suitable agent to serve as a perfectly certain medium (or priming material) for effecting the ignition of charges by means of the magneto-electric machine. For this purpose, a variety of compounds and mixtures of a more or less sensitive character were prepared for trial with the magnet.

Many of these compositions furnished results to a certain extent favourable, a number of fuzes, primed with them, having been fired in succession with the magnet, and from two to four charges in one circuit having been ignited, in a very few instances. But no perfect certainty of discharge was attained with any one of the materials used; the attempt to fire a fuze being frequently unsuccessful, while no difference between it and a successful fuze, containing the same composition, could be detected by careful examination.

Some successful results, obtained accidentally with one of the experimental compositions, which had become damp by exposure to air, led to a trial of the effect of moisture in promoting the ignition of but slightly sensitive compositions; and it was ultimately found that the impregnation of ordinary gunpowder with a small amount of moisture (by an expedient similar in principle to one adopted with considerable success by Captain Scott, R.E., in connection with charges to be fired by the induction coil-machine), rendered its ignition by means of the magnet a matter of certainty.

Some important precautions were, however, indispensable to the attainment of this definite result. If the slightly-damp powder was employed in a finely-divided condition, it very frequently became caked between the wire-terminals in the fuze, and the current would then pass through the composition without igniting it. This was found to take place occasionally, even when the powder was employed in its original granular condition. Several attempts were made to overcome this difficulty by modifying the form and position of the terminals or poles in the fuze, and I at last contrived a perfectly successful arrangement, in which only the *sectional surfaces* of the terminals, consisting of fine copper-wire (0·022 inch diameter), were exposed to the interior of the fuze (see *a*, *fig.* 782), so as not to project at all. The prepared gunpowder, therefore, simply *rested* upon the surfaces, and a perfect uniformity in the action of the fuze was attained. The priming composition consisted of fine-grain gunpowder, which had been soaked in an alcoholic solution of chloride of calcium, of a strength sufficient to impregnate the grains with from one to two per cent. of that salt. The prepared powder was exposed to the air for a short time, to permit of a sufficient absorption of moisture by the deliquescent salt. Upwards of 500 quill-fuzes (of the description employed for firing guns), primed with the prepared gunpowder, and fitted with the arrangement of the terminals above referred to (*fig.* 782), were fired with the larger lever-magnet. The failures did not amount to more than 3 per cent., and were all proved to be due to defective manufacture. In the experiments with these fuzes, one or two simple rheotomic arrangements were successfully employed for effecting the rapidly successive discharge of a series of fuzes.

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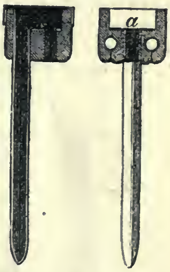

The above fuze was found to be easy of manufacture and permanently effective. While, however, it presented a certain means of effecting the ignition by the aid of a powerful magnet, of single charges, or of a large number, to be fired in moderately rapid succession, it was inapplicable to the ignition with certainty of more than one charge in circuit. After a great number of experiments, I at length succeeded in the production of a priming material for the fuze, which greatly exceeded in sensitiveness any of the other compositions hitherto tried.

The new priming composition consisted of a very intimate mixture of sub-phosphide of copper, chlorate of potassa, and levigated coke, the latter substance being employed to add to the conducting power of the mixture, which was found otherwise insufficient.

In the course of experiments subsequently carried on with fuzes which contained this composition, it was found that a slight residue, consisting principally of the coke employed, occasionally remained on the surfaces of the terminals in the fuze, after its discharge, and by forming a good conducting link between them, interfered with any future effects of the magnetic current in other directions, by the establishment of a complete circuit. This obstacle to the perfect success of the composition was entirely removed by the substitution, for the coke, of another material, more easily acted on by the chlorate of potassa, and answering equally well as a conducting medium; namely, the sub-sulphide of copper. No instance has occurred in the discharge of several thousand fuzes, primed with the mixture of sub-phosphide and sub-sulphide of copper with chlorate of potassa, in which the terminals have not been found quite free from adherent residue, after the ignition.

The sub-phosphide of copper, which is produced at an elevated temperature, is a compound of very stable character, and the mixture of the three constituents is quite as unalterable as the explosive mixtures which are in general use for the preparation of percussion caps, &c. The stability of the mixture has already been submitted to very satisfactory tests. Fuzes primed with it have been found to have lost none of their delicacy and certainty, when tried more than two years after preparation.

The sub-phosphide of copper, intimately blended with chlorate of potassa, forms a mixture in a high degree sensitive to the effect of heat, and possessed, at the same time, of some power of conducting electricity. With the employment, however, of magneto-electric machines of comparatively low power, and in cases where the resistance to be overcome by the current is considerable, this conducting property is not sufficient to insure the ignition of the mixture by assisting the passage of the current across the interruption in the metallic circuit (i.e. across the small distance between the terminals of the wire in the fuze). It must be borne in mind that the striking-distance, or the space between the terminals across which the current from even a powerful magneto-electric machine will leap, is very small. With the large lever-magnet the spark could only be produced when the wires were almost in contact. Since, however, it is indispensable to the proper insulation of the wires in the fuze-arrangement, that the terminals should be at least one-sixteenth of an inch apart, it will be readily understood how essential to success, in operations with these machines, it is that the priming material should possess considerable conducting power. Hence the necessity of increasing the conducting power of the mixture of sub-phosphide of copper and chlorate of potassa : a result which, it has been already stated, was obtained in the first instance by the employment of finely-levigated coke, and afterwards by the substitution of sub-sulphide of copper for that substance. Many experiments were of course required to determine the proportions in which it was advisable to employ the conducting constituent, so as to facilitate the passage of the current through the mass as far as possible, without interfering too much with the sensitiveness of the explosive mixture, or producing an almost perfectly continuous connection between the two poles in the fuze, and thus promoting the passage of the current so greatly as to prevent the ignition of the composition.

The fuzes contrived by me for use with magneto-electric apparatus are of two kinds, the one being adapted for mining purposes and the other for firing cannon. The fuze for mining purposes, *fig.* 783, consists of:—

a. A head for receiving the wires which connect the fuze with the magnet and the earth, *fig.* 784.

b. Of the insulated wires, with the terminals of which the priming material is in close contact.

c. Of a small cartridge or charge of powder, enclosing the terminals, upon which the sensitive composition rests.

The wooden fuze-head contains three perforations (*a a*, *b b*, *c c*, *fig.* 784); the one, passing downwards through the centre, receives about two inches of double insulated wire, *d*. The other two perforations, which are parallel to each other on each side of the central one, and at right angles to it, serve for the reception of the circuit-wires. The arrangement for securing the connection of these with the insulated wires in the fuzes is as follows :—

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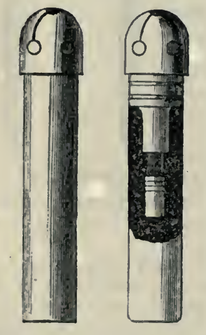

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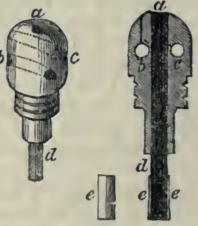

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The piece of double-covered wire above referred to, is originally of a sufficient length to allow of the gutta-percha being removed from about 1½ inch of the wires. These bare ends of the fine wires, which are made to protrude from the top of the fuze-head *a*, *fig.* 784, are then pressed into slight grooves in the wood provided for their protection, and the extremity of each is passed into one of the horizontal perforations in the head, in which position it is afterwards fixed by the introduction into the hole of a tightly-fitting piece of copper tube, so that the wire is firmly wedged betweeen the wood and the exterior of this tube, and is thus at the same time brought into close contact with a comparatively large surface of metal. It will be seen that it is only necessary to fix one of the circuit-wires into each of these tubes in the opposite sides of the fuze-head, in order to ensure a sufficient and perfectly distinct connection of each one of them with one of the insulated wires in the fuze.

The phosphide-of-copper fuze for firing cannon, *fig.* 785, differs somewhat in construction from the mining fuze. The head is somewhat longer, and of such a form that the double-covered wires are completely enclosed in it, the lower extremity of its central perforation still remaining free to receive the top of the quill or copper-tube, which is charged with gunpowder in the same manner as the ordinary tube arrangement for firing cannon.

The plan originally suggested by M. Savare, of arranging the charges in divided circuits was next tried, and furnished far more successful results. The simultaneous ignition of twenty-five charges was repeatedly effected; and forty charges were similarly exploded on several occasions. These results were all obtained with the large magnet constructed by Henley, the current being established by rapidly separating the armature from the poles by means of a lever. By a simple arrangement for shifting the connection of the main wire with the exploded charges from them to a second series, similarly arranged, twenty-five were almost simultaneously ignited on allowing the armature to return to the poles of the magnet.

The system of firing charges by means of magneto-electricity, with the aid of the phosphide-of-copper fuze, having been thus far successfully developed, a series of experiments was instituted at Chatham, for the purpose of thoroughly testing its certainty and applicability in the field, and subsequently for ascertaining the extent to which it admitted of application to the explosion of submarine charges. These experiments extended over a period of six months, and were performed under various conditions of weather. It will readily be understood that the best and most simple method of connecting the fuzes, enclosed in the charges, with the branch-wires and the earth, of arranging the experimental charges for explosion, and of carrying out the various small but essential details involved in the operations, were only gradually arrived at; and that, consequently, in many of the first experiments, which were only partially successful, the failures were traced to causes unconnected with the efficiency of the magneto-electric apparatus, or the fuze. It would be superfluous to enter into details with regard to those preliminary experiments, however important they were at the period of the investigation; the description of the operations at Chatham will therefore be confined to those which were carried on according to the plan which was ultimately proved to be most efficient. The magneto-electric apparatus employed in all the field experiments was Mr. Wheatstone's arrangement of six small magnets, the whole apparatus having been enclosed in a box, so that the only exposed portions were the binding screws for the attachment of the wires, a handle for setting the armatures in motion, and a key, by the depression of which, at a given signal, the circuit could be completed.

To employ the instrument at any moment, only the following operations were necessary: the insulated wire and the copper wire passing to the earth were fixed to the apparatus by means of binding screws: the instrument was raised from the ground by being placed on its packing-case; at that height, a man could operate with it when in a kneeling posture. At the signal 'Ready' the handle was turned with one hand, so as to cause the armatures to revolve with the greatest possible velocity, whilst the other hand was pressed against one corner of the instrument close to the key, so as to steady the box and to be ready, at the signal 'Fire,' to depress the key with the thumb.

The connection of the instrument with the earth was effected as follows: a moderately clean spade was selected from among those used by the men in digging holes for the charges. One end of a piece of stout copper-wire was placed under the edge of the spade, so that, when the latter was firmly forced into the ground, the wire was pressed by the earth on both sides against the iron surface. The protruding wire was wound once or twice round the bottom of the spade handle, and then attached to the binding screw of the magnet.

The gutta-percha covered wire used in the experiments having been in occasional service at Chatham for some years, the coating had sustained some injury in two or three places. Such defects were protected from possible contact with the earth by means of waterproof cloth or sheet India-rubber. The total length of wire used was 881 yards, of which 600 were extended, lying along the ground.

To the extremity of the covered wire a number (from 12 to 25) of pieces of similar insulated wire, varying in length between three and six yards, and serving to connect it with the individual charges, were attached in the following manner: about six inches of the extremity of the main wire and of each of the branch wires were laid bare and cleansed; the end of the former was then surrounded with those of the latter (placed in an opposite direction) and the whole tightly twisted together by means of pliers, so as to be brought thoroughly in contact with each other and with the main wire. The twisted wires were then bound round with moderately fine copper-wire, which was made to bring every portion of the exterior of the bundle into connection. The joint was made rigid with pieces of stick tied against it, and the whole securely enveloped in a piece of waterproof cloth or canvas, to protect it from damp and contact with the earth.

These connections, though of a very rough description and most readily prepared by any soldier, were thoroughly effectual. No instance occurred, in the whole of the experiments, of the failure of a charge, which could be attributed to an imperfect connection of its branch wire with the main wire.

The following was the method adopted for connecting the fuzes with their respective branch wires and with the earth :—

The fuzes, as they were manufactured, were always fitted with two pieces of covered wire twisted together, *fig.* 786, which were tightly fixed into their proper positions by forcing a short pin of copper-wire into the holes of the fuze-head. They were thus ready for insertion into the bag or other receptacle containing the charge of gunpowder, the ends of the covered wires protruding from the opening of the latter to a convenient distance for effecting the junction with the branch and earth-wires. The extremities of one of the fuse-wires and of a branch wire (from both of which the gutta-percha was removed to a distance of about two inches) were connected by hooking them firmly one in the other with pliers (in the manner shown in *fig.* 787). A piece of fine copper binding wire was then twisted over the whole of the connection, and the joint was finally enclosed in a small wrapping of oiled canvas, in a manner similar to that adopted at the principal junction with the main wire.

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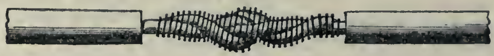

The extremity of the other fuze-wire was attached to an uncovered copper-wire, of sufficient length to bring the whole of the charges into connection with each other in this manner. The wire was fixed in a convenient position by being twisted round short stakes or pickets driven into the ground, and its extremities were buried in the earth, being attached either to spades, as already described, or to zinc plates about eight inches square.

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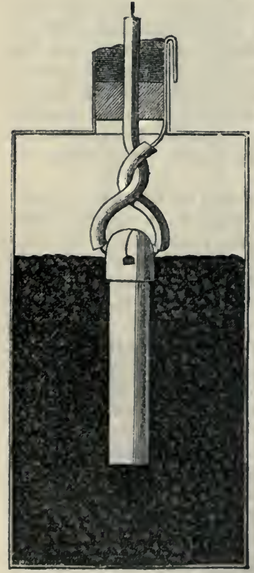

The experiments instituted at Chatham with the object of applying the magneto-electric current to the ignition of *submarine* charges were attended with greater difficulties than those which served to test the system in its application to land operations; nevertheless, the results ultimately attained were also of a character to lead to definite and favourable conclusions.

The method of establishing the connections of a charge with the wire and the earth differed naturally in some respects from the mode of proceeding already described. The charges of powder were contained in canisters of block tin carefully soldered so as to be watertight.[1] The fuze, with two wires attached as before, the one a few inches longer than the other, was inserted into the charge, and fixed in its proper position in the canister by means of a loose-fitting bung, (see *fig.* 788) pushed a little distance into the neck, and cut out on one side, so as to admit of the passage of the longer insulated wire, while the bare part of the shorter wire was firmly pressed by the cork against the inside of the neck. The latter was then completely filled up with melted gutta-percha, and the extremity of the short uncovered wire was bent back over its side, so as to be in close contact with the metal surface. In this manner, the enclosed fuze was brought into good metallic connection with the wet earth, or water, by which the canister was surrounded.

The insulated wire, projecting from the mouth of the canister, was connected with one of the branch wires in the manner already described; but in order thoroughly to protect the connection from the water, in which it would become immersed, a piece of

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[1] Any vessels of this material, such as turpentine cans, may be employed, provided they be perfectly coated inside with marine glue, or some other description of varnish.

vulcanised India-rubber tubing, of suitable length, and a tin tube, rather longer and wider than the latter, were slipped on to the branch wire, before it was joined to the fuze-wire, and, when the junction had been effected, the India-rubber tube was pulled over it, and tied very firmly at both ends on to the gutta-percha covering of the wires, *fig.* 789. A small quantity of a cement (consisting of bees'-wax and turpentine) was

789

rubbed in between the latter and the ends of the India-rubber tube, so as thoroughly to ensure the exclusion of water, and finally the tin tube was pulled over the joint, and fixed (by compressing the ends) for the purpose of imparting rigidity to the junction, and thus protecting it from injury by any sudden twist or strain. By these arrangements, when carried out with moderate care, the perfect exclusion of water from the charge and from its connection with the branch wire was effected.

The first trials of these charges were made in a shallow canal with a mud bottom, and from which, at the time of experiment, the water was receding so rapidly, that before the whole of the charges had been immersed, several of them were exposed to view, being partly imbedded in the mud. Twenty-five charges were arranged, of which thirteen were exploded, though less rapidly than in the experiments on land. On the next occasion, when twenty-five charges were entirely surrounded by water (simply resting upon the firm bed of a pond of some depth), only four of the charges were exploded. Several other attempts were made to fire a smaller number of (ten and five) charges similarly immersed, but in every instance only four were ignited. A careful examination into the cause of the invariable explosion of so comparatively limited a number of charges under water led to the following explanation:

It will be remembered that the explosion of numerous charges in a divided circuit by the magneto-electric apparatus with revolving armatures is effected by the action of an exceedingly rapid succession of currents. The rapidity with which they follow each other, however great, cannot equal that with which the terminals of a fuze, enclosed in a small charge, under water, come into contact with the latter after the explosion. The instant this occurs, a complete circuit is established through the water, and any further action of the current is at once arrested. By the time, therefore, that four charges had been ignited in extremely rapid succession, so as to be apparently exploded at once, a sufficient interval of time had in reality elapsed to allow the water to re-occupy the space filled for a brief period by the gaseous products of the first explosion, and thus to rush in upon, and complete the circuit with, the terminals of the fuze. It appears probable that, with the employment of larger charges of powder (about eight ounces was the quantity exploded in each charge) when the volume of water displaced by the explosion would be more considerable, a great number of charges would be exploded before the circuit could be completed by the water.

ELECTRIC LIGHT. Various attempts have been made, from time to time, to employ electricity as an illuminating power; but hitherto without the desired success. The voltaic battery has been employed as the source of electricity, and in nearly all the arrangements, the beautiful arc of light produced between the poles, from the points of the hardest charcoal, has been the illuminating source. One of the great difficulties in applying this agent arises from the circumstance that there is a transference of the charcoal from one pole to the other, and consequently an alteration in the distance between them. This gives rise to considerable variations in the intensity and colour of the light, and great want of steadiness. Various arrangements, many of them exceedingly ingenious, have been devised to overcome these difficulties.

The most simple of the apparatus which has been devised is that of Mr. Staite, which has been modified by M. Archereau. Two metal columns or stems, to which any desired form can be given, are connected together by three cross pieces, so as to form one solid frame; one of these cross pieces is metallic, namely the one which occupies the upper part of the apparatus; the others must be of wood. These latter serve as supports and points of attachment to a long bobbin placed parallel to the two columns and between them, and which must be made of tolerably thick wire, in order that the current, in traversing it without melting it, may act upon a soft iron rod placed in the interior of the bobbin. This iron rod is soldered to a brass stem of the same calibre, and of the same length, carrying at its free extremity a small pulley. On the opposite side the iron carries a small brass tube, with binding screws, into which is introduced one of the carbons, when the entire rod has been placed in the interior of the bobbin. Then a cord fixed to the lower cross piece, and rolling over a pulley of large diameter, is able to serve as a support to the moveable iron rod, running in the groove of the little pulley. For this purpose, it only requires that a counterpoise placed at the end of the cord shall be enabled to be in equilibrio with it. The metal cross piece which occupies the upper part of the apparatus, carries a small brass tube, which descends perpendicularly in front of the carbon that is carried by the electro-magnetic stem, and into which is also introduced a carbon crayon. By means of a very simple adjustment, this tube may besides be easily regulated, both for its height and for its

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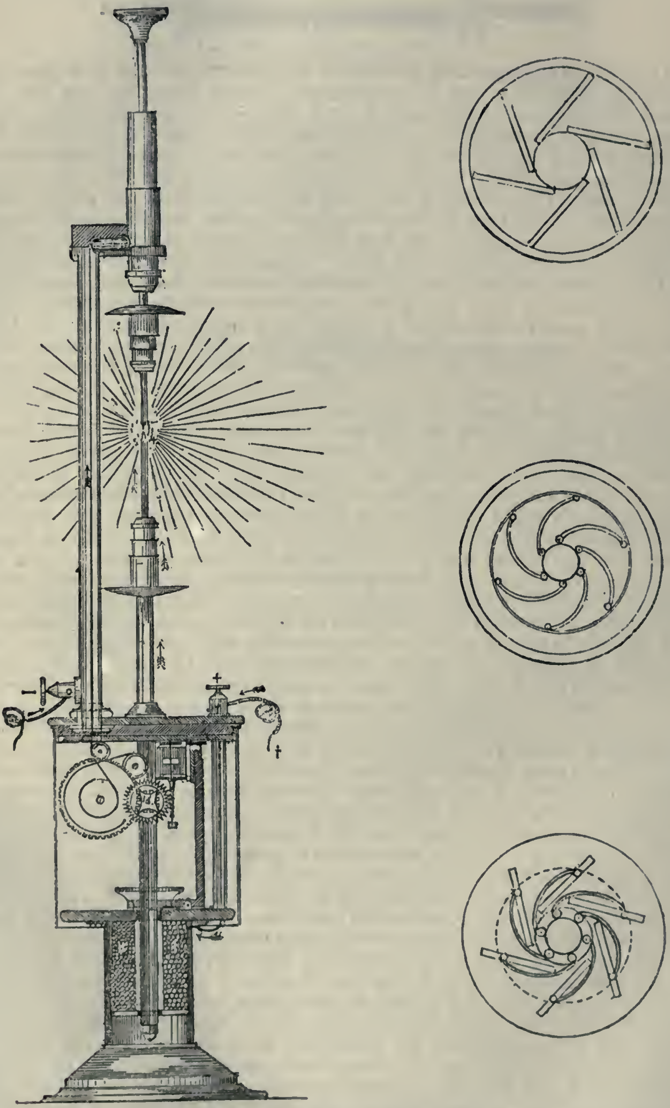

direction; and consequently the two carbons may be placed very exactly above one another. The apparatus being adjusted, we place one of the two metal columns of the apparatus in connection with one of the poles of the pile, and cause the other pole to abut upon the copper-wire of the bobbin (one end of which is soldered upon its socket). The current then passes from the bobbin to the lower carbon by the rod itself that supports it, and passing over the interval separating the two carbons, it arrives at the other pole of the pile by the upper cross piece of the apparatus and the metal column, to which one of the conducting wires is attached.

So long as the currrent is passing and producing light, the bobbin reacts upon the iron of the electro-magnet rod, which carries the lower carbon and attracts it on account of the magnetic reaction that solenoids exercise over a moveable iron in their interior. It is this which gives to the carbons a *separation sufficient for the luminous effect.*

But immediately the current ceases to pass, or is weakened, in consequence of the consumption of the carbons, this attraction ceases, and the moveable carbon, acted on by the counterpoise, is found to be drawn on and raised until the current passes again; equilibrium is again established between the two forces, and the carbons may be employed again. Thus, in proportion as the light tends to decrease, the counterpoise reacts; and this it is that always maintains the intensity of the light equal.

M. Breton has an apparatus which differs somewhat from the above, and M. Foucault has also devised a very ingenious modification.

M. Duboscq has made by far the most successful arrangement (*fig.* 790), for a description of which we are indebted to De la Rive's 'Treatise on Electricity,' translated by C. V. Walker.

The two carbons, between which the light is developed, burn in contact with the air, and shorten at each instant; a mechanism is consequently necessary, which brings them near to each other, proportionally to the progress of the combustion; and since the positive carbon suffers a more rapid combustion than the negative, it must travel more rapidly in face of this latter; and this in a relation which varies with the thickness and the nature of the carbon. The mechanism must satisfy all these exigencies. The two carbons are unceasingly solicited towards each other, the lower carbon by a spiral spring, that causes it to rise, and the upper carbon by its weight, which causes it to descend. The same axis is common to them.

The galvanic current is produced by a Bunsen's pile of from 40 to 50 elements: it arrives at the two carbons, as in apparatus already known, passing through a hollow electro-magnet, concealed in the column of the instrument. When the two carbons are in contact, the circuit is closed, the electro-magnet attracts a soft iron, placed at the extremity of a lever, which is in gear with an endless screw. An antagonist spring tends always to unwind the screw as soon as a separation is produced between the two carbons; if it is a little considerable, the current no longer passes, the action of the spring becomes predominant, the screw is unwound and the carbons approach each other until the current, again commencing to pass between the two carbons, the motion that drew them towards each other is relaxed in proportion to the return of the predominance of the electricity over the spring; the combustion of the carbons again increases their distance, and with it the superior action of the spring; hence follows again the predominance of the spring, and so on. These are alternatives of action and reaction, in which at one time the spring, at another time the electricity, has the predominance. On an axis, common to the two carbons, are two pulleys: one, the diameter of which may be varied at pleasure, communicates by a cord with the rod that carries the lower carbon, which corresponds with the positive pole of the pile; the other, of invariable diameter, is in connection with the upper or negative carbon. The diameter of the pulley, capable of varying proportionately to the using of the carbon, with which it is in communication, may be increased from three to five. The object of this arrangement is to preserve the luminous point at a convenient level, whatever may be the thickness or the nature of the carbons. It is only necessary to know that at each change of kind or volume of the carbon, the diameter of the pulley must be made to vary. This variation results from that of a moveable drum, communicating with six levers, articulated near the centre of the sphere; the moveable extremity of the six arms of the lever carries a small pin, which slides in cylindrical slits. These slits are oblique in respect of the sphere; they form inclined planes. A spiral spring always rests upon the extremity of the levers; so that if the inclined planes are turned towards the right, the six levers bend towards the centre, and diminish the diameter. If, on the contrary, they are turned towards the left, the diameter increases, and with it the velocity of the translation of the carbon, which communicates with the pulley. We may notice, in passing, that this apparatus is well adapted to the production of all the experiments of optics, even the most delicate; and that, in this respect, it advantageously supplies the place of solar light.

Mr. (now Justice Sir William) Grove calculated, some years ago, that for acid, zinc, wear and tear, &c. of batteries, a light equal to 1,444 wax candles could be obtained for about 3*s.* 6*d.* per hour. The cost of the light employed for about five minutes at Her Majesty's Theatre, as an incident in the ballet, which was obtained by employing 75 cells of Callan's battery of the largest size, was said to be 2*l.* per night. In this calculation we expect we have not a fair representation of all the conditions. To obtain a light for ten minutes, a battery as large must be used as if it were required to be maintained in activity for hours—and probably the batttery was charged anew every evening. There can be no doubt but the cost of light or of any other *force* from electricity, with our present means of producing it, must be greatly in excess of any of our ordinary means of producing illumination. For a consideration of this subject, see Electro-motive Engines. Mr. Grove proposed a light which should be obtained from incandescent platinum, but the objection to this was, that after a short period, the platinum broke up into small particles, the electric current entirely disintegrating the metal. Mr. Way exhibited a very continuous electric light, produced from a constant flow of mercury rendered incandescent by the passage of the electric current. The light obtained by the action of a magneto-electric engine, especially in the form employed by Mr. Holmes, is not by any means so expensive as the electric light obtained from the voltaic battery. After the first cost of the machine, the only cost of importance is the mechanical power produced by a small steam-engine. The following is perhaps the most important advance which has been made in the direction of the useful application of electrical power.

Wilde's Magneto-Electric Machine.—The principle of this apparatus, which has been invented by Mr. Wilde of Manchester, for the purpose of obtaining the electric light more promptly and of higher density than had hitherto been done, consists in directing a current of electricity from an electro-magnetic machine armed with permanent magnets, so as to excite a still more powerful electro-magnet. This electro-magnet is again used by Mr. Wilde as the basis of a still larger electro-magnetic machine, in which induction currents are generated by its agency. The electric current is obtained by the well-known means of causing the rotation of an armature close to the poles of a permanent magnet, this electric current being made to pass round an electro-magnet, which causes it to produce a far greater amount of magnetism than was possessed by the first magnet. If, again, the amount of magnetism thus obtained is passed round a still larger electro-magnet, we should produce a vastly greater development of electric force; therefore, by the application of sufficient power to rotate the several armatures, there seems to be no limit to this multiplication of force, excepting the excessive heat developed by the rotation of the armatures and the intensity of the light produced. The construction of this machine will be more readily understood by the annexed diagram (*fig.* 791), representing an end view. At *a* are sixteen permanent horse-shoe magnets, which are bolted on to a hollow magnetic cylinder, *b c b*, composed of brass and iron, and so arranged that the iron portions of it, *b b*, are screwed on to the respective poles of the magnets at *d*, separated from each other by the brass pieces *c*, and forming one entire north pole and one entire south pole to the sixteen magnets. The armature *n*, which is made to revolve in close proximity to the interior of this cylinder, in suitable bearings at the extremities, consists of a cylinder of cast iron on which is wound, in direction of its length, about fifty feet of insulated copper wire one-eighth of an inch in diameter, and is bound round with brass rings, in order that the centrifugal force caused by the rapid rotation may prevent the wires from flying out of position; the inner extremity of this wire is fixed in good metallic contact with the armature, the other end being connected with the insulated half of a commutator which is placed on one end of the armature. The armature is made to revolve at the rate of 2,500 revolutions per minute, by a driving band working on a pulley attached to the other end of the armature. During each revolution of this armature two waves of electricity, moving in opposite directions, are induced in the insulated copper-wire surrounding the armature; the rapid succession of the alternating waves thus generated at the rate of 5,000 per minute, are converted by means of the commutator into an intermittent current moving in one direction only, which is conducted along the wires.

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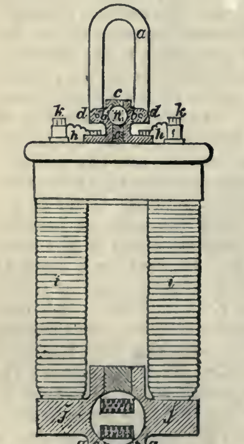

The electro-magnetic machine by which the light is produced is of precisely the same construction as the magneto-electric machine above described, except that instead of the permanent magnets *a*, an electro-magnet *i* is substituted; this electro-magnet is formed of two rectangular plates of rolled iron, 36 in. in length, 26 in. in width, and 1 in. in thickness; they are bolted parallel to each other, to the magnetic cylinder *j*, which is similar in construction but of larger dimensions to that described above. These plates are connected together at their upper extremities by a cross piece formed of two thicknesses of the same iron; around the sides of this electro-magnet is coiled an insulated conductor 3,300 feet long, consisting of a bundle of seven No. 10 copper-wires, laid parallel to each other and bound with a double covering of linen tape; the extremities of this conductor are connected with the studs *k k*, thereby connecting them with the wires *h h*. The currents of electricity which produce the light are taken from steel collars by means of springs *g g*, thence to the studs at *l l*, from which they can be conveyed by conductors to any required place. The power necessary to work such a machine as this is derived from a seven-horse engine, at a cost for coal of one halfpenny per hour. In addition to this must be added the expense of the carbon rods for the lamps, which will be about ten inches per hour, worth perhaps a penny. The total cost of working, including interest on the cost of purchase of machines, expense of maintenance and repairs, would be perhaps about 4*d*. or 8*d*. per hour. The light produced is estimated to have an intensity equal to 6,000 wax candles. A more detailed account of this machine will be found in the 'Quarterly Journal of Science,' No. XII. October 1866.

Mr. Wilde has lately introduced some improved apparatus for the production of light of great intensity. His machine, as recently employed, consists of two parts—an electro-magnetic induction machine for producing the electricity, and an arrangement for regulating the light produced by the current, and projecting it upon distant objects.

The electro-magnetic induction machine is founded upon a new and somewhat paradoxical principle discovered by Mr. Wilde—that magnets and electric currents indefinitely weak can produce magnets and currents of indefinite strength. The machine consists of a circular or cylindrical framing of cast iron, round the interior of which are arranged a number of electro-magnets at equal angular distances from each other. A cast-iron disc is mounted on a driving shaft, running bearings fitted to each side of the framing, and carries a number of armatures revolving before the electro-magnets. A slight charge of magnetism is imparted to the electro-magnets before the machine is used for the first time by transmitting a momentary current through the wires surrounding the iron cores, or by touching their extremities with the poles of a permanent magnet. This initial charge is always retained by the electro-magnets, and is the basis of the augmentations of the electricity and magnetism produced by the rotations of the armatures. As the armatures revolve they become slightly magnetised in their passage between the poles of the electro-magnets, generating weak currents in the insulated wires surrounding them. These currents are transmitted by means of a commutator through the wires surrounding the electro-magnets, so as to increase their magnetism, until, by a series of actions and reactions of the armatures and electro-magnets on each other, the magnetism is exalted to the highest degree of intensity and the most powerful currents of electricity are produced. A small fraction of the current thus produced is sufficient to sustain the power of the electro-magnets, while the major portion of the current produces the light. The machine is 28 in. high, 34 in. in length, and 21 in. in diameter. Its weight is 11 cwt. About four-horse power is required to drive it a velocity of 600 revolutions per minute, and this driving power is obtained from the fly-wheel of a small steam-engine. At this velocity the current will fuse an iron wire 6 ft. long and 0·05 in. in diameter, and will burn 'carbons' half an inch square. In this machine the alternating current is used for producing the light, past experience in lighthouse illumination having proved it to be greatly superior to the direct or continuous current, since it has the important advantage of consuming the carbons equally, and thus always retains the luminous point in the focus of the optical apparatus used in connection with the machine. The alternating current also dispenses with commutators, and the destructive spark on the rubbing surfaces is also avoided when the light may be accidentally extinguished, or when the circuit becomes broken from any other cause. The carbons as they consume are made to approach each other by means of a right- and a left-handed screw, the screws being made to act independently of each other, so as to allow of the adjustment of the carbons to the focus of the optical apparatus used for projecting the light. The regulator with its carbon points is placed in the focus of a catadioptric lens, which parallelises the divergent rays of the light into a single beam of great intensity.

This machine has been introduced to the Admiralty by Mr. Wilde, and the following account of some experiments made at Portsmouth, on board the 'Comet,' with a view to test the power of this electric light as a means of detecting the advance of torpedos, or anything indeed, at night, over the sea, is quoted from the 'Times' of February 23, 1874:—

'The Naval Torpedo Committee have given the subject of attack by torpedo boats at night upon ships at anchor considerable attention, and have proved by experimental practice that in the majority of instances the torpedo attack upon the ship must be successful. The "Monarch," one of the ships experimented upon, was anchored at Spithead, and on one occasion was considered to have been made almost impregnable against any attack by a strong crinoline framework of booms and spars built up round her, supplemented by her boats rowing guard round her within hailing distance. The ship had also the advantage of knowing that a boat torpedo attack would be made upon her, and the time when the attack might be expected. Notwithstanding these important advantages in the ship's favour the torpedo boats—steam pinnaces—burst through the "Monarch's" cordon of guard boats, got over the difficulty of the projecting crinoline spar defence, and struck the frigate with their dummy torpedoes. These results proved that any vessel lying at anchor at night must be fatally deficient in her defensive powers in a want of means for searching with lightning quickness and distinctness the surface of the water to a considerable distance around the ship.

'To supply this want effectually, Mr. H. Wilde, of Manchester, some time since submitted to the Admiralty a proposition for the use of one of his electro-magnetic induction machines, fitted with a proper apparatus for projecting the beam of light produced upon distant objects. One of these machines has been fixed on board the "Comet," twin screw gun vessel at Portsmouth (one of the short and light draught-boats carrying one 18-ton gun on a rising and lowering platform, on the Armstrong-Rendell plan), and was tested during the nights of Thursday and Friday, under the supervision of Captain Boys, commanding the "Excellent" gunnery establishment, and members of the Naval and War Office Torpedo Committee, with the most complete success.

'On Thursday the "Comet" left Portsmouth Harbour for the eastern entrances to Spithead, from the Channel, at about 8 P.M.; but half an hour before leaving a first experiment was made with the machine and its projector lens in throwing the beam of light round the upper part of Portsmouth Harbour. The results were startling. The gunnery ship "Excellent," with her tenders and the boats alongside and at the boom-ends, the long lengths of the sea-wall enclosing the dockyard extension works, the mud-banks—it being nearly low water—the "Asia" and the vessels about her, and further away into Fareham Creek, Her Majesty's yacht "Victoria and Albert," the "Glatton" monitor, and the few men-of-war boats moving about between the ships at the time, all stood out with wonderful distinctness as the electric light touched them. But, beyond all the others, the "Glatton," in her French-grey paint, given her as an invisible dress at certain distances by daylight, shone out in weird splendour. It needed no subsequent experiment to prove that a vessel painted in neutral colour must stand out very much more distinctly under the influence of the electric light than another vessel at the same distance, and painted with the ordinary black coating of our broadside ironclads. When the "Comet" subsequently left the harbour and had taken on board the members of the Torpedo Committees off Southsea, she steamed to a position off Brading and the east end of the Isle of Wight, and anchored, attacks being then made upon her by two steam-pinnace torpedo boats, from directions, of course unknown on board the "Comet." When the boats had been away a certain time the electric light was brought into play, its beam sweeping the surface of the water, and in each instance discovering the torpedo boats before they could lessen a mile's distance between them and the "Comet." Discovered at such a distance, their attack, of course, was considered to have utterly failed.

'On Friday the "Comet" was anchored in Stoke's Bay, near the west end of the measured mile, and buoyed off for the speed trials of Her Majesty's ships. Captain Boys and the members of the Torpedo Committees made a number of experiments with the light, upon which official reports will be made, as will also be done with the experiments conducted on the previous day. If we knew, which we do not, the exact details of all these experiments, comment upon them here would be out of place as anticipating the reports to be yet made by Captain Boys and the members of the committees. What was evident to all afloat and on the look-out for the trial of the new light on the nights of Thursday or Friday was that its power was immense, and of this we may speak freely and yet briefly. On Friday, as on Thursday, no boat could approach the light within a mile without being at once discovered, and the grey or white painted steam-pinnace was always much more prominently and longer in view under the light than the other in its coat of black paint. In a boat at 2,000 yards distance from the "Comet," and with the beam of light brought to bear upon the boat, the "Times" could be read with the greatest ease.'

For a description of Gramme's Magneto-electric machine, see ELECTRO-MOTIVE ENGINES.

ELECTRIC TELEGRAPH. See ELECTRO-TELEGRAPHY.

ELECTRIC WEAVING. M. Bonelli devised a very beautiful arrangement, by which all the work of the Jacquard loom is executed by an electro-magnetic arrangement. The details of the apparatus would occupy much space in the most concise description, and as the invention has not passed into use, although M. Froment has modified and improved the machine, we must refer those interested in the subject to the full description given in De la Rive's 'Treatise on Electricity' by Walker.

ELECTRO-GILDING BATH. See CYANIDES.

ELECTRO-METALLURGY. The art of working in metals was carried on exclusively by the aid of fire until the year 1839. At that epoch a new light dawned upon the subject; considerable interest was excited in the scientific world, and much astonishment among the general public by the announcement that electricity, under proper management, and by most easy processes, could supersede the furnace in not a few operations upon metals; and that many operations with metals, which could scarcely be entertained under the old condition of things, might be placed in the hands of a child, when electricity is employed as the agent.

Public attention was first directed to the important discovery by a notice that appeared in the 'Athenæum' of May 4, 1839, that Professor Jacobi of St. Petersburg had 'found a method of converting any line, however fine, engraved on copper, into a relief, by galvanic process.' Jacobi's own account of the matter was that, while at Dorpat, in February 1837, prosecuting his galvanic investigations, a striking phenomenon presented itself, which furnished him with perfectly novel views. Official duties prevented his completing the investigation, thus opened out to him, during the same year; and it was not until October 5, 1838, that he communicated his discovery, accompanied with specimens, to the Academy of Sciences at St. Petersburg; an abstract of which paper was published in the 'German News' of the same place on October 30 of the same year. And in a letter of Mr. Lettsom, dated February 5, 1839, the nature of the discovery is thus given in the following March number of the 'Annals of Electricity.' Speaking of a recent discovery of Professor Jacobi's, he says, 'He observed that the copper deposited by galvanic action on his plates of copper could by certain precautions be removed from those plates in perfect sheets, which presented in relief most accurately every accidental indentation on the original plate. Following up this remark, he employed an engraved copper-plate for his battery, caused the deposit to be formed on it, and removed it by some means or other; he found that the engraving was printed thereon in relief (like a woodcut) and sharp enough to print from.' This paragraph does not appear to have caught the eye of the public so readily as the briefer note that appeared a couple of months later in the 'Athenæum.'

On May 8, or four days after the appearance of the notice in the 'Athenæum,' Mr. Thomas Spencer gave notice to the Polytechnic Society of Liverpool that he had a communication to make to the society relative to the application of electricity to the arts. He subsequently desired to communicate the result of his discoveries to the British Association, whose meeting was at hand; but, for some cause, which does not appear, the communication was not made; and it eventually was made public, as at first proposed, through the Polytechnic Society of Liverpool, on September 12, 1839. In the meantime, namely on May 22, Mr. C. J. Jordan, referring to the notice in the 'Athenæum,' wrote to the 'Mechanics' Magazine' that, at the commencement of the summer of 1838, he had made 'some experiments with the view of obtaining impressions from engraved copper-plates by the aid of galvanism.' His letter describing this process appears in the number for June 8. It occurred to him, from what he had gathered from previous experience, that an impression might be obtained from an engraved surface; and so it was, 'for on detaching the precipitated metal, the most delicate and superficial markings, from the fine particles of powder used in polishing to the deeper touches of a needle or graver, exhibited their correspondent impressions in relief with great fidelity.'

Mr. Spencer in his communication, besides noticing the fidelity with which the traces on an original plate were copied, recorded the case of a copper-plate that had become covered with precipitated copper, excepting in two or three places, where by accident some drops of varnish had fallen; whence it occurred to him, and experiment confirmed his conjecture, that a plate of copper might be varnished, and a design made through the varnish with a point, and copper might be deposited upon the metal at the exposed part, and thus a raised design be procured.

In the 'Philosophical Magazine' for December, 1836, Mr. De La Rue, after describing a form of voltaic battery, refers to the well-known condition on which the properties of the battery in question mainly depend, that 'the copper-plate is also covered with a coating of metallic copper, which is continually being deposited;' and he goes on to describe that 'so perfect is the sheet of copper thus formed, that being stripped out, it has the counterpart of every scratch of the plate on which it is deposited.' Daniell himself, whose battery is here in question, noticed as he could not fail to do in common with all who had employed his battery to any extent, the same peculiarities; but it does not appear that either he or De La Rue, or any one else, to whom the phenomenon presented itself before Jacobi, Jordan, or Spencer, caught the idea of its applicability in the arts. It would also appear that the impression came with the greater vividness to the two latter; for, while but little time seems to have been lost to them in realising their idea, twenty long months elapsed between the time when the 'perfectly novel views' first presented themselves to Professor Jacobi, and the time when his 'well-developed galvanic production' was communicated to the

Imperial Academy of Sciences. But, on the other hand, neither Mr. Jordan nor Mr. Spencer appears, as far as we are aware, to have been so sensible of the importance of the results to which they had arrived as to have taken any steps to secure them as an invention or to publish them, until their attention was roused by the previous publication of the successes of Jacobi.

Jacobi's 'Galvano-plastik,' Smee's and also Shaw's 'Electro-metallurgy,' Walker's 'Electrotype Manipulation,' four well-known works on the subject before us, present the different names under which the art is known; and from which it is gathered that metals may become, as it were, plastic under the agency of galvanic electricity, and may be worked and moulded into form. Voltaic pairs are described in general terms in the article on Electro-Telegraphy. The particular voltaic pair which led to the discoveries now before us, here requires special notice; because, on the one hand, while in use for other purposes, it was the instrument which first directed attention forcibly to the behaviour of metals under certain conditions of electric current; and, on the other hand, it has been itself extensively used in electrotype operations. Professor Daniell first described his mode of arranging a voltaic pair, in the 'Philosophical Transactions,' for 1836. *Fig.* 792 shows one cell complete of Daniell's combination, which from its behaviour is called a constant battery. A is a copper vessel; B a rod of zinc, contained in a tube C of porous earthenware. The liquid within the tube C is salt and water, in which case the zinc is in its natural state; or, sulphuric acid and water, in which case the zinc is amalgamated; the latter arrangement being the more active of the two. The liquid in the outer vessel A, consists of crystals of sulphate of copper, dissolved in water. At *c* is a perforated shelf of copper below the surface of the liquid, upon which are placed spare crystals of sulphate of copper, which dissolve as required, and serve to keep up the strength of the solution in proportion as the copper already there is extracted by the voltaic action hereafter to be described. *a* and *b* are screws, to which wires may be attached, in order to connect up the cell and convey the current from it into any desired apparatus. Certain chemical changes take place when this instrument is in action: oxygen, from the water within the porous tube, combines with zinc, making oxide of zinc, which enters into combination with sulphuric acid, producing as a final result sulphate of zinc; hydrogen is liberated from water in the outer cell, and itself liberates oxygen from oxide of copper, and combines with it producing water, and leaving copper free. As far as the metals are concerned, zinc is consumed *from* the rod B, at the one end, and copper is liberated *upon* the plate A, at the other end. These actions are slow and continuous; and the copper, as it is liberated atom by atom, appears upon the inner surface of the cell; and after a sufficient quantity has been accumulated, may be peeled off or removed; when it will be found to present the marks and features of the surface from which it has been taken, and which, as we have already said, arrested the attention of many into whose hands this instrument fell. A slight modification of the above arrangement gives us a regular electrotype apparatus. The cell *c* in this arrangement (*fig.* 793), is of glass or porcelain, or gutta-percha, filled as before with a saturated solution of sulphate of copper, to which a little free acid is generally added; it is provided with a shelf or other means of suspending crystals of sulphate of copper. A zinc rod *z* is placed in a porous tube *p*, as already described; and *m*, the other metal of the voltaic pair, is suspended in the copper solution and connected with the zinc *z* by the wire *w*. The electric current now passes; zinc is consumed, as in *fig.* 792, but copper is now deposited on the metal *m* front and back, and on as much of the wire *w* as may be in the liquid; or, if Mr. Spencer's precaution is taken of varnishing the wire and the back of the metal *m*, all the copper that is liberated will be accumulated on the face of *m*. If salt and water, or very weak acid water, is contained in the porous tube *p*, and the zinc *z* does not considerably exceed in size the metal *m*, the conditions will be complied with for depositing copper in a compact reguline form.

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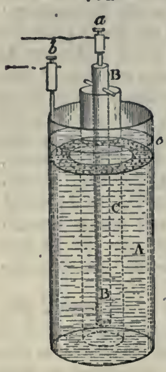

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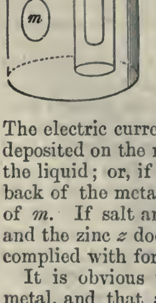

It is obvious that, with this arrangement, *m* may be a mould or other form in metal, and that a copy of it may be obtained in copper. Fusible metal, consisting of 8 parts of bismuth, 4 of tin, 5 of lead, and 1 of antimony; or 8 parts bismuth, 3 tin, and 5 lead, is much used for taking moulds of medals. The ingredients are well melted together and mixed; a quantity sufficient for the object in view is poured upon a slab or board and stirred together till about to set; the film of dross is then quickly cleared from the surface with a card, and the cold medal is either projected upon the bright metal, or being previously fitted in a block of wood is applied with a sudden blow. Moulds of wax or stearine variously combined, or more recently and better in many cases, moulds of gutta-percha, are applicable to many purposes. But, as none of these latter materials conduct electricity, it is necessary to provide them with a conducting surface. Plumbago or black-lead is almost universally employed for this purpose; it is rubbed over the surface of the mould with a piece of wool on a soft brush, care being taken to continue it as far as to the conducting wire, by which the mould is connected with the zinc. With moulds of solid metal, the deposit of copper commences throughout the entire surface at once; but, with moulds having only a film of plumbago for a conductor, the action commences at the wire and extends itself gradually until it has been developed on all parts of the surface.

The nature of the electro-chemical decompositions that are due to the passage of voltaic currents through liquids, especially through liquids in which metal is contained in certain forms, can be best understood by studying the arrangement that is most commonly used in the arts, wherein the voltaic apparatus, from which the electric current is obtained, is distinct and separate from the vessel in which the electro-metallurgical operations are being brought about. Such an arrangement is shown in *fig.* 794, where A is a Daniell's cell, as in *fig.* 792; and B a trough filled with an acid solution of sulphate of copper; *m* is a metal rod, on which the moulds are hung; and *c* a metal rod, upon which plates of copper are hung facing the moulds; the copper-plates are connected by the wire *z* with the copper of the battery cell, and the moulds by the wire *x* with the zinc rod. The voltaic current is generated in the cell A, and its direction is from the zinc rod, through the solutions to the copper of the cell; thence by the wire *z* to the plates of copper *c*; through the sulphate solution to the moulds *m*; and thence by the wire *x* to the zinc rod. In this arrangement, no shelf is necessary in the trough B for crystals of sulphate of copper to keep up the strength of the solution; for the nature of the electro-chemical decompositions is such, that in proportion as copper is abstracted and deposited upon the moulds *m*, other copper is dissolved into the solution from the plates *c*. Water is the prime subject of decomposition. It is a compound body, consisting of the gases oxygen and hydrogen, and may be represented by *fig.* 795, where the arrows show the direction in which the current, by the wire *p*, enters the trough B of *fig.* 794, by the plate of copper *c*, and passes through the water in the direction shown, and leaves it after traversing the mould by the wire *n*. Two atoms of water O H and O′ H′, as bracketed 1 and 2, are shown to exist before the electric current passes; and two atoms, one of water H O′ (bracketed 1′), and one of oxide of copper *o c*, exist after the action. On the one hand, an atom of copper C has come into the solution; and, on the other hand, the atom of hydrogen H′, belonging to the second atom of water, is set free and rises in the form of gas. The explanation is to show that oxygen is liberated where the current enters, and combines there in its nascent state with *copper*; it would not have combined, for instance, with gold or platinum. We might easily extend this symbolical figure, and show how that, when free sulphuric acid is in the solution, the oxide of copper on its formation combines with this acid to produce the sulphate of copper required; and how, when free sulphate of copper

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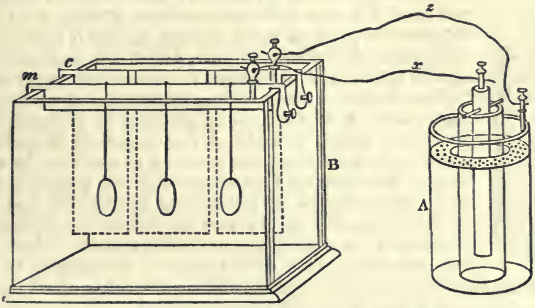

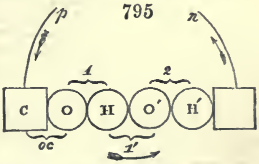

is present, the hydrogen, instead of being freed in the form of gas, combines with oxygen of the oxide of copper, and liberates the metal, which in its nascent state is deposited on the mould, and produces the electrotype copy of the same. One battery cell is sufficient for working in this way in copper; it is increased in size in proportion to the size of the object operated upon. And, although for small subjects, such as medals, a vertical arrangement will act very well; for large objects, it has been often found of great advantage to adopt a horizontal arrangement, placing the mould beneath the copper-plate. The varying density of a still solution in the vertical arrangement is not without its effect upon the nature of the deposit, both on its character and its relative thickness. This has been in some instances obviated, and the advantage of the vertical method retained by keeping the solution in motion, either by stirring or by a continuous flow of liquid.

We have described principally Daniell's battery as the generating cell in electro-metallurgical operations; but Mr. Smee's more simple arrangement of platinised silver and zinc, excited with diluted sulphuric acid, has been found in practice more economical and convenient.

Fig. 796 is a Smee's cell; a vessel of wood, glass, or earthenware, contains diluted sulphuric acid, one part of acid in eight or ten of water; a platinised silver plate s, sustained by a piece of wood *w*, is furnished with a plate of zinc, z z, on each side, so as to turn to useful account both sides of the silver plate. The zinc plates are connected by the binding screw *b*. Platinisation consists in applying platinum in fine powder to the metallic surface. When hydrogen is liberated by ordinary electric action upon a surface so prepared, it has no tendency to adhere or cling to it; but it at once rises, and in fact gets out of the way, so that it never, by its presence or lingering, interferes with the prompt and ready continuance of the electric action; and in this way the amount of supply is well kept up.

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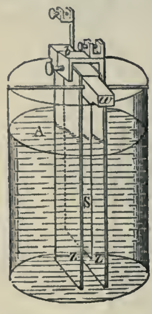

Platinisation is itself another illustration of working in metal by electricity. A few crystals of chloride of platinum are dissolved in diluted sulphuric acid. A voltaic current is made to enter this solution by a plate of platinum and to come out by a silver plate. Two or three Daniell's or Smee's cells are necessary for the operation. The chloride of platinum is decomposed, and the metal is deposited upon the silver plate; not, however, in the reguline compact form, as in the case of copper, but in a state of black powder in no way coherent. This affords also an illustration of the different behaviour of metals under analogous circumstances. Copper is of all metals the most manageable; platinum is among the more unmanageable.

Mr. C. V. Walker has, with great advantage, substituted graphite for silver. The material is obtained from gas retorts, and is cut into plates a quarter of an inch thick, or thicker, when plates of a larger size are cut. He platinises these plates in the usual way as above described, and deposits copper on their upper parts, also by electrotype process, and solders a copper slip to the electrotype copper, in order to make the necessary connection.

Utilisation of Copper Scraps in Electro-Plating.—The following description of M. C. Guérin's method of utilising scraps of copper, in lieu of plates, as a soluble anode in electro-plating, has been published by the 'Scientific American.' By this process the inventor utilises cuttings and other scraps, previously-deposited films, and, in a word, all the metal which would be otherwise thrown aside as useless for such a purpose.

Fig. 797 is a representation of the receptacle used for holding the copper scraps. It is simply a prismatic box about 1½ in. broad, sustained in the bath by the two longitudinal rods shown at the top. The acting sides are pierced each with about 100

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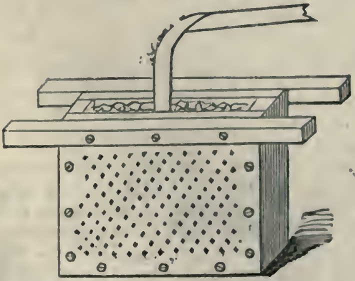

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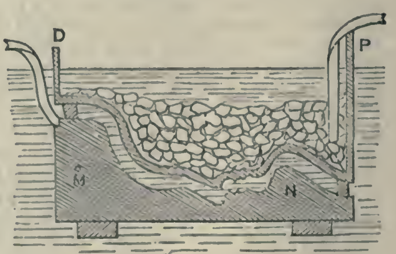


holes, of 0·1 in. in diameter, per 16 square inches, and are of oak or beech wood, and about 0·2 in. thick. Before it is put together, the apparatus is plunged in a bath of melted wax, and is covered with several coats of gum-lac varnish, in order to protect the parts from the action of the acid, brass screws being used to connect it.

The following practical hints will be of use in selecting scraps to fill the receptacle:—Choose pieces free from solder or rivets of brass or iron. Flatten out with a hammer such bits as are curled up, and divide with shears those of irregular form, so that all may fit closely upon each other. With these, pack the receptacle as uniformly as possible. For the band of copper, which serves as a conductor, choose a long piece, so that it may bury anew in the mass as its lower end becomes dissolved. Every four or five days stir the pieces vigorously with a brass rod.

The soluble anode, in its rectangular form as before described, acts as a plate, and hence gives proofs of unequal thickness; but if the active surface of the receptacle, instead of being flat, be so disposed as to form a sort of counterpart, following the contour of the mould, the deposit will have a uniform thickness. This is illustrated in *fig.* 798.

M N is the mould in section; over it, at a distance of 0·3 in., is arranged a gutta-percha box D P, of which the bottom is perforated with a large number of small holes. This box first has its bottom covered with linen cloth, and is then filled with copper scraps, and the copper conducting band is inserted.

In order to localise or concentrate the galvanic action at certain places, it is only necessary to heap up the copper pieces at the desired points; and conversely, when a part has become covered with a deposit of sufficient thickness, it is obviously unnecessary to employ the protecting coverings of wax or gutta-percha ordinarily used with plate anodes. The mode of forming the gutta-percha counterpart consists in coating the interior of the mould with several layers of fine thin plaster for a thickness of 0·3 in. This is allowed to harden. Into the hollow cast the gutta-percha, softened by warm water, is pressed by the hand, so as to cause it to conform to the indentations of the plaster, care being taken to keep it of uniform thickness. After cooling, it is easily removed, and after perforation is ready for use as above described. It is of course a reduced copy of the interior of the mould.

With the exception of silver and gold, copper is the metal which has been most extensively worked by these electro-metallurgical processes.

Seals are copied by obtaining impressions in sealing-wax, pressing a warm wire into the edge for a connection; rubbing black-lead over the wax to make the surface conducting; fastening a slip of zinc to the other end of the wire; wrapping the zinc in brown paper, and putting the whole into a tumbler containing sulphate of copper, a little salt-water having been poured into the brown paper cell.

Plaster-of-Paris medallions may be saturated with wax or stearine, and then treated, if small, like seals; if large, in a distinct trough, as in *fig.* 794. In this case the copy is in intaglio, and may be used as a mould for obtaining the facsimile of the cast. More commonly, the cast is saturated with warm water, and a mould of it taken in wax, stearine, or gutta-percha. This is treated with black-lead, and in other respects the same as seals.

Woodcuts are treated with black-lead, and a copper reverse is deposited upon them. This is used as a mould to obtain electrotype duplicates, or as a die for striking off duplicates.

Stereotype plates are obtained in copper by taking a plaster copy of the type, treating it plaster fashion, depositing a thin plate of copper upon it, and giving strength by backing up with melted lead.

Old brasses may be copied by the intervention of plaster.

Embossed cards or paper may be copied by first saturating with wax and then using black-lead.

Fruit may be copied by the intervention of moulds, or may be covered with copper. *Leaves, twigs,* and *branches* may have copper deposited upon them. The same for *statuettes, busts,* and *statues.*

Leaves and flowers are furnished with a conducting surface by dipping them into a solution of phosphorus in bisulphide of carbon, and then into a solution of nitrate of silver. Silver is thus released in a metallic state upon their surface.

Plaster busts, &c., have been copied in copper, by first depositing copper on the plaster prepared for this operation; when thick enough, the original bust is destroyed, the copper shell is filled with sulphate of copper, as in *fig.* 794, and copper is deposited on its inner surface till of sufficient thickness; the outer shell is then removed.

Tubes and *vessels* of capacity do not appear to have been profitably multiplied by electrotype.

Plates have been prepared for the *engraver* to work on by depositing copper on polished copper-plates, and removing the deposits when thick enough.

For the multiplication of *engraved copper-plates*, the electrotype process has been very extensively adopted. A reverse of the plate is first obtained by the deposition of copper; this serves as a mould, from which many copies of the original plate are obtained by depositing copper upon it, and then separating the two. The mode practised by the Duke of Leuchtenberg is to print from an engraved plate on very thin paper with a mixture of resin of Damara, red oxide of iron, and essence of turpentine. While the impression is wet, the paper face downwards is pressed upon a polished plate of copper. When dry the paper is washed away, and the impression remains. An electrotype copy from this is obtained in intaglio, and is fit for the use of the printer.

Galvanography is a picture drawn originally in varnish on the smooth plate, and then treated in a similar way to the above.

The *plates* on rollers used by *calico printers* have been multiplied like engraved plates.

Glyphography is a name given by Mr. Palmer to his process. He blackens a fair copper-plate with sulphuret of potassium, covering it uniformly with a coating of wax and other things, then draws the design through the wax with fine tools. From the plate thus prepared, an electrotype is taken in the usual way, and is backed up and mounted as an electro-glyphic cast to print from as from a wood-block. For a *stereoglyphic* cast to work from as a stereotype-plate, a plaster copy is taken of the original drawing, the high lights are cut out, and then an electrotype copy is made.

Electro-tint is done by drawing with wax or varnish any design on a fair copper-plate, and making an electrotype copy for the printer's use.

Fern-leaves, &c., are copied by being laid on a sheet of soft gutta-percha, pressed into the surface by a smooth plate to which pressure is applied, and then removed in order to subject the gutta-percha mould to the electrotype process. This is NATURE PRINTING, which see.

MM. Auer and Worring have copied *lace, embroidery*, flowers, leaves of trees, entire plants, fossils, insects, &c., in their natural relief, by laying the objects upon a plate of copper, after having soaked them in spirits of wine and turpentine so as to fix them. A plate of clean lead is laid over, and, on being pressed, an intaglio copy is produced on it of the object. From this an electrotype is obtained.

Undercut medallions, &c., are copied in elastic moulds made of treacle and glue in the proportions of 1 to 4. Masks and busts may also be obtained in such moulds.

Electro-cloth was made by saturating the fibre of canvas or felt, making it conducteous in the usual way; it was proposed in place of tarpaulins as a water-tight cover.

Retorts and *crucibles*, &c., of glass or porcelain, have been successfully coated with electrotype copper by first varnishing or otherwise preparing the surface to retain the black-lead, and then treating them as usual.

Soldering copper surfaces has been accomplished by galvanic agency. The ends to be united are placed together in the solution of sulphate of copper, and connected with the battery as for ordinary deposition. Parts not included in the process are protected off by varnish; copper is then deposited, so as to unite the separate pieces into one.

Iron may be coated with *copper*. But here a new feature comes into view. Sulphuric acid leaves the copper of the sulphate, combines with iron, and deposits copper on its surface without the aid of the voltaic apparatus. The iron surface is imperfectly covered with copper, and no firm perfect deposit occurs. In order to obtain solid deposits of copper on iron, it is necessary to use a solution that has no ordinary chemical reaction upon iron. Cyanide of copper is used, which may be obtained by dissolving sulphate of copper in cyanide of potassium. This solution requires to be raised to and retained at a temperature not greatly below 200°, in order to give good results.

Electro-zincing is applied to surfaces of iron, in order to protect them from corrosion. A solution is made of sulphate of zinc, which is placed in a trough B, *fig.* 794. Two or three battery cells are required. The iron to be zinced is connected with the zinc end of the battery, and a plate of zinc with the copper end.

Voltaic brass does not appear to have been obtained in a solid distinct form, but has been successfully produced as a coating upon a copper surface. Separate solutions are made of sulphate of copper and of sulphate of zinc in cyanide of potassium. The two solutions are then mixed, and placed in a decomposing trough. Two or three cells of a battery are used, and a brass plate connected with the copper end. An electrotype copper medal or other prepared surface is connected with the zinc. Brilliant and perfect brass soon appears, and will deposit slowly for some hours; but after a while, the character of the solution changes, and copper appears in place of brass.

This hasty glance at the leading applications of this art will give an idea of its utility. It also comes into play in cases where least suspected. Pins were tinned by electrotype long before the art was known. Brass pins are thrown into solution of tin in cream of tartar, and are unchanged; but when a lump of tin is thrown among them, a voltaic pair is formed, and tin is deposited on all the heap. Any stray pins detached from the mass, escape the influence.

Space would fail us were we to go through the list of crystalline and of simple bodies formed by these processes; as for instance, octahedral crystals of protoxide of copper; tetrahedral crystals of proto-chloride of copper; octahedral crystals of sulphide of silver; crystals of subnitrate of copper; bibasic carbonate of copper, and others too numerous to name, have all been formed by slow voltaic actions. The alkaline metals, potassium, sodium, &c., were first obtained by Davy in the galvanic way; magnesium, barium, aluminium, calcium, &c., are obtained by M. Bunsen by operating upon the chlorides of these metals either in solution or in a state of fusion.

Electro-etching is produced at the place where the current *enters* the decomposing trough, as at the copper-plates *c* of *fig.* 794. A plate of copper is prepared as if for the graver; its face is then covered with an etching ground of asphalte, wax, black pitch, and burgundy pitch; and its back with varnish. The design is then traced through the etching ground with a fine point; the plate is then placed in the trough B, containing either sulphate of copper or simply diluted sulphuric acid, and connected with the copper of the battery. After a few minutes it is removed, and the fine lines are stopped out with varnish; it is then replaced, and again, after a few minutes is removed, and the darker shades are stopped out; the parts still exposed are again subjected to the action, and the etching is complete. When the ground is removed, the design will be found etched upon the copper-plate ready for the printer.

Daguerreotype etching is a delicate operation, and requires much care. The solution employed by Professor (now Sir W.) Grove was hydrochloric acid and water in equal parts, and a battery of two or three cells.

Platinized silver is used in face of the daguerreotype, instead of copper. The result comes out in about half a minute. An oxy-chloride of silver is formed, and the mercury of the plate remains untouched.

A *Photo-galvano-graphic* Company was formed in London for carrying out the process of Paul Pretsch. He made solutions of bichromate of potash in glue-water, or in solution of gelatine, instead of in pure water. He then treated the glass or plate with these, and in the usual way took a picture. He washed the gelatine picture with water, or solution of borax or carbonate of soda, which left the picture in relief; when developed, he washed with spirits of wine, and obtained a sunk design. The surfaces thus prepared, or moulds made from them, were placed in a galvano-plastic apparatus for obtaining an engraved plate from which to print. The process was not, commercially, successful. See PHOTO-GALVANOGRAPHY.

The Duke of Leuchtenberg prepares a plate for etching by leaving the design on the ground, and removing the ground for the blank parts. When his electrotype operation is complete, the design is in relief instead of being in intaglio as in ordinary etching.

Metallo-chromes consist of thin films of oxide of lead, deposited sometimes on polished plates of platinum, but most commonly on polished steel plates. The colours are most brilliant and varied. Nobili is the author of the process.

A saturated solution of acetate of lead is prepared and placed in a horizontal trough. Three or four battery cells are required. A steel plate is laid in the acetate of lead with its polished surface upward, and is connected with the copper of the battery. If a wire is connected with the zinc end of the battery, and held over the steel plate in the solution, a series of circles in brilliant colours, arise from the spot immediately beneath the wire, and expand and spread, like the circles when a stone is thrown into a pond. Silver-blond is the first colour; then fawn-colour, followed by the various shades of violet, and indigoes and blues; lake, bluish lake, green and orange, greenish violet, and passing through reddish yellow to rose-lake, which is the last colour in the series.

According to the shape of the metal by which the current enters—be it a point, a slip, a cross, a concave, or a convex disc—so is the form of the coloured figure varied. And if, in addition to this, a pattern in card or gutta-percha is cut out and interposed between the two surfaces, the action is intercepted by the portions not removed, and the design is produced on the steel plate, in colours, that may be greatly varied, according to the duration of the experiment. The different colours are due to the different thicknesses of the thin films of peroxide of lead.

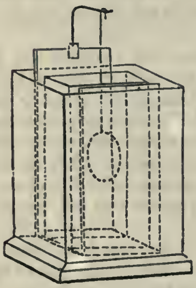
M. Becquerel proposed the deposit of peroxide of lead, and also the red peroxide of iron, for protecting metals from the action of the atmosphere. For the latter, protosulphate of iron is dissolved in ammonia solution, and operated upon by two or three batteries.

The most important application of electro-metallurgy in the arts has been for *plating* and *gilding*, which is most extensively carried on both at home and abroad. Results that were unattainable, and others attainable only at great cost, are readily produced by this mode of manipulating. The liquids most in use are the cyanide solutions, first introduced by Messrs. Elkington. They are prepared in various ways. Cyanide of potassium is added carefully to dilute solution of nitrate of silver; and the white deposit of cyanide of silver is washed, and then dissolved in other cyanide of potassium; or lime-water is added to the nitrate solution, and the brown deposit of oxide of silver is washed, and, while moist, is dissolved in cyanide of potassium; or common salt is added to the nitrate solution, and the white deposit of chloride of silver is washed and dissolved in cyanide of potassium. Or a solution of cyanide of potassium is placed in the trough B, *fig.* 794, and the current from three or four cells is passed into it from a silver plate at *c*, which combines with and is dissolved in the liquid, converting it into a cyanide of silver solution. To prevent silver being abstracted by deposition at *m*, as the current leaves the trough, the metal at *m* is placed within a porous cell of cyanide solution, so as to limit the action.

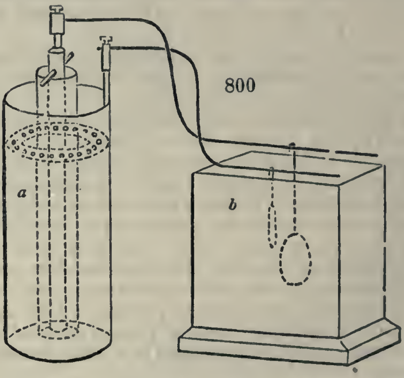
Gold solution is obtained by dissolving the anhydrous peroxide of gold in cyanide of potassium, or by treating chloride of gold with cyanide of potassium, or by using a gold plate and a voltaic current with a solution of cyanide of potassium in the same way as described for silver, and allowing the action to continue until the solution is sufficiently strong of gold. With these solutions electro-plating and gilding are readily accomplished. There are other solutions more or less valuable, which will be found in the books that treat upon the subject.

Fig. 799 shows a single-cell arrangement for plating. The zinc is outside, and is bent to embrace both sides of the porous cell. The article to be plated is within this cell, because, being the vessel of smaller capacity, less of the more valuable silver solution is required, and there is less of loss or waste. The same holds good in a greater degree of gold. In a few minutes the article is covered with silver. If a few drops of sulphuret of carbon are added to the silver solution, the silver is deposited bright. Gold does not come down quite so rapidly as silver.

799



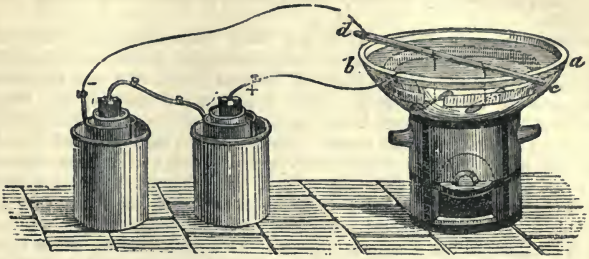
800



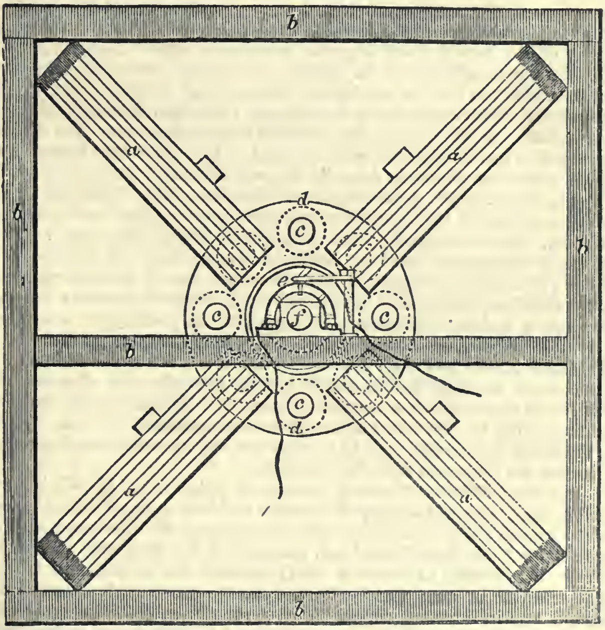
Except for mere experiment, these operations are better accomplished, and with less waste, by using distinct batteries, as *a*, *fig.* 800, the solution of gold or silver being in a distinct trough *b*, plates of silver or gold, as the case may be, being suspended in front of the article to be coated. One or two cells, according to the result required, are used for plating; and three or four for gilding. But gilding is never so well accomplished as it is with hot solutions. The modes of keeping solutions hot vary with circumstances, and with the extent of the operations. *Fig.* 801 is an arrangement for operations on a small scale. The vessel *a b*, containing the gold solution, rests over a small stove or spirit-lamp. The objects to be gilt are suspended by wires to the conducting rod *d*, in connection with the zinc end of the battery; and the gold wire or plate *c* is connected with the other end. A temperature of from 100° to 200° is desirable; the higher temperatures require fewer battery cells; with the highest, one will suffice. The solution, of course, evaporates under the influence of heat; and distilled water must be added to supply the loss, before each fresh operation.

Plating and gilding are successfully, and, in point of economy, advantageously, carried on at Birmingham, in more than one manufactory, by means of magneto-electricity. In the article on ELECTRO-TELEGRAPHY will be found a description of this form of electric force, and the means by which it is produced. An electro-magnet is

801



802



set in motion in front of the poles of a permanent magnet, in such a manner that the soft iron core of the electro-magnet becomes alternately a magnet and not a magnet: in the act of becoming a magnet, it raises up a current in one direction in the wire with which it is wound; in the act of ceasing to be a magnet, it raises up a current in the reverse direction. The ends of the wire are led away and insulated. The instrument is fitted with a commutator, so adjusted that it collects the currents from the ends of the wire, and guides them in a uniform direction into the vessel that contains the solution and articles to be gilded or plated. In practice, a single machine consists of many electro-magnets grouped together, and many powerful magnets for exciting them; by which means a continuous flow of a large amount of electricity is obtained. *Fig.* 802 is an illustration of such an arrangement as adapted by Mr. Woolrich: *a a a a* are four clusters of permanent steel magnets, seen from above; *b b b b b* is the frame-work of the machine; *c c c c* are four bars of soft iron, wound with large size insulated copper-wire; *d* is a circular disc, on which they are mounted, and which rotates on a vertical axis, of which *f* shows the upper end; *e* is the commutator, from which two wires are led off to the solution to be operated upon. The permanent magnets are U-shaped; one pole only of each bundle is visible; the other is beneath the disc *d*, and its freight of electro-magnets *c c*, &c. The axis is set in rotation by a strap passing over the drum of a shaft of the steam-engine, that does the ordinary work in a factory; and the disc carries the electro-magnets between the poles of the permanent magnets, and exposes them to the most favourable action of these poles. The number of coils and magnets varies in proportion to the work required. By this arrangement, not only does each coil pass under the influence of many magnets, but each magnet acts successively on many coils; and a proportionate supply of electricity is the result.

Electro-Deposition of Iron. This has been often attempted, without much success until recently. A process has now been discovered which answers admirably.

This new process has been perfected by M. Eugène Klein, who is at the head of the chemical department in the Imperial State paper manufactory in St. Petersburg. Many difficulties have arisen and have been successfully surmounted in developing this process to its present practical issue. Attempts were made to effect the object so far back as the year 1846, but which were unsuccessful, and it was about twenty years before the problem was definitely solved. The importance and reality of the progress, however, are now unquestionable, and an extended knowledge of the process must inevitably lead to its general adoption. At the present time we believe its application is confined to the Russian Imperial State paper works, where it has been in active operation for some time, the iron plates replacing those of copper for bank-note printing and for other similar purposes. The application of the invention, however, extends to all the other branches of the art of electrotyping.

From a paper upon the present subject, read by the late Prof. Jacobi before the Academy of Sciences in Russia, in 1868, it appears that in the previous year M. Feuquières sent to the Paris Exhibition some specimens of iron electrotype which presented a fair appearance as regarded surface, but still were inferior to those produced by M. Klein in the year following. M. Feuquières does not appear to have published the process by which he obtained his results, and he moreover only spoke of it with the greatest reserve. Professor Jacobi, however, states, on the authority of Professor Varrentrapp of Brunswick, that the process and the bath employed differ essentially from those of M. Klein, whose results may be considered as being perfectly independent.

Referring to the process of electrotyping in iron, Professor Jacobi observes that the good quality of the iron deposit depends principally upon the greater solubility of the anode. The augmentation of its surface not having produced the desired effect, M. Klein conceived the idea of combining the anode of iron with another of copper. The Professor varied this combination by replacing the copper with horn-charcoal, which gave more powerful results. The effects of this combination were thus rendered complete, the negative metal combined with the iron in the same bath formed a duplicate layer, which worked as a cathode opposite the iron, and as an anode by its combination with the copper-wire, or the positive pole of the pile which furnished the principal current. The surface of this electrode consequently disengaged hydrogen and oxygen simultaneously, which combined in the proportions which form water. The surplus hydrogen freely disengaged itself, or produced a polarisation of the electrotype. If, observes the Professor, the oxygen is most abundant, and if the electrotype consisted of an inoxidisable substance, such as horn-charcoal, it would also have disengaged gas, and have given a feeble polarisation. If, however, the electrotype is oxidisable like copper, it will be oxidised and dissolved. By immersing a galvanometer in the circuit, Professor Jacobi has observed the deviation of the needle diminish by degrees whilst the current was very feeble, and it became perfectly still after the force of the current had been increased to a certain degree. At length, passing that degree, the Professor noted that the deviation again became inconstant. By means of the galvanometer, therefore, it becomes easy to so regulate the current as to disengage neither the oxygen nor the hydrogen from the cathode.

So far Professor Jacobi. Turning now to a letter from M. Klein, which was placed before the Russian Academy of Sciences in 1868, we have recorded the methods employed by him in the production of iron electrotype. M. Klein saw M. Feuquières' specimens at the Paris Exhibition, and, encouraged by Professor Jacobi, he, on his return to St. Petersburg in October 1867, renewed his attempts to electrotype in iron. The scientific interest which attached to the new development, and the eminently useful applications of which he saw it was susceptible, especially in the departments of engraving and printing, stimulated M. Klein, and in the early part of 1868 he had accomplished his object. The medals produced in the early part of M. Klein's researches showed, on their reverse, porosities and deep hollows which penetrated nearly through the thickness of the deposit. These cavities were also observable in great numbers in the productions of M. Feuquières. In M. Klein's later specimens these singular cavities—which probably proceeded from bubbles of gas—entirely disappeared, and their reverses are no way inferior to those of copper specimens produced under the best conditions. The starting point of M. Klein was the steeling of engraved copper-plates, which process was effected in a bath composed of the chlorates of ammonia and iron, to which he added a small proportion of glycerine, Those however, who have paid attention to this steeling process, have had occasion to remark that in giving the deposit of iron a greater thickness, the surface cracked, and the deposit detached itself from the cathode in excessively brittle flakes. It became necessary, therefore, to employ baths of two different classes, composed of sulphate of iron and sulphate or chlorate of ammonia. Finally, M. Klein devised three baths, after the formula $FeO, SO^3 + NH^4O, SO^3 + 6HO$. The first bath consists of a concentrated solution of crystals of this double salt. The second bath was composed by mixing the concentrated solution of each of these two salts in the proportions of their equivalents. At length M. Klein obtained the third bath by taking a solution of sulphate of iron, precipitating the iron by carbonate of ammonia, and dissolving the precipitate by sulphuric acid, getting rid of all excess of acid. In preparing the baths of the second class, M. Klein, as we have stated, mixed the solutions of chlorate of ammonia and sulphate of iron in the proportions of their equivalents. Another method employed is to dissolve in a solution of iron as much chlorate of ammonia as it will readily absorb at a temperature of about 66° Fahr. All these baths were concentrated as highly as they could be. As an anode, M. Klein employed iron plates giving a surface about eight times that of the copper cathode. In using a Daniell battery for the decomposition, the deposit was formed in twenty-four hours upon the whole of the cathode. The deposit, however, was full of flaws, and was easily detached and broken up into fragments. As it often happens that the solution of sulphate of copper improves by use, M. Klein hoped that the iron solutions would act in a similar manner. He therefore continued the experiments for several days, without, however, obtaining any better results. Under the advice of Professor Jacobi, instead of a pair of Daniell cells for each of the five stages of decomposition, he then employed four pairs of feebler Meidinger cells, uniting them in series with the five stages of decomposition. This arrangement was found to give a smaller development of hydrogen at the cathodes, and better final results. The deposits, however, were not yet perfect, some exhibiting porosity, and others being furrowed.

Conceiving from previous experience that this was due to acidification of the bath, M. Klein tested it, and found a very decided acid reaction. He attributed this acidification to the circumstance that the quantity of iron deposited on the cathode was greater than that dissolved by the anode. It was, therefore, necessary to give the anode a greater degree of solubility, and as that could only be effected by increasing its area, M. Klein conceived the idea of placing in the bath a plate of copper and uniting it with the iron. The result of this combination was very remarkable; not only were the baths of the first class rendered neutral after several hours, but the deposits became much more uniform. Their colour was a dull grey; they adhered perfectly to the cathode without warping or cracking in any part. During the first 24 hours the surfaces remained perfectly even; but afterwards they began to exhibit minute cavities similar to the appearances often produced upon galvanic deposits of copper. These cavities, however, rarely penetrated to the depth of the deposit. Their production is attributed to the superabundant disengagement of gas on the surface of the cathode. It probably happens that these bubbles attach themselves strongly enough to hinder the formation of the deposit. If the energy of the current becomes too great, these annoying phenomena are produced more frequently. By reducing this energy in the process, and having only an imperceptible disengagement of gas, by diminishing the concentration of the bath, or augmenting the resistance of the solid portions of the circuit, the formation of these cavities entirely disappeared, and the beautiful results to which we have already referred have been obtained. A microscopical examination of the reverses of the deposits produced by M. Klein's final process fails to discover any porosity or irregularity in the specimens.

On leaving the bath the iron is as hard as tempered steel and very brittle. Reheated to a dull red heat it loses much of its sharpness and hardness. Heated to a cherry-red, it becomes malleable and may be engraved as easily as soft steel. If the deposits are produced in good condition and annealed uniformly and with the necessary precautions, they are neither subject to warp nor bend. There is no contraction, but on the contrary, a slight degree of expansion, almost imperceptible however. Owing to the necessity of having bank-note and similar plates identical in every respect, it is of the first importance that they should not be distorted, nor have their dimensions altered in the process of annealing. It appears that the galvanic deposit of iron has not only permanent magnetism, but that, like soft iron, it receives the magnetism of position.

We have now reviewed both the failures and the successes of M. Klein. Of the importance of the practical application of the process there can be no doubt whatever. By replacing plates of copper by those of iron greater facilities will be afforded for producing publications, works of art, and especially bank-notes and cheques. Iron electrotype plates are found to be almost indestructible. They not only can be printed from an almost unlimited number of times; but they are better calculated than those of copper to withstand those inevitable accidents constantly occurring in printing establishments. Printers are sometimes obliged to set aside as useless their best plates, which are often damaged by a grain of sand, or by a chance knot in the paper. These accidents not only involve the expense of renewing the plates, but sometimes occasion interruptions and delays in works of a very pressing nature. These are some amongst the many advantages which may be expected to accrue from the introduction of iron electrotype.'

ELECTRO-DEPOSITION OF NICKEL. 'It is only within the last few years that nickel-plating has been brought prominently into notice but Mr. Smee, in his "Elements of Electro-metallurgy," published in 1852, has the following on the subject:—'The nitrate and sulphate of nickel, the ammonio-nitrate, and sulphate of nickel, the nickelo-cyanide of potassium, but especially the chloride of nickel, require consideration. The nitrate is very soluble, but the metal has no great inclination to be precipitated, for the hydrogen appears rather to prefer being evolved than to reduce the metal. The sulphate of nickel is also used as a double salt, and the metal is reduced more readily from it than from the nitrate. It is best reduced by the compound battery process with a platinum positive pole, though a nickel positive pole may be employed. The solution of either nitrate or sulphate combined with alkalis, those of ammonia deserving the preference, ought to be as strong as possible. The chloride forms an excellent material for precipitation, by means of a nickel positive pole with one or two batteries. The nickel so deposited has a peculiar white, brilliant lustre, looking almost like glass. The deposit is so beautiful when removed from the negative pole that it forms a great contrast to the common nickel metal, and no person would ever suppose that there was any similarity of composition between that substance, still less identity. For practical purposes the chloride is first, and next to it is the sulphate for the reguline deposit." Several processes for nickel-plating have been patented within the last four years, but it is difficult to see how the inventors can claim any right to more than the exclusive use of some probably immaterial detail. Napier coated articles with nickel in 1847; and although there have doubtless been improvements in the various methods, it will be seen from the extract from Smee above quoted, that it is only some special detail of the process that can be claimed. In one of the latest of these patents, taken out in the United States this year, the inventor claims a solution of either of the soluble salts of nickel, which must be free from potash, soda, lime, alumina, or nitric acid, the said solution to be perfectly neutral. M. Becquerel, however, states that potash in no way affects the deposition of the nickel, the double sulphate of nickel and potash being as useful as the double sulphate of nickel and ammonia. The batteries in use for nickel-plating are, we believe, principally the Smee and the Bunsen with their modifications, although the Daniell and the Grove elements are also suitable; but the chief requirement from the battery is a uniform and unchanging current perfectly free from variation. Napier says it is indispensable that the battery should be so arranged that the quantity of electricity generated should correspond with the extent of surface to be coated; and it appears to us that Napier is correct in this, but we take from Dr. Feuchtwanger the details of the apparatus employed in an extensive nickel-plating establishment in the United States. The plating-trough consists of a large wooden box 5 ft. 6 in. long, 2 ft. wide, and 14 in. deep, lined with asphaltum varnish. (We have reason to believe that good dry oak is the best wood of which to make the troughs used in electro-plating: other woods will answer, but oak is both cheapest and best in the long run.) The capacity of this vat is about 70 gallons, the liquid consisting of hot water, to each gallon of which three quarters of a pound of the double sulphate of nickel and ammonia is allowed. The battery consists of six zinc plates, 9 × 10 in., well amalgamated, and six carbon plates of the same dimensions. The box containing these is lined with lead, and holds ten gallons of water, to which 20 ozs. of sulphuric acid are added. This battery is said to remain in active operation for two weeks, the zinc plates needing no re-amalgamation for four months. The articles to be plated are suspended from copper and brass wires stretched across the vat, and require from 6 to 10 hours' immersion. The battery is kept constantly at work; as soon as one set of articles is plated another replaces it. According to Dr. Feuchtwanger, the plating solution must be kept neutral, litmus-paper being frequently used, and if acid is present caustic ammonia must be added till the liquid is brought to the normal state, the tendency being to work acid. It is also necessary, of course, to replace the consumed salts. If chloride of nickel and ammonia is used, the proportions are four ounces of the salt to a gallon of water. Dr. Feuchtwanger also describes what he terms "a simple nickel-plating apparatus;" but his account is not so explicit as may be deemed needful. However, the apparatus consists of a "bath or vat containing the usual nickel solution of double salt (the sulphate, we presume), three quarters of a pound to the gallon of hot water; five gallons is to be applied to the porous cell which contains the amalgamated zinc pole, three inches broad, seven inches deep, and seven inches long; but touching within one-half of an inch all around from the cell. The copper-wire is connected to hold suspended the articles, such as faucets, pistols, or other ware to be plated with nickel; the operation goes on at once and deposits the metallic nickel from its solutions in the space of three or four hours." It must be acknowledged that the details here given are not of the clearest kind, and some portions of the apparatus appear to have been forgotten. Mr. Beardslee, whom Dr. Feuchtwanger says is the veteran nickel-plater of the States, gave the latter valuable information. Mr. Beardslee finds the best results to be given by the chloride of nickel and a certain quantity of ammonia. He uses the chromium negative plate battery in two cells. The amount of battery-power required for a given amount of work should be in zinc surface equal to the surfaces to be coated at one time. The surface of a nickel anode should never be less than the surface to be coated. "The anode surface for a nickel solution may be much greater than the surface to be coated; and more and better work will be the result." A nickel solution of 40 gallons requires 10 anodes of 6 × 12 in. and so in proportion to the greater or less quantity of gallons. The nickel anodes are connected to the chromium or carbon plates of the battery (Mr. Beardslee prefers chromium); the articles to be coated with the zincs. In the small way Mr. Beardslee employs in one gallon of the nickel solution a nickel anode of 4 × 6 in., with two one-gallon cells of the chromium negative plate battery; and he states that the chloride solution works better when it exhibits an acid reaction. Possibly, however, Stolba's method is the simplest of all, and is easily applicable. To some chloride of zinc add double the quantity of water, boil and add hydrochloric acid slowly till the precipitate is re-dissolved. A very little zinc powder is added, and in a few minutes the vessel is coated with zinc wherever the liquid touches it. The nickel salt (either the chloride or sulphate) is then added in sufficient quantity to turn the liquid of a greenish tint. The articles are then introduced with some cuttings of zinc; the whole being boiled for about 15 minutes, when the coating will be found complete. It is scarcely necessary to say that whatever process is employed, the surfaces to be coated must be perfectly clean, which is best secured by dipping in acid; and when they are plated they must be washed with hot water and polished with cloth buffs and crocus, rouge, or other polishing powder. By means of the thin coating of nickel, articles of iron and steel are prevented from rusting, while those of brass, copper, lead, or zinc, are preserved from tarnish; nickel-plating, too, has the advantage over silver-plating that it lasts four times as long and costs about one-fourth, while it is less liable to lose its polish.'

Electro-deposition of nickel has been effected from several of the salts of nickel in solution; but, until recently, the process has not been worked commercially. The Plating Company working Brookes' patent have been eminently successful by the following processes: which we copy from their Specification of Patents:—

'The solutions from which nickel has been heretofore most successfully deposited are the chloride of nickel, the cyanide of nickel and potassium, the double sulphate of nickel and ammonia, and the double chloride of nickel and ammonium. The inventor of the recently-patented process believes the chloride is the best, but the deposits obtained from it are very far from what is required for the general purposes to which the electro-deposition of this metal may be applied. As this solution is ordinarily prepared, it is a good conductor of electricity as compared with most liquids, and the nickel is deposited from it freely, but in a spongy, brittle condition, and more or less mixed with the peroxide of nickel, which gives it a brownish appearance. The deposit has also a great tendency to accumulate on the edges of the plate on which it is made in nodules or warty protuberances. Therefore, although the deposits may be obtained of considerable thickness, they are practically useless for electrotyping or electro-plating. Moreover, a portion of the electricity is expended in forming a sub-chloride of nickel, which falls to the bottom of the vessel as an insoluble precipitate. In consequence of this, the solution is soon exhausted, both of nickel and chlorine, and the process of deposition stops. Even when the solution is formed in the best-known manner, by subliming a pure nickel-chloride, the deposited metal, though free from the oxide, and therefore white, is deposited in the brittle, warty condition, accompanied with the precipitation of sub-chloride. The double cyanide of nickel and potassium is a poor conductor of electricity, and requires high battery-power. With a low battery-power very little metal can be deposited, and that little is accompanied with the deposition of peroxide of nickel to such an extent as to be black or nearly black. With a high battery-power a film of white nickel may be obtained, but not thick enough to satisfy the ordinary requirements of electro-plating.

'Neither of these solutions gives for any great length of time the full equivalent of metal for the electricity employed; and, so far as the patentee has been able to discover, these two solutions are inherently incapable of giving a coherent, tenacious, flexible metal, such as is required in the arts of electrotyping and electro-plating. Of the other two solutions named, the inventor believes that, before his improvements, the best results were obtained from the double chloride of nickel and ammonium, but the metal deposited from it is of such a character as to be worthless when deposited to any appreciable thickness. It is accompanied with the deposit of peroxide, and is therefore brown or black. It is extremely liable to split up into thin scales, which may be rubbed off even with the hand. This want of coherence and tenacity unfits it for the requirements of the arts. The metal deposited from the double sulphate of nickel and ammonia is substantially the same as the above, but it is not so easily obtained. If, with these solutions, a battery-power is used of an intensity of two Grove cells, or thereabouts, a white deposit may be obtained of considerable thickness, but still with such a tendency to split up in scales that it is practically useless, and neither solution gives the full equivalent due to the current.

'It has been discovered, however, that the difficulties attending the use of these last-named solutions, and the character of their deposits, are not inherent in the nature of the solutions, but are due to the modes of preparing them, or to the presence in minute quantities of certain substances which are generally employed in making them, or in the reduction of the nickel used in making them. In order, therefore, to prepare these solutions in such a manner as to give the results reached, it is necessary to adopt processes in their preparation and observe precautions which shall either dispense with the use of these substances altogether or shall effectually remove them if they are employed.'

The patentee then proceeds to give the following directions:—'In preparing this solution, I prefer the use of pure nickel; but commercial nickel may be used. Commercial nickel almost always contains more or less of the re-agents employed in the purification or manufacture of the metal, such as sulphate of lime, sulphide of calcium, sulphide of sodium or potassium, chloride of sodium, and alumina. When any of these substances are present it is necessary to remove them; this can be done by melting the nickel, or by boiling it in water containing at least 1 per cent. of hydrochloric acid. The boilings must be repeated with fresh acid and water until the waste-waters give no indication of the presence of lime when treated with oxalate of ammonia. When the metal is purified by melting, the foreign substances collect on the top of the melted metal in the form of a slag, which can be removed mechanically. If the nickel contains zinc it should be melted, in order to volatilise the zinc and drive it off. The crucible in such case must not be closed so tightly as to prevent the escape of the zinc fumes. If copper, arsenic, or antimony is present in the nickel it can be removed after the nickel is dissolved by passing sulphuretted hydrogen through the solution. The acid to be used in dissolving the metal consists of one part strong nitric acid, six parts muriatic acid, and one part water. Nitric acid or muriatic acid may be used separately, but the above mixture is preferred. A quantity of this acid is taken, sufficient to dissolve any given amount of the metal, with as little excess of the former as possible; a gentle heat is all that is required. The resulting solution is then filtered, and to prepare the solution of the double sulphate of nickel and ammonia, a quantity of strong sulphuric acid, sufficient to convert all the metal into sulphate, is added, and the solution is then evaporated to dryness. The mass is then again dissolved in water, and a much smaller quantity than before of sulphuric acid is added, and the whole again evaporated to dryness, the temperature being raised finally to a point not to exceed 650° Fahr. This temperature is to be sustained until no more vapours of sulphuric acid can be detected. The resulting sulphate of nickel is pulverised and thoroughly mixed with about $\frac{1}{50}$th of its weight of carbonate of ammonia, and the mass again subjected to a gradually-increasing temperature, not to exceed 650° Fahr. until the carbonate of ammonia is entirely volatilised. If any iron is present, the most of it will be converted into an insoluble salt, which may be removed by filtration. The resulting dry and neutral sulphate of nickel is then dissolved in water by boiling, and if any insoluble residue remains, the solution is filtered. From the weight of the nickel used before solution, the amount of sulphuric acid in the dry sulphate can be calculated. This amount of sulphuric acid is weighed out, diluted with four times its weight of water, and saturated with pure ammonia or carbonate of ammonia; the former is preferred. This solution, if it is at all alkaline, should be evaporated until it becomes neutral, to test-paper. The sulphate of ammonia of commerce may likewise be used, but pure sulphate of ammonia is to be preferred. The two solutions of the sulphate of nickel and sulphate of ammonia are then united and diluted with sufficient water to leave 1½ oz. to 2 ozs. of nickel to each gallon of solution, and the solution is ready for use.

'In preparing the solution of the double chloride of nickel and ammonium, the nickel is to be purified and dissolved in the same manner as is described for the previous solution, and it is to be freed from copper and other foreign matters in the same manner. The solution is then to be evaporated to dryness; it should be made as nearly anhydrous as possible. The salt is then placed in a retort and heated to a bright red heat. The salt sublimes and is collected in a suitable receiver, the earthy matter being left behind. The salt thus purified is dissolved in water, and to the solution is added an equivalent quantity of pure chloride of ammonium. The solution is then ready for use: it may have a specific gravity of 1050 to 1100.'

Of these two solutions the inventor much prefers the double sulphate, as it gives a softer metal, which can be polished, or otherwise worked more readily than that obtained from the double chloride solution. The double sulphate solution has this important advantage over any other solution, that it gives a deposit with a smooth surface, which can be polished with comparatively little labour. When the process is properly conducted, the deposit can be made much thicker than is ordinarily required for plating other metals before it acquires a rough or matted surface. With a metal so hard as nickel this is a matter of great importance.

The Specification of the Patent and the Disclaimer and Memorandum of Alteration of The Plating Company (Limited) to Brookes' patent give still further directions for securing the purity of the nickel solution. These are points, however, to which those only who are likely to carry out the electro-deposition of nickel on a large scale need attend, and to such the papers referred to are always available.

Having prepared the solutions and anodes, nickel may be readily deposited; but, in order to carry on the deposition continuously, it is necessary to observe certain precautions.

First. The use of a battery of too high an intensity must be avoided; an intensity of two Smee's cells is sufficient. A high intensity decomposes the solution and liberates free ammonia, thus rendering the solution alkaline, and impairing its value. Whenever the smell of free ammonia arises from the decomposing cell, the operator may be sure that the solution is being injured. It is important that the depositing shall not be forced by the use of too strong a current.

Second. It is important that great precaution should be used to prevent the introduction into the solution of even minute quantities of potash, soda, or nitric acid. When an article to be coated is cleaned in acid or alkaline water, or is introduced into it for any purpose, the greatest care must be taken to remove all traces of these substances before the article is introduced to the nickel solution, as the introduction of the most minute quantities of acids or alkalis will surely be injurious.

Third. The anode of the depositing cell—a nickel plate of the utmost purity--of copper, or alloyed with a little iron to secure the precipitate, should present a surface to the action of the solution somewhat larger than the surface upon which the deposit is being made, particularly in the double sulphate solution. The reason is that nickel dissolves so slowly that if the exposed surface is not larger than the surface on which the deposit is made, the solution will not keep saturated. On the other hand, if the anode is very much larger than the positive pole, it tends to give a deposit of black powder.

Fourth. With solutions and anodes thus prepared and used, the deposition of nickel can be carried on continuously, and almost as surely and certainly as the deposition of copper from the common sulphate solution, though the limits of the battery-power which may be used are narrower. The metal deposited is compact and tenacious. It may be deposited of nearly uniform thickness over any surface, however large. The deposited metal is capable of being annealed by a heat below a low red heat; it then becomes flexible, malleable, and ductile, either to furnish effectual protection to the metal on which it is deposited, or to be removed and used separately from the surface on which it may be deposited. Thus electro-type plates of nickel may be produced, either as copies of irregular surfaces which it is desired to reproduce, or as plain sheets of nickel, which, after being annealed, may be rolled, hammered, or spun into a variety of forms or articles.

Far more extensive use has been made of these properties in America than in this country. There it is used for carriage and harness fittings, for guns and pistols, for various scientific instruments, and for numerous domestic utensils and articles of furniture from fenders to flat-irons. For brass and iron fittings on board ship, and for lever handles of engines of all kinds it is especially adapted, and for the metals mentioned in all places where they are liable to oxidation or corrosion. The process is, we believe, carried on in London on an extensive scale, but one establishment, or even half-a-dozen, cannot supply the needs of the public when the value of the process becomes better known. even if they can keep pace with the present demand. Without doubt many improvements upon the process introduced by Prof. Boettger in 1843 will be introduced as soon as the utility of nickel-plating becomes known.

ELECTRO-MOTIVE ENGINES. The following remarks on this subject are an abstract of a communication read by the editor to the Institution of Civil Engineers, for which they awarded him their Telford Medal.

Numerous electro-magnetic machines have been made, but a few only of these require to be described. In 1832, Salvatore dal Negro published an account of the attempts made by him in this direction. As Dal Negro's engine was of a very simple and effective kind, the Professor's description of it may be quoted:—'As I had been successful in producing temporary magnets of very great power, with very small electro-motors, I endeavoured to apply this power to moving machinery. I will now briefly state by what means I endeavoured to set a lever in motion. I first used a magnetic steel bar, placed vertically between one end of a temporary magnet. The bar vibrated from the attractions and repulsions which took place between its north pole and the north and south poles of the electro-magnet. In the same way a motion may be effected in a horizontal plane. I also set in motion a similar bar, by allowing a piece of iron, set free from the magnet at the moment when its power became = 0 to fall on one of its ends, after this it was immediately re-attracted. This can be effected in two ways: the one may be employed when a quick motion is to be produced, and the second when a greater force is wanted; in the first case the weight falls only just out of the power of the magnet's attraction, and the instant the weight has fallen upon the bar, or lever, it is re-attracted by the magnet that the action may be repeated: it is always small in comparison with that which the magnet cannot support whilst in contact. In the second case the whole weight which the magnet can carry is employed, and use is made of the force which draws it to the magnet.' Upon this was founded several other attempts, particularly one by Dr. Schulthess, who was so satisfied with the result, that he wrote in 1833:—'If we consider that electro-magnets have already been made, which were capable of carrying 20 cwts., and that there is no reason to doubt that they may be made infinitely more powerful, I think I may boldly assert that electro-magnetism may certainly be employed for the purpose of moving machines. Professor Bottò, of Turin, also employed 'a lever put in motion (in the manner of a metronome) by the alternating of two fixed electro-magnetic cylinders, exerted on a third moveable cylinder, connected with the lower arm of the lever, the upper part of which maintains a metallic wheel, serving in the ordinary way, as a regulator in a continuous gyratory motion.' It will be evident to any one who has observed the motion of many of the electric clocks, that this is in several respects similar to the pendulous motions adopted.

In 1835, the late Prof. Jacobi, of St. Petersburg, published an account of his experiments, which were carried out on a large scale, regardless of cost, at the expense of the Emperor Nicholas. His first idea was to employ the attractive and repellant powers of magnetic bars, so that he might obtain an advancing and receding motion, which could be easily changed into a continuous circular motion. A great many machines have been made upon this principle; but Jacobi alone, as far as can be learned, has pointed out the true cause of their failure. 'We know,' he says, 'the ill effects of shocks in the movements of machines, but there is here another inconvenience which is not simply mechanical. The soft iron, by these repeated shocks and vibrations, gradually acquires at the surface of contact the nature of steel; there will be a considerable permanent magnetism, and the transient magnetic force which alone produces the movement, will be weakened in proportion. A number of experiments, which I have made upon the magnetic force of a bar of soft iron, bent into a horseshoe form, has shown me the great disadvantage of often-repeated shocks, proceeding from the sudden contact of the armature.'

Jacobi, finally setting aside all oscillating motions, produced a machine giving continuous circular motion, by fixing eight electro-magnetic bars on a disc, moveable round an axis—and eight fixed bars similarly arranged upon a fixed platform. The arrangement of the bars admitted of much variety, provided it was exactly symmetrical, and that it allowed the poles to approach each other as nearly as possible. Arrangements were made, with much ingenuity, by which the poles of the magnets were inversed directly, and so that inversion should take place precisely at that point where the bars were opposite each other. One hundred and forty-four inversions in the second were readily effected, and Jacobi declared it would be easy with his apparatus to change, or to completely interrupt, the electric current one thousand or more times in a second.

A machine constructed upon this principle was, at the desire and at the cost of an Imperial Commission, put on board a ten-oared shallop, equipped with paddle-wheels, to which the electro-magnetic machine communicated motion. The boat was 28 feet long, and 7½ feet in width, and drew 2½ feet of water. In general, there were 10 or 12 persons on board, and the voyage on the Neva was continued during several entire days. By these experiments Jacobi was led to the conclusion that a battery of

20 square feet of platinum would produce power equivalent to one horse; and the vessel went at the rate of four miles an hour. In 1839, Jacobi tried another experiment, with a battery of 64 platinum plates, each having 36 square inches of surface; when the boat, with a party of 14 persons on board, went against the stream at the rate of three miles an hour.

In 1837, Mr. Thomas Davenport, of the United States, constructed a rotary engine, in which permanent and electro-magnets were employed. Mr. Taylor, in 1839, patented an electro-magnetic engine, both in America and in this country, the principal novelty in which was, that instead of changing the poles of the magnets, the electric action was, at fixed rapid intervals, entirely suspended. In 1837, Mr. Davidson, of Edinburgh, constructed an engine, in which he produced motion by simply suspending the magnetism, without a change of the poles. Mr. Robert Davidson placed an electro-magnetic locomotive on the Edinburgh and Glasgow Railway; the carriage was 16 feet long and 6 feet broad, and weighed about 5 tons. All the arrangements appear to have been very complete, but when put in motion on the rails, it was not possible to obtain a greater speed than four miles an hour.

Professor Page's electro-magnetic engine was for some time looked upon as a triumph. The fundamental principle of it is thus described:—'It is well known that when a helix of suitable power is connected with the poles of a battery in action, an iron bar, within it, will remain held up by the induced magnetism, although the helix be placed in a vertical position; and if the bar is partly drawn out of the helix by the hand, it goes back with a spring, when the hand lets go its hold. This power —the action of the helix upon the metallic bar within it—is the power used in Page's engine.' Professor Page exhibited one of his engines, of between 4 and 5 horse-power, at the Smithsonian Institution; the battery to operate with being contained within a space of 3 cubic feet. It was a reciprocating engine of 2-feet stroke, and the whole, including the battery, weighed about one ton. Professor Page stated that the consumption of 3 lbs. of zinc per day would produce one horse-power. This statement requires further investigation.

Many similar attempts have been made to construct effective machines to be moved by the power of the voltaic battery. Among others, Mr. Henley constructed an electro-magnetic engine of considerable power for Mr. Talbot, and another for Professor Wheatstone. In these there were many ingenious mechanical arrangements, invented to overcome some of the difficulties hitherto encountered; but the physical conditions were similar to those already described. Mr. Talbot's engine was 3 ft. 6 ins. long, and 2 ft. 6 ins. wide; when excited by a Grove's battery, consisting of four cells with double plates of zinc, 9 ins. by 6½ ins., platinum plates 9 ins. by 5½ ins., excited by diluted sulphuric acid in the proportions of 1 to 4, and concentrated nitric acid, it drove a lathe, with which was turned a gun-metal pulley, 5 ins. in diameter; but in three quarters of an hour the battery was quite exhausted.

Mr. Hjörth, a few years since, exhibited in London a large machine, constructed somewhat on the principle of Page's; this, however, failed to produce any great mechanical effect, and it appears to have been abandoned. Dr. Lardner stated, in 1851, that M. Gustave Froment, of Paris, was using, with much advantage, an electro-magnetic engine in his workshops for turning lathes, planing machines, &c. Its use, however, appears to have been abandoned, on account of the great cost of the battery power.

Hankel and Fessel, on the Continent, the Rev. James William M'Gauley, Dr. Kemp, and others, in Great Britain, have, at different times, excited much attention by the ingenious machines which they have constructed.

Notwithstanding these numerous trials, and, connected with them, an almost infinite amount of experiment, it does not appear that any satisfactory explanation has ever been given of the causes which have led to the abandonment of the idea of employing electricity as a motive power. It was mainly with the view of directing attention to these causes, that the essay read was written.

Electro-magnetism undoubtedly affords an almost unlimited power. An electro-magnet may be constructed which shall have a lifting power equal to many tons. It is probable, that there are limits beyond which it would not be possible to increase the power of electro-magnets; those limits have not yet been reached; but supposing them to be attained, there is nothing to prevent the multiplying of the number of electro-magnets in the arrangements. It may be stated, in connection with this part of the subject, that from experiments made with Hearder's magnetometer, it appears that the development of magnetism in iron observes some special peculiarities. These may be thus stated:—With the same electro-magnet there is, as the voltaic pairs in the battery are increased, a gradual increase of magnetic force. With from one to seven elements there appears an average excess of 31 lbs.; after this point, with the increase of battery power, by the addition of pair after pair of zinc and platinum elements, the production of power bears a decreasing ratio to the power employed, and at last, the addition of five elements was not found to produce an increase of effect equivalent to the value of one element. In all experiments, therefore, on electro-magnetic machines, the experimentalist has first to determine the utmost power which the soft iron is capable of assuming, in relation to—1st, the number of coils of wire on the iron; and 2nd, the number of elements employed in the exciting source—the voltaic battery. The length of the iron and its thickness are also points demanding special considerations from the constructor of an electro-magnetic machine.

There remains now to examine the production of the power, Electro-Magnetism.

The electro-mechanician is dependent upon his battery, in the same way as a steam engineer is dependent upon his fire and his boiler, for the production of mechanical effect.

Voltaic batteries vary in their effects, and hence arise statements which differ widely from each other, as to the result obtained, by the destruction (? change of form) of a given quantity of metal in the battery.

Dr. Botto states, that 45 lbs. of zinc, consumed in a Grove's battery, are sufficient to work a one-horse power electro-magnetic engine for twenty-four hours.

Mr. Joule says the same results would have been obtained, had a Daniell's battery been used, by the consumption of 75 lbs. of zinc.

It is impossible, on the present occasion, to enter into the theory of the voltaic battery, or to describe the varieties of arrangement which have been adopted for generating (developing) electrical force in the form of a current, with the greatest effect, at the smallest cost.

On this point the evidence of Jacobi may be quoted:—'With regard to the magnetic machine, it will be of great importance to weaken the effects of the counter current, without at the same time weakening the magnetism of the bars. It is the alternate combination of the pairs of plates in the voltaic pile, which permits us to increase the speed of rotation at will. We know the magnetic power of the current is not sensibly augmented by increasing the number of the pairs of plates, but the counter current is considerably weakened by its being forced to pass through a great many layers of liquid. In fact, on using twelve voltaic pairs, each, half a square foot, instead of four copper troughs, each with a surface two square feet, which I had hitherto used, the speed of rotation rose at least 250 or 300 revolutions in a minute.'

Mechanical force, whether obtained in the form of man-power, horse-power, steam-power, or electrical power, is the result of a change of form in matter. In the animal, it is the result of muscular and nervous energy, which is maintained by the due supply of food to the stomach. In the steam-engine, it is the result of vapour-pressure, which is kept up by the constant addition of fuel to the fires, under the boilers. In the magnetic machine, it is the result of currents circulating through wires, and these currents are directly dependent upon the chemical change of zinc or of some other metal in the battery. Then,

Animal-power depends on food.
Steam-power depends on coal.
Electrical power depends on zinc.

An equivalent of coal is consumed in the furnace—that is, it unites its carbon with oxygen to form carbonic acid, and its hydrogen with oxygen to form water, and during this change of state the quantity of heat developed has a constant relation to the chemical action going on.

Mr. Joule has proved by a series of most satisfactory experiments, that: 'The quantity of heat capable of increasing the temperature of a pound of water by one degree of Fahrenheit's scale is equal to, and may be converted into, a mechanical force capable of raising 838 lbs. to the perpendicular height of one foot.'

Mr. J. Scott Russell has shown that in the Cornish boilers, at Huel Towan and the United Mines, the combustion of one pound of Welsh coal evaporates of water, from its initial temperature, 10·58 lbs. and 10·48 lbs. respectively. 'But,' says Mr. Joule, 'we have shown that one degree is equal to 838 lbs. raised to the height of one foot. Therefore the heat evolved by the combustion of one pound of coal is equivalent to the mechanical force capable of raising 9,584,206 lbs. to the height of one foot, or to about ten times the duty of the best Cornish engines.'

Such are the conditions under which heat is employed as a motive power. An equivalent of zinc is acted on by the acid in the cells of the battery, and is oxidised thereby. In this process of oxidation a given quantity of electricity is set in motion; but the quantity available for use falls very far below the whole amount developed by the oxidation of the zinc. The electricity, or electrical disturbance, is generated on the surface of the zinc; it passes through the acidulated fluid to the copper plate or platinum plate, and in thus passing from one medium to another it has to overcome certain mechanical resistances, and thus a portion of the force is lost. This takes place in every cell of the voltaic arrangement, and consequently the proportion of zinc which is consumed, to produce any final mechanical result, is considerably greater than it should be theoretically.

Joule gives as the results of his experiments, the mechanical force of the current produced in a Daniell's battery as equal to 1,106,160 lbs. raised one foot high, per pound of zinc, and that produced in a Grove's battery as equal to 1,843,600 lbs. raised one foot high, per pound of zinc.

It need scarcely be stated, that this is infinitely above what can be practically obtained. A great number of experiments, made by the Author some years since, enabled him to determine, as the mean average result of the currents, produced by several forms of battery-power, that one grain of zinc, consumed in the battery, would exert a force equal to lifting 86 lbs. one foot high. Mr. Joule and Dr. Scoresby thus sum up a series of experimental results: 'Upon the whole, we feel ourselves justified in fixing the maximum available duty of an electro-magnetic engine, worked by a Daniell's battery, at 80 lbs. raised a foot high, for each grain of zinc consumed.' This is about one-half the theoretical maximum duty. In the Cornish engines, doing the best duty, one grain of coal raised 143 lbs. one foot high. The difference in the cost of zinc and coal need scarcely be remarked on. The present price of the metal in sheets is 28*l.* per ton, and coal can be obtained, including carriage to the engines, at less than 1*l.* per ton; and the carbon element does two-thirds more work than can possibly be obtained from the metallic one.

By improving the battery arrangements, operators may eventually succeed in getting a greater available electrical force. But it must not be forgotten, that the development of any physical force observes a constant law. Whether in burning coal in the furnace, or zinc or iron in the battery, the chemical equivalent represents the theoretical mechanical power. Therefore, the atomic weight of the carbon-atom being 6, and that of the zinc-atom being 32, it is not practicable, under the best possible arrangements, to obtain anything like the same mechanical power from zinc which can be obtained from coal. Zinc burns at an elevated temperature; in burning a pound of zinc there should be obtained, as heat, the same amount of mechanical power which is obtained as electricity in the battery. The heat being more easily applied as a prime mover, it would be far more economical to burn zinc under a boiler, and to use it for generating steam-power, than to consume zinc in a voltaic battery for generating electro-magnetical power.

With the advance of our knowledge some of the difficulties may be overcome. An important and substantial step in advance has been made in practical electricity by M. Gramme, of Paris, who substitutes a rotatory for a reciprocating motion in the mechanical arrangement employed in the production of an electrical current. Hitherto magneto-electric machines have acted upon a principle analogous to that of the ordinary pump, and the current produced has consequently been intermittent in its character. The new machine acts in a similar manner to the rotary pump, and, like that apparatus, gives a continuous stream, and with a very small expenditure of power, while the great drawback to other systems, self-heating, is in it scarcely appreciable, It is, moreover, the first recorded instance of a perfectly continuous magneto-electric current having been obtained on a practical scale, and the circumstance derives additional interest from the fact that the inventor is from the ranks of mechanical workers in electrical science, and not a highly-educated electrician. Had he been one, the probability is that the present apparatus would never have been invented by him, for to obtain a continuous stream an electrician would have followed a course of experiment and inductive reasoning which would have landed him in an entirely opposite direction. Even M. Gramme's explanation of the reasons operating to produce the results he has achieved are at variance with several known facts in electrical science, and with the views entertained by electricians upon the subject. The production of the apparatus is therefore to be attributed more to intuition on the part of its inventor than to the study and practical application of the laws which govern the artificial production of electrical currents. The machine by means of which this important improvement is effected is composed of three rings of soft iron encircled with an endless coil of copper-wire. Each of these rings is made to rotate between the two poles of a strong electro-magnet. The magnets are vertical cylinders of soft iron 3 ft. 6 in. high by 3½ in. in diameter, and are coiled round with insulated copper-wire. They are connected at the top by a square cast-iron plate, and at the bottom are let into a base-plate 2 ft. 8 in. square. In operation the half of each ring which is in proximity with the north end of the magnet takes south polarity, while the opposite half near to the south end takes north polarity. The two neutral points of the system are equi-distant on each side. The rings or bobbins are rotated on a horizontal axis, and when they are set in motion their polarity remains unchanged in position with regard to the operator. The action is therefore equivalent to the coils alone being rotated over a stationary ring-shaped magnet. The effect of this is to produce currents in the two halves of each ring in opposite directions between its two neutral points. At these points, however, contacts are placed, which touch in succession a series of studs connected, at regular intervals, with the wire-coil. Thus the opposite currents in the two halves of each ring, instead of neutralising each other, unite and form a single current. The machine requires a very small amount of force to drive it—much less than one horse-power being ample—and it produces a very intense and steady flow of light. With this apparatus some interesting experiments have lately been made by Mr. Robert Sabine at the works of Messrs. Whieldon and Cooke, in the Westminster-bridge Road, where the machines are being manufactured. It was shown that the current is producible in large quantities, at a much cheaper rate, and of greater constancy than by galvanic batteries. A further superiority over the batteries was also demonstrated in the fact that the resistance remains the same no matter at what speed the machine is driven, within reasonable limits. Therefore, by driving it at double speed twice as much electromotive force is obtained, which represents, therefore, more than twice as much current. In the experiments the machine was driven at a speed of about 320 revolutions per minute, and the first object of the exhibitors was to show the power developed by the system. In the next place a length of 10 ft. of platinum-wire was made red-hot in a few seconds. This experiment was afterwards repeated with a chain of about the same length and composed of alternate links, six inches long, of silver and platinum. While the platinum rapidly became red-hot, and remained so, the silver never became more than inconveniently heated. The light-producing power of the apparatus was then exhibited from the rear portion of Messrs. Whieldon's works. The light was produced in the usual way from carbon points and condensed in a concave reflector, which threw the rays down a by-street on to premises in the York Road, a long distance off, and which were brilliantly lighted up. The light was very intense and remarkably steady, and would doubtless have fallen brightly on the Thames Embankment had not the rays been intercepted by the York Road premises. After the light had been exhibited for some time, the experimenters illustrated the power of the current to fuse metals. This was done in the interior of the building, and platinum, aluminium, silver, magnesium, strontium, metallic sodium, and steel were successively and successfully burnt, the spectrum of each being thrown on a screen. The invention will undoubtedly prove of great importance, for use in lighthouses and for metallurgical purposes, as well as on shipboard, owing to the portability of the apparatus, the small space it occupies, and the slight power required to drive it. It has already been in use for some time past with the best results at the electro-plating works of Messrs. Christofle and Co., of Paris, and is at present under trial by the Postal Telegraph Department. Messrs. Whieldon and Cooke have constructed a machine which has been employed for exhibiting a light in the clock-tower of the Houses of Parliament during the sittings of the House, so that the public had an opportunity of judging of its merits. This application of the electric light has not at present (1874) been adopted, why, we know not. M. Gramme certainly deserves credit for this most important contribution to applied science, by means of which he has practically solved the problem of the production of cheap dynamic electricity.

ELECTRO-PLATING AND GILDING IRON. Professor Wood, of Springfield, Massachusetts, in a paper, which he has communicated to the 'Scientific American,' recommends the following as useful recipes for the electro-metallurgist. He says, 'I believe it is the first time that a solution for plating direct on iron, steel, or Britannia metal has been published. In most of the experiments I have used Smee's battery; but for depositing brass I prefer a battery fitted up as Grove's, using artificial graphite—obtained from the inside of broken coal-gas retorts—in the place of platinum. With one large cell (the zinc cylinder being 8 by 3 inches, and excited with a mixture of one part sulphuric acid and twelve parts water, the graphite being excited with commercial nitric acid) I have plated six gross of polished iron buckles per hour with brass. I have also coated type and stereotype-plates with brass, and find it more durable than copper-facing.

'*To prepare Cyanide of Silver.*—1. Dissolve 1 oz. of pure silver in 2 oz. of nitric acid and 2 oz. of hot water, after which add 1 quart of hot water. 2. Dissolve 5 oz. of the cyanide of potassium in 1 quart of water. To the first preparation add by degrees a small portion of the second preparation, until the whole of the silver is precipitated, which may be known by stirring the mixture and allowing it to settle. Then drop into the clear liquid a very small quantity of the second preparation from the end of a glass rod: if the clear liquid is rendered turbid, it is a proof that the whole of the silver is not separated; if, on the other hand, the liquid is not altered, it is a proof that the silver is separated. The clear liquid is now to be poured off, and the precipitate, which is the cyanide of silver, washed at least four times in hot water. The precipitate may now be dried and bottled for use. *To prepare Cyanide of Gold.*—Dissolve 1 oz. of fine gold in 1·4 oz. of nitric acid and 2 oz. of muriatic acid; after it is dissolved add 1 quart of hot water, and precipitate with the second preparation, proceeding the same as for the cyanide of silver. *To prepare Cyanides of Copper and Zinc.*—For copper, dissolve 1 oz. of sulphate of copper in 1 pint of hot water. For zinc, dissolve 1 oz. of the sulphate of zinc in 1 pint of hot water, and proceed the same as for cyanide of silver. The electro-plater, to insure success in plating upon all metals and metallic alloys, must have two solutions of silver; the first to whiten or fix the silver to such metals as iron, steel, Britannia metal, and German silver; the second to finish the work, as any amount of silver can be deposited in a reguline state from the second solution. *First, or Whitening Solution.*—Dissolve 2½ lbs. (troy) of cyanide of potassium, 8 oz. carbonate of soda, and 5 oz. cyanide of silver in one gallon of rain or distilled water. This solution should be used with a compound battery, of three to ten pairs, according to the size of the work to be plated. *Second, or Finishing Solution.*—Dissolve 4½ oz. (troy) of cyanide of potassium, and 1½ oz. of cyanide of silver, in 1 gallon of rain or distilled water. This solution should be used with one large cell of Smee's battery, observing that the silver plate is placed as near the surface of the articles to be plated as possible.—N.B. By using the first, or whitening solution, you may insure the adhesion of silver to all kinds of brass, bronze, red cock-metal, type-metal, &c., without the use of mercury, which is so injurious to the human system. *To prepare a Solution of Gold.*—Dissolve 4 oz. (troy) of cyanide of potassium, and 1 oz. of cyanide of gold, in 1 gallon of rain or distilled water. This solution is to be used warm (about 90° Fahr.) with a battery of at least two cells. Gold can be deposited of various shades to suit the artist, by adding to the solution of gold a small quantity of the cyanides of silver, copper, or zinc, and a few drops of the hydro-sulphuret of ammonia.'

ELECTRO-PLATING BATH. See CYANIDES.

ELECTRO-SORTING APPARATUS. M. Froment devised an apparatus for the separation of iron from matters by which it may be accompanied. The apparatus consists of a wheel carrying on its circumference eighteen electro-magnets. The iron ore, reduced and pulverised, is spread continually upon one of the extremities of a cloth drawn along with it, and passed under the electro-magnets in motion. The iron in the ore which has of course been brought into a magnetic state by any of the processes by which this may be effected, is separated by the magnets, and the impurities carried onward. See De la Rive's 'Electricity.'

ELECTRO-TELEGRAPHY. The simultaneous appearance of the electric spark at the respective ends of a long conducting wire forcibly arrested the attention of electricians in the early days of the science.

A series of remarkable experiments were made by Dr. Watson, commencing on July 14th, 1747; when he passed an electric discharge from the Thames bank at Westminster to the opposite bank at Lambeth, by means of a wire suspended to Westminster Bridge. He continued his researches; and, on August the 5th of the following year, he arranged 12,276 feet of wire at Shooter's Hill, the beginning, the middle, and the end of which were led into the same apartment. He discovered that the electric signs at the middle of the wire coincided in time with the discharge at the two ends, proving that the passage, at least in such a length of wire, was instantaneous. In reference to these results, Professor Muschenbroeck wrote to Dr. Watson: 'Magnificentissimis tuis experimentis, superasti conatus omnium,' Dr. Franklin made similar experiments in 1748 across the Schuylkill at Philadelphia, and in the next year Du Luc repeated them across the Lake of Geneva.

The idea of applying this property to the transmission afar of telegraph signals proper was an early and natural result of these discoveries. But many onward steps were necessary before the idea could assume any definite form; and further advances in knowledge were essential before the idea could be realised.

Locked up, as it were, in all bodies, is a large store of electric force, the equilibrium of which is disturbed in a greater or less degree by a variety of causes, some extremely simple, others more complex; and, according as one or other cause is in operation, the conditions under which the electric force is manifested vary; some conditions being very unfavourable, and others very favourable to the object in view.

The rapidity with which electric force traverses conductors depends upon the circumstances under which the conductors are placed; in the case of wire suspended in the air, the electric force has little else to do than to travel onward and be discharged from the far end of the wire; in the case of buried wire, it has to disturb the electric equilibrium of the gutta-percha as it travels onward, and thus suffers considerable retardation. The greatest recorded velocity of a signal through a suspended copper telegraph wire is 1,725,800 miles per second, by M. Hipp; the lowest velocity through a buried copper-wire, 750 miles per second by Faraday. Intermediate velocities are recorded, for which the nature of the wire or the conditions under which it was placed were different. Wheatstone found the velocity of electricity under different conditions from the above to be 288,000 miles per second. His wire was copper, and was wound on a frame. The electricity that was employed by Mr. Wheatstone in these experiments was obtained from the friction of glass against an amalgam of tin. The various velocities are due partly to the conditions under which the conducting wire is placed, and partly, no doubt, to the varied properties of electricity from various sources.

Electricity is obtained from other sources than friction with so much greater facility, and in forms so much more applicable and manageable for telegraphic purposes, that frictional electricity has not been applied in real practice. It must not, however, be passed over in this place, because one of the earliest telegraphs, perhaps the very first in which a long length of wire was actually used, was actuated by this form of electricity. In February 1753 a writer, dating from Renfrew, and signing himself 'C. M.' wrote to the Scot's Magazine on 'An expeditious mode of conveying intelligence.' The method proposed differed in no respect from that adopted by Dr. Watson, frictional electricity being employed, and the signals being the movements of pith-balls. He, however, proposed the use of bells, upon which the electrified balls were to strike, and thus, he says, the experimentalist 'will inform his correspondents by the sound what wires have been touched; and thus by some practice, they may come to understand the language of the chimes in whole words, without being put to the trouble of noting down every letter.'

Lesage, we are informed by Moigno, in his '*Télégraphie Electrique*,' erected at Geneva in 1774 a line of twenty-four insulated metallic wires, insulated from each other, each wire being connected at its farthest end with a pith-ball electrometer, which corresponded to one of the letters of the alphabet. Lomond, in 1787, employed a single electroscope, and by arranging a system of signals given by the divergence of the pith-balls, transmitted intelligence by means of a single wire. This was seen by Arthur Young, and described by him in his 'Travels in France.' In 1816 Mr. Ronalds established, in the grounds attached to his residence at Hammersmith, eight miles of wire suspended by silk to dry wood, besides 175 yards of buried wire in glass tubes embedded in pitch and enclosed in troughs of wood. He obtained his electricity from a common electrical machine, and his signals from the motion of light bodies, balls of elder-pith, produced under circumstances analogous to those to which we have already referred. At the far end of his telegraph wire two pith-balls were suspended close together. Electricity applied at the home end of the wire at once diffused itself throughout the conducting system, including the pair of light balls. Just as we have seen gold-leaf recede after having approached rubbed amber, and acquired an electric charge, so the pith-balls, each being charged with electricity, derived from the same source, recede from each other; and this in obedience to the fundamental laws of static electricity, for which we must refer readers to treatises on the subject. Here, then, we have one solitary signal. The manner in which Mr. Ronalds turned it into language was ingenious. He pressed time into his service, and by combining time and motion he obtained a language. He provided a clock movement at each station; the clocks were so regulated as to be synchronous in their movements; each of them carried, in lieu of a hand, a light disc, having the letters of the alphabet and other signals engraved on it. The disc was hidden by a screen, in which was *one* opening. It is obvious that if the clocks were started together, and had uniform rates, the same letter at the same time would be visible through the opening in each screen; and letter by letter would pass seriatim and simultaneously before the respective openings. If absolute uniformity is difficult for long periods, it is practicable for shorter. The sender of a message watched the opening of his screen; the moment the letter approached that he desired to telegraph he charged the wire with electricity, and the balls at the far station moved; the letter then visible there corresponded with the one at the home station, and was read off. The sender watched till the next letter he required came round, and so on.

Let us now pass on to some of the leading features of electro-telegraphy, as it has been realised of late years, and to a description of some of the telegraph instruments that are most in use.

Chemical action is the most fertile source of electricity. If a silver fork and a steel knife are connected together by a piece of wire, and the fork is thrust into a piece of meat, say a hot mutton-chop, the moment an incision is made in the meat with the knife, electricity will pass along the wire and continue to do so while the above disposition of things remains. Upon the proper test being applied, the electricity is readily detected. This is the *current form* of electricity. The amount of force in circulation in this particular combination is not very great, and its power of travelling to a distance is not very high, but still it is quite capable of producing good signals, on a delicate arrangement of the needle instrument—the galvanometer, with which we are now so familiar.

The amount of electricity obtained by means of chemical action is increased to the required extent by a judicious selection of the two metals forming the galvanic series and of the liquid or liquids in which they are immersed. Zinc is invariably used as one of the metals. Copper, silver, and platinum or graphite (gas carbon) is selected for the other. When the two metals are immersed in the same liquid, a mixture of sulphuric acid with salt-water, or fresh, is employed. When two liquids are used, they are separated by a porous partition; the zinc is usually placed in the sulphuric acid solution, and the other metal in a solution varying with the nature of the arrangements proposed. Zinc is naturally soluble in the acid solution in question; and would therefore waste away and be consumed at the expense also of the acid, unless precautions were taken to make it resist the ordinary action of the solvent. When zinc is dissolved in mercury it is not attacked, under ordinary circumstances, by sulphuric acid solution. Hence the plate of zinc employed in all good Voltaic combinations, as they are called after Volta, into which this acid, in a free state, enters, are protected by being well amalgamated, that is, they are dipped in a strong acid mixture and well washed; and are then dipped into a mercury bath, and are placed aside to drain. The operation is generally repeated a second time; and, in the best arrangements, the further precaution is taken of standing the zinc plate, while in the acid water, in some loose mercury, placed either in the bottom of the containing vessel, or in a gutta-percha cell: by the latter arrangement, mercury is economised. In single-liquid arrangements, it is desirable to select a metal that is not attacked by the acid. Copper has been extensively used, and is very valuable; but it possesses the defect of being slowly attackable. The waste, however, that it suffers in itself from this cause, is of small moment compared with certain secondary results, which terminate in the consumption of the acid and the zinc, and the destruction of the functions of the apparatus. Gold or platinum are free from these defects, but are too costly. Silver is to a great extent free from them, and has been much and successfully used, especially when platinised, that is, having its surface covered with finely-divided powder of platinum. The accumulated carbon from gas-retorts, cut into plates, and similarly treated, forms, with amalgamated zinc, one of the cheapest and most effective combinations. See Galvanism of Plates.

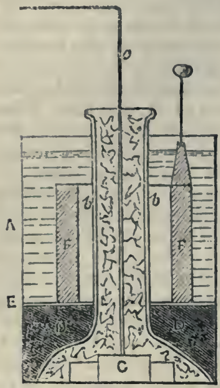
After the discovery of the electrical pile by Volta, and after Nicholson and Carlisle had shown that water could be decomposed by the electric current produced by the chemical action in the battery, Herr S. T. Sömmering communicated a system of telegraphing, in 1808, to the Academy of Sciences at Munich. A series of twenty-four wires were arranged to correspond with the letters of the alphabet, and ten to correspond with numerals. One end of each wire being furnished with a gold point was brought into a tube of water. When contact was made by the other end of one of the wires with the pile or battery, a bubble of gas appears in the water of one of the glass tubes. Thus, by a little careful arrangement, it was possible to convey intelligence from one point to another by the decomposing power of the galvanic battery.

A single pair of plates, no matter what their character, is unable to produce a force that can overcome the resistance of a wire of any length, and produce an available result at a distant station; and hence a series of pairs of plates are employed in the telegraphic arrrangements. E (*fig.* 804) represents a common mode of arranging a series of pairs of plates. It consists of a wooden trough made water-tight, and divided into water-tight cells. The metals are connected in pairs by copper bands; each pair is placed astride over a partition, and all the zincs face one way. When the plates (copper and zinc) are placed in, and the cells are filled up with pure white sand, and the acid water poured in, we have the very portable battery that was originally used by Mr. Cooke, and is still much employed. When batteries of a higher class are employed, the cells are distinct pots or jars; and great precautions are taken to prevent any conducting communication existing between the neighbouring cells, save by means of the copper band. In the trough form there is a leakage and loss of force from cell to cell. The c, or copper, is the positive end of such a series, and the z, or zinc, the negative; and both are in a condition to discharge, either each to the other, by means of a wire led from one to the other, or each to the earth, one by a wire leading to the earth at the place where the battery stands, and the other by a long wire (say a telegraph wire), leading to the earth at a distant place. The resistance to be overcome is, in the former case, less; and the current of force in circulation is proportionately greater.

It is not practical or expedient in a work of this character to enter into any detailed description of all the varieties of galvanic battery which have been employed. A few only can be named. For use with the needle telegraph the *sand battery* is very commonly employed. This consists simply of amalgamated zinc and copper plates, the spaces between them being filled with sand moistened with dilute sulphuric acid. These batteries are usually arranged in boxes of one dozen elements; they remain tolerably constant for some weeks without attention and are readily recharged.

The Marié-Davy battery is much used in France. A zinc plate is immersed in pure water—in practice the zinc cylinders are packed in wet sponge—and carbon plates in porous cylinders are immersed in a paste of proto-sulphate of mercury and water. This battery requires very little attention, and it is said to retain its original force for six months.

803



Meidinger produced a modification of Daniell's battery, which was charged with a solution of Epsom salts and sulphate of copper. This has, however, given way to the battery of Siemens and Halske, in which the peculiarity is the use of paper-pulp, in addition to the porous earthenware diaphragm, to prevent the mixing of the fluids too readily. Into a glass jar A A, *fig.* 803 is placed a cross-shaped plate of copper C, united to a copper-wire *c*, which rises above the jar. Over this is placed a porous earthenware cylinder *b b*, widened out at the bottom into a bell shape. Between this porous bell and the glass jar, paper-pulp D, saturated with a quarter of its weight of sulphuric acid, which converts it into a gelatinous mass, and then worked up with four times its weight of water is pressed so as to form a compact mass; this about half fills the jar, and upon it is placed an annular disc of brown paper or of cotton cloth E E. The zinc cylinder F F, cast with a neck which rises above the fluid, rests upon this disc, reaching to within an inch of the top of the jar. Crystals of sulphate of copper are dropped into the porous cylinder, and then both compartments are filled to the same height with water, which may be fresh or acidulated. This battery only requires to be supplied with sulphate of copper from time to time, and water added to supply the waste by evaporation. It has been found that at the end of six months the electro-motive force was ninety per cent. of what it was originally.

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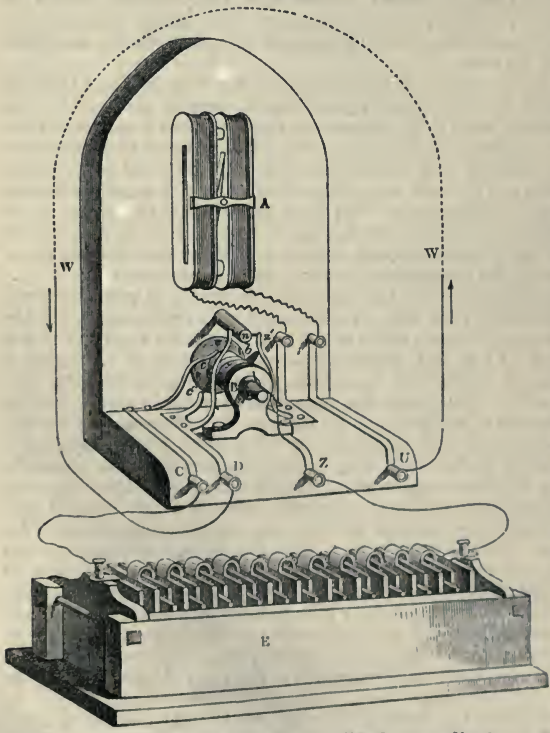

Under whatever circumstances a wire takes part in promoting the discharge of a voltaic apparatus, the whole of the said wire is in a condition to indicate the presence of the force that is pervading it; and as the force may be presented to the wire in either of two directions, that is to say, the copper or the zinc, namely, the positive or the negative end of the battery, may be presented to the given end of the telegraph wire, the relative condition of the wire will be modified accordingly. Not only can the direction of this current-force be inverted at pleasure, but it can be maintained for any length of time, great or small, and in either direction. This is accomplished by various mechanical arrangements, which are the keys, commutators, or handles of the various telegraph instruments, and are often the only parts presenting any complexity about them. In *fig.* 804, the source of electricity, E, we have already described; the test-instrument for the abnormal state of the wire, that is to say, the telegraph proper, is the part A. The complex part, consisting of springs, cylinders, and studs, shown below A, is nothing more than the necessary mechanical arrangement for directing at pleasure the current from the battery E, in either direction through the wire, and through the part A. By following the letters in the order here given, the course of the current may be traced from its leaving, say the positive or copper end of the battery, till its return to the zinc or negative end; C *c′* D W W U A Z′ *b* B Z. If a companion instrument were in any part of the circuit of the wire W W, it would correspond in its signals with the home instrument, *fig.* 804.

In 1820 Oersted of Copenhagen made the capital discovery that a magnetic needle suspended in the neighbourhood of a wire, through which a current of electricity was passing, was deflected from its position of rest, the angle of deflection varying with the amount of electricity passing along the wire. Ampère found the law by which this influence was governed, numerous investigators continued the inquiry with more or less success, and eventually Michael Faraday, by a series of the most perfect inductive experiments which adorn the annals of British science, made the two discoveries of Volta-electric induction and of magneto-electricity. These completed the series which were necessary for the full development of electro-telegraphy, and it only remains for us now to deal with the practical application of those great laws to which we have alluded.

One of the properties possessed by a wire, during the discharge of a voltaic battery is to deflect a magnetised needle. If the needle and the wire are parallel in the normal state of the wire, the needle is deflected this way or that, when the wire is in the abnormal state; and if the needle is very delicate, and a large enough amount of electricity is circulating through the wire, the needle will reach the maximum deflection of 90°. This is an extreme case, and cannot be approached in practice. Indeed, the deflection of any ordinary needle, under the action of an ordinary telegraph wire, would not be appreciable. But, as *every* foot of the wire has the *same* amount of reaction, we have merely so to arrange things that many feet shall be made to react upon the needle at the same time, and thus the effect is multiplied in proportion to the length of wire so concentrated. This is managed by covering a considerable quantity of fine wire with silk or cotton, and winding it on a frame A (*fig.* 804), suspending the needle within the frame. Such an instrument is called, from its properties, a *multiplier*. It is seen at a glance that the wire of the multiplier is an *addition* over and above the length of the actual telegraph wire required for reaching the distant station, and thus it practically increases the distance to be traversed. The multipliers commonly used add a resistance equal to six or seven miles of telegraph wire.

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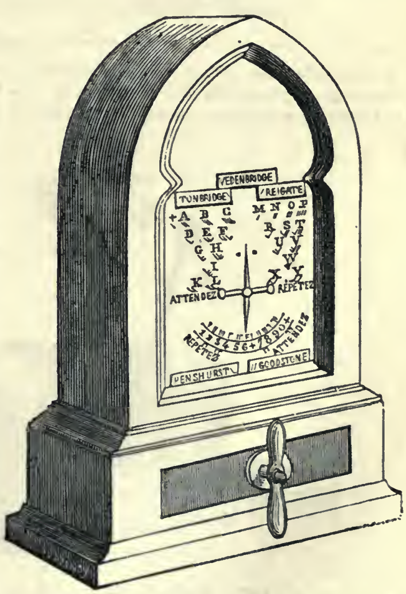

Let us now turn to the face of the instrument. Here we have a dial and an index, which is on the same axis as the magnetised needle above described, capable of being deflected to the right or left, and limited in its motion by ivory pins. We have a handle for working the mechanical part so connected that, as it moves to the right, it directs a current into the wire such that the needle moves to the right, and *vice versâ*. An alphabet is constructed from the combination of these two elementary motions, one or more of either or both kinds of deflection being used for the various letters, as shown on the engraved dial. This is Cooke and Wheatstone's single-needle instrument, *fig.* 805.

The form and character of their double-needle instrument is shown in *fig.* 806. It is precisely a duplicate of the former: two handles, and their respective springs, studs, and cylinders, two multipliers, and two magnetised needles, with their external indexes, and two telegraph wires. One battery, however, is sufficient. One

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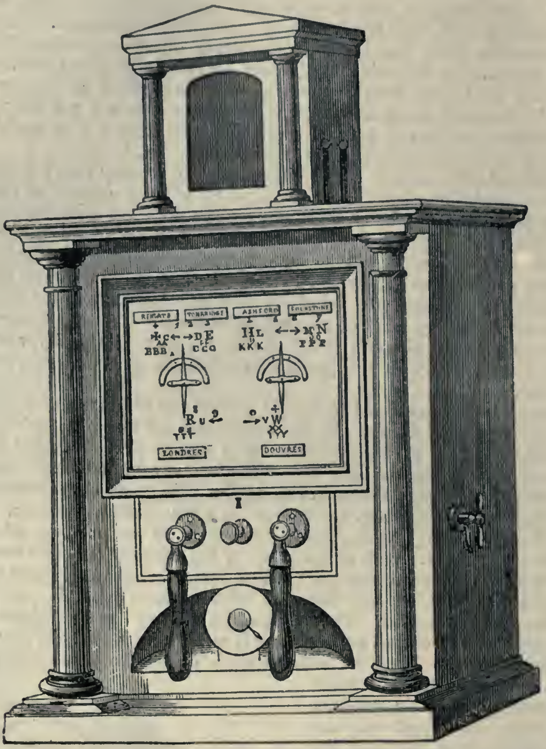

or more of either or both kinds of deflection of either or both needles, according to the code engraved on the dial, constitutes the alphabet. This instrument is very extensively employed; messages are sent by it with extreme rapidity.

807

Another property possessed by a wire conveying a current is that of converting soft iron, for the time, into a magnet. The attractive power, which can thus be given to, and withdrawn from, the soft iron at pleasure, is turned to useful account, either in producing direct mechanical action, or in liberating the detents of a clock movement. Here also the effect of the solitary wire is inappreciable, and many convolutions around the iron are necessary in order to obtain a useful result.

The simplest application of this principle is shown in *fig.* 807. Here are two brass reels, filled with cotton-covered copper-wire in one length. They are hollow, and a U-shaped bar of iron passes through them, presenting its ends at the face turned toward us in the drawing. This bar becomes magnetic,—forms what is called an *electro-magnet* every time and as long as an electrical current circulates in the wire; and its ends become respectively north and south poles. A narrow plate of iron, an *armature*, as it is termed, is mounted on pivots in front of the ends or poles of the magnet; it carries a vertical stem upon which the hammer is fixed. Every time the iron bar is magnetic the armature is attracted, and the hammer strikes the bell. The spring or contact-maker for introducing the current of electricity into the circuit, is shown in front on the right-hand side. This is Mr. Walker's bell for signalling railway trains from station to station. The language consists of one or more blows. One, two, and three blows are the signals for common purposes, half a dozen blows is the limit. The acknowledgment of a signal is its repetition. By a simple arrangement of an index, that moves in fellowship with the hammer, the eye, as well as the ear, may read the bell signals.

Fig. 808 shows another application of the direct action of an electro-magnet in producing telegraph signals. It is Morse's printing telegraph, very generally used in America, and to no small extent in Europe. The coils of wire are shown at M, the armature at H, fixed at one end of the lever *p*, which is itself carried on centres at *c*. The range of motion here is small in order to produce rapid utterance; it is regulated by the screws *d* and *i*. The reaction of the spiral spring *f* restores the lever to its normal position each time the magnetism ceases. The signals consist of dots or dashes, variously combined, made by the pointed screw *t* upon the slip of paper P, running from the drum at the right in the direction of the arrows; a few such signals are shown upon the end of the paper slip. We have described the telegraph proper, which is seen to be extremely simple. The only parts at all complex are, as with the needle instruments already described, the mechanical parts, namely, the train of wheels for carrying on the paper band, and the key or contact-maker, not shown in the figure. The amount of pressure required from the point *t* in order to produce a mark, is such that it cannot conveniently be produced by the magnetic attraction, derived from a current of electricity that has come from a far distant station in order to circulate in the coils of wire M. This difficulty does not prevail in the signal-bells, *fig.* 807, which are, at most, not required to be more than eight or ten miles apart, and in which also momentum can be and is accumulated so as to conspire in producing the final result. Morse has, therefore, had recourse to a *relay*, as he calls it. This, in principle, is pretty much the same thing as the instrument itself; but it has no heavy work to do, no marks to make; it has merely to act the part of a contact-maker or key; it can hence be made very delicate, so as to act well by such currents as would not produce any motion in the instrument itself. The batteries which furnish the electricity for doing the actual printing work in Morse's telegraph are in the same station with the instrument itself. The office of the relay is to receive the signals from afar, and to make the necessary connections with the local battery and instrument so as to print off the signals on the paper in the usual way. It is obvious that the motions of the instrument and the relay are sympathetic, and that what a trained eye can read off from the one a trained ear can read off from the other. The relays are constructed with much finer wire than is required for the instrument itself, so that the current circulating in them, although very low in force, is multiplied by a very high number, and becomes equal to the delicate duty required of it.

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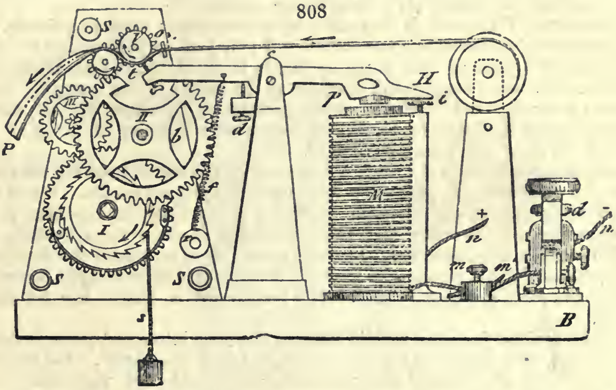

It is, we hope, now understood, that, whatever form the needle telegraph may take it consists essentially of a magnetic needle, which is deflected by an electric current passing through considerable lengths of wire carefully coiled around it. Several attempts have been made to render these instruments in the highest degree sensitive to electrical influences. Professor Weber employed a galvanometer the magnetic needle of which is a circular steel mirror reflecting the divisions of an illuminated scale placed at some distance from it, into a telescope through which the observer reads off the deflections of the mirror. Sir William Thomson has greatly improved upon Weber's instrument. He employs a mirror whose weight does not exceed a few grains, and he dispenses with the telescope by throwing a spot of light directly upon the scale and lessening its distance. For all measurements in which the instrument serves as a galvanoscope, and when the readings are not very different in value, Sir W. Thomson's instrument is superior to Weber's.

Mr. Sabine, in his work on the Electric Telegraph, remarks: 'Mr. Becker has given it a very convenient form, by fixing the coil in the back of a brass barrel or cylinder, in the front of which a glass plate enables the interior to be seen from before, and prevents dust and currents of air getting to the needle.

'In the centre of the coil is suspended by a fine cocoon fibre, in a frame, a small silvered mirror[1] of microscope glass, between $\frac{1}{2}$ and $\frac{1}{4}$ of an inch diameter. A little magnet, made of a piece of thin watch-spring, is fastened to the back or silvered side of the glass, and, being magnetised, operates as the needle of the system. Above the brass barrel a vertical rod carries a curved permanent adjusting magnet, and a rack and pinion enables the latter to be turned horizontally to bring the point of light to any part of the scale which may be desired.

'The adjusting magnet is elevated or depressed on the vertical rod for the purpose of increasing or decreasing the directing force upon the magnet needle. When the ends of the adjusting magnet coincide with the poles of the earth's magnetism, it adds to the directive force of the latter, and the instrument becomes proportionally unsensitive. The magnet may, however, be turned round, so as to oppose the directive force of the earth, and in this position be lowered towards the mirror, until it very nearly neutralises the earth's directive force. The instrument so placed has its maximum sensibility.

'The scale, divided from the middle towards the ends into equal parts, is fixed upon a wooden stand, at a distance of two or three feet from the mirror. Behind the scale is a paraffin lamp, whose light falls through an adjustable slit underneath on to the mirror, which reflects it back upon the scale; and, in order that the point of light shall be as well defined as possible, a small plano-convex lens is placed before the mirror, through which the rays converge into a focus, throwing a sharp image of the slit upon the scale.

'Mr. Darley has made some of these instruments for the measurements of the Atlantic cable, and has substituted a plano-convex lens silvered on the curved side, for the mirror in Professor Thomson's instrument dispensing of course with the lens in front.'

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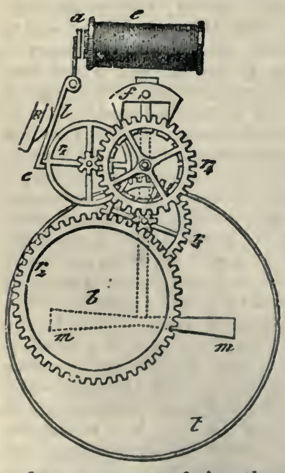

We may here refer to the case of another bell or alarum, in which the magnetic attraction derived from the current that arrives, is not equal to the mechanical work of striking a blow and sounding a bell; but which is able to raise a detent, that had restrained a train of wheels; and so allow the mechanism of the latter to do the work required. This arrangement is shown in Cooke and Wheatstone's alarum, *fig.* 809; *t* is the bell; *m m*, is the double-headed hammer, which is in fact the pendulum, attached to the pallets *f*, which work in a scape-wheel hidden in the figure, and in gear in the usual way with a coiled spring in the box *b*, by the train r_4, r_1, r_3, r_2. The electro-magnetic part here, as in other instruments, is simple enough; *a c* is a lever moving on a centre above *l*, having at one end an armature *a*, facing the poles of the electro-magnet *e*; and at the other end *c*,

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[1] The process of depositing metallic silver upon glass is as follows:—(A) Dissolve 10 parts of nitrate of silver in 50 parts of water, and neutralise with (about) 6 parts of liquor ammonia; add to this a solution (B) of 1 part of tartaric acid in $4\frac{1}{2}$ parts of water, and dilute the whole (A + B) with 500 parts of water. The things to be silvered should be placed conveniently in a vessel, the solution poured in, and then put away in a quiet place for a few hours, at a temperature of from 40° to 50° C. When silvered they may be washed by a gentle stream of water, dried, and varnished with a solution of amber in chloroform.

a hook which faces the wheel r_1, and by catching in a notch on its circumference, keeps the train at rest. But when a current circulates through the coils *e*, the armature is attracted, the hook is raised, the train is liberated, and the pendulum-hammer vibrates and strikes a succession of blows. R is a support carrying a small spring, which reacts on the lever, and restores it to its normal position when the magnetism ceases. This alarum is used for calling the attention of telegraph clerks. It requires a little attention to keep up the proper adjustment between the spring on the one hand, and the magnetic attraction on the other.

The telegraph originally adopted and still largely used by the French Administration, is somewhat akin to the alarum just described. It has a train of wheels, a scape-wheel with four teeth, and a pair of pallets. There is, however, no pendulum; but the pallets are connected with the armature of an electro-magnet, in such a manner that, for each attraction or repulsion of the armature, the scape-wheel is liberated half a tooth; for an attraction and a repulsion a whole tooth; so that four successive currents, producing of course four consecutive attractions and repulsions, produce a whole revolution of the scape-wheel. The axis of the latter projects through the dial of the instrument (*fig.* 810), and carries an arm *a* or *b* (*fig.* 811), which, following the motion of the wheel, is able to assume eight distinct positions. The apparatus is generally double, as shown in the figure; and the signals are made up of the various combinations of the eight positions of each of the two arms. The arm is half black, the other half white. The position of the black portion is read off; the white portion is merely a counterpoise. When only one half of the dial, or one index is in use, the combinations are shown by producing with the one index successively the positions of the two, whose combination makes the signal, always giving first the position of the left-hand index, then that of the right. The handles shown in front are the contact-makers; and are so constructed that the position of the arm on the dial coincides with the position given to the handle. *Fig.* 811 is a front view of the two arms; part of the dial is supposed to be removed, so as to expose the four-toothed-wheel already mentioned, and the pallets *x* and *y*; which, in their movement to and fro, allow of the semi-tooth advances of the wheel.

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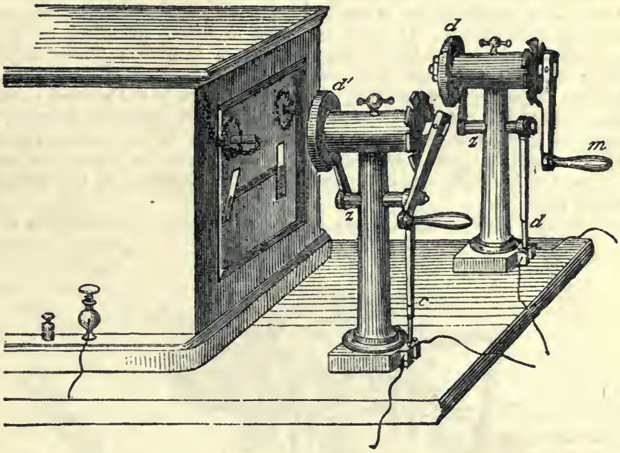
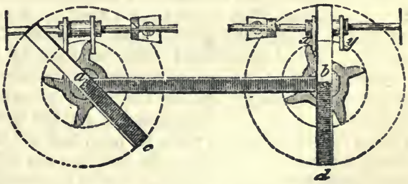


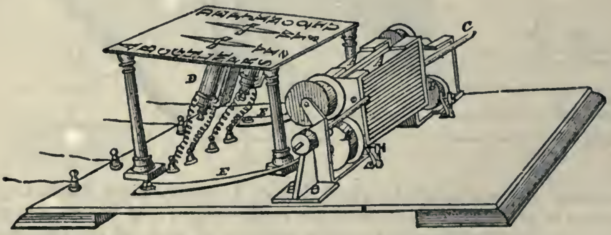
811



In these various applications of the electro-magnet, the armature has been of soft iron, and the only action of the electric-magnet has been to attract it. It has been withdrawn from the magnet after the electricity has ceased to circulate, either by its own gravity, by a counterpoise, or by a reacting spring. We now come to a telegraph that is well known and much used, Henley's magneto-electric telegraph, in which there is no reacting spring; and in which the movement or signal is produced by the joint action of attraction and repulsion; and the return to its normal state by the same joint action. Each pole of Henley's electro-magnet has a double instead of the single termination that we have been considering in all preceding cases. A piece of soft iron, like a crescent, is screwed upon each of the poles; the horns or cusps of the respective crescents are facing and near to each other; and a magnetised steel needle is balanced between them. This arrangement is somewhat like the following (|). So long as no current is circulating in the coils of the electro-magnet, the crescents are impassive soft iron, and no one point of either of them has more tendency than any other point to attract either end of the magnetised needle that is between them. But while a current is circulating, one of the crescents is endowed with north magnetic polarity, which is especially developed at its horns, and the other with south polarity. Suppose the horns of the right-hand crescent are north poles, those of the left south poles, and the top end of the needle is north. Four forces will conspire to move the needle to the left. Its top will be attracted by the left-hand crescent and repelled by the right; its bottom will be repelled by the left, and attracted by the right. When this current ceases to circulate, the simple attraction between the magnetised needle and the soft iron of the crescent tends to retain it in a deflected position. This tendency is increased by a little residual magnetism, that is apt to remain in the best iron, notwithstanding every care in its preparation. In order, therefore, to restore the needle to its normal position, a short quick current in the reverse direction is given. These instruments are single or double. Only one kind of deflection of the needle is available for actual signals; the other motion being merely the return to the normal state. The single-needle alphabet is composed of deflections of a short or a long duration; these are produced by holding on the current for an instant or for more than an instant; and the various combinations of short and long correspond to Morse's dot-and-dash system. The double-needle alphabet consists of combinations of the deflection of either or both needles.

Fig. 812 shows Henley's instrument; and, in completing the description of it, we have to describe another source of electric current to which no allusion has been hitherto made. The electricity here employed is obtained neither by friction nor by chemical action, but by means of magnetism *and* motion. If a piece of metal is moved in the presence of a magnet, or a magnet is moved in presence of a piece of metal, a current of electricity is generated in the metal. The results are multiplied when the metal is a coil of covered wire; so that we have here the converse of the electro-magnet; in the one case electricity had produced magnetism, in the other magnetism produces electricity; hence the name *magneto-electric* telegraph. We have here a powerful set of steel magnets A A, all the north ends pointing in one direction, and bound together with a plate of iron, and all the south ends similarly arranged in the other direction. Facing each end, but not quite in front when at rest, is an electro-magnet proper, B B, consisting of the U-shaped iron rod and the coil of covered wire, as described in *fig.* 807. Each electro-magnet is mounted upon an axis. C is a short lever or key; on depressing this the electro-magnet moves from its normal position in a region of lesser magnetic force, into a new position in the region of greatest magnetic force, and thus is the double condition, enunciated above, complied with; the copper-wire is moved in the presence of a magnet, and this under the most favourable conditions; and the U-iron, rising from a feeble to a strong magnet, its lines of magnetic force move in presence of the copper wire. Just as a current, *coming* from a long distance, had to be received in Morse's arrangement (*fig.* 808) in an electro-magnet of a long coil of fine wire, so as to be much multiplied in order to do its work, so here a magneto-electric current, that has to be *sent* to a long distance, must be

812

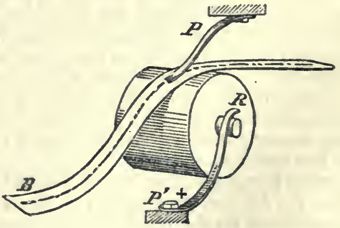


generated in a long coil of very fine wire in order to have electro-motive force sufficient to overcome the resistance opposed to it. In like manner the electro-magnets of the instrument D, in which it is received at the far-off station, have the same multiplying characteristics. The magneto-electric current exists only during the motion of the electro-magnet in front of the steel magnets, and this motion must be rather brisk, or the change of place is slow and the current feeble; but the current ceases with the motion. The needle, however, remains deflected from causes to which we have already referred, and if the hand is raised gently, so that the coils return slowly to their normal position, the needle will remain deflected; but, if the hand is so removed that the coils return quickly from the region of greatest to one of lesser magnetic force, a reverse current of lesser force than the original is generated, which releases the needle from its deflected position and restores it to its normal place, ready for making the next signal. In a recent form of this instrument Mr. Henley has obviated the necessity of moving the electro-magnets, still retaining the same fundamental principles. He uses a set of large U-shaped permanent magnets, and places the electro-magnet in the space between the branches of the permanent magnet, and so that the four poles of the two magnets, the permanent and the electro, shall be flush with each other or in the same plane. A couple of iron armatures are mounted on a disc in front of the magnets. The disc has a motion on a centre; the armatures are curved or crescent-shaped. Their form is so adjusted to the relative positions of the poles of the respective magnets that, in their normal or ordinary position, one crescent connects the N. pole of the magnet with one, say the *upper* pole of the electro-magnet, and the other crescent connects the S. pole of the permanent magnet with the *lower* pole of the electro-magnet. On pressing a key the disc moves, and the armatures so change in position that the N. pole of the magnet is connected with the *lower*, and the S. pole with the *upper* poles of the electro-magnet. By this arrangement the polarity of the electro-magnet is reversed at pleasure; and in its transition from being a magnet with poles in one direction, to becoming a magnet with poles in the reverse direction, an electric current is generated in the wire with which it is wound, and the direction of the current is this way or that according as the transition is from this direction of polarity to that. This form of magneto-electric machine allows of larger electro-magnetic coils being used, and gives the manipulator comparatively very little weight to move in signalling.

We have shown how an electric current generates magnetism, and how magnetism generates another electric current; it would follow logically that one electric current should therefore generate another electric current; for the magnetism produced by a current circulating in one wire, must have *all* the properties of magnetism, and among them, that of producing another current in another wire; and so it is. A few convolutions of a large-sized wire are coiled round an iron rod; and outside the larger wire is a very great length of finer wire. The current from the battery is called the *primary* current in this arrangement; and the moment it begins to circulate in the large wire, it magnetises the iron and generates a current, called *secondary*, in the fine wire, which is able to penetrate to a very great distance. When the primary current ceases, magnetisation ceases, the lines of magnetic force disappear, and a reverse secondary current is produced. This was the method proposed for obtaining the secondary current for traversing the Atlantic Ocean from Ireland to Newfoundland. The large wire is not necessarily first coiled on; in the coils for the Transatlantic telegraph it was coiled outside. Nor is the presence of iron essential to obtaining secondary currents.

It will have been noticed in all the arrangements which have hitherto been described, that the signals are produced by motions—that the electric current on reaching the far station is multiplied by being directed through many convolutions of wire, and is made to act upon either a piece of soft iron or a piece of magnetised steel, and to move them, the motion being turned to account directly, or by the intervention of mechanism. We have yet another property of electricity, that has been very successfully applied to the production of telegraphic signals by Mr. Bain, in his *electro-chemical* telegraph. If a current of electricity is led into a compound fluid body, say into water, by one wire and out of it by another wire, the body is decomposed into its constituent elements, one of which, the oxygen in the case in question, makes its appearance at one wire, and the other, the hydrogen, makes its appearance at the other wire. The same holds good with bodies of a more complex

813



character in solution in water. The compound selected by Mr. Bain is ferrocyanide of potassium. With a solution of this, he saturates a long ribbon of paper, similar to that employed in Morse's telegraph. He causes the paper B (*fig.* 813) to pass over a drum of brass R, between the metal of R and an iron point or stylus P. The electric current enters the apparatus by the point P, passes through the solution of ferrocyanide of potassium, with which the paper B is saturated, and out by the spring P′, which is in metallic contact with the drum R. Decomposition takes place, and the well-known ferrocyanide of iron (Prussian blue) is formed at the point of contact of the iron stylus P with the paper, the iron of the compound being supplied by the stylus itself. The paper is carried on by ordinary mechanism; and a dot-and-dash alphabet is formed, according to the duration of contacts at the sending station. There is a single-wire and a double-wire code; and the signals appear as deep blue marks upon the paper. Supplies of paper saturated with the solution are kept in reserve. This is unquestionably a telegraph of extreme simplicity. It has been employed with much success.

Mr. Whitehouse prepared for the Atlantic Telegraph a system in which motion and chemical action each play their part. The secondary currents that he employed were not able to produce the chemical decomposition that he requires for his signals. He therefore received them in a very sensitive relay, either an electro-magnet or a multiplier. The relay was a contact-maker, and connected the necessary number of local batteries with the printing apparatus, which consists of a ribbon of paper, saturated with a chemical solution and passing between a drum and a steel point.

We should exceed our limits were we to attempt the description of some of the many other forms that have been proposed. The above are good illustrations of the leading principles, and are all in successful use. Some telegraphs will print in ordinary characters; this result is only attained by much complexity, and its value is more than questionable, it being as easy to learn a new code as a new alphabet; telegraph clerks read their signals as readily as they read ordinary writing or printing, and they acquire their knowledge in a very short time. Hence probably it is that telegraphs to print in ordinary characters are but little known in real practice; nevertheless, some very promising instruments of the class have been produced by House, and especially one more recently by Hughes, both of the United States.

The following remarks on printing telegraphs have been handed to us, and we give them insertion as they appear to point to an improved system:—

'The needle and bell instruments, however, have hitherto transmitted messages with far greater rapidity than has been possible by the ink writer; but the advantage of a system which is self-recording recommends itself to all, inasmuch as, without some record, it is impossible to trace an error to its source, either at the sending or receiving station.

'The ink-writer now in use by the Telegraph Department of the Post Office, can only record the telegraphic signals by breaking a line formed longitudinally, on a band of paper, the operator, whether skilful or unskilful, breaking that line where he pleases into the requisite "dots" and "dashes." Thus, apart from the time occupied in writing or drawing the "dashes"—which, being formed of strokes three times the length of the strokes forming the "dots," require three times longer to draw them than the "dots"—a certain amount of skill is needed to work the instrument, and, of course, accuracy is not insured. Indeed, a short "dash" followed by a long "dot" may be read either as two dashes or two dots.

'Attempts to remedy this confusion have been made by Mr. Herring, who has endeavoured to unite the chief advantages of the Morse ink-writer, which was the favourite instrument of the Electric Company, with the speed of the bell-instrument, which was an equal favourite with the Magnetic Company; and, without necessitating any new method of sending or receiving messages, but simply by substituting for the double bell a printing instrument, he appears to have perfectly succeeded. Instead of wasting the currents upon merely fleeting appeals to the eye by needle, or to the ear by bell, or adopting an uncertain and tedious method of writing the signs in ink, he has contrived a telegraph printing instrument, whereby the signs may be instantaneously stamped in printing ink, on the paper, with their actual types, thus insuring positive correctness. This instrument which costs very little more than that now used by the Telegraph Office, has been described by Mr. Scudamore as 'much superior to the numerous methods which have been brought forward from time to time during the last twenty years,' and he adds, that it 'admits of the signs being produced faster and in less compass.

'The telegraphic instrument invented by Mr. Herring was so constructed as to produce the dot and the dash of the Morse code in such a manner that one could never be mistaken for the other. This was effected by the use of two distinct levers: an arrangement which also permitted the dash to be made vertical, instead of horizontal, and to be produced instantaneously, instead of by continued pressure, thus saving the time of the operator, and diminishing the length of the message slip.

'In this instrument the slip of paper, on which the message is received, is made to travel by clockwork in the ordinary way. It passes directly over a metallic disc, placed transversely to the course of the slip, revolving on an axis, and dipping into an ink well; over the paper is a lever, terminating in a broad style, placed vertically above the disc, so that the descent of the lever compresses the slip of paper between the disc and the style. This lever is double, in the sense that its central portion, carrying the central portion of the style, can be acted upon either independently of the lateral portions, or together with them. In the former case, only the narrow central portion of the style descends, and the slip of paper is pressed upon the inking disc at only a single point of contact, which produces a dot. In the latter case, the style descends as a whole, and, having a concave edge, it presses the paper into contact with the disc, by more or less of this edge, thus producing a vertical dash. There is an adjusting screw, by which the paper may be raised or lowered at pleasure, and by which means the contact-surface, and hence the boldness of the mark, may be increased or lessened at the pleasure of the operator. The pressure of the style stops for the moment the revolution of the inking disc, upon the immediate recommencement of which the ink supply depends. The inventor has, therefore, placed upon the axle of the disc a box containing a spiral spring, so arranged that, when the disc itself is checked, the power of the clockwork coils the spring. The moment the disc is released the coiled spring gives the necessary impulse to produce immediate revolution.

'The operator is furnished with two keys, one of which commands the central or dot portion of the lever, the other the lever as a whole. One, therefore produces the dot and the other the dash, and no mistake can occur between the two, except by the use of the wrong key. The printing is remarkably clear, distinct, and compact, and gives a legibility to the messages which no other modification of the Morse system has at present attained. The instrument is worked with a double current, like that used for the double bell, with the great advantage over the latter that the signals are printed and permanently recorded, instead of being fleeting impressions upon the ear of the recipient.'

The adoption of Mr. Herring's printing instrument would at once admit of the registration of telegrams, an advantage which is so much needed, but at present denied. By simply starting the instrument at the sending station, a perfect fac-simile might be retained of the message as recorded at the distant receiving station; and as the width of the telegraph paper slip is just half the diameter of the ordinary post-office letter-stamp, the two ends of the message slip laid side by side might be impressed with the town and date in the usual way, and thus the slip itself would become of legal importance. Not only would the address be registered, as in the case of a letter, but also the actual communication itself. A solicitor or a broker, sending a registered telegram, would virtually receive from the Department a certified copy of his letter; and this being handed to him in an envelope on which the key to the code was printed, which is extremely simple, he would at once be enabled to satisfy himself of its correctness, and to put it away as usual with his letters.

Another, and a very great advantage would be gained in adopting a similar course in case of pressure at any terminal station. The Telegraph Department only undertakes to transmit messages upon the understanding that it 'is not liable for losses incurred through the incorrect transmission, delay, or non-delivery of telegrams.' It is nevertheless urged by postal facilities to avoid delay in delivery, and, probably, nothing tends more to delay than doubts and errors in transmission, which, at, present necessitate repeating the message back again, thus consuming the time twice over, not only of the wire, but of the clerks at both stations; and delay once arising, especially if aggravated by a little extra business, causes hurry, confusion, and liability to an increase of error. At such a time, relief might be instantly afforded by delivering a few of the message slips with the printed key, and the business of the office would then proceed in the usual way, and with accustomed quietness, without any excuse for either error or delay.

In case of need, as, for instance, when required to telegraph in cipher for the Government, it would be possible, by Mr. Herring's invention, to make an addition to the ordinary signs 'dot and dash.' Two other signs, which might be sent by the same single wire, could be introduced by means of two extra levers and styles working over the same inking disc, and operated by a second battery, stronger than that used for the dot and dash. Thus, with four signs, any requisite number of combinations might be devised capable of insuring secrecy, certainty, and speed.

The following table has been drawn out as an illustration of the codes of some of the chief instruments that have been the subject of this article. It shows the number and nature of the signals (deflections, dots, dashes) for producing the name of the great discoverer of electro-magnetism, which is the foundation of electro-telegraphy.

The figures on the right show the number of marks or signs used in printing the same word in each kind of telegraph.

		O	E	R	S	T	E	D	7
1. Single	Cooke and Wheatstone.	///	\\/	\/	\//	\///	\\/	\/	20
2. Double		//	/	/ /	// //	/// ///	/	\/	18
3. Single	Henley	• • • •	•	— — –	— —	—	•	—• • •	16
4. Double		\///	//	\\ /	\\\ /	\ //	//	/	19
5. Morse	. .	– –	•	•—•	• • •	—	•	—• •	15
6. Single	Bain	• •	•	— — •	— • •	— • — —	•	• • —	17
7. Double		— –	—	 — —	— – —	— — — –	—	— – –	16

Herring's Telegraph Alphabet.

E	I	S	H	A	U	V	W	J	R	P	L	F
•	••	•••	••••	•│	••│	•••│	•││	•│││	•│•	•││•	•│••	••│•

T	M	O	C	N	D	B	G	Z	K	X	Y	Q
│	││	│││	│•│•	│•	│••	│•••	││•	││••	│•│	│••│	│•││	││•│

The *Rheo-electro-static* system of telegraphy was first described by M. Botto, in 1848. It is applicable to some, but not to all forms of telegraph. It has been applied on the South-Eastern Railway to the signal bells (*fig.* 814), for the purpose of reducing the amount of battery power required under other circumstances to be maintained. The wire, by which a pair of bells are connected, is in its normal state in permanent connection with the similar pole, say the positive, of batteries of equal power at the respective stations, so that two currents of equal power are opposed to and balanced against each other. Under these circumstances, the wire is in a null, or rheo-electrostatic state; neither current circulates. If the connection of one of the batteries is reversed, so that its negative pole is presented to the wire, then the currents of both batteries are in the same direction, and they circulate as one current, equal in value to the combined force of the two batteries. The application is obvious; that, whereas, under the ordinary system, a *whole* battery, of force sufficient to traverse the distance and do effective work, must be at each station, under this system only *half* such battery is necessary at each station for producing the same effective work. Also, if a little more battery power is placed at each station than is necessary for the actual work required, signals of higher power are obtained under common circumstances; and also the equilibrium of the two opposed currents may be disturbed at any place between the two stations, and signals may be made by merely making a connection between the line-wire and the earth; because the negative pole at each station is fitted up in permanent connection with the earth; and, as the positive poles are in like connection with the line-wire, each battery current is made to circulate through its own signal-bell every time the earth and line-wire are placed in connection. By this means the guard of a train can make signals of distress to the nearest station without the aid of portable apparatus. Considerable care is required to obtain good communication with the earth on the open railway for making distress signals, or otherwise the discharge is imperfect, and no signal is made. Fish-jointed rails are very valuable for this purpose; in their absence, especially at embankments, metal must be buried for the purpose at intervals in the moist earth, and a wire attached for use. Contact springs on the telegraph poles are proposed.

Telegraph wires are suspended to poles by insulators of earthenware, glass, or porcelain; the material and shape varying according to the experience of the engineer and the length of line to be insulated. In very short lengths, the battery power required for overcoming the resistance is not great; it will therefore not overcome the resistance of an insulator of moderate quality, and escape to the pole and thence to the earth; but the battery power required to overcome the resistance of very great lengths of wire is equally able to overcome the resistances presented by inferior insulators, and to escape in considerable quantities at every pole; so that the force which reaches the far station would not be equal to its work. It is for these long lines that the greatest ingenuity has been expended in constructing insulators. Fine porcelain is most in favour from its presenting a very smooth surface, and being less hygrometric than glass; and it is distorted into most mysterious-looking shapes in order to present as great a distance, and one as much sheltered as possible, between the part with which the line-wire is in contact, and the part that is in contact with the pole.

814

Telegraph signals pass with far less rapidity through buried and through submarine wires than along the ancient aërial wires. The slow travellings mentioned above were through wires of this kind. We must refer to treatises on Electricity for full details of the conditions presented by a telegraph cable. In practice it is found that on first sending a signal into a submerged wire, the electricity is delayed on its road, in order to produce a certain electrical condition upon the surface of the gutta-percha that is in immediate contact with the conducting wire. Nor is this all; before a second distinctive signal can be sent, it is necessary that the condition produced by the first signal shall be destroyed; and this is an operation requiring even more time than was consumed in the mere act of producing it. These two classes of retardation, especially the latter, were largely manifested in the Atlantic cable; and have called forth all the ingenuity of electricians in order to mitigate or to modify them.—C.V.W.

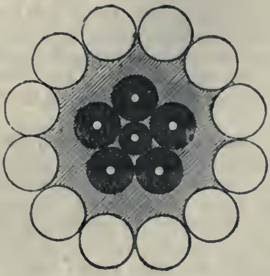
815

Fig. 814 represents the cable that has been lying in the British Channel between Dover and Calais, since September 1851. It contains four No. 16 copper-wires, each wire being doubly covered with gutta-percha. The four wires are then twisted into a rope; and the rope is thickly covered, first with hempen yarn, tarred, and finally with a jacket of ten No. 1 iron-wires. The cable is shown in perspective and in section. *Fig.* 815 shows the perspective and section of the Irish, a single-wire cable. It consists of a single central conductor, of one No. 16 copper-wire, doubly covered with gutta-percha, then with hempen yarn as before; and finally with a protecting jacket of ten No. 8 iron-wires. The Calais cable weighs 7 tons per mile; the Irish 2 tons per mile.

The first practical experiment with deep-sea telegraphs appears to have been made by Mr. Brett in 1850. This was a gutta-percha covered copper-wire sunk between Dover and Calais, which failed on the first day. In 1851, a cable consisting of four covered copper-wires was sunk across the Channel, which is still working. In 1853, Messrs. Newall made a line seventy miles long between Dover and Ostend. In this cable the conducting wires were increased to six.

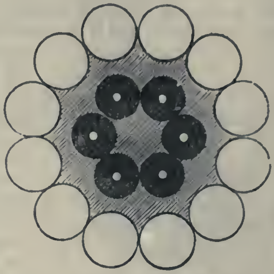
The Dover and Ostend cable was laid on May 6, 1853. This cable (*fig.* 816) is 70 miles long; it is composed of six copper-wires, insulated by a coating of gutta-percha, which are essentially the electrical cable, and these are secured by an armour of twelve iron-wires. The whole rope was capable of sustaining a strain of about 50 tons; it weighed 7 tons per mile, making a total weight of nearly 500 tons. It was made by Newall and Co., in 100 days, its cost being 33,000*l*. It required 70 hours to coil it into the ship, and it was submerged in the sea, from Dover to Ostend, in 18 hours. The arrangement of the inner wires did not prove entirely satisfactory.

816



Cable from Dover to Ostend
(1853. Length 70 miles),
and Zuyder Zee, 5 miles.

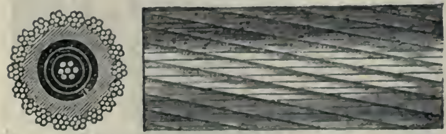
817



From Port Patrick to Donaghadee
(1853. Length 25 miles),
and Spezzia to Corsica, 110 miles.

After the success in sinking the Dover and Ostend cable, Messrs. Newall and Co. commenced laying a cable from Donaghadee, in Ireland, to Port Patrick, in Scotland, across the Irish Channel. This cable was of the same weight and size as *fig.* 816, but the conducting wires were differently arranged, as seen in *fig.* 817. The drawings given are of the natural size. This cable was made in twenty-four days, and at a cost of 13,000*l*. The Mediterranean cable is of the same construction as that across the Irish Channel, and was laid in 1854. This line runs from Spezzia to the Island of Corsica. Over this there is a land-line extending to the Straits of Bonifacio, where a short submarine line of 7 miles runs to the Island of Sardinia. Across this island there is a line 203 miles long, terminating at Cape Spartivento. The telegraphic communication between the Island of Sardinia and Africa seems to have been surrounded with great difficulties. Two attempts were unsuccessful; but the third proved, by its success, that perseverance accompanied by judgment usually attains the end desired. This cable, also made by Messrs. Newall, was composed of 4 sets of conducting wires, and these, in the deep-sea portion, were protected by 18 iron-wires, while the shore-end was surrounded by 12 much stouter wires. The shore-cable was 6 miles in length. The distance between Cape Spartivento in Sardinia, and Bona on the African coast, is 125 miles. Messrs. Newall and Co. also made the cable which unites Malta and Corfu with Sardinia. The electrical cord in this cable is composed of 7 small wires twisted together and insulated by a thick layer of gutta-percha. The deep-sea portion is protected by 18 small iron-wires; while the shore-end is covered by an armour of 10 stout iron-wires, and which is consequently much heavier than the deep-sea cable. The weight of the deep-sea section of this cable is 1,960 lbs. per mile, and its total cost was 125,000*l*. These may be regarded as typical examples of nearly all the submarine electrical cables which have been laid.

818



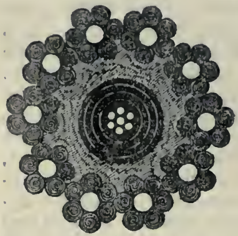
The Atlantic Cable, 1858. Length 1670 miles.

It becomes necessary to give a little more in detail the description of the Atlantic cable of 1858 (*fig.* 818). The electrical conductor was a copper strand, consisting of 7 wires—6 laid round 1, forming in fact, as far as electricity is concerned, only 1 wire. This weighed 107 lbs. per nautical mile of 2,028 yards. It was carefully insulated with gutta-percha, laid on in 3 coatings, and weighing 261 lbs. per nautical mile. Eighteen strands of charcoal iron-wire—each strand composed of 7 wires, 6 laid round 1—laid spirally round the core. This was, however, previously padded with a serving of hemp, saturated with a mixture of Stockholm tar. The weight of this cable in air was 20 cwts. per nautical mile, while in water it was only 13·4 cwts. This made it equal to 4·85 times its weight in water; or capable of bearing its own weight in a little less than 5 miles deep of that fluid. Its breaking strain was estimated to be 3 tons 5 cwts. This enterprise failed from causes which were foretold. Before the cable left this country it was imperfect; it had been carelessly kept, and greatly injured by the cutting-out of pieces while in Keyham yard, so that its power of carrying an electrical current was reduced to a minimum.

The unfortunate failure of this enterprise—in which both Europe and America were equally interested—led to considerable discussion, and to a careful examination of all the conditions which were supposed to influence such electric cords. All the laws regulating the flow of an electrical wave were re-examined by some of our best electricians, and many previous conclusions received some correction. It had been supposed that an insulated submarine wire conducts according to a different law from that of a suspended circuit. This difference was thought to depend upon a system of induced earth currents influencing the submerged wire, which would not influence a wire when suspended in the air. A simple example to render this clear to the non-scientific reader may be necessary. If a wire insulated by means of gutta-percha, or any other non-conducting substance, is connected, so as to complete the circuit, with the two ends of a voltaic battery, a current is said to flow through it. This means that an electrical wave of motion is propagated along it in a given direction. If another copper-wire is placed near it—though not in contact with either it or the battery—another current, or wave, is generated, that is, *induced*, in it. This induced current interferes, to a greater or less extent, with the primary current; and where great lengths of cable are concerned it becomes an element of serious consideration. If a coated wire is placed on the earth, and an electrical current is established in it, the earth acts the part of the second wire, and induction is developed on its surface. Mr. S. A. Varley has examined this problem with much care, and has arrived at the following conclusions. In a suspended wire the insulatory medium of the air takes the place of the gutta-percha of the submarine circuit. The earth, which is the nearest conductor, is a considerable distance off, and is only on one side of the wire; therefore, but little induction can take place between the wire and the earth. Nevertheless, induction to a certain extent does take place, and it can be detected with delicate apparatus in circuits of very moderate lengths. If the distance between the wire and the earth is decreased, induction will be developed more strongly, and the wire could be brought down step by step, until the condition of a submarine circuit would be approached, where the earth surrounds the wire on all sides, and is only separated from it by the thickness of one-eighth or three-sixteenths of an inch of gutta-percha, a substance possessing, moreover, specifically a much greater inductive capacity than air. It, therefore, appears that the conditions are precisely the same, only differing in degree. It is, nevertheless, evident from this, that a submarine wire is placed under circumstances of greater difficulty than those which surround an aërial wire. This difficulty increases with the length of the wire, retardation becoming more and more powerful as the distance through which the wave has to move is extended. A submarine cable may be regarded as a Leyden jar, and the telegraphic indications are analogous to the discharges of a coated glass. An impulse is given by making a connection with a voltaic battery at one end of a wire suspended in air—and it indicates telegraphically by producing magnetic disturbance at the other—and a succession of impulses will rapidly give a succession of indications. Now, in an insulated submarine wire this is not exactly what takes place. A distinction has to be drawn between the simple arrival of a current—which may be regarded as instantaneous—and the production of a telegraphic signal. After having charged the wires sufficiently to develope an appreciable current, owing to the wire taking some time to empty itself, if currents are sent in succession with any rapidity, they will blend into one another, and, instead of getting a series of distinct impulses at the further extremity, a continuous undulating wave will be obtained. This sluggishness has been obviated, to a great extent, in circuits of moderate length, by employing opposite currents of electricity in succession. The effect of this is to absorb the preceding wave, and to neutralise it much more quickly than would be the case if the wire were left to discharge itself in the usual way. In a suspended wire, as there is but little induction, there can be no accumulation of static charge worth noticing; whereas a submarine wire, unless attention be paid to this, becomes useless for telegraphy.

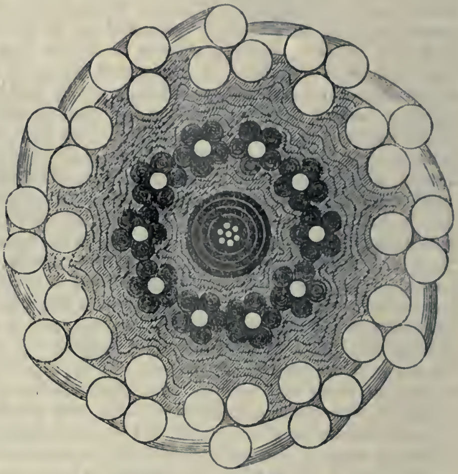
The electric conductor of the Atlantic cable is formed of 7 wires, 6 around 1 (*fig.* 819). Seven wires are used rather than 1 to give greater freedom to the electricity in passing by presenting a more extensive surface to it. There are mechanical reasons also why a band of wires is preferable to one wire. The most serious accident that can happen to a submerged wire is its severance. Copper-wire cannot always be depended upon to present the same amount of strength in every part. It frequently happens that an inch, or even a less portion of a wire, is crystalline, and therefore liable to break in being coiled. By using 7 sections instead of 1, the probability of a fatal breach of continuity is greatly reduced. It is scarcely to be expected that 7 weak places would occur at the same spot, and, if a single wire were broken, it would not interfere, to any sensible degree, with the passage of the current. In constructing the Atlantic cable, however, the utmost care prevailed in every department. Every portion of the copper-wire was submitted to exact examination, and no wire was used which possessed a lower conducting power than 85 per cent. of that of pure copper. The insulation of this conductor was thus effected. The centre wire of the copper strand was first covered with 'Chatterton's compound' (that is, gutta-percha rendered viscid with Stockholm tar). This first coating was so thick that, when the other six wires forming the strand were laid spirally around it, every interstice became filled and air excluded. The mechanical solidity of the core thus formed was very great, This cable is nearly 3 times as heavy as the old Atlantic conductor, its weight being 300 lbs. to the nautical mile against 107 lbs. The complete exclusion of air, which is a most important object, is believed to be effected by this arrangement. The conductors of some cables have suffered from their being to some extent loose with their insulating covering. The core being thus formed, next received another coating of Chatterton's compound, which quickly solidified, and thus thoroughly protected the whole. It was then surrounded with a coating of the purest gutta-percha, which was pressed round it in a plastic state, by means of a very accurate die, and sheathed the core in a continuous tube. Over this was again laid another coating of Chatterton's compound, for the purpose of effectually closing up any pores or flaws which may have escaped detection in the gutta-percha tube. To this covering succeeds a second tube of gutta-percha, then another coating of Chatterton's compound, and so on alternately until the wire was covered with 4 coatings of gutta-percha and 4 of the compound. This being completed, it weighs 400 lbs. to the nautical mile. It is well known that the insulating power of gutta-percha sensibly decreases by heat. The whole of the conductor was immersed in water of a temperature of 75° Fahr., in which it remained for 24 hours, and during that time it was constantly submitted to electrical tests. The core, after having been subjected to this and other tests to prove the perfect character of its insulation, was then submitted to the process of being protected by its iron-wire armour.

819



Section of the Atlantic Cable, 1865.

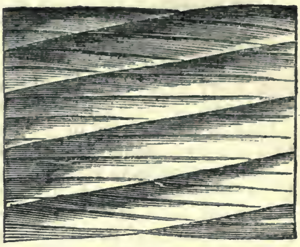
820



The Atlantic Cable—Shore-End, 1865.

Jute, which had been submitted to the action of catechu, in order to preserve it from decay, was very carefully wrapped round the core, and as fast as the wrapping proceeded, it was coiled in water. If the water at any time penetrated to the wire, it would at once conduct away the electric current to the earth, and the loss of insulation would be at once detected. This wrapping of jute is surrounded by 10 wires manufactured from homogeneous iron; each separate wire being itself, in the first instance, covered with tarred Manilla yarn, by which the iron was protected, and the specific gravity of the mass lessened. By a very ingenious arrangement, which our space will not allow us to describe, the 10 wires covered with the tarred Manilla hemp are spirally wound round the core, and the deep-sea cable is completed. The section and side-view of the electric cable will be fully understood by reference to *figs.* 819 and 821. As the-shore end of any cable is more exposed to the action of the waves than those parts are which remain in a state of rest at the bottom of the deep sea, it becomes necessary to give this portion a greatly-increased degree of protection. *Fig.* 820, which is of the exact size of the shore-end of the Atlantic cable, will fully illustrate the conditions of this portion. The core was formed by the main cable, which was wrapped with a serving of yarn to a size sufficient to receive round it 12 strands of iron wire, each strand being composed of 3 galvanised iron-wires, each of which being nearly a quarter of an inch in diameter; the weight of the completed shore-end was nearly 20 tons to the mile. Its diameter is 2½ inches, but at its junction with the main cable it is made to taper down to the size of the latter by a gradual diminution in diameter extending over 500 yards. This shore-end was laid out for about 28 miles from the coast of Valentia Island, when it reached water of the depth of 100 fathoms. From Hope's Content, Newfoundland, about 8 miles of shore-cable only would have been required.

821



Side view of the Atlantic Cable.

The weight of the deep-sea cable—according to the Company's statement—in air was 35 cwts. 3 qrs. per nautical mile of 2,028 yards. Its weight in water, 14 cwts. to each nautical mile, or equal to 11 times its weight in water per knot; that is to say, it will bear its own weight in 11 miles deep of water. Its breaking strain was 7 tons 15 cwts. The length of cable shipped was 2,300 nautical miles; the actual distance from the point of departure, Valentia, on the West of Ireland, to the point Heart's Content, in Trinity Bay, Newfoundland, on which it was to have been landed, being 1,670 nautical miles.

As every one knows, this great experiment failed, the cable breaking when the Great Eastern had reached the mid-Atlantic. Another experiment was made in 1866, and the result has proved in the highest degree satisfactory. Not only has the new cable been securely lowered to its ocean-bed in the depths of the Atlantic, but the old cable has been recovered and repaired, and we have now several electrical nerves uniting the new with the old continents. These electric cables have now been for some time in constant use, and their powers of transmitting electric currents appear to improve.

It is not necessary in this place to notice the various electrical cables which now girdle the earth. There are a few points, however, which are of sufficient interest to find a place in these volumes. The condition of the cable in the ship is one of these. For the following remarks we are indebted to Mr. Robert Sabine's excellent work on 'Electro-Telegraphy':—

'At present, all cables of any importance are sent to sea in water-tanks on board the transport ships. The tanks are circular, with as large a diameter and as high as the room of the ship will allow between the bottom of the tank and the deck; they are made of plates of iron, riveted together, caulked, and painted with red lead to prevent rusting. There are usually two such tanks, the forehold and afterhold, on board a cable ship. In the centre of each tank a hollow cone of iron is erected, and above this a series of rings of 2-inch round iron, which are lowered in the tank as the cable is paid out, are suspended for guiding the cable as it leaves the tanks, and preventing it flying out by centrifugal force, and going into kinks. On leaving the tanks, the cable passes through the rings in the circular space between them and the top of the cone, which it rubs against continually. The friction which the cable exerts against the sides and bottom of the trough assists the breaks in preventing its too rapid egress from the ship.

'No good electrical measurements are possible during the passage out on account of the motion of the ship, and the difficulty of keeping the apparatus dry; the measurements which are made are only of value qualitatively and approximately in the event of a fault occurring. The electrical conditions of the cable are, however, always kept under surveillance.

'Messrs. Siemens have constructed a galvanometer purposely for use on board ship. It consists of an astatic system of magnetic needles on a vertical bar, moving in stone pivots, and surmounted by an aluminium pointer. Each needle turns in the centre of an independent coil of wire. Above the glass cover of the dial-plate is a tall rod of brass carrying a horizontal adjusting magnet, which, in different positions and at different distances from the magnet system, increases or diminishes its directive force, and with this the sensibility of the instrument.

'Professor Thompson has succeeded in eliminating the directive force of the earth's magnetism entirely from his marine galvanometer by surrounding it with a heavy armour of soft iron, which gives it the advantage of retaining its constant of sensibility and zero point in whatever position the ship's head may be put; he also keeps his mirror magnet steady by suspending it to a tightly-drawn cocoon fibre.

'The measuring apparatus on board does not materially differ from that used on shore, only, where it is possible, it is made simpler. On the sea everything is damp, and with a dampness caused by the particles of salt water carried by the wind; these particles of water are conductors, and provide a short circuit for the current to earth from every corner of the apparatus. Therefore, the fewer the pieces used, the fewer the chances are that the "subtle fluid" departs from the way it should go.

'Before commencing to pay out a cable, and while the ship is quiet in harbour, careful measurements are made of its insulation, copper resistance, and temperature.

'In commencing to pay-out a cable, one end of the shore-cable is put upon the land and carried into the station. The ship pays this out to the end, when it is joined to the middle-cable, or to the deep-sea-cable if no middle-cable is employed. At this point, the officer of the ship takes the bearings carefully in his nautical way, and the telegraph engineer takes his bearings in a less scientific and much simpler way. These consist in rough sketches of marked points on the coast. The line which a church makes with a hill, or two hills together, or an inlet with a hill behind should be carefully noted. There are very few coasts which do not present such inequalities as to enable the engineer to find lines between distant objects. Of these lines two at least should be noted, if possible making an angle of 90° with each other; and the objects noticed on the land should be, one as near to the water and the other as far from it as the nature of the coast permits. In the long run, this method is the most valuable, and enables the engineer to return at any time to the exact locality of the point, in case he may want to pick it up.

'From this point begins the most difficult and risky part of submarine telegraphy. The manufacture requires a constant supervision and care; it has, however, the advantages of terra-firma, and any accident may be repaired, because the essential element —time, is to be had; but the laying demands untiring courage and caution, and that, because when once under way, there is no stopping without danger to the cable, notwithstanding the innumerable casualties which invariably attend a sea voyage.'

In his new book on telegraphy ('Traité sur le Télégraphie') M. du Moncet says that in order to lay a cable successfully the speed of the ship should be precisely that of the outlying cable. Unfortunately for the telegraph engineer, this physicist's ideas of the sea bottom do not correspond with the reality. Instead of being level like a street, it is found that as great irregularities occur in the earth under the water, as in the earth above it. The sea has its mountains, its valleys, its precipices, as well as the dry land, and over these mountains, and across these valleys, and up and down these precipices, the cable must be laid, and not hung from peak to peak like a tight rope. It must everywhere rest upon the bottom; if not, it must sooner or later break by its own weight between the points of suspension, or abrade against the rocks until it is cut through.'

The following conclusions appear to have been arrived at by those connected with the working of the Atlantic electric cable: 1st, That an insulated submarine wire conducts according to a different law to that of a circuit suspended in air; 2nd, That the rate at which a voltaic signal travels along a wire is not affected by the intensity of the battery; and 3rd, that magneto-electric induced currents have the property of travelling much faster than voltaic ones, and increase in the rapidity of travelling, when their intensity is increased. Mr. Samuel Alfred Varley, in a paper read before the Institution of Civil Engineers, makes the following remarks on these points:—

'In examining these conclusions, it has first to be considered whether the conditions of a submarine circuit and of a suspended one are different. In a suspended wire, the insulating medium of the air takes the place of the gutta-percha of the submarine circuit. The earth, which is the nearest conductor, is a considerable distance off, and is only on one side of the wire; therefore, but little induction can take place between the wire and the earth. Nevertheless, induction to a certain extent does take place, and can be perceived in circuits of very moderate length. The author has noticed indications of it in a circuit 60 miles long, and he feels confident that, with delicate apparatus, it could be perceived in much shorter circuits. If the distance between the wire and the earth is decreased, induction will be developed more strongly, and the wire could be brought down, step by step, until the condition of a submarine circuit would be approached, where the earth surrounds the wire on all sides, and is only separated from it by the thickness of $\frac{1}{8}$th or $\frac{3}{16}$ths of an inch of gutta-percha, a substance possessing, moreover, specifically a much greater inductive capacity than air. It therefore appears that the conditions are precisely the same, only differing in degree.

'In a Leyden jar, the inner and outer coatings are perfectly insulated one from the other. If they were not insulated, there could be no statical charge, as is well understood by all electricians. Induction, therefore, involves insulation. But in a submarine circuit this is not the case. If the wire was disconnected at the further extremity from the telegraph instrument, and was sealed up with gutta-percha, the conditions would be nearly the same. In practice, however, it is quite open through the instrument to the earth, and the resistance opposed by the very long length of wire is the only insulation between the inner and outer coatings; for it unites both, being in connection with the earth at both ends. It is, therefore, evident that, if the wire offers no resistance, there will be no insulation, and, as a consequence, no induction to retard the passage of the current. It is also equally plain, that precisely in proportion to the resistance which the wire opposes, provided always the insulating medium is of the same thickness, will induction manifest itself, and retardation be experienced. There is also another difference between a Leyden jar and a submarine circuit. The Leyden jar is charged uniformly all over, whilst in a submarine wire, the tension of the charge varies in different portions of the circuit, being at its maximum at the end where contact with the battery is made, and gradually vanishing to nothing at the further extremity.

'The fact has already been adverted to, that if a battery capable of developing, when in short circuit, a much greater quantity of electricity than it does when connected through a fine wire, is connected through a long wire of small dimensions, the quantity evolved through one length of this fine wire will be twice the amount of that evolved through double the length. From this it appears that double the length of wire opposes the same resistance to a given quantity of electricity, as a wire of half this length does to double that quantity of electricity. Hence, any length of wire opposes an infinitely small amount of resistance to an infinitely small quantity of electricity. An idea seems to prevail, that if the wire becomes attenuated at any one spot, the conducting power of the whole circuit will be brought down to that of a wire of no greater thickness than it is at the attenuated portion. It will be at once seen, from what has just been said, that this cannot be the case, but that the effect will be precisely the same as increasing the length of the circuit. For if the circuit is attenuated, say throughout a mile of its length, to half its normal diameter, it will possess, in this space, only one-fourth of the sectional area; consequently, it will oppose 4 times as much resistance as a mile of wire of its original size. In other words, this mile will oppose as much resistance as 4 miles of any other portion of the circuit. If the resistance offered by 1 mile of the circuit, is put down as 1, then the resistance opposed by the attenuated mile would be 4; and if the normal resistance, or 1, is subtracted from this, there will remain 3, as the excess of resistance over what it should be, owing to this attenuation. The effect will therefore be the same, as increasing the length of the circuit by 3 miles. It seems surprising that this should have escaped observation, for if true the conducting power of the whole circuit would be brought down to that of a wire of no greater diameter than that made use of in the coils of the instruments, which may be considered simply as a continuation of the cable, and is only about one-eightieth of an inch in diameter. Electricity flowing through a long circuit which is attenuated at one portion, may be compared to water flowing through a long tube of small dimensions, and therefore opposing a great amount of friction to the passage of the water. If the tube is indented at any one part, it will decrease the flow to a certain extent, but not nearly so much as if the bore of the pipe was reduced throughout its length to the same size as it is where indented.

'Incidentally connected with, and following as a natural sequence to what has just been said, is the bearing and the value of the resistance opposed by the coils of the telegraph instrument. If an electro-magnet is enveloped with a single convolution of wire, and a battery is connected with it, there will be little resistance to the free passage of the electricity, as owing to the short length of wire, but very little magnetism will be developed. Under such conditions, with a great expenditure of battery power, a very small equivalent of magnetic force will be obtained. If the number of convolutions be increased until the resistance opposed by the greater length of wire begins sensibly to reduce the dynamic quantity flowing, the magnetic force will then be found to be increased proportionately to the number of convolutions, less certain other considerations, which need not now be entered upon, and with actually less expenditure of battery power. Resistance encountered and overcome, under these conditions, implies so much work done; and the larger the proportion of it in the instruments, relatively to that opposed by the cable, the more economically will the electricity be expended. If the cable is supposed to offer 10 times the resistance of that opposed by the coils of the telegraph instrument, which is nearly the case in some printing circuits of 200 miles in length, the whole of the cable, as well as the coils, will be rendered magnetic. Ten-elevenths of the magnetism will be developed in the cable itself, where it will be useless, and one-eleventh only in the coils of the apparatus, where it will be available as a motive force. But, if the coil-wires are increased in length, so as to oppose a resistance equal to 40 miles of the cable, an amount of magnetism equal to one-fifth of that developed in the cable, instead of one-tenth, as in the former instance, will now be developed in the telegraph instrument, if the same quantity of electricity as in the former case is forced through. Hence, the reason is apparent, why such fine wire, and so great a length of it, is found to answer best for the coils of telegraphic apparatus. In practice, there is of course a limit, to which the coil-wire may be increased in length, or be diminished in sectional area, with advantage.

'These are not new facts, for the bearing of the resistance in the coils, to that opposed by the cable itself, is pretty well understood and appreciated by many electricians; but it is believed that attention has not been publicly directed to it before. The remarks which are constantly made show that it is not so well comprehended as it should be. When it was urged upon the projectors of the Atlantic cable that attenuation at any one portion of the cable would seriously decrease the conducting power of the whole throughout, it was put to the test of a practical experiment. Finding it did not perceptibly affect the working, it was accounted for, not from the reasons here given, but from its being at the attenuated portion, a Leyden arrangement of smaller dimensions. This shows that the idea, that reduction at one spot is tantamount to reduction throughout, is entertained by some, whose practical experience deservedly gives weight to their opinions. In the work before alluded to it is said, "The fact is, that this fear of the conducting wire of the cable being telegraphically disabled by attenuation, is based upon the notion that the insulated strand is to act as a *simple conductor*, and not as an *inductively charged Leyden jar*. It may be, and probably is true, that a simple conductor transmits an electrical current with a facility which is in a measure proportioned to its capacity at the smallest part of its length; the entire conductor being virtually reduced in its dimensions to the standard of this smallest part. But it is not true that the transmitting power of an insulated submarine wire, which is virtually a Leyden jar, and open to inductive charges, is modified, from the same cause, to anything like the same extent. Here the induction, which has taken a mischievous part in producing retardation of electrical movement in coated wires, turns round and makes amends for its interference, by causing small and easily-laid wires to be more manageable for submarine telegraphy than large ones could be."

'The next point for consideration is, what will be the action of a galvanic battery when connected to send a current on a long submarine circuit? The wire and the earth being only separated by the thin layer of gutta-percha, induction can readily take place between them; whilst the wire itself opposes a very great resistance to the flowing of the large quantity of fluid which the battery can generate, and wants to force through. As the wire offers but little resistance to a small quantity of electricity, a small amount will travel through almost instantly, the wire being statically charged at the same time; and as the wire becomes more and more highly charged, so will the stream flow out, in larger and larger quantities, at the further extremity.

'It has been already shown that induction manifests itself in proportion to the resistance offered by the wire, other circumstances being the same, and that a wire offers comparatively speaking, no resistance to very small amounts of electricity. This, at first sight, might lead to the idea, that if very sensitive instruments could be employed, supposing the wire to be perfectly insulated, as the induction would be less, the signals would be passed through more quickly, or, in other words, that increasing the delicacy of the instrument would be the same thing as magnifying the wire. A little reflection will, however, show the fallacy of such a supposition, for in proportion as the wire opposes less resistance, so will the tension of the current be lowered, and therefore it will possess a proportionately smaller amount of energy to urge forward the current. If the diameter of the cable is increased to double the size, it will then possess four times the sectional area, and consequently have four times the conducting power of a wire of half this diameter. But the outside surface, on which induction depends, will, at the same time, be doubled, and hence there will be twice the inductive force. Nevertheless, there will be a gain; for if, in the original wire, the resistance was one, and the induction one also, in the wire of twice the diameter, although the inductive force would be two, the resistance of the wire would be brought down to one fourth, the relative balance of the forces being reduced one half. Therefore, there would be a proportionate gain in favour of rapidity of conduction, and as doubling the diameter of the wire has reduced the retarding induction, one-half signals might be expected in this case to travel twice as fast. Supposing four cables to be ranged side by side, it is evident they will oppose one-fourth less resistance than one would do; and, consequently, the same tension of current would force four times the dynamic quantity of electricity through as would be forced through one alone. Signals would not, however, be passed more quickly through the four cables than through one cable, for, although the resistance has been reduced to one-fourth, the induction has been quadrupled at the same time, which will exactly counterbalance the smaller resistance. If the cables are merged into one, the case will then be altered, for the surface will at once be brought down to one-half, and therefore there will only be half the amount of induction to retard the rapidity of signalling, whilst the conducting power will remain the same as it was before. As the outer surface of the gutta-percha does not increase so rapidly as its substance, there will be a gain on that head, for if the conductor is $\frac{1}{10}$th of an inch in diameter, and it is coated to the depth of $\frac{1}{10}$th of an inch with gutta-percha, making a total diameter of $\frac{3}{10}$ths of an inch, the united exterior surface of four such cables would be 3·6 square inches, but if the four conductors are merged into one, the exterior surface will be 1·2 square inch, or less than half the exterior surface of the four cables, in the proportion of 4 to 6.

'The next question which has to be considered is whether the rate of transmission of signals is affected by increasing the number of cells, when a voltaic battery is employed. The author is of opinion that this would be the case. It has already been explained how the wave of electricity rises and falls on connecting and disconnecting a battery from a submarine circuit. The effect of a higher intensity would be to raise the wave to its maximum height more quickly, and as the arrival of the current takes place at the instant when the wave has risen sufficiently high at the further extremity to record itself on the instrument, and not at the time it actually begins to flow, this height would be attained more quickly, and signals also would be obtained sooner. An experiment made by the Atlantic Telegraph Company seems inadvertently to prove the truth of this reasoning. A Lilliputian battery of seven cells, reduced to the smallest dimensions, having been connected to a cable 600 miles long, the signals occupied $\frac{9}{10}$ths of a second in arriving. This battery was then disconnected, and another joined up in its place, but of twelve cells, and with a much larger extent of surface in each cell, when signals arrived in $\frac{44}{100}$ths of a second. This great difference of speed is almost in regular proportion to the number of cells employed. Had the signals, in the case of the battery of seven cells, occupied $\frac{7}{10}$ths, instead of $\frac{9}{10}$ths of a second in arriving, the speed would have been exactly in proportion to the number of cells, one cell taking $\frac{49}{10}$ths, seven cells occupying $\frac{7}{10}$ths, and twelve cells a little more than $\frac{4}{10}$ths of a second in arriving. When it is remembered that no two cells of batteries differently constructed will have precisely the same intensity, even supposing these minute differences of time were quite accurately recorded, there would still be reasons sufficient to account for the irregularity. It should be mentioned that this experiment is stated to be given in order to show that increasing the battery surface alone, affects the rate of transmission. No explanation of how it does this is attempted, and the difference in the intensity of the two batteries seems to have been overlooked as a matter of no importance. The author believes the increase of rate to have been chiefly due to the larger number of cells employed in the second part of the experiment, and not so much to the increased surface. He has already explained the conditions under which an increased battery-surface would raise the tension of the current, and so increase the rapidity of signalling. In this experiment the tension of the currents used was so low, and the resistance opposed by the 600 miles of wire so great, that it is probable a very much smaller dynamic quantity was generated through the whole length of the wire than even the Lilliputian battery would generate through a circuit of nominally no resistance. If this was the case, increasing the battery surface only, without adding to the series, would have but little effect in increasing the quantity flowing. The experiment, therefore, as a trial of the effect of large battery-surface alone, cannot be considered a fair one. Attention has been drawn to it here, as it may help to throw some light upon the matter under consideration.'

The following note of a gold-leaf electrometer, and the introduction of an induction coil, promises to give increased sensibility. It is the invention of Mr. Highton, who introduces an induction coil, the especial object of which is to multiply the current at the receiving end of a telegraphic line. This recording instrument is also a novelty, and consists of a strip of gold-leaf, about an inch and a half in length, and weighing $\frac{3}{1000}$th parts of a grain, suspended between the two poles of an electrometer. Near the leaf is a magnet which causes the leaf to be deflected, either to the right hand or to the left, according as a positive or negative current is brought into action. The vibrations of the leaf are magnified by an ordinary magic-lantern arrangement, and are thrown on a screen, from which they are read off by the operator.

ELECTRO-TINT. The art of preparing tinted plates by the action of electricity on copper. One process consists in putting a perfectly clean copper plate into a solution of acetate of lead, and making it one of the terminal poles of a voltaic battery, the other pole being a piece of pure lead dipping into the solution. Tints of the most exquisite character and colour can, by a little careful manipulation, be thus produced.

ELECTROTYPE. See Electro-Metallurgy.

ELECTRUM, or **ELECTRON.** Amber was so called by the Greeks, and from it we derive our word 'electricity.' The Romans used the term at first, for a compound of gold and silver, which was of the colour of amber; subsequently it was applied to a definite mixture of gold and silver, used for coins.

Native alloys of gold and silver are now called electrums, when they contain sufficient silver to make their colour lighter, and their specific gravity less than that of gold. According to Klaproth, electrum is composed of gold 64, silver 36. Hausmann applied the term to all native alloys that contain from 20 to 50 per cent. of silver.

A base metal in modern use has received the name of electrum. It is an alloy of copper, zinc, and tin, with sometimes nickel.

ELEMENTS. This name is now given to bodies which have not been reduced to any more simple form of matter than that in which we find them. The elements of the ancients, *air*, *fire*, *earth*, and *water*, had quite a different meaning from the elements of the modern chemist; so had the *salt*, *sulphur* and *mercury* of the early alchemists. In their philosophy those terms represented the ultimate forms into which matter could be resolved, or out of which all matter could be created. The number of elements at present known is 63:—

Table of Chemical Elements.

Aluminium
Antimony
Arsenic
Barium
Bismuth
Boron
Bromine
Cadmium
Cæsium
Calcium
Carbon
Cerium
Chlorine
Chromium
Cobalt
Copper
Didymium
Erbium
Fluorine
Glucinum
Gold
Hydrogen
Indium
Iodine
Iridium
Iron
Lanthanum
Lead
Lithium
Magnesium
Manganese
Mercury
Molybdenum
Nickel
Niobium
Nitrogen
Osmium
Oxygen
Palladium
Phosphorus
Platinum
Potassium
Rhodium
Rubidium
Ruthenium
Selenium
Silica
Silver
Sodium
Strontium
Sulphur
Tantalum
Tellurium
Thallium
Thorinum
Tin
Titanium
Tungsten
Uranium
Vanadium
Yttrium
Zinc
Zirconium

A list of the more important of these elements, with their symbols and atomic weights, will be found under the article Atomic Weights.

For a full examination of the laws regulating the chemical relations of these bodies, their atomic constitution, &c. see Watts's 'Dictionary of Chemistry.'

ELEMI. This appears to be the resinous product of various terebinthinous trees. The Edinburgh College states it to be a 'concrete resinous exudation from one or more unascertained plants.' And the London Pharmacopœia describes it as a concrete turpentine derived from an unknown plant. In the former edition *Amyris Elemifera* was named as the plant producing this resin. This error was due to Linnæus, who confounded under one name two distinct plants. The larger quantities of elemi come to us from the Dutch settlements through Holland. It is imported in '*the lump*,' and in masses weighing from one to two pounds, each enveloped in a palm-leaf. Elemi is employed in making lacquer. See Varnish.

ELEPHANTS' TUSKS. See Ivory.

ELEPHANTS' URINE. The celebrated Indian yellow, or *Purree*, is said to be a mixture of the earthy phosphate and urea deposited from this.

ELEUTRIATE. (*Soutirer*, Fr.; *Schlemmen*, Ger.) When any insoluble powder, such as chalk, is diffused through a large body of water, and then allowed to subside slowly, of course the larger particles will by their gravity be the first to subside. If then the supernatant liquor is poured off, or better, if drawn off by a siphon, the finer powder will be collected in the next vessel; and by repeating this process an impalpable powder may be obtained. This process is called *Eleutriation.*

ELEVATORS FOR MINES. Under this name Messrs. Alexander Alison and John Shaw have patented an arrangement for 'Raising water and minerals from collieries and mines, and for other purposes.' There is much ingenuity in the arrangements proposed, which are in point of fact modifications of the systems adopted by the Pneumatic Despatch Company. The principle involved will be sufficiently understood from the following description, taken from the Specifications of the patentees:—A cylinder or tube is placed in the shaft which rises a few feet above the top of it, and reaches to a few feet below the bottom of the mine; this cylinder is made of malleable or cast iron, or other suitable metal or material, and of a diameter according to the weight of minerals, water, or other substances to be lifted. In this cylinder or tube a double-headed piston works, and between the two heads of the piston a fixed or moveable receiver, or barrel, or waggon is placed, which holds the mineral or water to be raised.

An air-pump worked by a steam-engine or water-wheel, or other power, is used for forcing air down the shaft in a tube, which air passes into the cylinder below the under piston head. Forcing only may be used, but exhausting and forcing may be used in conjunction. When the load is put in at the bottom, a valve is opened so that the air is introduced under the piston, which with its load then rises to the top; on arriving at the top the load is removed, and on an escape-valve at bottom being opened, the piston descends, and the air which escapes ventilates the mine. This elevator not only acts as an elevator and ventilator, but provides a safe and expeditious mode of conveying workmen up and down the shaft.

The other improved elevator may be described thus:—Air is forced by an air-pump, worked by steam or other power, down a tube into one or more cisterns in the bottom of the shaft, into which the water of the mine runs. The water is in this way forced up to the surface through another tube. The cistern or cisterns are fitted with self-acting valves, which open and shut by means of a float. As the air escapes from the bottom this elevator acts as a ventilator as effectually as the one previously described. See MAN-ENGINE.

ELIASITE. An ore of uranium. A mineral allied to pitchblende, but differing from it widely in its large proportion of water and lower specific gravity (4·086 to 4·237).

It occurs with fluor, dolomite, quartz, &c., at the Elias mine, Joachimstal (whence its name), in large flattened pieces, sometimes half an inch thick, of a dull reddish-brown colour, approaching to hyacinth-red on the edges.

It is subtranslucent, with a greasy subvitreous lustre, and affords a dull streak, varying from wax-yellow to orange. Hardness between calcite and fluor spar.

It is composed of peroxide of uranium, 61·33; alumina, 1·17; peroxide of iron, 6·63; protoxide of iron, 1·09; lime, 3·09; magnesia, 2·20; oxide of lead, 4·62; silica, 5·13; carbonic acid, 2·52; phosphoric acid, 0·84; water, 10·68: Total, 99·30.

Before the blowpipe it affords a reaction like pitchblende; it is decomposed by muriatic acid.—H.W.B.

ELIQUATION. The separation of lead and silver from copper, the agent for doing this being lead. The copper containing silver was melted with a certain portion of lead, and cast into discs. These discs were exposed to a temperature sufficiently high to melt the lead. This metal then *liquated,* or separated from the copper, carrying the greater portion of the silver with it. The process is seldom now employed.

ELIXIR OF VITRIOL. A preparation of sulphuric acid, with some aromatics.

ELM. (*Ulmus,* Lat.; *Orme,* Fr.; *Ulme,* Ger.) Of this European timber tree there are five species. The *Ulmus campestris,* the English Elm, is regarded in this country as one of the finest of European deciduous trees for park scenery; it lives for upwards of 200 years, forming a remarkably straight tall trunk. The quality of timber depends a good deal on the soil in which it is grown, being always best on a dry, loamy soil, with plenty of air. The *Ulmus montana,* is the Mountain, Scotch, or Wych Elm: the trunk is not so lofty nor the wood so heavy as the English Elm; and though coarse-grained, is very highly prized by shipbuilders and cartwrights. It possesses great longitudinal adhesion, and is consequently one of our stiffest and straightest timbers. These woods are not liable to split; they bear the driving of nails or bolts better than any other timber, and are exceedingly durable when constantly wet. They are therefore much used for the keels of vessels, and for wet foundations, waterworks, piles, pumps, and boards for coffins. On account of its toughness, it is selected for the naves of wheels, and for the gunwales of ships.

ELVANITE. A quartziferous porphyry, forming the typical rock of the Cornish Elvans.

ELVANS. Granitic and felspathic porphyritic rocks, which are frequently found traversing both the granite and slate rocks.

'The elvans or veins of quartziferous porphyry—that is, a granular crystalline mixture of felspar and quartz, which are common both in Cornwall and Devon, and near the granite of the south-east of Ireland—are probably in reality granite veins, or veins proceeding from a granitic mass.'—*Jukes.*

'When these *granite veins* are of a large size they are termed *Elvan courses*; indeed, this is the only distinction between these two forms of elongated masses of granitic rock. In composition these elvans are either shorl rock, eurite, felsparite, or even varieties of fine-grained granite.'—*Boase.*

ELYTRA. The horny wing-cases of beetles, formed by the anterior wings becoming hardened, and therefore useless for flight. The brilliantly-coloured and iridescent elytra of some beetles are used for ornamental purposes.

EMAIL OMBRANT. A process which consists in flooding coloured but transparent glazes over designs stamped in the body of earthenware or porcelain. A plane surface is thus produced, in which the cavities of the stamped design appear as shadows of various depths, the parts in highest relief coming nearest the surface of the glaze, and thus having the effects of the lights of the picture. This process was introduced by the Baron A. De Tremblay of Rubelles, near Melun.

ÉMAUX CLOISONNÉS. See ENAMELS.

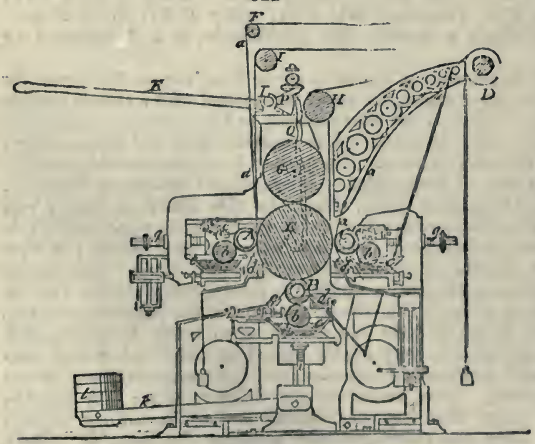
EMBALMING. (*Embaumement*, Fr.; *Einbalsamirung*, Ger.) An operation employed by the ancients to preserve human bodies from putrefaction. From their using *balsams* in the process, the name was derived. See DISINFECTION; PUTREFACTION.

EMBOLITE. A chloro-bromide of silver found in Chili and Mexico. It varies in colour from an asparagus green to an olive green, is perfectly malleable, and of resinous lustre. The ratio of the chlorine to the bromine appears to vary indefinitely, those varieties which are of a yellow or of a deep green tint being the richest in bromine. The name is derived from ἐμβόλιον, *intermediate*, in allusion to the mineral being intermediate in chemical composition between the chloride and the bromide of silver.

EMBOSSING. One of the plans introduced for EMBOSSING CLOTH by machinery which appears to be the most effective, is that of Mr. Thomas Greig, of Rose Bank, near Bury. This machine is thus constructed:—

Figs. 822, 823 represent three distinct printing cylinders of copper, or other suitable material, A, B, C, with their necessary appendages for printing three different colours upon the fabric as it passes through the machine; either of these cylinders, A, B, or C, may be employed as an embossing cylinder, without performing the printing process, or may be made to effect both operations at the same time.

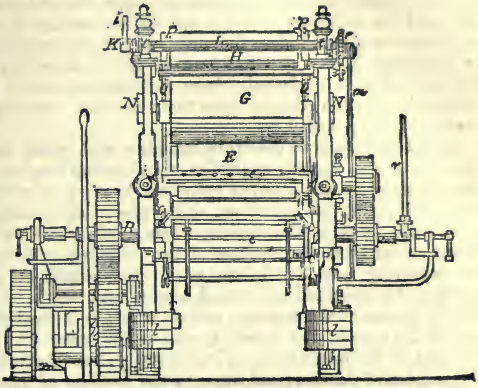
822



The fabric or goods to be operated upon being first wound tightly upon a roller, that roller is to be mounted upon an axle or pivot, bearing in arms or brackets at the back of the machine, as shown at D. From this roller the fabric *a*, *a*, *a*, *a*, is conducted between tension rails, and passed under the bed cylinder or paper bowl E, and from thence proceeds over a carrier roller F, and over steam-boxes not shown in the drawing, or it may be conducted into a hot room, for the purpose of drying the colours.

The cylinders A, B, and C, having either engraved or raised surfaces, are connected with feeding rollers *b*, *b*, *b*, revolving in the ink or coloured troughs *c*, *c*, *c*; or endless felts, called sieves, may be employed, as in ordinary printing machines, for supplying the colour, when the device on the surface of the cylinders is raised; these cylinders may be furnished with doctors or scrapers when required, or the same may be applied to endless felts.

823



The blocks have adjustable screws *g*, *g*, for the purpose of bringing the cylinders up against the paper bowl with any required degree of pressure; the cylinder B is supported by its gudgeons running in blocks, which blocks slide in the lower parts of the side frames, and are connected to perpendicular rods *i*, having adjustable screw nuts.

The lower parts of these rods bear upon weighted levers *k*, *k*, extending in front of the machine; and by increasing the weights *l*, *l*, any degree of upward pressure may be given to the cylinder B.

The colour boxes or troughs *c*, *c*, *c*, carrying the feeding rollers *b*, *b*, *b*, are fixed on boards which slide in grooves in the side frames, and the rollers are adjusted and brought into contact with the surface of the printing cylinders by screws.

If a black cloth should be required to be introduced between the cylindrical bed or paper bowl E, and the fabric *a*, *a*, *a*, as the ordinary felt or blanket, it may, for printing and embossing cotton, silk, or paper, be of linen or cotton; but if woollen goods are to be operated upon, a cap of felt, or some such material, must be bound round the paper bowl, and the felt or blanket must be used for the back cloth, which is to be conducted over the rollers H and I.

For the purpose of embossing the fabric, either of the rollers A, B, or C, may be employed, observing that the surface of the roller must be cut, so as to leave the pattern or device elevated for embossing velvets, plain cloths, and papers; but for woollens the device must be excavated, that is, cut in recess.

The pattern of the embossing cylinder will, by the operation, be partially marked through the fabric on to the surface of the paper bowl E; to obliterate which marks from the surface of the bowl, as it revolves, the iron cylinder roller G is employed; but as in the embossing of the same patterns on paper, a counter roller is required to produce the pattern perfectly, the iron roller is in that case dispensed with, the impression given to the paper bowl being required to be retained on its surface until the operation is finished.

In this case the relative circumferences of the embossing cylinder, and of the paper bowl, must be exactly proportioned to each other; that is, the circumference of the bowl must be equal, exactly, to a given number of circumferences of the embossing cylinder, very accurately measured in order to preserve a perfect register or coincidence, as they continue revolving between the pattern on the surface of the embossing cylinder and that indented into the surface of the paper bowl.

The axle of the paper bowl E, turns in brasses fitted into slots in the side frames, and it may be raised by hand from its bearings, when required, by a lever *k*, extending in front. This lever is affixed to the end of a horizontal shaft L, L, crossing the machine seen in the figures, at the back of which shaft there are two segment levers P, P, to which bent rods Q, Q, are attached, having hooks at their lower ends, passed under the axle of the bowl. At the reverse end of the shaft L, a ratchet-wheel *r*, is affixed, and a pall or click mounted on the side of the frame takes into the teeth of the wheel *r*, and thereby holds up the paper bowl when required.

When the iron roller G, is to be brought into operation, the vertical screws *t*, *t*, mounted in the upper parts of the side frames, are turned, in order to bring down the brasses N, which carry the axle of that roller and slide in slots in the side frames.

The cylinders A, B, and C, are represented hollow, and may be kept at any desired temperature during the operation of printing, by introducing steam into them; and under the colour boxes *c*, *c*, *c*, hollow chambers are also made for the same purpose. The degree of temperature required to be given to these must depend upon the nature of the colouring material, and of the goods operated upon. For the purpose of conducting steam to these hollow cylinders and colour boxes, pipes, as shown at *v*, *v*, *v*, are attached, which lead from a steam-boiler. But when either of these cylinders is employed for embossing alone, or for embossing and printing at the same time, and particularly for some kinds of goods where a higher temperature may be required, a red-hot heater is then introduced into the hollow cylinder in place of steam.

If the cylinder B is employed as the embossing cylinder, and it is not intended to print the fabric by that cylinder simultaneously with the operation of embossing, the feeding roller *b* must be removed, and also the colour box *c*, belonging to that cylinder; and the cylinders A and C are to be employed for printing the fabric, the one applying the colour before the embossing is effected, the other after it. It is, however, to be remarked, that if A and C are to print colours on the fabric, and B to emboss it, in that case it is preferred, where the pattern would allow it. A and C are wooden rollers, having the pattern upon their surfaces, and not metal, as the embossing cylinders must of necessity be.

It will be perceived that this machine will print one, two, or three colours at the same time, and that the operation of embossing may be performed simultaneously with the printing, by either of the cylinders A, B, or C, or the operation may be performed consecutively by the cylinders, either preceding or succeeding each other.

The situations of the doctors, when required to be used for removing any superfluous colour from the surface of the printing cylinder, are shown at *d*, *d*, *d*; those for removing any lint which may attach itself, at *e*, *e*, *e*. They are kept in their bearings by weighted levers and screws, and receive a slight lateral movement to and fro, by means of the vertical rod *m*, which is connected at top to an excentric, on the end of the axle of the roller H, and at its lower end to a horizontal rod mounted at the side of the frame; to this horizontal rod arms are attached, which are connected to the respective doctors; and thus, by the rotation of the excentric, the doctors are made to slide laterally.

When the cylinders A, B, or C, are employed for embossing only, those doctors will not be required. The driving power is communicated to the machine from any first mover through the agency of the toothed gear, which gives rotatory motion to the cylinder B, and from thence to the other cylinders A, and C, by toothed gear shown in *fig.* 822.

EMBOSSING LEATHER. Beautiful ornaments in basso-relievo for decorating the exteriors or interiors of buildings, medallions, picture-frames, cabinet work, &c., have been made by the pressure of metallic blocks and dies, by M. Claude Schroth. The dies are made of type-metal, or of the fusible alloy with bismuth, called d'Arcet's. The leather is beaten soft in water, then wrung, pressed, rolled, and fulled, as it were, by working it with the hands till it becomes thicker and quite supple. In this state it is laid on the mould, and forced into all its cavities by means of a wooden, bone, or copper tool. In other cases, the embossing is performed by the force of a press. The leather, when it has become dry, is easily taken off the mould, however deeply it may be inserted into its crevices, by virtue of its elasticity.

EMBOSSING WOOD. (*Bossage*, Fr.; *Erhabenes Arbeit*, Ger.) Raised figures upon wood, such as are employed in picture-frames, and other articles of ornamental cabinet work, are usually produced by means of carving, or by casting the pattern in plaster of Paris, or other composition, and cementing, or otherwise fixing it on the surface of the wood. The former mode is expensive; the latter is inapplicable on many occasions. The invention of Mr. Streaker may be used either by itself, or in aid of carving, and depends on the fact, that if a depression be made by a blunt instrument on the surface of the wood, such depressed part will again rise to its original level by subsequent immersion in the water.

The wood to be ornamented having been first worked out to its proposed shape, is in a state to receive the drawing of the pattern; this being put on a blunt steel tool, or burnisher, or die, is to be applied successively to all those parts of the pattern intended to be in relief, and, at the same time, is to be driven very cautiously, without breaking the grain of the wood, till the depth of the depression is equal to the intended prominence of the figures. The ground is then to be reduced by planing or filing to the level of the depressed part; after which, the piece of wood being placed in water, either hot or cold, the part previously depressed will rise to its former height, and will then form an embossed pattern, which may be finished by the usual operations of carving. See CARVING BY MACHINERY.

Another process which may be regarded either as carving or embossing wood, is that patented by Messrs. A. S. Braithwaite and Co.

Oak, mahogany, rose-wood, horse-chestnut, or other wood, is steeped in water for about two hours; and the cast-iron mould containing the device is heated to redness, or sometimes to a white heat, and applied against the wood, either by a handle, as a branding iron, by a lever press, or by a screw press, according to circumstances; the moulds are made by the iron-founder from plaster casts of the original models or carvings.

Had not the wood been saturated with water, it would be ignited, but until the moisture is evaporated, it is only charred; it gives off volumes of smoke, but no flame. After a short time the iron is returned to the furnace to be re-heated, the blackened wood is well rubbed with a hard brush to remove the charcoal-powder, which being a bad conductor of heat, saves the wood from material discoloration; and before the re-application of the heated iron, the wood is again soaked in water, but for a shorter time, as it now absorbs moisture with more facility.

The rotation of burning, brushing, and wetting is repeated ten or twenty times, or upwards, until, in fact, the wood fills every cavity in the mould, the process being materially influenced by the character and condition of the wood itself, and the degrees to which heat and moisture are applied. The water so far checks the destruction of the wood, or even its change of any kind, that the burned surface, simply cleaned by brushing, is often employed, as it may be left either of a very pale or deep brown, according to the tone of colour required, so as to match old carvings of any age; or a very little scraping removes the discoloured surface. Perforated carvings are burned upon thick blocks of wood, and cut off with the circular saw.

EMBROIDERING MACHINE. (*Machine à broder*, Fr.; *Steckmaschine*, Ger.) —This art has been from the earliest times a handicraft employment, cultivated on account of its elegance by ladies of rank. But M. Heilmann, of Mulhouse, invented a machine of a most ingenious kind, which enables a female to embroider any design with 80 or 140 needles as accurately and expeditiously as she formerly could do with one. A brief account of this remarkable invention will therefore be acceptable to many readers. It was first displayed at the National Exposition of the Products of Industry in Paris for 1834. 130 needles were occupied in copying the same pattern with perfect regularity, all set in motion by one person.

Several of these machines are now mounted in France, Germany, and Switzerland, and, with some modifications, in Manchester, Glasgow, and Paisley.

The price of a machine having 130 needles, and of consequence 260 pincers or fingers and thumbs to lay hold of them, is 5,000 francs, or 200*l.* sterling; and it is estimated to do daily the work of fifteen expert hand embroiderers, employed upon the ordinary frame. It requires merely the labour of one grown-up person and two assistant children. The operative must be well taught to use the machine, for he has many things to attend to: with the one hand he traces out, or rather follows the design with the point of the pantograph; with the other he turns a handle to plant and pull all the needles, which are seized by pincers and moved along by carriages, approaching to and receding from the web, rolling all the time along an iron railway; lastly, by means of two pedals, upon which he presses alternately with the one foot and the other, he opens the 130 pincers of the first carriage, which ought to give up the needles after planting them in the stuff, and he shuts with the same pressure the 130 pincers of the second carriage, which is to receive the needles, to draw them from the other side, and to bring them back again. The children have nothing else to do than to change the needles when all their threads are used, and to see that no needle misses its pincers.

This machine may be described under four heads: 1. the structure of the frame; 2. the disposition of the web; 3. the arrangement of the carriages; and 4. the construction of the pincers.

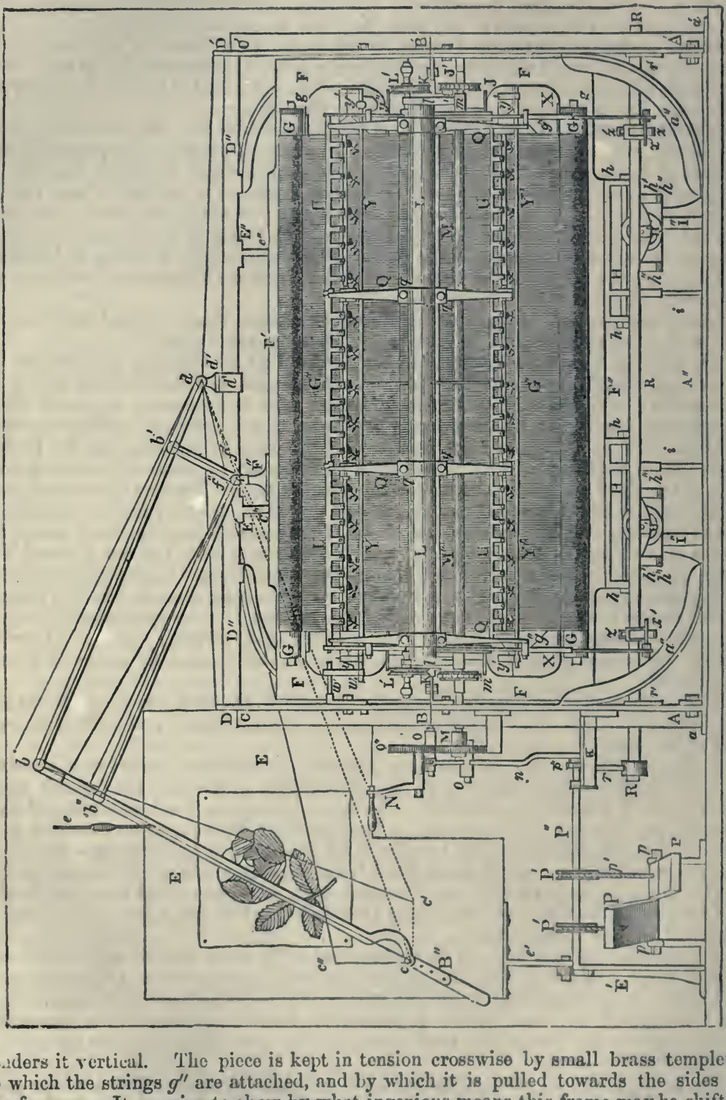
1. *The structure of the frame.*—It is composed of cast iron, and is very massive. *Fig.* 824 exhibits a front elevation of it. The length of the machine depends upon the number of pincers to be worked. The figure here given has been shortened considerably, so that the drawing might be brought within the page, but the other proportions are not disturbed. The breadth of the frame ought to be the same for every machine, whether it be long or short, for it is the breadth which determines the length of the thread to be put into the needles, and there is an advantage in giving it the full breadth of the model machine, fully 100 inches, so that the needles may carry a thread at least 40 inches long.

2. *Disposition of the piece to be embroidered.*—We have already stated that the pincers which hold the needles always present themselves opposite to the same point, and that in consequence they would continually pass backwards and forwards through the same hole, if the piece was not displaced with sufficient precision to bring successively opposite the tips of the needles every point upon which they are to work a design, such as a flower.

The piece is strained perpendicularly upon a large rectangular frame, whose four sides are visible in *fig.* 824; namely, the two vertical sides at F F, and the two horizontal sides, the upper and lower at F′ F″. We see also in the figure two long wooden rollers G and G, whose ends, mounted with iron studs, are supported upon the sides F of the frame, so as to turn freely. These form a system of beams, upon which the piece destined to receive the embroidery is wound and kept vertically stretched to a proper degree, for each of these beams bears upon its end a small ratchet wheel g, g;

the teeth of one of them being inclined in the opposite direction to those of the other. Besides the system of lower beams, there is another of two upper beams, which is however but imperfectly seen in the figure, on account of the interference of other parts in this view of the machine. One of these systems presents the web to the inferior needles, and the other to the upper needles. As the two beams are not in the same vertical plane, the plane of the web would be presented obliquely to the needles were it not for a straight bar of iron, round whose edge the cloth passes, and which renders it vertical. The piece is kept in tension crosswise by small brass templets, to which the strings g'' are attached, and by which it is pulled towards the sides of the frame F. It remains to show by what ingenious means this frame may be shifted in every possible direction. M. Heilmann has employed for this purpose the pantograph which draughtsmen use for reducing or enlarging their plans in determinate proportions.

824



$b\,b'\,f''\,b''$ (*fig.* 824) represent a parallelogram, of which the four angles b, b', f', b'', are jointed in such a way that they may become very acute or very obtuse at pleasure, while the sides of course continue of the same length; the sides $b\,b'$ and $b\,b''$ are prolonged, the one to the point d, and the other to the point c, and these points c and d are chosen under the condition that in one of the positions of the parallelogram, the line $c\,d$ which joins them passes through the point f; this condition may be fulfilled in an infinite number of manners, since the position of the parallelogram remaining the same, we see that if we wished to shift the point d further from the point b', it would be sufficient to bring the point c near enough to b'', or *vice versâ*; but when we have once fixed upon the distance $b'\,d$, it is evident that the distance $b''\,c$ is its necessary consequence. Now the principle on which the construction of the pantograph rests is this: it is sufficient that the three points d, f, and c be in a straight line, in one only of the positions of the parallelogram, in order that they shall remain always in a straight line in every position which can possibly be given to it.

We see in the figure that the side $b\,c$ has a handle B″ with which the workman puts the machine in action. To obtain more precision and solidity in work, the sides of the pantograph are joined, so that the middle of their thickness lies exactly in the vertical plane of the piece of goods, and that the axes of the joints are truly perpendicular to this plane, in which consequently all the displacements are effected. We arrive at this result by making fast to the superior great cross-bar D″ an elbow-piece d'', having a suitable projection, and to which is adapted in its turn the piece d', which receives in a socket the extremity of the side $b\,d$; this piece d' is made fast to d'' by a bolt, but it carries an oblong hole, and before screwing up the nut, we make the piece advance or recede, till the fulcrum point comes exactly into the plane of the web. This condition being fulfilled, we have merely to attach the frame to the angle f of the parallelogram, which is done by means of the piece F″.

It is now obvious that if the embroiderer takes the handle B″ in his hand and makes the pantograph move in any direction whatever, the point f will describe a figure similar to the figure described by the point c, and six times smaller, but the point f cannot move without the frame, and whatever is upon it, moving also. Thus in the movement of the pantograph, every point of the web describes a figure equal to that described by the point f, and consequently similar to that described by the point c, but six times smaller; the embroidered object being produced upon the cloth in the position of that of the pattern. It is sufficient therefore to give the embroidering operative who holds the handle B″ a design six times greater than that to be executed by the machine, and to afford him at the same time a sure and easy means of tracing over with the point c, all the outlines of the pattern. For this purpose he adapts to c, perpendicularly to the plane of the parallelogram, a small style terminated by a point c', and he fixes the pattern upon a vertical tablet E, parallel to the plane of the stuff and the parallelogram, and distant from it only by the length of the style $c\,c''$; this tablet is carried by the iron rod e', which is secured to a cast-iron foot E′, serving also for other purposes, as we shall presently see. The frame, loaded with its beams and its cloth, forms a pretty heavy mass, and as it must not swerve from its plane, it needs to be lightened, in order that the operative may cause the point of the pantograph to pass along the tablet without straining or uncertainty in its movements. M. Heilmann has accomplished these objects in the following way. A cord e attached to the side $b\,c$ of the pantograph passes over a return pulley, and carries at its extremity a weight which may be graduated at pleasure; this weight equipoises the pantograph, and tends slightly to raise the frame. The lower side of the frame carries two rods H and H, each attached by two arms $h\,h$, a little bent to the left; both of these are engaged in the grooves of a pulley. Through this mechanism a pressure can be exercised upon the frame from below upwards which may be regulated at pleasure, and without preventing the frame from moving in all directions, it hinders it from deviating from the primitive plane to which the pantograph was adjusted. The length of the rods H ought to be equal to the amount of the lateral movement of the frame. Two guides $i\,i$, carried by two legs of cast iron, present vertical slits in which the lower part of the frame F′ is engaged.

3. *Disposition of the carriages.*—The two carriages, which are similar, are placed the one to the right, and the other to the left of the frame. The carriage itself is composed merely of a long hollow cylinder of cast iron L, carrying at either end a system of two grooved castors or pulleys L′, which roll upon the horizontal rails K; the pulleys are mounted upon a forked piece l', with two ends to receive the axes of the pulleys, and the piece l' is itself bolted to a projecting car l cast upon the cylinder.

This assemblage constitutes, properly speaking, the carriage, resting in a perfectly stable equilibrium upon the rails K, upon which it may be most easily moved backwards and forwards, carrying its train of needles to be passed or drawn through the cloth.

M. Heilmann has contrived a mechanism by which the operative without budging from his place, may conduct the carriages, and regulate as he pleases the extent of their course, as well as the rapidity of their movements. By turning the axes M″ in the one direction or the other, the carriage may be made to approach to, or recede from the web.

When one of the carriages has advanced to prick the needles into the stuff, the other is there to receive them; it lays hold of them with its pincers, pulls them through, performs its course by withdrawing to stretch the thread, and close the stitch, then it goes back with the needles to make its pricks in return. During these movements, the first carriage remains at its post waiting the return of the second. Thus the two chariots make in succession an advance and a return, but they never move together.

To effect these movements M. Heilmann has attached to the piece O′ made fast to the two uprights A C and A D of the frame, a bent lever *n o n′ n″*, moveable round the point *o*; the bend *n′* carries a toothed wheel O′, and the extremity *n″* a toothed wheel O″; the four wheels M, M′, O′, and O″, have the same number of teeth and the same diameter; the two wheels O′ and O″ are fixed in reference to each other, so that it is sufficient to turn the handle N to make the wheel O″ revolve, and consequently the wheel O′; when the lever *n o* is vertical, the wheel O′ touches neither the wheel M nor the wheel M′; but if it be inclined to the one side or the other, it brings the wheel O′ alternately into gear with the wheel M or the wheel M′. As the operative has his two hands occupied, the one with the pantograph, and the other with the handle of impulsion, he has merely his feet for acting upon the lever *n o*, and as he has many other things to do, M. Heilmann has adapted before him a system of two pedals, by which he executes with his feet a series of operations no less delicate than those which he executes with his hands.

The pedals P are moveable round the axis *p*, and carry cords *p′* wound in an opposite direction upon the pulleys P′; these pulleys are fixed upon a moveable shaft P″ supported upon one side by the prop E′, and on the other in a piece K attached to the two great uprights of the frame. In depressing the pedal P (now raised in the figure), the upper part of the shaft P″ will turn from the left to the right, and the lever *n o* will become inclined so as to carry the wheel O′ upon the wheel M′, but at the same time the pedal which is now depressed will be raised, because its cord will be forced to wind itself upon its pulley, as much as the other cord has unwound itself; and thus the apparatus will be ready to act in the opposite direction when wanted.

4. *Disposition of the pincers.*—The shaft L′ carries, at regular intervals of a semi-diameter, the appendages *q q* cast upon it, upon which are fixed, by two bolts, the curved branches Q destined to bear the whole mechanism of the pincers. When the pincers are opened by their appropriate leverage, and the half of the needle, which is pointed at each end, with the eye in the middle, enters the opening of its plate, it gets lodged in an angular groove, which is less deep than the needle is thick, so that when the pincers are closed, the upper jaw presses it into the groove. In this way the needle is firmly held, although touched in only three points of its circumference.

Suppose now, that all the pincers are mounted and adjusted at their proper distances upon their prismatic bar, forming the upper range of the right carriage. For opening all the pincers there is a long plate of iron, U, capable of turning upon its axis, and which extends from the one end of the carriage to the other. This axis is carried by a kind of forks which are bolted to the extremity of the branches Q. By turning that axis the workman can open the pincers at pleasure, and they are again closed by springs. This movement is performed by his feet acting upon the pedals.

The threads get stretched in proportion as the carriage is run out, but as this tension has no elastic play, inconveniences might ensue, which are prevented by adapting to the carriage a mechanism by means of which all the threads are pressed at the same time by a weight susceptible of graduation. A little beneath the prismatic bar, which carries the pincers, we see in the figure a shaft Y, going from one end of the carriage to the other, and even a little beyond it; this shaft is carried by pieces *y* which are fixed to the arms Q, and in which it can turn. At its left end it carries two small bars *y′* and *w′*, and at its right a single bar *y′*, and a counterweight (not visible in this view); the ends of the two bars *y′* are joined by an iron wire, somewhat stout and perfectly straight. When the carriage approaches the web, and before the iron wire can touch it, the little bar *w* presses against a pin *w′*, which rests upon it, and tends to raise it more and more. In what has preceded we have kept in view only the upper range of pincers and needles, but there is an inferior range quite similar, as the figure shows, at the lower ends of the arms Q. In conclusion, it should be stated, that the operative does not follow slidingly with the pantograph the trace of the design which is upon the tablet or the picture, but he must stop the point of the style upon the point of the pattern into which the needle should enter, then remove it, and put it down again upon the point by which the needle ought to re-enter in coming from the other side of the piece, and so on in succession. To facilitate this kind of reading off, the pattern upon the tablet is composed of right lines terminated by the points for the entrance and return of the needle, so that the operative (usually a child) has continually under her eyes the series of broken lines which must be followed by the pantograph. If she happens to quit this path an instant, without having left a mark of the point at which she had arrived, she is under the necessity of looking at the piece to see what has been already embroidered, and to find by this comparison the point at which she must resume her work, so as not to leave a blank, or to repeat the same stitch.

Explanation of Figure.

A, lower cross bars, which unite the legs of the two ends of the frame.

a, the six feet of the front end of the frame.

a′, the six feet of the posterior end of the frame.

a″, curved pieces which unite the cross bars A″ to the uprights.

B″, handle of the pantograph.

b, *b*′, *b*″, three angles of the pantograph.

c, point of the side *b b*″ on which the point is fixed.

C″, point of the pantograph.

D″, cross bar in form of a gutter, which unites the upper parts of the frame.

d, fixed point, round which the pantograph turns.

E, tablet upon which the pattern to be embroidered is put.

E′, support of that tablet.

e, cord attached at one end to the side *b c* of the pantograph passing over a guide pulley, and carrying a weight at the other end.

e′, iron rod by which the tablet E is joined to its support E′.

F, F, uprights of the cloth-carrying frame.

F′, F′, horizontal sides of the same frame.

G, four roll beams.

G″, the piece of cloth.

g″, the strings, which serve to stretch the cloth laterally.

This machine has not been applied for embroidering nets or muslins, as these fabrics are not sufficiently close to hold the needles; it has been hitherto used for embroidering cloth for vests and other purposes, and silk for ladies' dresses. We learn, however, that some very satisfactory experiments have been made by the Messrs. Houldsworth of Manchester, which promise to lead to the successful application of these machines to the finer description of fabrics.

EMERALD. (*Émeraude*, Fr.; *Smaragd*, Ger.) A precious stone of a pure green colour, ranking in value next to the oriental ruby and sapphire. Although susceptible of a fine polish, its hardness is considerably inferior to that of most other gems, being indeed but little higher than that of quartz. Its specific gravity is also remarkably low, not exceeding 2·75. The mineral occurs crystallised in regular six-sided prisms, more or less modified on the edges and angles, and offering a tolerably easy cleavage parallel to the basal plane. Heated before the blowpipe it loses its transparency, and at a higher temperature fuses to a vesicular glass; whilst with borax it forms a transparent bead of a fine green colour. It is quite unaffected by acids.

The chemical composition of the emerald, and its relation to the beryl and aquamarine, were first determined, in 1797, by Vauquelin, whose analyses showed it to be a silicate of alumina, combined with a silicate of a peculiar earth, called glucina or beryllia. The most recent analyses of the typical emerald from Muzo, are those by M. Lewy, of which the following is the mean:—

Silica	67·9
Alumina	17·9
Glucina	12·4
Magnesia	0·9
Soda	0·7

Slight traces of sesquioxide of chromium are included in this analysis, but, according to Vauquelin's experiments, the amount of this chromic oxide may rise as high as 3·5 per cent.

Since this oxide is well known to communicate a fine green tint to glass, the colour of the emerald was naturally referred to its presence; but this opinion was contradicted a few years ago by M. Lewy, who maintained that the extremely minute trace of chromic oxide which he found in the emerald would be utterly inadequate to produce the intense green colour: moreover, according to his researches, the gem entirely loses its colour at a dull red heat, whilst those minerals that are truly coloured by chromium are unaffected in this respect by temperature. In his experiments the loss on ignition amounted to nearly 2 per cent., of which 0·12 consisted of a hydrocarbon, derived probably from the associated organic remains; and since the amount of this hydrocarbon was found to be greatest in those stones that possess the deepest colour, Lewy was induced to regard this organic compound as the true colouring agent in the gem; comparing it with chlorophyll, or the green colouring matter of plants, a compound well known to possess intense tinctorial power.

Soon after its announcement, this opinion was called in question by the experiments of Hofmeister on the Salzburg emerald; and it was further controverted by the researches of Wöhler and Gustav Rose on the emerald of Muzo. The latter chemists showed not only that the colour of the emerald is unaffected by ignition, but also that the amount of chromic oxide present in a given emerald is quite competent to impart an intense green colour to a quantity of glass equal to that of the mineral from which the oxide was derived. The subsequent researches of Boussingault also confirmed the opinion that the emerald is coloured by oxide of chromium; and the yet more recent investigations of Dr. Greville Williams lead to the same conclusion. The latter chemist has found that certain colourless beryls may contain as large a proportion of carbon as is to be found in the richest-tinted emeralds, and that the Muzo emerald may bear a bright red heat without loss of colour. He also finds that on fusing the emerald an opalescent green glass is first formed, but that this, on prolonged heating, becomes transparent and almost colourless. The density and hardness of the emerald are diminished by fusion.

Dr. Greville Williams's experiments are of so much interest that we give his own account of them:—

'I have carefully repeated and extended those experiments (those of Hofmeister). The emeralds employed were *cañutillos* (finely-crystallised emeralds) from Santa Fé de Bogotà. The following values were obtained in a determination of their specific gravities before fusion:—

No. of Experiment	W.	W′.	*t.*	*st.*	D.
1	4·4964	2·8293	16·5°	·998921	2·69
2	4·4961	2·8294	17·0°	·998841	2·69
3	1·6655	1·0486	16·0°	·999002	2·70

The formula used was:—

$$D = st\,\frac{W}{W - W'}.$$

W is the weight in air; W′ the weight in water; *st* the specific gravity of water at *t*°; *t* the temperature of the water; D the specific gravity.

'One of the above emeralds was exposed for three hours in a platinum crucible to a bright reddish-yellow heat. At the end of the operation it was opaque at the edges, but the green colour was not destroyed. This experiment completely confirms those of Wöhler and Rose, and Hofmeister. It is, I think, quite evident that no organic colouring matter could withstand such a temperature for so long a time.

'The announcement by Lewy, that the depth of colour of emeralds is in proportion to the amount of carbon present, made it appear improbable that beryls contained that element. The power of this colouring matter to resist a red heat having, however, made me inclined to disconnect the question of colour from that of the presence of carbon, I made experiments to determine whether beryls contained that element, and, if so, to what amount.

'An experiment made at this stage of the enquiry showed that the beryl analysed contained the same amount of carbon as Lewy's emerald. To settle the question definitely, as to the presence of carbonic anhydride, I burnt 1·2 grm. of beryl in a platinum boat in a current of oxygen. The water produced was absorbed by sulphuric acid; the carbonic anhydride was received in a Geissler's potash tube containing lime-water. Carefully-purified oxygen was allowed to stream through the lime-water to prove its freedom from carbonic anhydride. The beryl was then heated to redness in the stream of gas, and in a few seconds the lime-water became milky; thus not only proving the presence of carbon in a colourless beryl, but, taken in conjunction with the quantitative determination, showing conclusively that the depth of colour is not, in this class of stones, in the ratio of the amount of carbon present.

'But it was still possible that the carbon might have been derived from the decomposition of a carbonate in the beryl. To settle this question, I arranged an apparatus in which, in a current of pure air passing through lime-water, a finely-levigated beryl was boiled with dilute sulphuric acid. No carbonic anhydride was evolved. It was, therefore, evident that the carbon found in the beryl did not proceed from the decomposition of a carbonate.

'Five milligrammes of charcoal treated in the same way, produced a milkiness in all the lime-water bulbs in four minutes. In another experiment, after the usual precautions, 53 milligrammes of graphite were acted on. In four minutes the first bulb, in eight minutes the whole of the bulbs, were rendered milky.

'The above experiments show, therefore, that the beryl (experiment on one which was from Ireland) contains carbon, not in the state of a carbonate, but in a condition which is more slowly attacked than either free charcoal or graphite; and it is, I think, probably in the form of diamond, as has been shown to occur with the water contained in artificially-crystallised boron.

'The presence of carbon in beryls does not appear to be invariable. After repeated experiments upon another large beryl from Haddam County, North America, I was unable to satisfy myself that it contained carbon. It is true there were traces found in the experiment, but they were so minute that they might have been due to organic dust accidentally present.

'The next point I wished to ascertain was the relation borne by the quantity of carbon in the Irish beryl, to that in the emerald. Minute precautions were necessary, since 1 grm. of the beryl or emerald only yielded 3 milligrammes of carbonic anhydride.

Experiment 1.	0·9725 grm.	beryl gave	0·0030	CO^2	and	0·0131	H^2O
„ 2.	1·0082 „	„ „	0·0031	„		0·0174	„
„ 3.	1·1690 „	emerald	0·0030	„		0·0140	„

Expressed per cent.:—

	Irish Beryl		Emerald	Lewy's Emerald (Mean.)
	I.	II.		
Carbonic anhydride	0·31	0·31	0·26	0·28
Water	1·32	1·73	1·20	1·89.'

Among the ancients the emerald was very highly esteemed, being ranked by Pliny next to the diamond and pearl. During the middle ages it maintained a very high position; but on the discovery of the Peruvian mines, in the middle of the sixteenth century, it suffered a sudden reduction in value, from which it has never entirely recovered. A stone of 4 grains' weight is said to be worth from 4*l.* to 5*l.*; one of 8 grains, 10*l.*; one of 15 grains, being fine, is worth 60*l.*; one of 24 grains fetched, at the sale of M. de Drée's cabinet, 2,400 francs, or nearly 100*l.*

From the descriptions of the *smaragdos*, or emerald of the ancients, it is evident that they confounded under this name a number of green minerals differing widely from each other in general characters; such, for example, as malachite, chrysoprase, green fluor-spar, amazon-stone, and even green glass. The true emeralds of the ancients were probably in great part derived from Mount Zabara, in Upper Egypt, where the old workings were discovered some years back by the French traveller M. Cailloud, and were re-opened by Mohammed Ali; but the emeralds obtained being only of poor quality, the operations were soon suspended.

For many years past, the emerald has been obtained almost exclusively from the famous mine of Muzo, a large open excavation on the eastern cordillera of the Andes, 75 miles N.N.W. of Santa Fé de Bogotà. It there occurs, associated with crystals of iron pyrites and the rare mineral parasite, in veins of calcareous spar traversing a black bituminous limestone, containing ammonites and other fossils, apparently of lower cretaceous age. When first removed from the rock, the emeralds are excessively fragile; and numbers of them crack spontaneously, in spite of careful protection from the sun. The emeralds are indeed so rarely free from flaws that they are often imitated in fictitious gems.

The Muzo mines were leased, in 1864, to a French Company, in consideration of an annual payment to the Government of Columbia of about 3,000*l.* The workings are conducted under the direction of M. Lehmann, and the emeralds which are obtained are sent direct to Paris. The present agreement expires this year—1874—and it is understood that it will not be renewed.

A fine crystal of Muzo emerald, 2 inches long, exhibited in the Great Exhibition of 1851, is now in the cabinet of the Duke of Devonshire; it measures across its three diameters 2¼ in., 2⅕ in. 1⅞in., and weighs 8 oz. 18 dwts.: owing to flaws, it is but partially fit for jewellery.

Emeralds of less beauty, but larger than the South American gems, occur in Siberia. One specimen in the Imperial Russian collection measures 14½ inches long and 12 broad, and weighs 16¾ lbs. troy; another is 7 inches long and 4 inches broad, and weighs 6 lbs. troy. The Siberian emerald occurs near Ekaterinburg, embedded in mica-slate. A similar rock forms the matrix of the emerald found in the Habachthal, in Salzburg. From this locality some interesting specimens were exhibited in the Austrian Department of the International Exhibition of 1862. These were stated to be found in a steep cliff, at an altitude of 8,700 feet. Masses of rock containing emeralds having fallen into the neighbouring valley, this locality was discovered, and it is now worked by the possessor, S. Goldschmidt of Vienna.

The *Oriental Emerald* is an Indian Stone, entirely distinct from the common emerald described in this article; it is, indeed, a green transparent variety of corundum, differing, therefore, from the sapphire and ruby only in colour. From its extreme rarity, and its great hardness, the oriental stone is very highly prized, although far inferior in point of colour to the common emerald.

EMERALD COPPER. Dioptase, a hydrous silicate of copper See Copper.

EMERALD GREEN. Scheele's arsenical green. See Copper.

EMERALD NICKEL. A native hydrocarbonate of nickel. See Nickel.

EMERALDINE. See Aniline Green.

EMERY (*Émeri*, Fr.; *Schmergel*, Ger.). This mineral was long regarded as an ore of iron, and was called by Haüy, *fer oxide quartzifère*. It is, however, a massive granular, or compact variety of corundum, more or less impure. It is very abundant in the island of Naxos, at Cape *Emeri*, whence its name. From this place it is imported in large quantities. It is said to be found in Jersey; it occurs, though rare, in Spain, Poland, Saxony, Sweden, Persia, and a few other places. Its colour varies from red brown to dark brown: its specific gravity is about 4; it is so hard as to scratch quartz and many precious stones.

We have accounts of emery discoveries in the United States, but nearly all that is used at present in the arts comes from Turkey, near ancient Smyrna. Dr. Lawrence Smith, an American geologist, made a discovery of a deposit of emery while residing in Smyrna, and he made an examination of the locality in 1847. Dr. Smith having reported his discoveries to the Turkish Government, a commission of enquiry was instituted, and the business soon assumed a mercantile form. The monopoly of the emery of Turkey was sold to a mercantile house in Smyrna, and since then the price has diminished in the market.

The following analyses are quoted by Dana, from an elaborate paper by J. Lawrence Smith, in the 'American Journal of Science':—

	Hardness, Sapphire being 100	Specific Gravity	Alumina	Peroxide of iron	Lime	Silica	Water
Kulah . . .	57	4·28	63·50	33·25	0·92	1·61	1·90
Samos . . .	56	3·98	70·10	22·21	0·62	4·00	2·10
Nicaria . . .	55	3·75	71·06	20·32	1·40	4·12	2·53
Kulah . . .	53	4·02	63·00	30·12	0·50	2·36	3·36
Gumuch . .	47	3·82	77·82	8·62	1·80	8·13	3·11
Naxos . . .	46	3·75	68·53	24·10	0·86	3·10	4·72
Nicaria . . .	46	3·74	75·12	13·06	0·72	6·88	3·10
Gumuch . .	42	4·31	60·10	33·20	0·48	1·80	5·62
Kulah . . .	40	3·89	61·05	27·15	1·30	9·63	2·00

Valuable deposits of corundum, a purer form of alumina than emery, have recently been discovered in the United States. The following description of the Corundum of North Carolina, Georgia, and Montana, is by Mr. J. Lawrence Smith:—

'The corundum formations in North Carolina and Georgia are the second in importance in the United States that have been brought to my notice; and the one in North Carolina is by far the most interesting in this country, and perhaps of any yet known, in the extent of the formation, the distribution of the corundum, and the purity of the mineral.

'This mineral was first discovered in North Carolina in 1846—about the time I was engaged in developing the geology of emery in Asia Minor and the Grecian Archipelago; and upon communicating to American geologists my discoveries in relation to the associate-minerals of the emery in Asia Minor, and directing them to search for the same in connection with the corundum found in different parts of America, the same associates were discovered in connection with the North Carolina corundum as well as that from other localities.

'At this time there had been discovered but one detached block, but no other specimen could be found in that locality. There the matter rested until 1865, when Mr. C. D. Smith (to whom I am indebted for valuable information contained in this paper), assistant of Professor Emmons, geologist of North Carolina, had brought to him by one of the inhabitants of the country west of the Blue Ridge Mountains a specimen of rock which was recognised as being corundum, and on visiting the spot this geologist discovered the corundum *in situ*, and a number of specimens were collected. Since that time public interest has increased in relation to this substance, and it has been discovered in such quantities as to make it an object of interest to the arts as a substitute for emery, and very rapidly other localities were brought to light along a distance of forty miles.

'The colours of the corundum as found along this zone of outcrops are blue, grey, pink, ruby, and white. Sometimes it has broad cleavage faces, and then again it occurs in hexagonal prisms. One hexagonal prism weighed over three hundred pounds. There is a difference in the cleavage and the associate-minerals at different localities.

'In the development in North Carolina the corundum occurs in chrysolite or serpentine rocks, and outside of serpentine it has not been found. These chrysolite rocks belong to a regular system of dykes, which have been traversed for the distance of about one hundred and ninety miles. This system of dykes lies on the north-west side of the Blue Ridge, and has a strike parallel to the main mass of the ridge, and has an average distance from the summit of the ridge of about ten miles. It continues this strike to the head of the Little Tennessee River, say from Mitchell to Macon County, one hundred and thirty miles. Here the ridge curves around the head of the Tennessee, and falls back about ten miles to the north-west. In conformity with this elbow in the ridge, the disturbing force shifts to the north-west and re-appears at Buck's Creek, having the same relative position to the Blue Ridge.

'The serpentine appears at intervals along this whole line of one hundred and ninety miles. There is a corresponding system of dykes traversing the southern slope of the Blue Ridge, but not so regular and compact as the system on this north-west side, nor are the outcrops so frequent. The main mass of the ridge bears no evidence of having been disturbed at all, at least none has been found. From Mitchell County to Macon the serpentine is usually enclosed in a hard crystalline gneiss, which bears rose-coloured garnets, cyanite, and pyrite. After its shifting to the right it occurs in hornblendic beds and gneiss. At Buck Creek and thence south-westward the hornblende beds assume very large proportions, and instead of common felspar have in them albite, making an albitic syenite. At Buck Creek (which is named Cullakenih) the chrysolite covers an area of about three hundred and fifty acres. One or two observers have fallen into the error of confounding the two dyke systems, whereas they have no connection whatever. According to them the northern system cuts through the Blue Ridge at right angles, and then turns back on the opposite side of the ridge. Now there are no such phenomena connected with these outcrops. They evidently belong to separate systems. The outcrops along the northern system occur at intervals ranging from one to fifteen miles. The belt or zone along which these outcrops occur never exceeds four miles in width on the northern side of the ridge. On the opposite side the system is not so well defined, and the outcrops are rarer.

'Upon these serpentine beds there exist chalcedony, chromite on some of them, chlorite, talc, steatite, anthophyllite, tourmaline, emerylite, epidote on some of them, zoisite, and albite, with occasionally asbestus and picrolite, as also actinolite and tremolite. The corundum at some places seems to occur mostly in ripidolite in fissures of the serpentine. At Cullakenih the corundum with its immediate associates is in chlorite, except the red variety, which is in zoisite, containing a minute quantity of chrome.

'Throughout all the range of rocks for the great extent referred to, corundum forms a geognostic mark of this chrysolite rock, just as it does of the calcareous rock bearing corundum described by me in Asia Minor. They belong to the same geological epoch, and overlie the gneiss.

'The closest investigation shows that the chrysolite in North Carolina takes the place of calc-rock in Asia Minor; that these are invariably the gangue-rock in the two different quarters of the globe; but as remarked above, the contiguous rock shows them both to be of the same geological period, overlying directly the primary rocks; and both of them are also identical geologically with the Chester emery-formation of Massachusetts.

'While all the localities of corundum and emery I have examined exhibit certain marked and prominent characteristics common to them all, and evince unmistakeable evidence of geological identity, yet each locality has its peculiar characteristics. In all cases, however, the masses of corundum give evidence of having been formed by a process of segregation, as described in my memoir on the Asia Minor emery.

'In Asia Minor the Gumuch-dagh emery has but little black tourmaline associated with it, and instead chloritoid in crystals or lamellæ; also its disapore is rare, but when found is prismatic, affording the finest perfect crystals yet seen, from which M. Dufrénoy made his last study of the crystallography of this mineral; and the emery is associated with calcareous rock overlying gneiss. The Kulah emery from the same part of the world is equally in calcareous rock, and has very little chloritoid or chloritic mineral associated with it.

'The Naxos and Nicaria emery of the Grecian Archipelago is also in connection with calcareous rock, but has no chloritoid associated with it, but in its place black tourmaline is abundant.

'While in the above localities the rock bearing the corundum is calcareous, that in Chester, Mass., has hornblendic gneiss immediately on one side of the vein, and is accompanied with a large amount of magnetic oxide of iron. Tourmaline also abounds in this corundum, and, like the Asiatic variety, it contains rutile, ilmenite, &c.'

The mining of emery in the East is of the simplest character. The natural decomposition of the rock in which it occurs facilitates its extraction. The rock decomposes into an earth, in which the emery is found imbedded. The quantity procured under these circumstances is so great that it is rarely necessary to explore the rock. The earth in the neighbourhood of the block is almost always of a red colour, and serves as an indication to those who are in search of the mineral. Sometimes, before beginning to excavate, the spots are sounded by an iron rod with a steel point, and when any resistance is met with, the rod is rubbed in contact with the resisting body, and the effect produced on the point enables a practised eye to decide whether it has been done by emery or not. The blocks which are of a convenient size are transported in their natural state, but they are frequently broken by large hammers; when they resist the action of the hammer they are subjected to the action of fire for several hours, and on cooling they most commonly yield to blows. It sometimes happens that large masses are abandoned, from the impossibility of breaking them into pieces of a convenient size, as the transportation, either on camels or horses, requires that the pieces shall not exceed 100 lbs. each in weight.

When reduced to a powder, emery varies in colour from dark grey to black. The colour of its powder affords no indication of its commercial value. The powder, examined under the microscope, shows the distinct existence of two minerals, corundum and oxide of iron. Emery, when moistened, always affords a very strong argillaceous odour. Its hardness is its most important property in its application to the arts, and was ascertained by Mr. Smith in the following manner:—Fragments were broken from the piece to be examined, and crushed in a diamond mortar with two or three blows of a hammer, then thrown into a sieve with 400 holes to the inch. The powder is then weighed, and the hardness tested with a circular piece of glass, about four inches in diameter, and a small agate mortar. The glass is first weighed, and placed on a piece of glazed paper; the pulverised emery is then thrown upon it at intervals, rubbing it against the glass with the bottom of the agate mortar. The emery is brushed off the glass from time to time with a feather, and when all the emery has been made to pass once over the glass, it is collected, and passed through the same operation three or four times. The glass is then weighed, again subjected to the same operation, the emery by this time being reduced to an impalpable powder. This series of operations is continued until the loss sustained by the glass is exceedingly small. The total loss in the glass is then noted, and when all the specimens of emery are submitted to this operation under the same circumstances, an exact idea of their relative hardness is obtained. The advantages of using glass and agate are, that the latter is sufficiently hard to crush the emery, and in a certain space of time to reduce it to such an impalpable state that it has no longer any sensible effect on the glass; and, on the other hand, the glass is soft enough to lose during this time sufficient of its substance to allow of accurate comparative results. By this method, the best emery was found capable of wearing away about half of its weight of common French window-glass.

In the ordinary process, the lumps of emery ore are broken up in the same manner as stone is for repairing macadamised roads, and into lumps of similar size. These lumps are then crushed under stampers, such as are used for pounding metallic ores, driven by water- or by steam-power. It is supposed that the stampers leave the fragments more angular than they would be if they were ground under runners, a mode which is sometimes employed. The coarse powder is then sifted through sieves of wire-cloth, which are generally cylindrical, like the bolting cylinders of corn-mills; but the sieves are covered with wire-cloth, which vary from ninety to sixteen wires to the inch. No. 16 sieve gives emery of about the size of mustard-seed; and coarser fragments, extending nearly to the size of pepper-corns, are also occasionally prepared for the use of engineers. The sieves have sometimes as many as 120 wires in the inch; but the very fine sizes of emery are most commonly sifted through lawn sieves.

The finest emery that is obtained from the manufacturers is that which floats in the atmosphere of the stamping-room, and is deposited on the beams and shelves, from which it is occasionally collected. The manufacturers rarely or never wash the emery; this is mostly done by the glass-workers, and such others as require a greater degree of precision than can be obtained by sifting.

The following table shows the number of wires usually contained in the sieves, and the names of the kinds respectively produced by them:—

	Wires.
Corn emery	16
Coarse grinding emery	24
Grinding emery	36
Fine grinding emery	46
Superfine grinding emery	53
Coarse flour emery	60
Flour emery	70
Fine flour emery	80
Superfine flour emery	90

Washing emery by hand is far too tedious for those who require very large quantities of emery, such as the manufacturers of plate glass and some others, who generally adopt the following method:—Twelve or more cylinders of sheet copper, of the common height of about two feet, and varying from about three, five, eight, to thirty or forty inches in diameter, are placed exactly level, and communicating at their upper edges, each with the next, by small troughs or channels; the largest vessel has also a waste-pipe near the top. At the commencement of the process, the cylinders are all filled to the brim with clean water; the pulverised emery is then churned up with abundance of water in another vessel, and allowed to run into the smallest or the three-inch cylinder, through a tube opposite the gutter leading to the second cylinder. The water during its short passage across the three-inch cylinder, deposits in that vessel such of the coarsest emery as will not bear suspension for that limited time; the particles next finer are deposited in the five-inch cylinder, during the somewhat longer time the mixed stream takes in passing the brim of that vessel; and so on. Eventually the water forms a very languid eddy in the largest cylinder, and deposits therein the very fine particles that have remained in suspension until this period; and the water, lastly, escapes by the waste-pipe nearly or entirely free from emery. In this simple arrangement, time is also the measure of the particles respectively deposited in the manufacture to which the emery is applied. When the vessels are to a certain degree filled with emery, the process is stopped, the vessels are emptied, the emery is carefully dried and laid by, and the process is recommenced.

Holtzapffel informs us that he has been in the habit, for many years, of employing emery of twelve degrees of fineness, prepared by himself by washing over.

For optical purposes, Mr. Ross mixes four pounds of the flour of emery of commerce, with one ounce of powdered gum-arabic, and then throws the powder into two gallons of clear water; and he collects the deposit at the end of 10″ and 30″, and 2′, 10′, 20′, and 60′, and that which is not deposited by one hour's subsidence is thrown away as useless for grinding lenses.

Emery paper is prepared by brushing the paper over with thin glue, and dusting the emery-powder over it from a sieve. There are about six degrees of coarseness. Sieves with thirty and ninety meshes per linear inch are in general the coarsest and finest sizes employed. When used by artisans, the emery-paper is commonly wrapped round a file or a slip of wood, and applied just like a file, with or without oil, according to circumstances. The emery-paper cuts more smoothly with oil, but leaves the work dull.

Emery-cloth only differs from emery-paper in the use of thin cotton cloth, instead of paper, as the material upon which the emery is fixed by means of glue. The emery-cloth, when folded around a file, does not ply so readily to it as emery-paper, and is apt to unroll. Hence smiths, engineers, and others, prefer emery-paper and emery-sticks; but for household and other purposes, where the hand alone is used, the greater durability of the cloth is advantageous.

Emery-sticks are rods of board about eight or twelve inches long, planed up square; or with one side rounded like a half-round file. Nails are driven into each end of the stick as temporary handles; they are then brushed over, one at a time, with thin glue, and dabbed at all parts in a heap of emery-powder, and knocked on one end to shake off the excess. Two coats of glue and emery are generally used. The emery-sticks are much more economical than emery-paper wrapped on a file, which is liable to be torn.

Emery-cake consists of emery mixed with a little bees'-wax, so as to constitute a solid lump, with which to dress the edges of buff and glaze wheels. The ingredients should be thoroughly incorporated by stirring the mixture whilst fluid, after which it is frequently poured into water, and thoroughly kneaded with the hands, and rolled into lumps before it has time to cool. The emery-cake is sometimes applied to the wheels whilst they are revolving; but the more usual course is, to stop the wheel and rub in the emery-cake by hand. It is afterwards smoothed down by the thumb.

Emery-paper, or patent razor-strop paper, is an article in which fine emery and glass are mixed with paper-pulp, and made into sheets as in making ordinary paper; the emery and glass are said to constitute together 60 per cent. of the weight of the paper, which resembles drawing-paper, except that it has a delicate fawn colour. The emery-paper is directed to be pasted or glued upon a piece of wood, and when rubbed with a little oil, to be used as a razor-strop.

In 1842, Mr. Henry Barclay took out a patent for a method of combining powdered emery into *discs* and *laps* of different kinds, suitable to grinding, cutting, and polishing glass, enamels, metals, and other hard substances. The process of manufacture is as follows:—Coarse emery-powder is mixed with about half its weight of pulverised Stourbridge loam and a little water or other liquid, to make a thick paste; this is pressed into a metallic mould by means of a screw-press, and after having been thoroughly dried, is baked or burned in a muffle or close receiver at a temperature considerably above a red heat and below the full white heat. In this case, the clay or alumina serves as a bond, and unites the particles very completely into a solid artificial emery-stone, which cuts very greedily, and yet seems hardly to suffer perceptible wear.

Superfine grinding-emery is formed into wheels exactly in the same manner as the above, but the proportion of loam is then only one-fourth instead of one-half that of the emery. Those emery-stones, which are of medium fineness, cut less quickly, but more smoothly than the above.

Flour-emery, when manufactured into artificial polishing stones, requires no uniting substance, the moistened powder is forced into the metal mould and fired; some portions of the alumina being sufficient to unite the whole. These fine wheels render the works submitted to them exceedingly smooth, but they do not produce a high polish on account of the comparative coarseness of the flour-emery.

A similar method has been adopted by Mr. F. Ransome—at the suggestion, we believe, of Mr. Bessemer—for the production of emery wheels, by a process similar to that employed for the production of artificial stone by the use of silicate of potash, as a cementing material for the finely-divided emery.

Under the name of 'metalline,' Messrs. Bond, Russell, and Fisher, of Newport, Monmouthshire, patented a preparation of blast-furnace slag, which they proposed to introduce as a substitute for emery. See CORUNDUM.

EMERYLITE. A micaceous mineral associated with the emery of Asia Minor. It is identical with *margarite.*

EMETINE. An organic bark obtained from the ipecacuanha root.

EMPATAGE. A French term for the combination of an alkali with the fatty acids.

EMPLECTITE. An ore of bismuth, called also *Tannenite.* See BISMUTH.

EMPYREAL AIR. The name given to oxygen gas shortly after its first discovery. Scheele, in his 'Experiments on Air and Fire,' says:—'Since this air (oxygen) is absolutely necessary for the generation of fire, and makes about one-third of our common air, I shall henceforth for shortness call it *empyreal air* (literally *fire-air*). The air which is unserviceable for the fiery phenomenon, and which makes about two-thirds of common air, I shall for the future call *foul air* (literally *corrupted air*).'—*Chemical Observations and Experiments on Air and Fire.* By Charles William Scheele. Translated by J. R. Forster, LL.D., F.R.S. 1780.

EMPYREUMA. The smell produced by fire applied to organic matters, chiefly vegetable, in close vessels. Thus, empyreumatic vinegar is obtained by distilling wood at a red heat, and empyreumatic oil from many animal substances in the same way.

EMULSIN. The vegetable albumen of the almond. See Watts's 'Dictionary of Chemistry.'

ENAMELS (*Émaux*, Fr.; *Schmelzglas*, Ger.) are varieties of glass, generally opaque or coloured, always formed by the combination of different metallic oxides, to which certain fixed fusible salts are added, such as the borates, fluates, and phosphates.

The ancients carried the art of enamelling to a very high perfection, and we occasionally find beautiful specimens of their work. Then, as at present, each artist made a mystery of the means that succeeded best with him, and thus a multitude of curious processes have been buried with their authors.

The enamel was applied to the metallic ground in several distinct ways, giving rise to very different kinds of enamel-work, which it is desirable to distinguish. In the process called *cloisonné enamelling*, the plan was to braze on to a plain surface of metal, the bars or *cloisons* which were intended to hold the coloured paste which was to be vitrified in the enamel furnace. The vases from China, probably some 500 or 600 years old, are enamelled by the true cloisonné process. After the sacking of the Summer Palace at Peking, large numbers of Chinese cloisonné enamels were brought to Europe, and the English market thus becoming glutted, they sold at prices very much lower than what they would have realised in the East. The cloisonné method was also much used in Mediæval Greek and Byzantine art, and fine examples are to be seen in the celebrated Pala d' Oro, or Altar-front, of the Church of St. Mark at Venice, in the crown of Charlemagne at Vienna, and in the shrine of the Magi at Cologne. Theophilus, who described the cloisonné process in the twelfth century, applied the term *electrum* to these enamels.

A similar yet distinct method is that known as *champ levé enamelling*. Here, instead of fillets of metal being soldered on to the metal ground, the field or ground itself is incised or hollowed out so as to leave the outline of the design in slender elevated bands of metal; the parts which are sunk, or in intaglio, are then filled in with enamel powder, which is vitrified in the furnace, and the surface is finally smoothed down by grinding and polishing. The difference, therefore, between the two processes is this: in the champ levé enamels the metallic fillets, or *cloisons*, forming the partitions between one colour and another, are part of the metallic plate itself, whilst in the cloisonné enamels they are separate bands of metal soldered on to the metallic plate. Champ levé enamels are generally executed in copper; the cloisonné often on gold. The art of champ levé enamelling was extensively practised at Limoges, in France, from the eleventh to the fourteenth century, especially for the decoration of ecclesiastical objects.[1]

Beautiful enamels of modern French workmanship are now produced, in which the enamel colours are surrounded by filigree work obtained by the electrotype process, and many pleasing designs result from the facilities thus afforded of producing this beautiful mixture of metal and enamel—the '*émaux cloisonnés à champ levé*.'

After the champ levé enamelling had long flourished at Limoges, a different and simpler method became popular. This was a method in which the subject was executed in slight relief, by a process of engraving or chasing, and the surface was then encrusted with *translucid* enamels of brilliant colours, through which the design on the subjacent metal was visible. The technicalities of this process were carefully described by Benvenuto Cellini in his 'Trattato dell' Oreficeria.'

Finally, the school of Limoges introduced the method of painting on an enamelled surface. The plate of metal, usually copper, is coated with an opaque white enamel ground, which is fired, and on this ground the design is then painted in enamel colours. All the later Limoges enamels are of this character. The old English enamels made at Battersea and at Bilston in Staffordshire were also produced by this process; snuff-boxes, patch-boxes, tea-caddies, candlesticks, &c., were made of enamelled copper, in the last century, and are now much prized. Modern enamel paintings are also examples of superficial enamelling, but are less popular now than they were some few years ago; the family of Bones for three generations were celebrated as enamel-painters, and Mr. Essex has also obtained reputation in this art. The kind of enamel used as a ground by the artist is known as 'Venetian white hard enamel,' and is composed of silica, borax, and binoxide of tin.

The Venetians are still in possession of the best enamel processes, and they supply the French and other nations with the best kinds of enamel, of every coloured shade.

Enamels are either transparent or opaque; in the former all the elements have experienced an equal degree of liquefaction and are thus run into crystal glass, whilst in the latter, some of their elements have resisted the action of heat, so that their particles prevent the transmission of light. This effect of opacity is produced particularly by the oxide of tin.

The simplest enamel, and the one which serves as a basis to most of the others, is obtained by calcining, first of all, a mixture of lead and tin, in proportions varying from 15 to 50 parts of tin for 100 of lead. The middle term appears to be the most suitable for the greater number of enamels; and this alloy has such an affinity for

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[1] For the history of Enamelling, the reader may refer to Jules Labarte's 'Recherches sur la Peinture en Émail dans l'Antiquité et au Moyen Age.' Paris, 1856.

oxygen, that it may be calcined with the greatest ease in a flat cast-iron pot, and at a temperature not above a cherry red, provided the dose of tin is not too great. The oxide is drawn off to the sides of the melted metal, according as it is generated, new pieces of the alloy being thrown in from time to time, till enough of the powder be obtained. Great care ought to be taken that no metallic particles be left in the oxide, and that the calcining heat be as low as is barely sufficient; for a strong fire frits the powder, and obstructs its subsequent comminution. The powder when cold is ground in a proper mill, levigated with water, and elutriated. In this state of fineness and purity, it is called *calcine* or flux, and it is mixed with siliceous sand and some alkaline matter or sea-salt. The most ordinary proportions are, 4 of sand, 1 of sea-salt, and 4 of *calcine*. Chaptal states, that he has obtained a very fine product from 100 parts of calcine, made by calcining equal parts of lead and tin, 100 parts of ground flint, and 200 parts of pure sub-carbonate of potash. In either case, the mixture is put into a crucible, or laid simply on a stratum of sand, quicklime spontaneously slaked, or wood-ashes placed under a pottery or porcelain kiln. This mass undergoes a semivitrification, or even a complete fusion on its surface. It is this kind of frit which serves as a radical to almost every enamel; and by varying the proportions of the ingredient, more fusible, more opaque, or whiter enamels are obtained. The first of these qualities depends on the quantity of sand or flux, and the other two on that of the tin.

The sea-salt employed as a flux may be replaced either by salt of tartar, by pure potash, or by soda; but each of these fluxes gives peculiar qualities to the enamel.

Most authors who have written on the preparation of enamels, insist a great deal on the necessity of selecting carefully the particular sand that should enter into the composition of the frit, and they even affirm that the purest is not the most suitable. Clouet states, in the 34th volume of the 'Annales de Chimie,' that the sand ought to contain at least 1 part of talc for 3 of siliceous matter, otherwise the enamel obtained is never very glassy, and that some wrinkled spots from imperfect fusion are seen on its surface; and yet we find it prescribed in some old treatises, to make use of ground flints, fritted by means of salt of tartar or some other flux. It would thence appear that the presence of talc is of no use towards the fusibility of the silica, and that its absence may be supplied by increasing the dose of the flux. In all cases, however, we ought to beware of metallic oxides in the sand, particularly those of iron and manganese, which most frequently occur, and always injure the whiteness of the frit.

The frits for enamels that are to be applied to metallic surfaces require greater fusibility, and should therefore contain more flux; and the sand used for these should be calcined beforehand with one-fourth its weight of sea-salt; sometimes, indeed, metallic fluxes are added, as minium or litharge. For some metallic colours, the oxides of lead are very injurious, and in this case recourse must be had to other fluxes. Clouet states that he has derived advantage from the following mixtures, as bases for purples, blues, and some other delicate colours:—

Three parts of siliceous sand, one of chalk, and three of calcined borax; or, three of glass (of broken crystal goblets), one of calcined borax, one-fourth of a part of nitre, and one part of well-washed diaphoretic antimony. These compositions afford a very white enamel, which accords perfectly well with blue.

It is obvious that the composition of this primary matter may be greatly varied: but we should never lose sight of the essential quality of a good enamel; which is, to acquire, at a moderate heat, sufficient fluidity to take a shining surface, without running too thin. It is not complete fusion which is wanted, but a pasty state, of such a degree as may give it, after cooling, the aspect of having suffered complete liquefaction.

Dead-white Enamel.—This requires greater nicety in the choice of its materials than any other enamel, as it must be free from every species of tint, and be perfectly white; hence the frit employed in this case should be itself composed of perfectly pure ingredients. But a frit should not be rejected hastily because it may be somewhat discoloured, since this may depend on two causes; either on some metallic oxides, or on fuliginous particles proceeding from vegetable or animal substances. Now the latter impurities may be easily removed by means of a small quantity of peroxide of manganese, which has the property of readily parting with a portion of its oxygen, and of thus facilitating the combustion, that is to say, the oxidation of the colouring carbonaceous matter. Manganese, indeed, possesses a colouring power itself on glass, but only in its highest state of oxidisement, and when reduced to the lower state, as is done by combustible matters, it no longer communicates colour to the enamel combinations. Hence the proportion of manganese should never be in excess; for the surplus would cause colour. Sometimes, indeed, it becomes necessary to give a little manganese-colour (i.e. a pink tint) in order to obtain a more agreeable shade of white; as a little azure blue is added to linens, to brighten or counteract the dulness of their yellow tint.

A white enamel may be conveniently prepared also with a *calcine* composed of two parts of tin and one of lead calcined together; of this combined oxide, one part is melted with two parts of fine crystal and a very little manganese, all previously ground together. When the fusion is complete, the vitreous matter is to be poured into clear water, and the frit is then dried, and melted anew. The pouring into water and fusion are sometimes repeated four times, in order to secure a very uniform combination. The crucible must be carefully screened from smoke and flame. The smallest portions of oxide of iron or copper admitted into this enamel will destroy its value.

Some practitioners recommend the use of washed diaphoretic antimony (antimoniate of potash, from metallic antimony, and nitre deflagrated together) for white enamel; but this product cannot be added to any preparation of lead or other metallic oxides; for it would tend rather to tarnish the colour than to clear it up; and it can be used therefore only with ordinary glass, or with saline fluxes. For three parts of white glass (without lead) one part of washed diaphoretic antimony is to be taken; the substances are well ground together, and fused in the common way.

Blue Enamel.—This fine colour is almost always obtained from the oxide of cobalt or some of its combinations, and it produces it with such intensity that only a very little can be used, lest the shade should pass into black. The cobalt blue is so rich and lively that it predominates in some measure over every other colour, and masks many so that they can hardly be perceived; it is also most easily obtained. To bring it out, however, in all its beauty, the other colours must be removed as much as possible, and the cobalt itself should be tolerably pure. This metal is associated in the best known ores with a considerable number of foreign substances, as iron, arsenic, copper, nickel, and sulphur, and it is difficult to separate them completely; but for enamel blues, the oxide of cobalt does not require to be perfectly free from all foreign metals; the iron, nickel, and copper being most prejudicial, should be carefully eliminated. This object may be most easily attained by dissolving the ore in nitric acid, evaporating this solution to a syrupy consistence, to expel the excess of acid, and separate a portion of arsenic. It is now diluted with water, and solution of carbonate of soda is dropped slowly into it with brisk agitation, till the precipitate, which is at first of a whitish grey, begins to turn of a rose-red. Whenever this colour appears, the whole must be thrown on a filter, and the liquid which passes through must be treated with more of the carbonate of soda, in order to obtain the arsenate of cobalt, which is nearly pure. Since arsenic acid and its derivatives are not capable of communicating colour themselves, and as they moreover are volatile, they cannot impair the beauty of the blue, and hence this preparation affords it in great perfection.

Metallic fluxes are not the most suitable for this colour; because they always communicate a tint of greater or less force, which never fails to injure the purity of the blue. Nitre is a useful addition, as it keeps the oxide at the maximum of oxidation, in which state it produces the richest colour.

Yellow Enamel.—There are many processes for making this colour in enamel; but it is somewhat difficult to fix, and it is rarely obtained of an uniform and fine tint. It may be produced directly with some preparations of silver, as the phosphate or sulphate; but this method does not always succeed, for too strong a heat or powerful fluxes readily destroy it, and nitre is particularly prejudicial. This uncertainty of success with the salts of silver causes them to be seldom employed; and oxides of lead and antimony are therefore preferred, which afford a fine yellow when combined with some oxides that are refractory enough to prevent their complete vitrification. One part of white oxide of antimony may be taken with from one to three parts of white lead, one of alum, and one of sal-ammoniac. Each of these substances is to be pulverised, and then all are to be exactly mixed, and exposed to a heat adequate to decompose the sal-ammoniac. This operation is judged to be finished when the yellow colour is well brought out. There is produced here a combination quite analogous to that known under the name of Naples yellow.

Other shades of yellow may be procured either with the oxide of lead alone, or by adding to it a little red oxide of iron; the tints varying with the proportion of the latter.

Clouet says, in his 'Memoir on Enamels,' that a fine yellow is obtained with pure oxide of silver, and that it is merely necessary to spread a thin coat of it on the spot to be coloured. The piece is then exposed to a moderate heat, and withdrawn as soon as this has reached the proper point. The thin film of metallic silver revived on the surface being removed, the place under it will be found tinged of a fine yellow, of hardly any thickness. As the pellicle of silver has to be removed which covers the colour, it is requisite to avoid fixing this film with fluxes: and it ought therefore to be applied after the fusion of the rest. The yellows require in general but little alkaline flux, as they answer better with one of a metallic nature.

Green Enamel.—It is known that a green colour may be produced by a mixture of yellow and blue; but recourse is seldom had to this practice for enamels, as they can be obtained almost always directly with the oxide of copper; or, still better, with the oxide of chrome, which has the advantage of resisting a strong heat.

There are two oxides of copper, the suboxide of an orange colour, which communicates its colour to enamels, but it is difficult to fix; the protoxide is blue in the state of hydrate, but blackish-brown when dry, and it colours green all the vitreous combinations into which it enters. This oxide requires, at most one or two proportions of flux, either saline or metallic, to enter into complete fusion; but a much smaller dose is commonly taken, and a little oxide of iron is introduced. To 4 pounds of frit, for instance, 2 ounces of oxide of copper and 48 grains of red oxide of iron are used; and the ordinary measures are pursued for making very homogeneous enamel.

The green produced by oxide of chrome is much more solid; it is not affected by a powerful fire, but it is not always of a fine shade. It generally inclines too much to the dead-leaf yellow, which depends on the degree of oxygenation of the chrome.

Red Enamel.—We have just stated, that suboxide of copper afforded a fine colour when it could be fixed, a result difficult to obtain on account of the fugitive nature of this oxide; slight variations of temperature enabling it to absorb more oxygen. The proper point of fusion must be seized for taking it from the fire whenever the desired colour is brought out. Indeed, when a high temperature has produced peroxidation, this may be corrected by adding some combustible matter, as charcoal, tallow, tartar, &c. The copper then returns to its lower stage of oxidation, and the red colour which had vanished, reappears. It is possible, in this way, and by pushing the heat a little, to accomplish the complete reduction of a part of the oxide; and the particles of metallic copper thereby disseminated in a reddish ground, give this enamel the aspect of the stone called *aventurine.* The surest and easiest method of procuring suboxide of copper is to boil a solution of equal parts of sugar, and sulphate or rather acetate of copper, in four parts of water. The sugar takes possession of a portion of the oxygen of the cupric oxide, and reduces it to cuprous oxide; when it may be precipitated in the form of a granular powder of a brilliant red colour. After about two hours' moderate ebullition, the liquid is set aside to settle, decanted off the precipitate, which is washed and dried.

The suboxide properly employed by itself, furnishes a red which vies with the finest carmine, and by its means every tint may be obtained from red to orange, by adding a greater or smaller quantity of peroxide of iron.

The preparations of gold, and particularly the oxide and purple of Cassius, are likewise employed with advantage to colour enamel red, and this composition resists a powerful fire tolerably well. For some time back, solutions of gold, silver, and platinum have been used with success instead of their oxides; and in this way, a more intimate mixture may be procured, and, consequently, more homogeneous tints.

Black Enamel.—Black enamels are made with peroxide of manganese or protoxide of iron; to which more depth of colour is given with a little cobalt. Clay alone, melted with about a third of its weight of protoxide of iron, gives, according to Clouet, a fine black enamel.

Violet Enamel.—The peroxide of manganese in small quantity by itself furnishes, with saline or alkaline fluxes, an enamel of a very fine violet hue; and variations of shade are easily had, by modifying the proportions of the elements of the coloured frit. The great point is to maintain the manganese in a state of peroxidation, and, consequently, to beware of placing the enamel in contact with any substance attractive of oxygen.

Such are the principal coloured enamels hitherto obtained by means of metallic oxides; but it is to be wished that new trials be made with such oxides as have not yet been employed. From such researches some interesting results would unquestionably be derived.

Of painting on Enamel.—Enamelling is only done on gold and copper; for silver swells up, and causes blisters and holes in the coat of enamel. All enamel paintings are, in fact, done on either copper or gold.

If on gold, the goldsmith prepares the plate that is to be painted upon. The gold should be 22 carats fine: if purer, it would not be sufficiently stiff; if coarser, it would be subject to melt; and its alloy should be half white and half red, that is, half silver and half copper; whereby the enamel with which it is covered will be less disposed to turn green, than if the alloy were entirely copper.

The workman must reserve for the edge of the plate a small fillet, which he calls the *border.* This ledge serves to retain the enamel, and hinders it from falling off when applied and pressed on with a spatula. When the plate is not to be counter-enamelled.

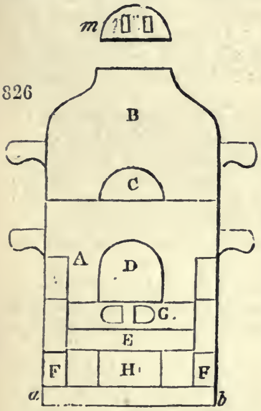
it should be charged with less enamel, as, when exposed to heat, the enamel draws up the gold to itself, and makes the piece convex. When the enamel is not to cover the whole plate, it becomes necessary to prepare a lodgment for it. With this view, all the outlines of the figure are traced on the plate with a black-lead pencil, after which recourse is had to the graver.

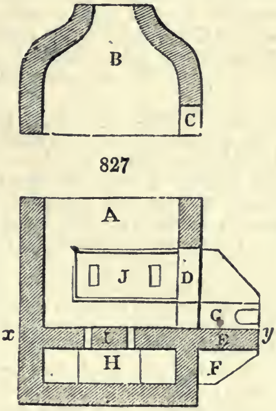
The whole space enclosed by the outlines must be hollowed out in *bas-relief*, of a depth equal to the height of the fillet, had the plate been entirely enamelled. This sinking of the surface must be done with a flat graver as equally as possible; for if there be an eminence, the enamel would be weaker at that point, and the green would appear. Some artists hatch the bottom of the hollow with close lines, which cross each other in all directions; and others make lines or scratches with the edges of a file broken off square. The hatchings or scratches lay hold of the enamel which might otherwise separate from the plate. After this operation, the plate is cleansed by boiling it in an alkaline lye, and it is washed first with a little weak vinegar, and then with clear water.

The plate thus prepared is to be covered with a coat of white enamel, which is done by bruising a piece of enamel in an agate or porcelain mortar to a coarse powder, like sand, washing it well with water, and applying it in the hollow part in its moist state. The plate may meanwhile be held in an ordinary forceps. The enamel powder is spread with a spatula. For condensing the enamel powder, the edges of the plate are struck upon with a spatula.

Whenever the piece is dry, it is placed on a slip of sheet iron perforated with several small holes (see *fig.* 825), which is laid on hot cinders, and left there until it ceases to steam. It must be kept hot till it goes to the fire; for were it allowed to cool, it would become necessary to heat it again very gradually at the mouth of the furnace of fusion, to prevent the enamel from decrepitating and flying off.

826





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Before describing the manner of exposing the piece to the fire, we must explain the construction of the furnace. It is square, and is shown in front elevation in *fig.* 826. It consists of two pieces, the lower part A, or the body of the furnace, and the upper part B, or the capital, which is laid on the lower part, as is shown in *fig.* 827, where these two parts are separately represented. The furnace is made of good fire-clay, moderately baked, and resembles very closely the assay or cupellation furnace. Its inside dimensions are 9 inches in width, 13 inches in height in the body, and 9 in the capital. Its general thickness is 2 inches.

The capital has an aperture or door, C, *fig.* 826, which is closed by a fire-brick stopper *m*, when the fire is to be made active. By this door fuel is supplied.

The body of the furnace has likewise a door D, which reaches down to the projecting shelf E, called the bib (*mentonnière*), whose prominence is seen at E, *fig.* 826. This shelf is supported and secured by the two brackets, F, F; the whole being of earthenware. The height of the door D, is abridged by a peculiar fire-brick G, which not only covers the whole projection of the shelf E, but enters within the opening of the door D, filling its breadth, and advancing into the same plane with the inner surface of the furnace. This plate is called the hearth; its purpose will appear presently; it may be taken out and replaced at pleasure, by laying hold of the handle in its front.

Below the shelf E, a square hole, H, is seen, which serves for admitting air, and for extracting the ashes. Similar holes are left upon each side of the surface.

On a level with the shelf, in the interior of the furnace, a thin fire-tile I rests, perforated with numerous small holes. This is the grate represented in a ground view in *fig.* 825. *Figs.* 828, 829, 830, represent, under different aspects, the muffle: *Fig.* 828 shows the elevation of its further end; *fig.* 829 its sides; and *fig.* 830 its front part. At J, *fig.* 827, the muffle is seen in its place in the furnace, resting on two bars of iron, or, still better, on ledges of fire-clay, supported on brackets attached to the lateral sides of the furnace. The muffle is made of earthenware, and as thin as possible. The fuel consists of dry beech wood, or oaken branches, about an inch in diameter, cut to the length of nine inches, in order to be laid in horizontal strata within the furnace, one row only being placed above the muffle. When the muffle has attained to a white red heat, the sheet-iron tray, bearing its enamel plate, is to be introduced with a pair of pincers into the front of the muffle, and gradually advanced towards its further end. The mouth of the muffle is to be then closed with two pieces of charcoal only, between which the artist may see the progress of the operation. Whenever the enamel begins to flow, the tray must be turned round on its base to insure equality of temperature; and as soon as the whole surface is melted, the tray must be withdrawn with its plate, but slowly, lest the vitreous matter be cracked by sudden refrigeration.

The enamel plate, when cold, is to be washed in very dilute nitric acid, and afterwards in cold water, and a second coat of granular enamel paste is to be applied, with the requisite precautions. This being passed through the fire, is to be treated in the same way a third time, when the process will be found complete. Should any chinks happen to the enamel coat, they must be widened with a graver, and the space being filled with ground enamel, is to be repaired in the muffle. The plate, covered with a pure white enamel, requires always to be polished and smoothed with sandstone and water, particularly if the article have a plane surface; it is then finally glazed at the fire.

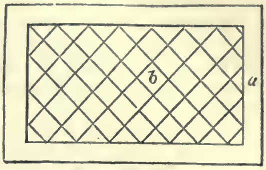
The painting operation now follows. The artist prepares his enamel colours by pounding them in an agate mortar, with a pestle of agate, and grinding them on an agate slab, with oil of lavender, rendered viscid by exposure to the sun in a shallow vessel, loosely covered with gauze or glass. The grinding of two drachms of enamel pigment into an impalpable powder will occupy a labourer a whole day. The painter should have alongside of him a stove in which a moderate fire is kept up, for drying his work whenever the figures are finished, It is then passed through the muffle.

The following was the process adopted by Henry Bone, R.A., and his son, Henry Pierce Bone, who produced the largest enamels ever painted; and beyond the time expended in producing them and consequent expense there appears no practical limit to the size of enamel paintings.

Preparing the plate.—For small plates (up to two inches long) *pure* gold is the best material. Silver (quite pure) is also used, but is apt to get a disagreeable yellow colour at the edges by repeated firings. For larger sizes, copper is used. The copper should be annealed until quite free from spring, and then cleaned with dilute sulphuric acid (one part acid, four water), and shaped in a wooden mould, afterwards used in making the plate so as to produce a convex surface, varying according to the size of the plate, taking care that the shaping does not reproduce the spring in the copper, in which case the process must be repeated. If the place is not raised in the centre, in the course of repeated firings the corners will rise irregularly, producing undulations over the plate, perfect flatness being next to impossible for large pictures. The copper is then laid face downwards on the convex wooden mould used for shaping, and enamel, ground fine with water, is spread over it with a small bone spoon; when covered, a fine cloth doubled is pressed gently on it to absorb the water, and then it is smoothed with a steel spatula. This forms the back of the plate, and when fired this part is finished. The copper is now reversed on a convex board the exact counterpart of the other, and covered with white enamel ground fine in the same way as above. The plate is now ready for firing, and after it has been fired and cooled, the surface must be ground smooth with a flat piece of flint or other hard substance, with silver sand and water. It must next be covered with a softer and more transparent kind of enamel called flux, ground and spread on in the same way as the first enamel, but this time only on the face of the plate. This is fired as before, and when cool the surface must be again ground smooth, and when glazed in the furnace the plate is finished. For the first coat a white solid enamel is used to prevent the green colour from the oxidised copper showing through; the second coat is a softer enamel, to enable the colours used to melt with less heat.

Firing.—The plate is placed on a planche of firestone, or well-baked Stourbridge clay, supported on a bed of whiting, thoroughly dried in the furnace, the exact shape of the plate as originally made, which must be used in all subsequent firings. After the whiting is formed in the shape of the plate it should be notched with a flat knife diagonally across, as in the accompanying diagram, (*fig.* 831). The use of this is to produce an effect of diagonal bracing while the plate cools, and experience has shown that it tends considerably to keep the plate in its original shape. When the plate is small (up to three inches in length) it may be annealed for passing into the hot muffle as follows:—The planche bearing the plate may be placed on another planche heated in the muffle and placed in the front of the muffle for a few minutes, until the steam of the plate or the oil of the picture shall have evaporated; it may then be put in the mouth of the muffle, and gradually inserted to the hottest part. After firing it should be placed on another hot planche, and allowed to cool gradually. Large pictures require a different arrangement of the furnace. Over the muffle there should be a fixed iron annealing box, with an iron shelf and door. The bottom should be of cast iron about one inch thick. This should be so arranged that when the muffle attains a white heat the bottom of the annealing box should be of a brightish red at the back, and a dull blood-red in front. Large pictures should be placed on the bottom of the box before the furnace is lit, and the larger the size of the picture the slower should the furnace be brought to its full heat, so as to allow five or six hours for the largest size, and two or three for smaller plates. When fired the picture should be returned to the shelf of the annealing box, and left there till quite cold, for which purpose large plates require at least twelve hours. The colours used are mostly the same as those prepared for jewellers and glass painters.

831



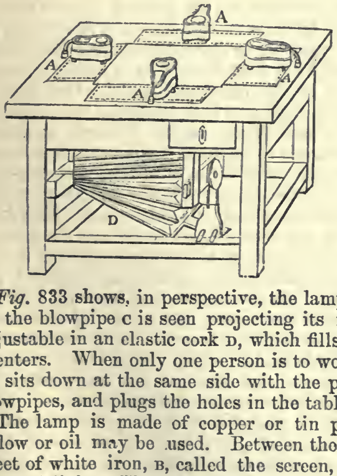
a Planche.
b Bed of whiting.

Enamelling at the Lamp.—The art of the lamp enameller is one of the most agreeable and amusing that we know. There is hardly a subject in enamel which may not be executed by the lamp-flame in very little time, and more or less perfectly, according to the dexterity of the artist, and his acquaintance with the principles of modelling.

In working at the lamp, tubes and rods of glass and enamel must be provided, of all sizes and colours.

The enamelling table is represented in *fig.* 832, round which several workmen, with their lamps, may be placed, while the large double bellows D below is set a-blowing by a treadle moved with the foot. The flame of the lamp, when thus impelled by a powerful jet of air, acquires surprising intensity. The bent nozzles or tubes A, A, A, A, are made of glass, and are drawn to points modified to the purpose of the enameller.

832



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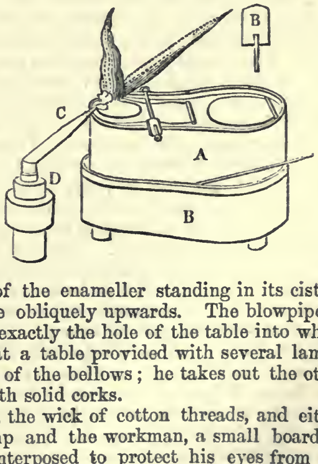


Fig. 833 shows, in perspective, the lamp A of the enameller standing in its cistern B; the blowpipe C is seen projecting its flame obliquely upwards. The blowpipe is adjustable in an elastic cork D, which fills up exactly the hole of the table into which it enters. When only one person is to work at a table provided with several lamps, he sits down at the same side with the pedal of the bellows; he takes out the other blowpipes, and plugs the holes in the table with solid corks.

The lamp is made of copper or tin plate, the wick of cotton threads, and either tallow or oil may be used. Between the lamp and the workman, a small board or sheet of white iron, B, called the screen, is interposed to protect his eyes from the glare of light. The screen is fastened to the table by a wooden stem, and it throws its shadow on his face.

The enamelling workshop ought to admit little or no daylight, otherwise the artist, not perceiving the flame distinctly, would be apt to commit mistakes.

It is impossible to describe all the manipulations of this ingenious art, over which taste and dexterity so entirely preside. But we may give an example. Suppose the enameller wishes to make a swan. He takes a tube of white enamel, seals one of its ends hermetically at his lamp, and while the matter is sufficiently hot, he blows on it a minikin flask, resembling the body of the bird: he draws out and gracefully bends the neck; he shapes the head, the beak, and the tail; then with slender enamel rods of a proper colour, he makes the eyes; he next opens up the beak with pointed scissors; he forms the wings and the legs; finally attaching the toes, the bird stands complete.

The enameller also makes artificial eyes for human beings, imitating so perfectly the colours of the sound eye of any individual as to render it difficult to discover that he has a blind and a seeing one.

It is difficult to make large articles at the blowpipe; those which surpass 5 or 6 inches become nearly unmanageable by the most expert workman.

Enamelling of Cast Iron and other Hollow Ware for Saucepans, &c. In December 1799, a patent was obtained for this process by Dr. Samuel Sandy Hickling. His Specification is subdivided into two parts:—

The coating or lining of iron vessels, &c., by fusion with a vitrifiable mixture, composed of 6 parts of calcined flints, 2 parts of *composition* or Cornish stone, 9 parts of litharge, 6 parts of borax, 1 part of argillaceous earth, 1 part of nitre, 6 parts of calx of tin, and 1 part of purified potash. Or, 2nd,

8 parts of calcined flints, 8 red lead, 6 borax, 5 calx of tin, and 1 of nitre. Or, 3rd,

12 of potter's composition, 8 borax, 10 white lead, 2 nitre, 1 white marble calcined, 1 argillaceous earth, 2 purified potash, and 5 of calx of tin. Or, 4th,

4 parts calcined flint, 1 potter's composition, 2 nitre, 8 borax, 1 white marble calcined, ½ argillaceous earth, and 2 calx of tin.

Whichever of the above compositions is taken, must be finely powdered, mixed, and fused; and the vitreous mass is to be ground when cold, sifted, and levigated with water. It is then made into a pap with water or gum-water. This pap is smeared or brushed over the interior of the vessel, dried and fused with a proper heat in a muffle.

Calcined bones are also proposed as an ingredient of the flux.

The fusibility of the vitreous compounds is to vary according to the heat to be applied to the vessel, by using various proportions of the siliceous and fluxing materials. Colours may be given, and also gilding.

The second part or process in his Specification describes certain alloys of iron and nickel, which he casts into vessels, and lines or coats them with copper precipitated from its saline solutions. It also describes a mode of giving the precipitated copper an enamel surface by acting upon it with bone-ashes and zinc with the aid of heat.

A factory of such enamelled hollow wares was carried on for some time, but it was given up for want of due encouragement.

A patent was granted to Thomas and Charles Clarke, on the 25th of May 1839, for a method of enamelling or coating the internal surfaces of iron pots and saucepans, in such a way as shall prevent the enamel from cracking or splitting off from the effects of fire. This Specification prescribes the vessel to be first cleaned by exposing it to the action of dilute sulphuric acid (sensibly sour to the taste) for three or four hours, then boiling the vessel in pure water for a short time, and next applying the composition. This consists of 100 lbs. of calcined ground flints; 50 lbs. of borax, calcined, and finely ground with the above. That mixture is to be fused and gradually cooled.

40 lbs. weight of the above product is to be taken with 5 lbs. weight of potter's clay; to be ground together in water until the mixture forms a pasty consistent mass, which will leave or form a coat on the inner surface of the vessel about one-sixth of an inch thick. When this coat is set, by placing the vessel in a warm room, the second composition is to be applied. This consists of 125 lbs. of white glass (without lead), 25 lbs. of borax, 20 lbs. of soda (crystals), all pulverised together and vitrified by fusion, then ground, cooled in water, and dried. To 45 lbs. of that mixture, 1 lb. of soda is to be added, the whole mixed together in hot water, and when dry pounded; then sifted finely and evenly over the internal surface of the vessel previously covered with the first coating or composition whilst this is still moist. This is the glazing. The vessel thus prepared is to be put into a stove, and dried at the temperature of 212° Fahr. It is then heated in a kiln or muffle like that used for glazing china. The kiln being brought to its full heat, the vessel is placed first at its mouth to heat it gradually, and then put into the interior for fusion of the glaze. In practice it has been found advantageous also to dust the glaze powder over the fused glaze, and apply a second fluxing heat in the oven. The enamel, by this double application, becomes much smoother and sounder.

Messrs. Kenrick, of West Bromwich, produced in their factory some excellent specimens of enamelled saucepans of cast iron. Dr. Ure exposed the finely-enamelled saucepans of Messrs. Kenrick to very severe trials, having fused even chloride of calcium in them, and found them to stand the fire very perfectly without chipping or cracking. Such a manufacture is one of the greatest improvements recently introduced into domestic economy; such vessels being remarkably clean, salubrious, and adapted to the most delicate culinary operations of boiling, stewing, making of jellies, preserves, &c. They are also admirably fitted for preparing pharmaceutical decoctions, and ordinary extracts.

The enamel of these saucepans is quite free from lead. In several of the saucepans which were at first sent into the market, the enamel was found on analysis to contain a notable proportion of oxide of lead. In consequence of the quantity of borax and soda in the glaze, this oxide was so readily acted upon by acids that sugar of lead was formed by digesting vinegar in them with a gentle heat.

A suitable oven or muffle for lining or coating metals with enamel may have the following dimensions:—

The outside, 8 feet square, with 14-inch walls; the interior muffle, 4 feet square at bottom, rising 6 inches at the sides, and then arched over; the crown may be 18 inches high from the floor; the muffle should be built of fire-brick, 2½ inches thick. Another arch is turned over the first one, which second arch is 7 inches wider at the bottom, and 4 inches higher at the top. A 9-inch wall under the bottom of the muffle at its centre divides the fire-place into two, of 16 inches width each, and 3 feet 3 inches long. The flame of the fire plays between the two arches and up through a 3-inch flue in front, and issues from the top of the arch through three holes about 4 inches square. These open into a flue, 10 x 9 inches, which runs into the chimney.

The materials for the enamel body (ground flint, potter's clay, and borax) are first mixed together, and then put into a reverberatory furnace, 6 feet 7 inches long, by 3 feet 4 inches wide, and 12 inches high. The flame from an 18-inch fire-place passes over the hearth. The materials are spread over the floor of the oven, about 6 inches thick, and ignited or fritted for 4 or 5 hours, until they begin to heave and work like yeast, when another coating is put on the top, also six inches thick, and fired again, and so on the whole day. If it be fired too much, it becomes hard and too refractory to work in the muffles. The glaze is worked in an oven similar to the above. It may be composed of about one-half borax and one-half of Cornish stone (partially-decomposed granite) in a yellowish powder procured from the potteries. This is fritted for 10 hours, and then fused into a glass which is ground up for the glaze.

The Patent Enamel Company use coloured enamel very extensively, and by the use of stencil plates produce cheaply very good designs in enamel upon articles of iron. Their manufacture by this process of street plates, and signs in enamel are of much interest. The following are recipes for enamels in general use:—

Grey Mixture Enamel.

	lbs.	oz.
Sand	10	0
Red lead	33	0
Boracic acid	20	0
Cullett	114	0
Bicarbonate of soda	16	0
Nitre	1	2
Manganese	0	8½
	194	10½

Another is—

	lbs.	oz.
Flint	36	0
Boracic acid	24	0
Bicarbonate of soda	24	0
Nitre	18	0
	102	0

White Mixture Enamel.

	lbs.	oz.
Cullett	11	0
Boracic acid	7	0
Bicarbonate of soda	0	4
Phosphate of lime	3	8
Oxide of antimony	0	2
	21	14

ENAMELLED LEATHER. Leather glazed upon one surface, the so-called enamelling composition being in all respects analogous to the ordinary varnishes. Instead of enamelling the grain surface, as is usually done, Mr. Nossiter removes that surface by splitting or buffing, and then produces what is called 'a finish' upon the surface thus formed, by means of a roller, or glass instrument. The flesh side of the skin may be thus prepared for enamelling; and it is less liable to crack, and the enamel to become cloudy on it than on the grain side. See LEATHER.

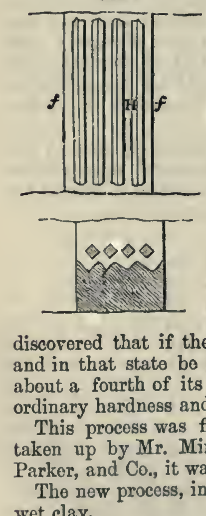
ENARGITE. An arsenio-sulphide of copper, occurring in the form of a grey or iron-black mineral with metallic lustre. It is found in certain mines in Mexico, Peru, and Chili.

ENCAUSTIC PAINTING. A mode of painting with heated or burnt wax, which was practised by the ancients. The wax, when melted, was mixed with as much colour, finely powdered, as it could imbibe, and then the mass was spread on the wall with a hot spatula. When it became cold, the designer cut the lines with a cold pointed tool, and other colours were applied and melted into the former. Many modifications of the process have been employed. Amongst the moderns, the term has been improperly given to some cements, which have nothing of an encaustic character about them.

ENCAUSTIC TILES are tiles in which any design has been produced by fusing in other colours than such as form the colour of the ground. Encaustic tiles are of all ages, and we find them representing every variety of subject.

The manufacture of encaustic tiles has been carried to great perfection in our own times. It will be well to consider this manufacture in connection with *Tesseræ*, there being, indeed, no difference in the first production of tiles or tesseræ, except that the latter are at first moulded with the spaces which are to be filled in with the coloured clays to form the patterns impressed upon them.

834



The Roman tesseræ, of which many very fine examples have been discovered in this country, were often formed of natural stones (sometimes coloured artificially), but generally of baked clay. The beauty of many of these has led to the production of modern imitations, which have been gradually improved, until, in the final result, they far exceed any work of the Romans.

About half a century since, Mr. C. Wyatt obtained a patent for a mode of imitating tesselated pavements, by inlaying stone with coloured cements. Terra-cotta, inlaid with coloured cements, has also been employed, but with no very marked success.

Mr. Blashfield produced imitations of those pavements, by colouring cements with the metallic oxides: these stood exceedingly well when under cover, but they did not endure the winter frosts, &c. Bitumen, coloured with metallic oxides, was also employed by Mr. Blashfield. In 1839 Mr. Singer, of Vauxhall, introduced a mode of forming tesseræ from thin layers of clay. These were cut into the required forms, dried and baked. In 1840 Mr. Prosser, of Birmingham, discovered that if the material of porcelain (china clay) be reduced to a dry powder, and in that state be compressed between steel dies, the powder is condensed into about a fourth of its bulk, and is converted into a compact solid substance of extraordinary hardness and density.

This process was first applied to the manufacture of buttons, but was eventually taken up by Mr. Minton, and, in conjunction with Mr. Blashfield, Messrs. Wyatt, Parker, and Co., it was carried to a high degree of perfection for making tesseræ.

The new process, invented by Mr. Prosser, avoided the difficulty altogether of using wet clay.

This change in the order of the potter's operations, although very simple in idea (and a sufficiently obvious result of reflection on the difficulties attending the usual course of procedure), has nevertheless required a long series of careful experiments to find out the means of rendering it available in practice.

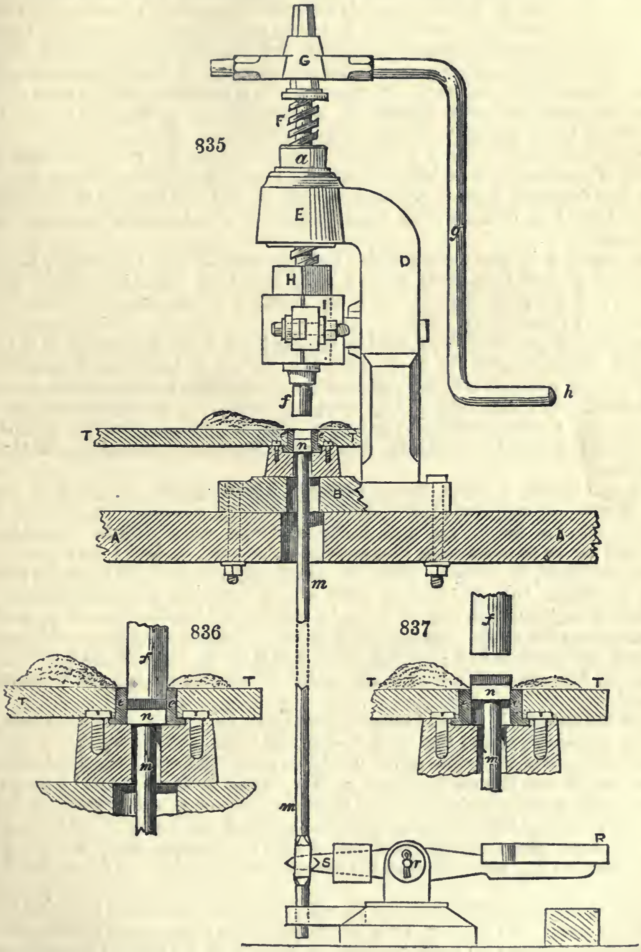
The power which the hand of the potter has exercised over his clay has been proverbial from time immemorial, but it is limited to clay in its moist or plastic state; and clay in its powdered state is an untractable material, requiring very exact and powerful machinery to be substituted for the hand of the potter; in order, by great pressure, to obtain the requisite cohesion of the particles of clay.

In the new process, the clay, or earthy material, after being prepared in the usual manner, and brought to the plastic state, as above described (except that no kneading or tempering is requisite), is formed into lumps, which are dried until the water is evaporated from the clay.

The lumps of dried clay are then broken into pieces, small enough to be ground by a suitable mill into a state of powder, which is afterwards sifted, in order to separate all coarse grains and obtain a fine powder, which it is desirable should consist of particles of uniform size as nearly as can be obtained. The powder, so prepared, is the state in which the clay is ready for being moulded into the form of the intended article by the new process.

The machine and mould used for moulding articles of a small size, in powdered clay, are represented in the annexed drawings, wherein *fig.* 835 is a lateral elevation of the whole machine.

A A is the wooden bench or table whereon the whole is fixed, that bench being sustained on legs standing on the floor. B D E is the frame, formed in one piece of cast



835

836

837

iron; the base, B, standing on the bench, and being fixed thereto by screw bolts; the upright standard, D, rising from the base, and sustaining at its upper end the boss, E, wherein the nut or box, *a*, is fixed for the reception of the vertical screw, F. The screw, F, works through the box, *a*, and has a handle, G, *g*, *h*, applied on the upper end of the screw; the handle is bended downwards at *g*, to bring the actual handle, *h*, to a suitable height for the person who works that machine to grasp the handle, *h*, in his right hand, and, by pulling the handle, *h*, towards him, the screw, F, is turned round in its box, *a*, and descends. The lower end of the screw, F, is connected with a square vertical slider, H, which is fitted into a socket, I, fixed to the upright part, D, of the frame, and the slider, H, is thereby confined to move up or down, with an exactly vertical motion, when it is actuated by the screw, without deviation from the vertical.

Thus far the machine is an ordinary screw press, such as is commonly used for cutting and compressing metals for various purposes. The tools with which the press is furnished for the purpose of this new process consist of a hollow mould, *e e*, formed of steel, the exterior cavity of the mould being the exact size of the article which is to be moulded. The mould, *e e*, is firmly fixed on the base, B, of the frame, so as to be exactly beneath the lower end of the piston *a*, or plug, *f*, which is fastened to the lower end of the square slider, H, and the plug, *f*, is adapted to descend into the hollow of the mould, *e e*, when the slider, H, is forced downwards by action of the screw, F, the plug *f* being very exactly fitted to the interior of the mould, *e e*.

The bottom of the mould, *e e*, is a moveable piece, *n*, which is exactly fitted into the interior of the mould, but which lies at rest in the bottom of the mould, *e e*, during the operation of moulding the article therein; but afterwards the moveable bottom, *n*, can be raised up by pressing one foot upon one end, R, of a pedal lever, R S, the fulcrum of which is a centre pin, *r*, supported in a standard resting upon the floor, and the end, S, of the lever operates on an upright rod, *m*, which is attached at its upper end to the moveable bottom, *n*, of the mould, *e e*.

A small horizontal table, T T, is fixed round the mould, *e e*, and on that table a quantity of powdered clay is laid in a lump in readiness for filling the mould.

The two detached figures, marked *figs.* 836 and 837, are sections of the mould *e e*, and the plug, *f*, on a larger scale than *fig.* 835, in order to exhibit their action more completely.

The operation is extremely simple: the operator, holding the handle, *h*, with his right hand, puts it back from him, so as to turn back the screw, F, and raise the slider, H, and the plug, *f*, quite out of the mould, *e e*, and clear above the orifice of the mould, as shown in *fig.* 835.

Then, with a spatula of bone, held in the left hand, a small quantity of the powder is moved laterally from the heap, along the surface of the table, T, T, towards the mould *e e*, and gathered into the hollow of the mould with a quiet motion, so as to fill that hollow very completely, and by scraping the spatula evenly across over the top of the mould, *e e*, the superfluous powder will be removed, leaving the hollow cavity of the mould exactly filled with the powder in a loose state, and neither more nor less than filled.

Then the handle, *h*, being drawn forwards with a gentle movement of the right hand, it turns the screw, F, so as to bring the slider, H, and the plug, *f*, which thereby descends into the mould, *e e*, upon the loose powder wherewith the mould has been filled, and begins to press down that powder, which must be done with a gentle motion without any jerk, in order to allow the air that is contained in the loose powder to make its escape; but the pressure, after having been commenced gradually, is continued and augmented to a great force, by pulling the handle strongly at the last, so as to compress the earthy material down upon the bottom, *n*, of the mould, into about one-third the space it had occupied when it was in the state of loose powder. The section, *fig.* 836, shows this state of the mould, *e e*, and the plug, *f*, and the compressed material.

Then the handle, *h*, is put backwards again, so as to turn back the screw, F, and raise up the slider, H, and the plug, *f*, until the latter is drawn up out of the mould, *e e*, and clear above the orifice of the mould, as in *fig.* 835, and immediately afterwards by pressure of one foot on the pedal, R, of the pedal lever, R, S, and by action of the upright rod, *m*, the moveable bottom, *n*, of the mould is raised upwards in the mould *e e*, so as to elevate the compressed material which is resting upon the bottom, *n*, and carry the same upwards, quite out of the mould *e e*, and above the orifice of the mould, as is shown in *fig.* 837, and then the compressed material can be removed by the finger and thumb.

The compressed material which is so withdrawn is a solid body, retaining the exact shape and size of the interior cavity of the mould, and possessing sufficient coherence to enable it to endure as much handling as is requisite for putting a number of them into an earthenware case or pan, called a sagger, in which they are to be enclosed, according to the usual practice of potters, in preparation for putting them into the potter's kiln for firing; the sagger protects the articles from discoloration by smoke, and from partial action of the flame, which, if a number of small articles were exposed thereto without being so enclosed, might operate more strongly upon some than upon others of those articles; but by means of the saggers the heat is caused to operate with cleanness, uniformity, and certainty upon a number of small articles at once.

After the firing is over, the articles being removed from the saggers, are in the state of what is termed biscuit, and are ready for use, unless they are required to be glazed, in which case they may be dipped into a semi-liquid composition of siliceous and other matters, ground in water to the consistency of cream, and the surface of the articles which are so dipped becomes covered with a thin coating of the glazed composition; then the articles are again put into saggers, and subjected to a second operation of firing in another kiln, the heat whereof vitrifies the composition and gives a glassy surface to the articles, all which is the usual course of making glazed earthenware or porcelain; but for articles formed by the new process, a suitable glazing composition is more usually applied within the saggers, into which the articles are put for the first firing, and the glazing is performed at the same time with the first burning, without any other burning being required. Or, in other cases, the composition of the earthy materials which are chosen for the articles may be such that they will become partially vitrified by the heat to which they are exposed in the kiln, and thereby external glazing is rendered unnecessary.

The great contraction which must take place in drying articles which have been moulded from clay in the moist state is altogether prevented, and consequently all uncertainty in the extent of that contraction is avoided. Tiles, tesseræ, and other articles are now made by this machine; and very beautiful pavements are constructed, excelling the finest works of the Romans in form, in colour, and in all the mechanical conditions.

It will be evident that any pattern can be impressed upon the clay by having a mould with the pattern in relief upon it. In some cases the coloured clay is placed in the depressed portions of the tile before firing at all; in others, it is subjected to the first firing before the coloured clay is introduced. In either case, the second or coloured clay, for the production of the kind of tile called encaustic, is spread in the state of a cream, so as to fill the pattern, every trace being carefully removed from the other part. See TILES.

ENCHASING. The art of ornamenting gold and silver metal work with designs punched out from behind, or engraved on the surface. It is also applied to enclosing gems in the metal for ornamentation.

ENCRINITAL or **ENTROCHAL MARBLE.** Marble containing the fossil remains of Encrinites, or 'stone-lilies.' Much of the encrinital marble used for ornamental purposes comes from the Mountain Limestone of Derbyshire.

ENDELLIONITE. An old name for Bournonite, in allusion to its occurrence at Endellion, in Cornwall.

ENDIRONS or **ANDIRONS.** Iron racks used in ancient houses when the fires were of wood, and on the hearth, to support the ends of the logs of wood.

ENDIVE. An esculent plant, the *Cichorium Endivium*, belonging to the natural order of the *Compositæ*.

ENDOGENOUS. See EXOGENOUS.

ENDOSMOSE. See EXOSMOSE.

ENGLISH VARNISH. Drying oil prepared with litharge is made to dissolve gum mastic until it assumes the appearance of a jelly. This is English Varnish, and is used by artists for glazing, flowing freely under the brush.

ENGRAVING, a word derived from ἐν, *in*, and γράφω, to *grave* or *write*, is the art of executing designs or devices upon metal, stones, and other hard substances. In the common acceptation of the word in the present day, it means the execution of such works on plates of copper or steel, for the purpose of obtaining from them impressions in ink or some other coloured fluid. Engraving, in the widest sense of the term, is the oldest of the fine arts; at least, the Scriptures mention it before any reference is made either to painting or sculpture. In the Book of Exodus, ch. xxviii. v. 29, we read that 'Aaron shall bear the names of the children of Israel in the breast-plate of judgment upon his heart;' and again, in the same chapter, Moses is commanded to 'make a plate of pure gold, and grave upon it, like the engravings of a signet, Holiness to the Lord.' Further on, in the 35th chapter of the same book, Moses speaks of Bezaleel, the son of Uri, as a man 'filled with the spirit of God, in wisdom, in understanding, and in knowledge, and in all manner of workmanship; and to devise curious works, to work in gold, and in silver, and in brass, and in the cutting of stones,' &c. Of him and of Aholiab it is said,—'Them hath he filled with wisdom of heart, to work all manner of work, of the engraver,' &c. &c. These extracts will suffice to show the antiquity of the art of incising, or cutting hard substances; whether or not it had its origin at a period anterior to the time of Moses there is no record; but it is not improbable that the Israelites acquired some knowledge of the art from the Egyptians during their lengthened captivity: an assumption strengthened by the fact, that numerous specimens of hieroglyphic engraving, on metal plates and on stone, have been discovered in Egypt and brought to this country; their dates, however, have not, in all cases, been ascertained with certainty.

It is unnecessary to trace back, among the nations of antiquity, all that might be written respecting the state of this art in its various applications; but, as an example of its adoption for a purpose altogether practical, a passage from Herodotus may be adduced. This historian, referring to a period about 500 years before the Christian era, says:—'Aristagoras exhibited to the king of Sparta a tablet, or plate, of brass, on which was inscribed every part of the habitable world, the seas, and the rivers;' or, in other words, Aristagoras, who was a native of Cuma, had in his possession a metallic map. Moreover, as it is intended to limit this notice to the art of engraving on steel or copper for printing purposes, we pass over those branches or departments of the art that relate to die-sinking, seal-engraving, and engraving on coins, the latter a common process with the Ancient Britons and Saxons, who also, according to the opinion of many modern antiquaries, used to ornament their weapons of war with designs cut by the graving tool.

The transition from all previous methods of engraving, to that which in some degree assimilates to what is now practised as the result of the discovery of printing, has been thus described by the late Mr. Landseer, who quotes an earlier writer, Mr. Strutt:—'Soon after the Conquest (though, from other information, I think it must have been at the least 250 years from that memorable era) a new species of engraving, entirely different from the mingled work of the engraver, goldsmith, and chaser, which had preceded it, was introduced into, or invented in, England, of which there is scarcely an old country church of any consequence, but affords some curious specimens, and England more than any other nation in Europe. The brass plates on our old sepulchral monuments are executed entirely with the graver, the shadows being expressed by lines or strokes, strengthened in proportion to the required depth of shade, and occasionally crossed with other lines a second and, in some instances, a third time, precisely in the same manner as a copper-plate is engraven that is intended for producing impressions. These engraved effigies are commonly found on those horizontal tombstones which form part of the pavement within the churches; and the feet of the congregation, which kept the lights bright by friction, filled the incisions with dust, and thus darkened the shades: very neat or exquisite workmanship is not therefore expected; yet some of them bear no small evidence of the abilities of the monks, or other workmen, by whom they were performed.' Impressions, technically called 'rubbings,' are taken from these monumental brasses by antiquaries, for the purpose of illustrating works in archæology. The process is simple enough: a sheet, or sheets, as may be required, of white paper, sufficiently large to cover the brass tablet, are laid upon it; these are then rubbed over with a lump of 'shoemaker's heel-ball,' a composition of wax and lamp-black, which leaves on the paper an impression of the raised portions of the metal.

The fifteenth century, which must always be considered as the dawn of universal light and knowledge, gave to the world the art of printing, and from this invention, arose a new era in the art of engraving. The earliest method of printing, both books and illustrations, was, as is described under the article ENGRAVING ON WOOD, from engraved blocks or tablets. It seems singular that, though engraving on various metals had been practised long before that on wood, no attempt had ever been made to obtain impressions from the plates; like many other important discoveries, this is said to have been the result of accident. Vasari, the historian of Italian art, says that, in the year 1460, Maso, or Thomaso Finiguerra, a Florentine goldsmith, chanced to let fall a small engraved plate, on which, as was customary with engravers, he had rubbed a little charcoal and oil, that he might better see the state of his work, into some melted sulphur, and observing that the exact impression of his engraving was left on the sulphur, he repeated the experiment, by passing a roller gently over it. It was successful, and Finiguerra imparted his discovery to Baldini, also a goldsmith of Florence, by whom it was communicated to others. But the most probable origin of the art of printing from metallic plates, is that which is attributed to the early Italian workers in *niello*, or inlaid modelling work, an art used for ornamenting table utensils, swords, armour, &c.: this art consisted in cutting or engraving the required design on silver, and filling up the incisions with a black composition, said to be made of silver and lead, which, from its dark colour, was called by the ancients *nigellum*, abbreviated by the Italians into *niello*; this mixture, when run into the engraved lines, produced a regular effect of *chiar-oscuro* in the entire work. From these engraved plates or objects, the artists in *niello*, who were the goldsmiths and silversmiths of that period, were accustomed to take impressions, by smoking the metal, and then, after cleaning the smooth surface with oil, impressing upon it a piece of damp paper. From such an origin, or from some other very similar to it, undoubtedly, came the art of chalcography, or plate-printing, and it is equally certain, that the art of engraving with the *burin*, or as it is now called, 'line engraving,' arose in the workshops of the gold- and silversmiths.

The practice of making paper from rags, without which the former art would have proved comparatively useless, had been adopted generally throughout Europe towards the end of the fourteenth century, whereby the chief obstacle to printing was removed.

Not very long after the discovery of plate-printing, the engravers, separating themselves from the manufacturing goldsmiths and chasers, formed themselves into a distinct body, opened schools for pupils, and took up their rightful position among the artists of the time.

Italy and Germany have each contended for the honour of being the first discoverers of the art of printing from engraved plates; but the best authorities give to the former country the priority of claim, though the Germans, to whom the printing press was earliest known, soon surpassed their rivals, both in that art and in engraving: but they have not always maintained the superiority.

The principal Italian engravers, contemporary with, or immediately following Finiguerra, were Baldini, Botticelli, and Andrew Mantegna; in Germany, the names of Martin Schön, who began his career about the year 1460, and engraved his own compositions, Israel van Mecheln, Leydenwurf, and Wolgemuth, stand prominently forward; but it was not till the commencement of the sixteenth century, that engraving occupied a high position among the arts of either country. Singularly enough, Italy, Germany, and Holland produced each an engraver, whose works to this day are held in the highest estimation: while Marc Antonio Raimondi (born at Bologna, in 1488), and Albert Dürer (born at Nuremberg, in 1471), were respectively practising the art in Italy and Germany, Lucas van Leyden (born at Leyden, in 1494) disputed in the Low Countries the palm with these distinguished competitors. As these artists have ever been considered the patriarchs of engraving, a few words respecting the merits of each may not inappropriately be introduced here.

Travelling to Venice for improvement, Marc Antonio saw there some prints, by Albert Dürer, of the Life of the Virgin; these he copied with tolerable fidelity; he soon, however, quitted Venice, and went to Rome, where he made the acquaintance of Raffaelle, a large number of whose works he engraved. 'The purity of his outlines,' says Bryan, 'the beautiful character and expression of his heads, and the correct drawings of the extremities, establish his merits as a perfect master of design.' His works frequently exhibit a deficiency in reflex light and harmony of *chiar-oscuro*, and he appears to have been ignorant of the principles of rendering local colour, or tints, in the abstract; neither did he attempt, or else was unable, to express the various textures of substances: these are, however, minor defects by comparison, and may easily be excused when the state of art generally at that period is taken into account. 'Raffaelle,' says Landseer, 'was Mark Antonio's object; and the blandishments, the splendour, and the variety which would have been indispensably necessary to the translation of Correggio or Titian, were not called for here.'

Albert Dürer, the head of the German school of engraving, laboured under disadvantages with which the artists of Italy had not to contend: the latter had frequently, if not constantly, the graceful forms and flowing outlines of antique sculpture made familiar to them: and hence their works exhibit, even from the earliest time, much greater elegance of manner, and refinement in execution, than those of Germany. The engravings by Dürer, whom Landseer supposes to be the first who corroded his plates with *aqua-fortis*, partake largely of the stiff, dry, and Gothic manner, peculiar to the country and the period, and which to this day is more or less discernible in German art. If Dürer had been so fortunate as to have had the pictures of Raffaelle to engrave, he would doubtless have left the world prints of a very different character from those we now see: we should have had more grace of expression, and freedom of lines, but less originality in the style of execution, and probably, less vigour. Dürer engraved only his own designs, and his faults or defects were those of his time: but notwithstanding his Gothic bondage, nothing that has ever appeared in more recent periods surpasses, in executive excellence, his 'St. Jerome seated in a Room;' here all the objects are rendered with a fidelity that only the camera could emulate. That very remarkable and mysterious composition known as 'The Death's Head,' is also a masterly example of execution: the helmet, with all its pomp of heraldic appendage, and the actual and reflex lights on its polished surface, are characteristically, though minutely, expressed: the skull is accurately drawn, and its bony substance unmistakably described. The head of the Satyr, with its beard and wild redundance of snaky tangled hair, has considerable and well-managed breadth of light and shade: the drapery of the female, quaint as it is in style, is not, as we see it in Dürer's other works, hard, stiff, and formal, but relaxes into freedom and simplicity, and has quite a silky texture; in fact, it approaches very nearly to what we now call 'picturesque composition of forms, and light and shade.' Dürer's etching appears to have been bitten in, or corroded with the acid, at once. He seems either not to have known, or did not care to practise, the process now adopted, of 'stopping out,' for the purpose of producing gradation of shade. The admirable wood engravings by this artist are referred to in their proper place.

The works of Van Leyden, the Dutchman, are even more Gothic in taste and style than those of Dürer, with whom he is said to have been intimately acquainted: they exhibit the same amount or degree of stiff, angular drapery; as much, perhaps even more, inattention to grace and dignity of form, without his fertile imagination, his occasional vigour, and his truthful observation of individual nature. His execution is neat and clearly defined, but his plates are deficient in firmness and harmonious effect, and his lines are without variation in substance; those that represent near objects, and those that express objects at a distance, are equally fine and delicate; hence the monotony apparent in his prints. They are almost entirely sacred or legendary subjects, from his own designs; among the finest are 'The Temptation of St. Anthony,' engraved in 1509, when he was only thirteen years of age, 'The Crucifixion,' and the 'Adoration of the Magi.

It would be beyond the province of this notice to record the progress of the art, through the continental schools, till it took root in England; yet a short history of its introduction and growth on our soil may not be considered out of place.

Until the middle of the last century, neither painting nor engraving had attained any eminence in this country; the latter art, especially, was practised chiefly by foreigners, as Hollar, Simon, Vaillant, Blooteling, &c.; previously to whom we had, of our own countrymen, Faithorne, an admirable engraver of portraits, Payne, White, and one or two others of inferior merit; but, with the exception of Faithorne, none whose works are now held in much esteem. The encouragement afforded by George III., almost as soon as he ascended the throne, to the fine arts generally, and the establishment of the Royal Academy, which offered to artists a position in the country they had never before held, gave an impulse to every section or branch of art professors. Hogarth's name had, however, become widely known many years before: his numerous plates, all of them from his own designs, are to this day much sought after, not so much, perhaps, for any especial excellence as examples of fine engravings, as for the talent and genius which the subjects display. 'Hogarth composed comedies as much as Molière,' was the remark of Walpole: he died just as art was beginning to be recognised and patronised in England. Francis Vivares, a Frenchman by birth, but long settled in England, where he studied the art under Chatelain, carried landscape-engraving to a high point of excellence; some of his prints after pictures by Claude and Gaspar Poussin exhibit remarkable freedom in the foliage of the trees, and truth in the texture of the various objects introduced in the landscape. Woollett, born at Maidstone, in Kent, who died in 1785, and Sir Robert Strange, a native of one of the Orkney Islands, who died in 1792, advanced the art still further; indeed, it is a question whether engraving has ever found more able exponents than these two distinguished men: the latter engraved several portraits, which have rarely been surpassed at any period in the history of art. The works of both these engravers are characterised by bold and vigorous execution, produced by the combined use of the etching-needle and the graver. Cotemporary with these, or their immediate successors, were Browne, who sometimes worked with Woollett, Bartolozzi, Hall, Rooker, Green, Ryland, Watts, Sharp, McArdell, Smith, Earlom, &c.; all aided, by their proficiency, to uphold the honour of the art; while John Landseer, Raimbach, Engleheart, Pye, and John Burnet, may be regarded as the chief connecting links between the past generation and the present.

Engraving on metal plates may be classed under the following heads:—*Etching*, *line*, *mezzotinto*, *chalk*, *stipple*, and *aquatint*. Before describing the processes of working these respective kinds, a notice of the instruments used by the engraver is necessary. These, with some modifications, are employed in all the styles.

The *etching-point*, or *needle*, is a stout piece of steel-wire inserted into a handle; two or three, varying in thickness, are requisite, and they should be frequently and carefully sharpened. This is best done by turning the needle round in the fingers while rubbing it on a hone, and afterwards on a leather strop prepared with putty powder, or on an ordinary razor-strop, to take off any roughness, and to make it perfectly round.

The *dry-point* is a similar instrument, used for delicate lines: it must be sharpened on the hone till a fine conical point is obtained.

The *graver*, or *burin*, is the principal instrument employed in engraving: several are required, differing from each other in form, from the extreme *lozenge* shape to the *square*; the former being used for cutting fine lines, the latter for broad: the graver fits into a handle about five inches and a half long, and it should be well tempered before using, an operation requiring great care. The angle at the meeting of the two lower sides is called the *belly*, and the breadth of the end, the *face*. To sharpen the former, lay one of the flat sides of the graver on the oilstone, keeping the right arm tolerably close to the side, and rub it firmly; next rub the other in the same way: the face is sharpened by holding it firmly in the hand, with the belly upwards, in a slanting direction; rub the end rather gently on the stone, at an angle of about forty-five degrees, taking care to carry it evenly along until it acquires a very sharp point: this being done, hold the engraver a little more upright to square the point, which a very few rubbings will effect. The graver for *line* work must be slightly turned up, to enable the engraver to run it along the plate; otherwise, the first indentation he makes on the metal would cause his instrument to become fixed: the graver for *stipple* should be slightly turned down, to make dots only.

The *scraper*, which should have three fluted sides, is used for taking off the *burr* left by the action of the needles on the metal.

The *burnisher* is employed to soften lines that have been *bitten in*, or engraved too dark, and to polish the plate, or get rid of any scratches it may accidentally have received.

The *dabber* used to lay the *etching-ground* evenly, is made by enclosing a small quantity of fine cotton wool very tightly in a piece of silk, the threads of which should be, as much as possible, of uniform thickness.

There are a few other materials which an engraver should have at hand, but they are not of sufficient importance to be mentioned here; we may, however, point out what is technically called a *bridge*, which is nothing more than a thin board for the hand to rest on; it should be smoothly planed, and of a length and breadth in proportion to the size of the plate; at each end a small piece of wood should be fastened to raise it above the plate when covered with wax. A *blind*, made of tissue-paper stretched upon a frame, ought to be placed between the plate and the light, to enable the engraver to see his work on the metal with greater facility and clearness.

In describing the processes of engraving the various styles enumerated above, little more than a general outline of each method can be given, yet sufficient, it may be presumed, to show the nature of the operation: to narrate all the details that might be included on the subject would supply matter enough for a small volume.

Etching may be classed under two heads: that which is made the initiatory process in line-engraving, and that which is known as *painter's-etching*: the latter was practised to some extent by very many of the old painters, particularly those of the Dutch school; and it has also come into fashion with many of the artists of our own day, but more for amusement, however, than for any other purpose; in both cases the method of proceeding is alike. Etching is the result of a chemical process resulting in corrosion of the metal on which the design has been laid down, or transferred, in the following manner. The plate must first be covered with a substance already spoken of as *etching-ground*, which may be purchased of most of the principal artists' colourmen, but many engravers make their own: the annexed receipt has been handed to us by Mr. C. W. Sharpe, who has engraved some very large steel-plates, as that which he always uses:—

	Parts
Black pitch	1
White wax	1
Burgundy pitch	¼
Asphaltum	1
Gum mastic	1

Melt the first three ingredients over a slow fire in a pipkin, then add the other two, finely powdered, stirring the whole together all the time; when well mixed, pour it into warm water, and make it up, while warm, into balls; if too soft, a little less wax should be used. Care must be taken not to let the mixture burn during the process of making.

The etching-ground resists the action of the *aqua-fortis*. It should be tied up in a piece of strong silk, and applied thus, which is called *laying the ground*:—Take the plate firmly in a small hand vice; hold it, with the polished face upwards, over a charcoal fire, that it may not get smoked, till it is well, but not too much, heated: rub the etching-ground, in the silk, over the plate till it is evenly covered; the wax, melting with the heat, oozes through the silk. To effect a more equal distribution of the *ground*, take the *dabber* and dab the plate gently all over, till it appears of an uniform colour; continue the dabbing till the plate begins to cool, but not longer. The ground is then blackened by being held over the smoke of a candle, or two or three tied together,—wax is far preferable to tallow; keep the plate in motion, so that every part be made equally dark, and also to avoid injury, by burning, to the composition; when cold the plate is ready to receive the design. To transfer this, a very correct outline of the subject is made with a black-lead pencil on a piece of thin hard paper: fasten the tracing, or drawing, at the top edge, with its face downwards, on to the etching-ground, with a piece of banking-wax, described hereafter, and by passing it through a printing-press—such as is used by plate printers, to whom it should be taken—the drawing is transferred to the ground. The *bridge* being laid over the plate, the process of etching may now be commenced; the points, or needles, which are used to complete the design, remove the ground from the metal wherever they pass, and expose the latter to the action of the acid during the process of what is termed *biting-in*. The needles with the most tapering points should be used for the skies and distances, changing them for others for the foreground, which generally requires broader and deeper lines. Any error that has been made may be remedied by covering the part evenly with the etching-ground mollified by spirits of turpentine, using a camel's-hair pencil for the purpose; and, when dry, the lines may be re-etched through it.

The next operation is that of *biting-in*, performed thus:—A wall or border of *banking-wax* is put round the edge of the plate: this wax, called sometimes *bordering-wax*, is made by melting over a slow fire, in a glazed pot, two parts of Burgundy pitch, and one of bees'-wax, to which is added when melted, a gill of sweet oil; when cold it is quite hard, but by immersion in warm water it becomes soft and ductile, and must be applied in this state: it will adhere to the metal by being firmly pressed down with the hand: the object in thus banking up the plate is to prevent the escape of the acid which is to be applied; but a spout or gutter must be left at one corner to pour off the liquid when necessary. Mr. Fielding,—to whose work on the art of engraving we are indebted for some of the practical hints here adduced, availing ourselves, however, of the improvements introduced into modern practice,—recommends the following mixture as the best:—'Procure some strong nitric acid, and then mix, in a wide-mouthed bottle, one part of the acid, with five parts of water, adding to it a small quantity of sal-ammoniac, in the proportion of the size of a hazel-nut to one pint of acid, when mixed for biting. The advantage of using the sal-ammoniac is, that it has the peculiar property of causing the aqua-fortis to bite more directly downwards, and less laterally, by which means lines laid very closely together are less liable to run into each other, nor does the *ground* so readily break up.' When the mixture is cool—for the acid becomes warm when first mixed with water—pour it on the plate, and let it continue there till the more delicate lines are presumed to be corroded to a sufficient depth; this will probably be in about a quarter of an hour; sweep off the bubbles as they appear on the plate, with a camel's-hair pencil, or a feather; then pour off the acid through the gutter at the corner, wash the plate with warm water, and leave it to dry. Next, cover those parts which are sufficiently bitten in with Brunswick black, applying it with a camel's-hair pencil, and leave it to dry; again put on the acid, and let it remain twenty minutes or half an hour, to give the next degree of depth required; and repeat this process of *stopping out* and *biting in*, until the requisite depths are all attained: three *bitings* are generally enough for a *painter's etching*. The work is now complete, unless the graver is to be used upon it, and the banking-wax may be removed, by slightly warming the margin of the plate; and, finally, wash the latter with a soft rag dipped in spirits of turpentine, and rubbing it with olive-oil. If, when the plate is cleaned, the engraver finds that the acid has acted as he wishes, he has secured what is technically termed 'a good bite.'

Steel plates require another method of *biting-in*, on account of their extreme hardness, and liability to rust; the mode just described is applicable only to copper, the metal generally used by painters for their etchings. For steel plates mix together

	Parts
Pyroligneous acid	1
Nitric acid	1
Water	3

This mixture should not be allowed to remain on above a minute; let it be washed off at once, and never use the same water twice; the plate must be set up on its edge, and dried as quickly as possible to avoid rust: the acid may be strengthened where a stronger tint is required.

Re-biting, a process frequently adopted to increase the depth of tint where it is required, or to repair any portion of a plate that has been worn by printing or accidentally injured, is thus performed. The plate must be thoroughly cleaned, all traces of grease removed, by washing it with spirits of turpentine and potass, and polished with whiting; it is then, when warmed over a charcoal fire or with lighted paper, ready for receiving the *ground*; this is laid by using a dabber charged with etching-ground, and carefully dabbing the surface; by this means the surface of the plate only is covered, and the lines already engraved are left clear; any part of the plate that it may not be necessary to *re-bite*, must be stopped out with Brunswick black, and then the acid may be poured over the whole, as in the first process.

Etching on soft ground is a style of engraving formerly much practised in imitation of chalk or pencil drawings; since the introduction of lithography, however, it has been entirely abandoned. The *soft ground* is made by adding one part of hog's lard to three parts of common, or hard, etching-ground, unless the weather be very warm, when a smaller quantity of lard will suffice; it should be laid on and smoked in the manner already described. Mr. Fielding gives the following method for working on it. 'Draw the outline of your subject faintly on a piece of smooth thin writing-paper, which must be at least an inch larger every way than the plate; then damp it, and spread it cautiously on the ground, and turning the edges over, paste down to the back of the plate; in a few hours the paper will be dry, and stretched quite smooth. Resting your hand on the bridge, take an H or HB pencil, and draw your subject on the paper exactly as you wish it to be, pressing strongly for the darker touches, and more lightly for the delicate parts, and, accordingly as you find the ground more or less soft, which depends on the heat of the weather or the room you work in, use a softer or harder pencil, remembering always that the softer the ground the softer the pencil' (should be). 'When the drawing is finished, lift up the paper carefully from the plate, and wherever you have touched with the pencil, the ground will stick to the paper, leaving the copper more or less exposed. A *wall* is then put round the margin, the plate bit in, and if too feeble, re-bit in the same way as a common etching, using *hard etching-ground* for the re-bite.'

Line-engraving unquestionably occupies the highest place in the category of the art; and, taking it as a whole, it is the most suitable for representing the various objects that constitute a picture. The soft, pulpy, and luminous character of flesh; the rigid, hard, and metallic character of armour; the graceful folds and undulations of draperies, the twittering, unsteady, and luxuriant foliage of trees, with the bright yet deep-toned colour of skies, have by this mode, when practised by the best engravers, been more successfully rendered than by any other. The process of line-engraving is, first, to etch the plate in the manner already described, and afterwards to finish it with the graver and dry point. An *engraver's etching* differs from a *painter's etching* in that every part of the work has an unfinished appearance, though many engravers, especially of landscapes, carry their etchings so far as to make them very effective: engravers of historical and other figure subjects, generally, do little more than etch the outlines, and the broad shadowed masses, or colours, of the draperies; the flesh being entirely worked in with the *burin*, or graver: no definite rules can be laid down as to the extent to which the etching should be advanced ere the work of the tool commences, as scarcely two engravers adopt the same plan precisely: much must always depend on the nature of the subject. Neither would it be possible to point out in what particular way the graver should be used in the representation of any particular object: this can only be learned in the studio of the master, or by studying the works of the best engravers: as a rule it may be simply stated, that in making the incision, or line, the graver is pushed forward in the direction required, and should be held by the handle, at an angle very slightly inclined to the plane of the steel or copper plate: the action of the graver is to cut the metal clean out.

Some years ago an instrument, called a *ruling machine*, was invented by Mr. Wilson Lowry, and has been brought into use for laying in flat tints in skies, buildings, and objects requiring straight, or slightly curved lines: considerable time is saved to the artist by its use, and more even tints are produced than the most skilful hand-work generally is able to effect; but to counterbalance these advantages, freedom is frequently sacrificed, and in printing a large number of impressions, the machine-work, unless very skilfully ruled in, is apt to wear, or to become clogged with ink, sooner than that which is graved.

Mezzotinto engraving is generally supposed to owe its origin to Colonel Ludwig von Siegen, an officer in the service of the Landgrave of Hesse; there is extant a portrait by him, in this style, of Amelia, princess of Hesse, dated 1643. Von Siegen is said to have communicated his invention to Prince Rupert, to whom many writers have assigned the credit of originating it: there are several plates executed by the Prince still in existence. It differs from every other style of engraving, both in execution and in the appearance of the impression which the plate yields: a mezzotint engraving resembles a drawing done in washes of colour, by means of a camel's-hair pencil, rather than a work executed with any sharp-pointed instrument; but a pure mezzotint engraving is rarely produced in the present day, even for portraits: the advantages derived from combining line and stipple, of which we shall speak presently, with it, to express the different kinds of texture in objects, have been rendered so obvious as almost to make them necessary: this combination is termed the *mixed* *style.* The distinguishing excellences of mezzotint are the rich depth of its shadows, an exquisite softness, and the harmonious blending of light and shade: on the other hand, its great defect is the extreme coldness of the high lights, especially where they occur in broad masses.

The instruments used for this kind of work are, *burnishers, scrapers, shading tools, roulettes*, and a *cradle*, or *rocking tool.* The burnisher and scraper differ in form from those already described: the roulette is used to darken any part which may have been scraped away too much; it ought to be of different sizes: the cradle is of the same form as the shading tool, and is used for the purpose of laying grounds.

The operation of engraving in mezzotint is precisely the opposite of that adopted in all other styles: the processes in the latter are from *light* to *dark*, in the former from *dark* to *light*, and are thus effected. A plate of steel or copper is indented all over its face by the *cradle*, an instrument which somewhat resembles a chisel with a *toothed* or serrated edge, by which a *burr* is raised on every part in such quantities that if filled in with ink, and printed, the impression would exhibit a uniform mass of deep black: this operation is called *laying the ground;* it is performed by rocking the cradle to and fro, and the directions, or *ways*, as the engravers call them, are determined by a plan, or scale, that enables the engraver to pass over the plate in almost any number of directions without repeating any one of them. When an outline of the subject has been first etched in the ordinary way before the ground is laid, the engraver proceeds to scrape away, and then burnish the highest lights, after which the next lightest parts are similarly treated, and the process is repeated after this manner till the work is finished; the deepest shades are produced from the ground that is left untouched. There is, however, no style of engraving for the execution of which it is so difficult to lay down any definite rules, for almost every engraver has his own method of working.

Chalk or *stipple* engraving, for the terms are synonymous, is extremely simple. The plate has first to be covered with the etching ground, and the subject transferred to it in the ordinary way: the outline is then laid in by means of small dots made with the stipple graver; all the darker parts are afterwards etched in dots larger and laid closer together. The work is then bitten in with the acid; and the ground being taken off, the stipple graver must again be taken up to complete the operation; the light parts and the dark are respectively produced by small and large dots laid in more or less closely together. Stipple is well adapted for, and is often used in, the representation of flesh, when all the other parts of the subject are executed in line: hence it is very frequently employed in portraiture, and in engravings from sculpture. *Chalk engraving* is simply the imitation of drawings in chalk, and is executed like stipple, only that the dots are made with less regularity, and less uniformity of size; in the present day, the two terms are generally considered as expressing the same kind of work.

Aquatint engraving, which represents a drawing in Indian-ink or bistre even more than does mezzotint, has been almost entirely superseded by lithography, and still more recently by chromo-lithography; and there seems little probability that it will ever come into fashion again. This being the case, and as any detailed description of the mode of working would, to be of any service, occupy a very considerable space, it will, doubtless, be deemed sufficient to give only a brief outline of its character and of the mode of operation; this we abbreviate from the notice of Mr. Fielding, formerly one of our most able engravers in aquatint. The process consists in pouring over a highly-polished copper-plate a liquid composed of resinous gum, dissolved in spirits of wine, which latter, evaporating, leaves the resin spread all over the plate in minute grains that resist the action of the aqua-fortis, which, however, corrodes the bare surface of the copper that is left between them: this granulated surface is called a *ground.* The ground having been obtained, the margin of the plate should be varnished over, or stopped out, and, when dry, the subject to be aquatinted must be transferred to the plate, either by tracing or drawing with a soft blacklead pencil, which may be used on the ground with nearly the same facility as paper; if the former method be adopted the tracing must be carefully fastened down to the copper by bits of wax along the upper edge. A piece of thin paper, covered on one side with lampblack and sweet oil, is placed between the tracing and the ground, with the coloured side downwards, and every line of the subject must be passed over with the tracing point, using a moderate pressure. The tracing being finished and the paper removed, a wall of prepared wax, about three quarters of an inch high, must be put round the plate, with a large spout at one corner, to allow of the acid running off.

The plate is now ready for use; and the completion of the design is commenced by stopping out the highest lights on the edges of clouds, water, &c., with a mixture of oxide of bismuth and turpentine varnish, diluting it with spirits of turpentine till of a proper consistence to work freely. Next pour on the acid, composed of one part of strong nitric acid and five parts of water; let it remain, according to its strength, from half a minute to a minute, then let it run off, wash the plate two or three times with clean water, and dry it carefully with a linen cloth. This process of stopping-out and biting-in is continued till the work is complete; each time the aqua-fortis is applied a fresh tint is produced, and as each part successively becomes dark enough it is stopped out; in this manner a plate is often finished with one ground bitten in ten or twelve times. We would recommend those who may desire to become thoroughly acquainted with this very interesting yet difficult mode of engraving to consult Fielding's 'Art of Engraving.'

A few remarks explanatory of the method of printing steel or copper plates seem to be inseparable from the subject. The press used for the purpose consists of two cylinders or rollers of wood, supported in a strong wooden frame, and moveable at their axes. One of these rollers is placed just above, and the other immediately below, the plane or table upon which the plate to be printed is laid. The upper roller is turned round by means of cogged wheels fixed to its axis. The plate being inked by a printer's inking-roller, an operation requiring great care, the paper which is intended to receive the impression is placed upon it, and covered with two or three folds of soft woollen stuff like blanketing. These are moved along the table to the spot where the two rollers meet; and the upper one being turned by the handle fixed to the fly-wheel, the plate passes through it, conveying the impression as it moves; the print is then taken off the plate, which has to undergo the same process of inking for the next and every succeeding impression. The *proofs* of an engraved plate are always taken by the most skilful workmen in a printing establishment; in the principal houses there are generally employed from two to six men, according to the amount of business transacted, whose duty it is to print proof impressions only; they are called *provers.* A careful, steady workman is not able to print more than from 180 to 200 good ordinary impressions from a plate, the subject of which occupies about seven inches by ten inches, even in what is considered a long day's work, that is, about fourteen hours; the *prover*, from the extreme care required in inking the plate, and from the extra time occupied in wiping it, and preparing the Indian-paper, will do from thirty to forty, according as the subject of the plate is light or heavy. This difference in the cost of production, taking also into account that the *proofs* are worked off before the plate has become worn, even in the least degree, and that very few proofs, compared with the ordinary prints, are generally struck off, is the reason why they are sold at a price so much greater than the latter.

Notwithstanding the vast multiplication of engravings within the last few years, it is generally admitted, by those best acquainted with the present state of the art, that it is not in a healthy condition. The highest class of pictorial subjects—history, and the highest style of engraving—line, have given place to subjects of less exalted character, and to a mixed style of work, which, however effective for its especial purpose, is not pure art. The pictures by the late Sir E. Landseer have gained for engravings of such subjects a popularity that has driven almost everything else out of the field, and have created a taste in the public which is scarcely a matter of national congratulation. We have engravers in the country capable of executing works equal to whatever has been produced elsewhere at any time, but their talents are not called into requisition in such a way as to exhibit the art of engraving in its highest qualities. Publishers are not willing to risk their capital on works which the public cannot appreciate, and hence their windows are filled with prints, the subjects of which, however pleasing and popular, are not of a kind to elevate the taste; while the conditions under which engravers generally are compelled to work, offer but little inducement for the exercise of the powers at their command. Engraving on copper is in the present day but rarely attempted; formerly nothing else was thought of; now the demand for engraving is so great that copper, even aided by the electrotype, is insufficient to meet its requirements. In consequence of the comparatively small number of impressions which it yields, a copper-plate will seldom produce more than 500 or 600 good prints; we have known a steel, with occasionally retouching, produce more than 30,000, when well engraved, and carefully printed; very much depends on the printer, both with regard to the excellence of the impression and the durability of the plate. The public demand is for prints both large and cheap, and to obtain this result, the engraver is too often obliged to sacrifice those qualities of his art which under other circumstances his work would exhibit. Such is the state of engraving with us now. There are few, even of the best artists we have, who by their utmost efforts can earn an income equal to that of a tradesman in a small but respectable way of business. This is an evil to be deplored, for it assists to deteriorate the art by forcing the engraver to labour hard for a maintenance, instead of placing him in a position that would enable him to exalt the art and his own reputation at the same time.

A process of depositing steel upon an engraved copper-plate was some time ago brought over to this country from France. M. Joubert, a French engraver long settled in England, introduced it here; he has informed us that a copper-plate thus covered may be made to yield almost any number of impressions, for as the steel coating becomes worn it can be entirely taken off, and a new deposit laid on without injury to the engraving, and this may be done several times. M. Joubert has repeated the experiment with the most satisfactory results. He thus describes his process in a communication made to the Society of Arts, and printed in their Journal:—

'If the two wires of a galvanic battery be plunged separately into a solution of iron, having ammonia for its basis, the wire of the positive pole is immediately acted upon, while that of the negative pole receives a deposit of the metal of the solution—this is the principle of the process which we have named "acierage."

'The operation takes place in this way: By placing at the positive pole a plate or sheet of iron, and immersing it in a proper iron solution, the metal will be dissolved under the action of the battery, and will form an hydrochlorate of iron, which, being combined with the hydrochlorate of ammonia of the solution, will become a bichloride of ammonia and iron; on a copper-plate being placed at the opposite pole and likewise immersed, if the solution be properly saturated, a deposit of iron, bright and perfectly smooth, is thrown upon the copper-plate, from this principle:—

'Water being composed of hydrogen and oxygen:

'Sal-ammoniac being composed of—

'1st. Hydrochloric acid, containing chlorine and hydrogen;

'2nd. Ammonia, containing hydrogen, nitrogen, and oxygen:

'The water is decomposed under the galvanic action, and the oxygen fixes itself on the iron plate, forming an oxide of iron; the hydrochloric acid of the solution acting upon this oxide becomes a hydrochlorate of iron, whilst the hydrogen precipitates itself upon the plate of the negative pole, and, unable to combine with it, comes up to the surface of the solution in bubbles.

'My invention has for its object certain means of preparing printing surfaces, whether for intaglio or surface printing, so as to give them the property of yielding a considerably greater number of impressions than they are capable of doing in their ordinary or natural state. And the invention consists in covering the printing surfaces, whether intaglio or relief, and whether of copper or other soft metal, with a very thin and uniform coating of iron, by means of electro-metallurgical processes. And the invention is applicable whether the device to be printed from be produced by engraving by hand, or by machinery, or by chemical means, and whether the surface printed from be the original, or an electrotype surface produced therefrom. I would remark, that I am aware that it has been before proposed to coat type and stereotypes with a coating of copper, to enable their surfaces to print a larger number of impressions than they otherwise would do; I therefore lay no claim to the general application of a coating of harder metal on to the surface of a softer one, but my claim to invention is confined to the application of a coating of iron by means of electricity on to copper and other metallic printing surfaces.

'In carrying out the invention I prefer to use that modification of Grove's battery known as Bunsen's, and I do so because it is desirable to have what is called an intensity arrangement. The trough I use for containing the solution of iron in which the engraved printing surface is to be immersed, in order to be coated, is lined with gutta-percha, and it is 45 inches long, 22 inches wide, and 32 inches deep. In proceeding to prepare for work, the trough, whether of the size above mentioned or otherwise, is filled with water in combination with hydrochlorate of ammonia (sal-ammoniac) in the proportion of 1,000 lbs. by weight of water to 100 lbs. of hydrochlorate of ammonia. A plate of sheet iron, nearly as long and as deep as the trough, is attached to the positive pole of the battery and immersed in the solution. Another plate of sheet iron, about half the size of the other, is attached to the negative pole of the battery, and immersed in the solution, and when the solution has arrived at the proper condition, which will require several days, the plate of iron attached to the negative pole is removed, and the printing surface to be coated is attached to such pole, and then immersed in the bath till the required coating of iron is obtained thereto. If, on immersing the copper-plate in the solution, it be not immediately coated with a bright coating of iron all over, the bath is not in a proper condition, and the copper-plate is to be removed and the iron plate attached and returned into the solution. The time occupied in obtaining a proper coating of iron to a printing surface varies from a variety of causes, but a workman after some experience and by careful attention will readily know when to remove the plate from the solution; and it is desirable to state that a copper-plate should not be allowed to remain in the bath and attached to the negative pole of the battery after the bright coating of iron begins to show a blackish appearance at the edges. Immediately on taking a copper-plate from the bath great care is to be observed in washing off the solution from all parts, and this I believe may be most conveniently done by causing jets of water forcibly to strike against all parts of the surface. The plate is then dried and washed with spirits of turpentine, when it is ready for being printed from in the ordinary manner.

'If an engraved copper-plate be prepared by this process, instead of a comparatively limited number of impressions being obtained and the plate wearing out gradually, a very large number can be printed off without any sign of wear in the plate, the iron coating protecting it effectually; the operation of coating can be repeated as many times as required, so that almost an unlimited number of impressions can be obtained from one plate, and that a copper one.

'This process will be found extremely valuable with regard to electrotype plates, and also for photogalvanic plates, since they can be so protected as to acquire the durability of steel, and more so, for a steel plate will require repairing from time to time, these will not, but simply recoating them whenever it is found necessary; by these means one electro copper-plate has yielded more than 12,000 impressions, and was found quite unimpaired when examined minutely.'—J. D.

For a more complete description of the process of precipitating iron by the electrotype process, as now practised, see ELECTRO-METALLURGY.

ENGRAVING ON WOOD. The art of wood-engraving is so intimately connected with that of book-printing, that it is impossible to dissever the one from the other, inasmuch as the earliest books were printed from large woodcuts, the entire page, text, and illustrations being engraved in one solid block. Hence the term 'block-books' given to these ancient works. The impression from these engraved pages is generally taken in a thin ink, sometimes of a brown hue, which occasionally spreads or blots on the lines or letters; and the printing is generally supposed to have been effected by friction on the back of the damped paper laid on the inked lines; the sheets so printed were afterwards pasted back to back, and thus formed consecutive pages of the volume. Such books originated from the large woodcuts of a devotional class, which, in the early part of the 15th century, were spread by the clergy among the common people, perhaps to counteract the evil produced by the use of playing cards, which were also printed in large sheets of cuts, and severed afterwards; but on this point typographical antiquaries are not agreed, as dates and other evidence are wanting to enable us to fix either time or place to these early productions. The earliest woodcut bearing a date is that belonging to Earl Spencer, and representing St. Christopher carrying the Saviour across an arm of the sea; it has two lines of text beneath it, and the date 1423 thus expressed: 'millesimo cccc° xx° tercio.'[1] The British Museum is possessed of some very early single-leaf woodcuts: one representing Christ brought before Pilate, is executed in bold coarse outline, the figures are very large, and retain the characteristic features of the drawings seen in manuscripts of the 14th century. Another undated cut is one of those fanciful inventions which the scholastic men of that early day delighted in constructing; it is termed *Turris Sapiencie*, every stone of which is inscribed with the name of some moral virtue, the foundation buttresses being prudence, fortitude, justice, and temperance; the windows which give it internal light being discretion, religion, devotion, and contemplation. Another representing the Seven Ages of Man is supposed to be a work of the middle of the 15th century. It was found pasted inside the covers of an old book, a practice which has preserved many specimens of old engraving which would else have been lost. On the opposite cover is a fragment of another large cut, representing the Virgin with St. Joachim and St. Anne. The St. Christopher above named was discovered in the cover of a volume in the conventual library at Buxheim, in Suabia. All these old woodcuts, as well as the block-books, are generally daubed with flat tints of coarse colour, supposed to have been done with stencil-plates, such as the card painters used on some occasions; but evidently rudely executed by hand in others. They are all precisely of the kind to attract the uneducated eye; and to this day similar coarse prints are used by the clergy to aid the devotions of the peasants of the Germanic nations.

The most celebrated of the block-books is that termed the 'Biblia Pauperum.' Each page is divided by architectural compartments into three subjects, from the Old and New Testament, selected to form 'parallel passages' of sacred writ; above and below are other compartments with heads of the Prophets, and in the intervening spaces, or upon scrolls, are explanatory inscriptions. The page measures 10 inches by 7½, and is one of the most elaborate works of its class; but it exhibits very small claims to attention as a specimen of art, certainly less than the 'Cantica Canticorum,' each

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[1] Much interest was excited some few years ago by the discovery of a cut in the library at Brussels apparently bearing an earlier date; but strict investigation has since proved that one of the C's in the date has been omitted; this makes just one hundred years difference in its age. But the date thus altered is quite in accordance with the general character of the design and execution of the cut, which, on the contrary, do not at all agree with the earlier date originally assigned to it.

page of which is divided horizontally into two pictures, with slight descriptive lines on scrolls; or the 'Apocalypsis Sancti Johannes,' which is similarly arranged, and in both of which we occasionally find much power of drawing and ability of grouping. The dates of these books can only be conjecturally given, but they are probably contemporary with the St. Christopher, or but a few years later. Judging from general characteristics, the 'Apocalypse' seems to be the earliest. The figures are executed entirely in outline, with no attempt at shadows, which appear sparingly on the St. Christopher, and are very freely introduced in the 'Canticles,' and still more abundantly in the 'Biblia Pauperum.' These effects are always produced by a series of short lines laid parallel to each other, nor is any attempt made to enrich the meagre character of the work by crossing the lines, as in more modern engraving. The debate, which has excited so many historians as to the place where printing first had birth, has included many doubts concerning the country where these old block-books were fabricated; but from the armorial bearings which appear on the shields of some figures in the 'Canticles,' Germany seems to be the country where that series was designed;[1] probably Flanders or Holland may claim the 'Biblia Pauperum,' which does not bear equal traces of refinement in art. The 'Speculum Humanæ Salvationis' has been claimed for Laurence Coster of Haarlem. This book was a combination of block-book and moveable type, having long cuts across the top of each page, divided by columns into two subjects, with moveable types beneath. It is not unusual to meet with woodcut pages of type alone at this period; and books with such pages, or with the addition of woodcuts, were produced by the old engravers after the invention of moveable types; but, as metal-cast letters speedily usurped the place of the wooden ones, the wood engravers seem to have soon confined themselves to the pictorial branch of the art.

The love of pictured illustrations of narrative history gave a permanence to the art of wood-engraving; and the works printed in Italy, as well as those introduced into England by Caxton, were adorned with cuts. They are, however, of the rudest kind, with broad heavy lines, and were most probably produced from coarse pen drawings made on the surface of the wood, and mechanically cut by the engraver. Toward the close of the fifteenth century 'cross-hatching' (as lines of shadow crossing each other are technically termed) is first seen, and in the 'Nuremburg Chronicle,' 1493, they are freely used. The designers and engravers of these cuts, perceiving the effect, which may be so readily obtained in wood-engraving, by leaving the wood untouched with the graver for solid masses of shadow, have availed themselves of it, and given stronger effect to their cuts thereby. Michael Wohlgemuth and William Pleydenwurff were the designers employed; the former artist was the master of Albert Dürer, who ultimately raised wood-engraving to the highest point of excellence.

Dürer's first great work was a series of sixteen large cuts illustrative of the Apocalypse. They were published in 1498, and attracted great attention from the vigour and strange originality of their design, and the artistic character of their treatment. In 1511 another series of cuts was published at Nuremberg by Dürer, illustrative of the Apocryphal Life of the Virgin. They evidence the great improvement which the artist had made during the interval, and are certainly the finest woodcuts which had ever been executed up to that period; but they are eclipsed by the series of eleven large cuts published soon after, representing scenes in the Passion of Christ; and which may be fairly considered triumphs of the art of wood-engraving, unsurpassed in design and execution by any successors. The art had now become appreciated wherever it was known, and a host of wood engravers found employ in Nuremberg, cutting the designs of Dürer, Hans Burgmair, Hans Schaufelein, and other artists; who found no lack of patronage in the old imperial city, for the Emperor Maximilian I., extensively employed them in various works illustrative of his real or fancied exploits.[2]

So important was this royal patronage, that the engravers set no bounds to the size of the works they attempted, and hit upon the plan of joining one block of wood to another, until in the engraving representing the triumphal arch in honour of this emperor, a woodcut was completed in this way, measuring ten feet by nine. The size is, however, not its only claim to attention, for it is throughout designed and engraved with the utmost care and beauty.

In all these cuts of the great masters of the art of wood-engraving, we only find the name of the designer recorded; thus, Dürer, and others of his era, whose names

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[1] Among them are the double-headed eagle of Austria, the black eagle of Germany, the three crowns of Cologne, the cross-keys of Ratisbon, the arms of Wurtemberg, Nymphenburg, and Alsace.

[2] Such were the adventures of the Knight Theurdank, under which form the emperor was figured; 'The Wise King,' an equally flattering picture of his early education and actions; and the magnificent series of cuts, known as the 'Triumphs of Maximilian.'

occur on cuts, were the designers and draughtsmen on the wood; but the engraver was considered in the light of a mechanician, and, except in a very few instances, his name was not displayed. To fully understand this, it is necessary here to explain the whole process of wood-engraving at this time. A block of wood being prepared from a perpendicular cutting of pear-tree, upon the surface was made a drawing, in which every line was delineated with pencil or reed-pen, exactly as the cut was ultimately to appear; the intervening spaces of plain wood between every line were then cut away; and in this manual dexterity consisted the whole merit of the engraver. The abundance of cross-hatching so constantly found in old woodcuts, is explained by the fact of this being the easiest and best mode for the draughtsman to employ in getting his effects of light and shade; the extreme labour it involves to the engraver not being considered; but when it is understood that each minute space has to be cut down from each angle of the lines, and the centre entirely cleared out, some idea may be formed of the labour required, when thousands of such squares occur on some of Dürer's large cuts, independent of other work. The backs of some of these old blocks, particularly those in the 'Triumphs of Maximilian,' are marked with the names of the engravers, and there is proof that women practised the art; but it is not at all likely that the artists who designed, and drew upon the wood these designs, went through the merely mechanical labour of engraving them.

The great impetus thus given to wood-engraving,[1] kept it prominently before the world during the whole of the sixteenth century, when the presses of the Continent continually brought forth a series of volumes remarkable for the beauty of the cuts by which they were illustrated. This practice of the book trade gave rise to a series of artists known as 'the little masters' of the German school, from the small size of their works; among whom the principal who connected themselves with engraving on wood were Virgil Solis, Henry Aldegraver, the two Behaims, Lucas Cranach, Urse Graff, Albert Altdorffer, Jost Ammon, and Solomon Bernard.

In Italy, Ugo da Carpi practised with success, from the year 1518, the art of engraving on wood imitations of tinted drawings: an art which originated with the Germans, but which he much enlarged and improved. It consisted in a series of blocks cut to imitate patches of colour, and made to print over each other in gradations of tint, until the chiar-oscuro of a drawing was secured; then the coarser and bolder lines defining the whole design were printed over all, and a capital imitation effected of the bold cartoons, consisting of vivid outline and broad washes of tint, used as first sketches for their pictures and frescoes by the artists of that era.

A perfect rage for book illustration seems to have beset the printers soon after the death of Dürer. The most prolific artists who supplied their wants were Jost Ammon and Solomon Bernard: the former executed a multitude of designs on every imaginable subject; the latter, equally prolific, devoted himself chiefly to the illustration of sacred or classic literature. The greatest publishers of such books were Sigismond Feyeraband, of Frankfort-on-the-Maine; Jean de Tournes, and Trechsel, of Lyons; and Plantyn, of Antwerp. From their presses issued a series of small volumes, which can only come under the generic title of 'picture books;' for they were got up for the sake of exhibiting the favourite art of wood-engraving, and only contain a few descriptive lines of type beneath each cut. The cuts executed by Ammon are all remarkable for correctness of drawing and vigorous effect; those of Bernard are less scholastically correct, but contain more evidence of grace and fancy. The designs of these artists abound in books published between 1550 and 1580; but the most admirable series were executed in a little volume, published at Lyons, in 1538, without the name of draughtsman or engraver, the 'Simulachres de la Mort,' known among bibliographers as the 'Lyon's Dance of Death,' a collection of cuts which, for minute beauty and perfection of design and execution, are completely unrivalled, and have not been equalled by any modern copyist.[2] This was the Augustan age of book illustration, which flourished in popular favour until the close of the sixteenth century, when a minute *tameness*, in contradistinction to the *vigour* of the earlier engravers, began to appear, and reached its culmination in such cuts as were given in Nicolay's 'Travels in Turkey' (Antwerp, 1576).

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[1] Dürer's engravings were so exceedingly popular, that they found their way all over Europe. Raphael admired them in Rome, and was induced to perpetuate his own designs by employing Marc Antonio Raimondi to engrave them on metal under his own superintendence. So originated the modern print trade. Dürer's designs were so much in request, that Lucas van Leyden imitated them on copper, for sale to such persons as could not perceive the great difference between the vigorous originals and his tame and disagreeable copies. Dürer was ultimately obliged to apply for legal restrictions against these piracies.

[2] The designs have been popularly ascribed to Holbein, and, apparently, with reason. An artist named Hans Lutzelburgher, of Basle, has been conjectured to have been the engraver, from the initials H. L. on one of them. By this time it had become usual to append the initials of engravers to woodcuts, as well as those of the designers.

Titian is said to have furnished designs for various woodcuts, particularly the series of Costumes published at Venice in 1590; and a very large coarse cut of the Destruction of Pharaoh and his Host, more than four feet long, is said to have been one among many of uncommon size executed from his designs; they were printed on separate blocks, and then pasted together in the manner of wall-papers. One representing the Sacrifice of Abraham is remarkable for the variously-tinted inks in which it is printed to exhibit gradations of distance.

Wood-engraving in the early part of the seventeenth century had sunk from its high estate. The last great artist who had employed himself in connection with the art was Hans Holbein; and we do not find a great name again conjoined with it until the middle of that century, when Rubens employed Jeghers, of Antwerp, to engrave some of his drawings on wood. The generality of woodcuts in books of this era rival in coarseness the older block-books; the wood-engravers seem to have sunk into mechanics, unassisted by good artists to furnish them with drawings. The art had become vulgarised, its profession a trade, and the demand and supply scarcely better than the requirements of the ballad-printer desired. They were ancillary to the commonest uses of the press, and all art speedily vanished from the cuts manufactured probably at a very cheap rate for temporary use. Of this kind are the cuts sprinkled through the English books of the time of James and Charles I. It is possible that the printers were supplied with them from Germany and Flanders. It was customary to use woodcuts repeatedly, particularly if merely ornamental; in this way initial letters were reproduced as the stock in trade of the printing-office;[1] and even scenes of adventure, adopted unscrupulously for other events, to which there was the slightest general resemblance.[2] The names of these 'wood-cutters' have not descended to our time; their works are widely scattered over general literature, and it is not until the middle of the century that we meet with any instance of an attempt to arrest the downward progress of the art. Then, as we have previously noted, Rubens, probably anxious to rival Dürer, engaged Christopher Jegher, of Antwerp, to execute, under his own superintendence and at his expense, a series of large drawings made by himself upon the wood. They differ from the style of the earlier masters, and frequently have a confused blotted look in the lines, which produce deep shadows; they possess, however, all that boldness and vigour of treatment for which the great Flemish painter was so deservedly celebrated; but the engraving is coarse and mechanical. Rubens appears to have felt this, and sometimes a tinted block is added over all, with high lights cut upon it, to give softness and brightness to the whole: an idea he may have adopted from the engravers of Italy who succeeded Ugo da Carpi (among whom may be honourably mentioned Andreas Andreani, of Mantua, born 1540, died 1620), or from the designs of Lalleman engraved by Businck, which were nearly contemporaneous in France.

Though 'fallen from its high estate,' the art never sank into complete decay, either in England or upon the Continent; there were always a few who followed the profession, and aided the printer with such cuts and diagrams as he might require. The family of the Jeghers practised in Antwerp until the end of the century: a clever series of woodcuts illustrative of the Service of the Mass was published at Ghent, and executed by Kraaft in 1732. In France, the family of Le Sueur were employed through three generations by booksellers; the last, Nicholas, died in 1764; while Papillon, the author of a *Traité de la Gravure en Bois*, had practised the art from the commencement of the century until 1770, and had been patronised so extensively by the booksellers of France and Holland that he counts his cuts by the thousand. In England, E. Kirkhall executed cuts for books, and from 1722 to 1724 a series of 12 block-prints, in imitation of Ugo da Carpi's work already alluded to; in this latter style he produced a greater pupil in J. Jackson, who very successfully copied some of the great works of Titian, Paul Veronese, and others, during the years 1738 to 1741; at this time he resided in Venice, after a short sojourn in Paris, where he was occasionally employed as a wood engraver. Many cuts scattered through English books about the same period bear the initials of F. H. for Francis Hoffman, whose name is engraved in full on a tail-piece, representing Cupids surrounding a lighted altar, to be

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[1] In the old printing office of Plantyn, at Antwerp, is still preserved a large quantity of woodcuts, originally engraved for the books he issued at the end of the 16th century, particularly the emblems of Alciati and Sambuco.

[2] The number of impressions a woodcut will yield has never yet been established. The elasticity of wood gives it a great advantage over metal in press-printing; and while copper and steel wear out, wood shows little sign of wear: many thousands of impressions may be taken by a moderately careful printer without injuring a woodcut. As an instance with what impunity a bad printer may use a coarse woodcut, may be mentioned the fact, that the ballad printers of the middle of the last century occasionally used cuts that had been engraved in the reign of Charles I., and had headed popular ballads for more than 100 years.

seen in the first edition of 'Gulliver's Travels,' 1726, vol. ii. p. 47. An engraver named Lister executed some cuts of a much better character than usual about 1760, particularly those in the 'Oxford Sausage;' and in Sir John Hawkins's 'History of Music' are some of the largest and most ambitious cuts at that time attempted anywhere. They were engraved by T. Hodgson. Three other persons named respectively, W. Pennock, S. Watts, and H. Cole, occasionally devoted themselves to wood-engraving, which seems to have been practised by such copper-plate engravers as occupied themselves with 'general work' for the printing trade or the public, and who varied their labours by occasionally engraving shop-bills or door-plates.

There is one great change in the cuts produced during this period, the result of a different style of drawing made for the wood engravers, and which discarded cross-hatching and its consequent tedious labour, for a tinted or washed drawing which could be cut into a series of lines by the tool, expressing the varied tints more simply and readily. The art of 'lowering' or scraping down to a lower level various parts of a cut that should appear light, and so assist the press in its labours, was also practised, and the harder wood of the box-tree used. Such was the state of the art when a Northumbrian peasant boy was destined to appear, again draw universal attention to the neglected profession, and found the modern school of wood engraving.

Thomas Bewick was the son of parents engaged in a colliery, who lived at Cherryburn twelve miles west of Newcastle-on-Tyne; he was born in 1753 and passed his early years helping his father's labour. His leisure hours were earnestly devoted to the small amount of knowledge a village school could impart; but as a strong love for nature, and for its imitation, soon developed itself in the boy, his father determined to apprentice him to an engraver of Newcastle, Mr. R. Beilby, whose work was of that 'general' kind undertaken in a busy country town. There he occasionally engraved initials on tea-spoons or names on door-plates, until, in the second year of his apprenticeship, his master received an application from Dr. Hutton for woodcut diagrams, such as were then executed in London, to illustrate his treatise on Mensuration. Beilby knew that young Bewick had been making some attempts in this style, and he encouraged him to persevere; he did so, and Hutton's book was published in 1770 with Bewick's cuts. The young engraver had many difficulties to contend against, and he had even to construct his own tools; among the rest, a double-pointed graver to enable him to cut both sides of a line at once, and so ensure its equal thickness throughout. In 1775, he executed a cut and sent it to the Society of Arts, in London, who awarded him a medal; and in the following year he visited London, and was employed by Hodgson, whom we have already noted as the engraver of the cuts in Hawkins's 'History of Music;' as well as by H. Cole. There need be little doubt that this visit to the London wood engravers was useful to Bewick, for he must have become by that means acquainted with the usual mode of practising the art, the proper kinds of tools used, and the various things which make the mechanical part of the profession; but he had fortunately formed a style of his own, so very original, and based so firmly on the study of nature, that wood-engraving in his hands became an art presenting many novel and attractive features never visible before. The wood engravers from the days of Dürer, or from the first invention of the art, depended slavishly on the drawings made upon the wood, and did little more than cut away the interstices; but Bewick cut out of the wood a vast deal of that which no draughtsman could so draw; for with the aid of a slightly-tinted drawing, he would cut the foliage of trees, the plumage of birds, the texture of animals, or small figures and birds, by the graving tool alone. His dextrous hand was guided by a perfect knowledge of nature, and every line he cut expressed drawing; in this was his great distinction over all other wood engravers; he cut his pictures out of the wood, the others cut the wood out of the pictures.

Bewick disliked London, and speedily returned to his native place. His first work was an illustrated edition of Gay's 'Fables,' published in 1779 by T. Saint, a printer of Newcastle, much engaged in the publication of children's books, and such as the travelling chapmen carried in their packs for the edification of the villagers. These cuts bear the earliest traces of that accurate delineation of nature, and minute truthfulness of expression, which ultimately gave his works universal renown. The wild plants and grasses, however minute they are cut, can always be distinguished by the naturalist; the proper foliage of every tree is truthfully cut by his graver; the birds and insects, however minute, are perfect in drawing; and the general effect of his woodcuts artistically powerful. As he fully felt the value of leaving the wood itself to express solid shadow, he had not the timidity which imagines labour to be necessary to success. The little cut of the Fox and Bramble in this volume is a good illustration of Bewick's mode. Every leaf of the bramble is cut out, white upon black, with the most truthful power of drawing; the spines on the stem of the bramble are visible to the eye; the fern beside it is similarly expressed by cutting the form of its foliage with the most perfect freedom upon the solid block of wood. Each bush has its distinctive leaf. The dogs in the distance are similarly cut out by the graver on a tinted ground; and the few lines which cover the body of the fox entangled in the bramble, express its texture with a spirit which no mere cutting of a drawing placed on wood by a professional draughtsman could ever give. Bewick's cuts are sometimes termed *coarse*, but no elaboration of labour will elevate the costliest woodcut above these works, for which Bewick obtained but nine shillings each; unless drawing can be expressed by the engraver as perfectly as Bewick could express it.

Assisted by his brother John, the Newcastle engraver issued a series of works devoted to natural history; the best being the 'History of British Birds.' Here Bewick's knowledge of nature and power of expression by means of his graver shone forth conspicuously. His books became equally celebrated for the humorous tail-pieces he occasionally introduced redolent of whim and original genius. He laboured stedfastly at his art to a good old age. His brother John left Newcastle to reside in London, where he was much employed, but a pulmonary complaint killed him at the early age of thirty-five. He died in 1795. Thomas Bewick lived to the advanced age of seventy-five. He died in 1828, having worked upon a large woodcut only a few days before his death.

The pupils educated by Bewick were few. The best were Charlton Nesbit, Luke Clennell, William Harvey, and John Jackson. Nesbit settled in London, and was extensively employed during a long life. Clennell after a while, devoted himself to painting. Harvey turned his attention to drawing on wood, and his designs for book illustration may be numbered by the thousand; his best are in Lane's edition of the 'Arabian Nights' Entertainments.' Jackson was greatly employed by the publisher of the latter work, Mr. Charles Knight, particularly on the best cuts in the once-famed 'Penny Magazine.'

At the early part of the present century, Mr. Robert Branston founded a London school of wood-engravers, of which he was the head. His style was peculiar, unlike Bewick's, though like him he was self-taught. His cuts have more refinement, but less knowledge of nature; his best pupil was John Thompson, who combines in his best cuts the refined knowledge of light and shade with much of Bewick's power of expressing drawing. Samuel Williams was one of the few modern engravers who made his own drawings upon the wood, and he produced very brilliant effects by frequently leaving the wood in solid masses of black. Drawings for wood engravers were at this time chiefly supplied by artists who devoted themselves to that particular branch of the art; and knew how to design their compositions so that they should best display the peculiarities of wood-engraved effects. Thurston, Craig, and Harvey were the principal artists so engaged.

A large number of wood engravers, the pupils of the Newcastle and London *ateliers*, helped to supply the booksellers at home and abroad for a considerable number of years. It was the custom, some thirty years ago, for the foreign booksellers, particularly in Paris, to send the blocks across the Channel to English engravers to execute; this led ultimately to several settling on the Continent, particularly in France and Germany. The French publishers always sent the wood-block with the drawing carefully executed on its surface by a native artist. These drawings were always elaborately executed in pencil, greatly resembling etchings; little was consequently left for the engraver to do, but follow the lines and cut away the spaces; patience hence became the chief virtue of the wood engraver; and it was ultimately found that its exercise produced so certain an effect, that apprentices knowing nothing of art might aid in thus working out good engravings; and the old style of tinted drawing on wood was discarded for this 'fac-simile' work; the best draughtsmen among the French and German artists having willingly furnished these drawings, English artists of a higher grade were induced to draw on wood, but they occasionally failed from not clearly understanding the peculiar effects their work should produce, and the characteristics of the art. Generally speaking, wood engravers prefer cutting from the drawings of professional draughtsmen on wood; who generally execute their work with such elaborate precision, that the engraver has nothing more to do than follow their lines; this, however, has made mere mechanism of much modern wood-engraving; and many expensive cuts exhibiting pencilling in crossed and re-crossed lines, occupying wearisome labour, and costing many ill-bestowed sovereigns, can only be classed with such 'art' as is devoted to engraving the Lord's Prayer in the compass of a silver penny; and merely produces the same general effect that Bewick would have obtained in a few bold lines.

The great difference between ancient and modern wood-engraving consists in this very boldness, and the practice of the art was essentially different in the sixteenth and eighteenth centuries. The old wood engravers cut on large blocks of soft wood, such as pear-tree, the way of the grain; the moderns, on small blocks of the hardest wood they can obtain—the turkey box, and across the grain. For printing paper-hangings, oil-cloths, and the like, wood-blocks cut on the old system, i.e. on the *side-grain* of the wood, is still employed. The old engravers cut the work downwards with small knives or gouges; the moderns use gravers of various widths to cut out the spaces between fine lines, and broader chisels or gouges to clear away the broad spaces of white. Wood-engraving is the exact opposite to copper-plate engraving in the mode by which the lines of engraving are produced. The copper-plate engraver produces his lines by cutting *into* the metal at once, the wood engraver produces his line by a double operation, by slicing away the wood on each side of it; for though it is recorded that Bewick invented a double cutting fork-shaped graver to cut away both sides of a line at once, no such tool has ever since been used in the profession.

In order to make the whole process of wood-engraving clear to the reader, we will now simply describe the production of a woodcut from the time it leaves the timber-merchant, until it is fit for the hands of the printer. The log of box is cut into transverse slices, ⅞ths of an inch in depth, in order that the face of the cut may be on a level with the surface of the printer's type, and receive the same amount of pressure; the block is then allowed to remain some time to dry, and the longer it is allowed to do so the better, as it prevents accidents by warping and splitting, which sometimes happen after the cut is executed, if the wood is too green. The slice is ultimately trimmed into a square block, and if the cut be large, it is made in various pieces strongly clamped and screwed together; and this enables engravers to get large cuts done in an incredibly short space of time, by putting the various pieces into different engravers' hands, and then screwing the whole together. The upper surface of the wood is carefully prepared so that no inequalities may appear upon it, and it is then consigned to the draughtsman to receive the drawing. He covers the surface with a light coat of flake white mixed with weak gum-water, and the thinner this coat the better for the engraver. The French draughtsmen use an abundance of flake white, but this is liable to make the drawing rub out under the engraver's hands, or deceive him as to the depth of the line he is cutting in the wood. The old drawings of the era of Dürer seem to have been carefully drawn with pen and ink on the wood; but the modern drawing being very finely drawn with the pencil or silver point is obliterated easily, and there is no mode of 'setting' or securing it. To obviate this danger the wood-engraver covers the block with paper, and tears out a small piece the size of a shilling to work through, occasionally removing the paper to study the general effect; in damp and wintry weather he sometimes wears a shade over the mouth to hinder the breath from settling on the block. It is now his business to produce in relief the whole of the drawing; with a great variety of tools he cuts away the spaces, however minute, between each of the pencil lines: and should there be tints washed on the drawing to represent sky and water, he cuts such parts of the block into a series of close lines, which will, as near as he can judge, print the same gradation of tint. Should he find he has not done so completely, he can re-enter each line with a broader tool, cutting away a small shaving, thus reducing their width and consequently their colour. Should he make some fatal error that cannot be otherwise rectified, he can cut out the part in the wood, and wedge a plug of fresh wood in the place, when that part of the block can be re-engraved. An error of this sort in a woodcut is a very troublesome thing; in copper engraving it is scarcely any trouble; a blow with a hammer on the back will obliterate the error on the face, and produce a new surface; but in wood the surface is cut entirely away, except where the lines occur, and it is necessary to cut it deep enough not to touch the paper as it is squeezed through the press upon the lines in printing. To aid the general effect of a cut, it is sometimes usual to lower the surface of the block before the engraving is executed in such parts as should appear light and delicate; they thus receive a mere touch of the paper in the press, the darker parts receiving the whole pressure and coming out with double brilliancy. When careful printing is bestowed on cuts they are first carefully brought to the height of the type, by *underlaying*, as it is termed, with paper of the required thickness; an impression is then taken with the tympan of the press, and the dark parts of the engraving *overlayed* with paper carefully cut out; another impression is then taken, and the same process is to be continued of *laying* on and cutting out for the light parts until a satisfactory impression be produced, corresponding with the engraver's proof, which the pressman should always keep under his observation.

Wood-engraving is a most useful adjunct to the author, and must always command a large amount of attention. In this country the art has been carried to the highest degree of perfection. In works like the present, the author is greatly aided by a diagram, which can more clearly explain his meaning than a page of letter-press;

and it can be set up and printed with the type, a mode which no other style of art can rival in simplicity and cheapness. The taste for elaborately-executed wood-engravings may again decrease, as we find it did for nearly two centuries; but it was never a lost art, and never will be, owing to the practical advantages we speak of, unless it be superseded by some simpler mode of doing the same thing hitherto undiscovered. The number of persons who practise wood-engraving in London alone is very large, and when we consider the quantity done in the great cities of the Continent, and the large amount of book illustration in constant demand, the creative power of one single genius—Thomas Bewick—shines forth in greater vigour than ever.—F.W.F.

When a large number of impressions are to be taken from a wood-block, a cast in metal is taken from it, in the manner described under STEREOTYPE. In some cases electrotype copies are taken in copper, and the comparatively thin sheet of copper produced is mounted upon a wood-block of the proper thickness.

Photography has been employed most serviceably by the wood engraver. Drawings are reduced by the aid of the camera to any required size, and the impression received directly upon the wood which is to be cut. Most of the wood-engravings which illustrate this volume have been produced by the use of the photographic process. See PHOTOGRAPHY.

Engraving on brass plates has been used as a cheap mode of superseding wood-engraving for works of a cheap character.

ENGRAVING ON GLASS. This work does not deal with mere matters of manipulation, therefore the process of engraving on glass, by means of the glass-cutter's wheel, and with tools, finds some notice under GLASS only. One process of engraving on glass is carried out by covering the glass with an etching wax, carefully cutting out the pattern, then covering the glass with powdered fluor-spar, and pouring sulphuric acid upon it. Or, by preparing fluoric acid in a metal bottle, and projecting the vapour as formed directly upon the exposed part of the glass. Attention has of late been drawn to a process of engraving glass by the sand-jet, an American invention.

Mr. Tilghman's attention seems first to have been directed towards cutting stone or hard metal by a jet of sand impelled by escaping steam under high pressure. His early experiments were with very high pressure; but, as he progressed in the knowledge of results obtainable with various velocities, a great use for this process seemed to develop itself in sand driven by moderate air-blasts, and applied to grinding or depolishing glass for ornamental purposes.

For grinding glass a common rotatory fan is used, 30 inches in diameter, making about 1,500 revolutions per minute, which gives a blast of air of the pressure of about 4 inches of water, through a vertical tube, 2 feet high by 60 inches long, and 1 inch wide.

Into the top of this tube the sand is fed, and falling into the air-current and acquiring velocity from it, is dashed down against the sheets of glass, which are slowly moved across, about 1 inch below the end of the tube. About 10 or 15 seconds' exposure to the sand-blast is sufficient to completely grind or depolish the surface of ordinary glass, so that sheets of it carried on endless belts may be passed under this 1 inch wide sand-shower at the rate of 5 inches forward movement per minute. In the machine in use for this purpose the spent sand is reconveyed to the upper hopper by elevators, and the dust made by the sand-blast (which might otherwise be a source of annoyance to the workman) is drawn back into the fan, and thence passes with the wind into the blast ton, and again mingles with the shower of sand upon the glass.

By covering parts of the glass surface by a stencil or pattern of any tough or elastic material, such as paper, lace, caoutchouc, or oil paint, designs of any kind may be engraved.

There is a kind of coloured glass made by having a thin stratum of coloured glass melted or 'flashed' on one side of an ordinary sheet of clear glass. If a stencil of sufficient toughness is placed on the coloured side, and exposed to the sand-blast, the pattern can be cut through the coloured stratum in from about 4 to 20 minutes, according to its thickness.

The theoretical velocity of a current of air of the pressure of 4 inches of water, Mr. Tilghman calculates, is (neglecting friction), about 135 feet per second; the actual velocity of the sand is doubtless much less.

If a current of air of less velocity is used, say about 1 inch of water, very delicate materials, such as the green leaves of the fern, will resist a stream of fine sand long enough to allow their outlines to be engraved on glass. By graduating the time of exposure with sufficient nicety, so as to allow the thin parts of the leaves to be partly cut through by the sand, while the thicker central ribs and their branches will resist, the effect of a shaded engraving may be produced.

The grinding of such a hard substance as glass by an agent which is resisted by such a fragile material as a green leaf, seems at first rather singular. The probable explanation is, that each grain of sand which strikes with its sharp angle on the glass pulverises an infinitesimal portion, which is blown away as dust, while the grains which strike the leaf rebound from its soft elastic surface.

The film of bichromatised gelatin, used as a photographic negative, may be sufficiently thick to allow a picture to be engraved on glass by fine sand, driven by a gentle blast of air.

For cutting stone, the inventor uses steam as the impelling jet; the higher the pressure the greater is the velocity imparted to the sand, and the more rapid its cutting effect.

In using steam of about 100 lbs. pressure, the sand is introduced by a central iron tube, about $\frac{3}{16}$ths-inch bore, while the steam is made to issue from an annular passage surrounding the sand tube.

A certain amount of suction of air is thus produced, which draws the sand through the sand-tube into the steam-jet, and both are then driven together through a tube, about 6 inches long, in which the steam imparts its velocity to the sand, and finally strike on the stone, which is held about an inch distant from the end of the tube.

At the part struck a red light is visible, as if the stone was red-hot, though really it is below 212° Fahr. The light is probably caused by the breaking-up of the crystals of the sand and stone.

The cutting effect is greatest when free escape is allowed for the spent sand and steam. In making a hole of diameter but slightly greater than that of the steam jet, the rebounding steam and sand greatly interfere with, and lessen the efficiency of the jet.

Under favourable conditions, using steam which he estimated as equal to about $1\frac{1}{2}$ horse-power, at a pressure of about 125 lbs., the cutting effect per minute was about $1\frac{1}{2}$ cubic inch of granite, or 3 cubic inches of marble, or 10 cubic inches of soft brown sandstone.

By means of flexible or jointed connecting tubes, the blast-pipe is made moveable in any direction; grooves and mouldings of almost any shape can thus be made, or by means of stencil plates, letters or ornaments can be cut either in relief or in intaglio, with great rapidity in the hardest stone.

At a high velocity, quartz sand will cut substances much harder than itself, as before stated. With a steam jet of 300 lbs. pressure, a hole $1\frac{1}{2}$ inch in diameter was cut through a piece of corundum $1\frac{1}{2}$ inch thick in 25 minutes.

A hole 1 inch long and $\frac{1}{4}$ inch wide was cut through a hard steel file $\frac{1}{4}$ inch thick, in 10 minutes, with a jet of 100 lbs. steam.

A stream of small lead shot driven by 50 lbs. steam, wore a small hole in a piece of hard quartz; the shot were found to be only very slightly flattened by the blow, showing their velocity to have been moderate.

Among the curious examples of glass cut by this sand-blast was shown a piece of ordinary window-glass, which, having been partially protected by a covering of wire gauze, had been cut entirely through, thus producing a glass sieve, with openings about $\frac{1}{12}$th of an inch, the intervening glass meshes being only $\frac{1}{16}$th of an inch wide. This seems to have been produced more as a curiosity than for any practical purpose. Should such a sheet of perforated glass be required, it is questionable if it could be produced from a solid sheet by any other method.

A microscopic examination of the sheet glass depolished by this process shows a succession of pits formed by the blows of the impinging grains of sand, and looks more uniform than do surfaces ground by the rubbing process.

One curious fact connected with the use of this process is that when a surface to be cut in intaglio or otherwise is partially protected by templates of metal, these templates curl up under the blows of the sand, so that paper patterns are really more durable than patterns cut from brass. Sheet steel, cut into shapes and then hardened, will also curl up under the blows of the fine particles of sand, unless protected by sheets of yielding material. Fine lace will protect glass during the depolishing process, and leave its designs in polished lines on a ground surface. This account is derived from the 'Journal of the Franklin Institute.' See Glass.

ENGRAVING ON STONE; SEAL OR GEM ENGRAVING. Some very delicate and beautiful results are obtained by engraving upon lithographic stones. The art, is not, however, of sufficient importance to occupy our already crowded space. Seal or gem engraving is an art of great antiquity. We may here simply allude to the apparatus in general use by the workman, and which consists of a lathe turned by a treddle, and moving a small horizontal steel cylinder, into which the tools are inserted, allowing them to revolve against the gem, which is held by the hand of the workman close to each point, cutting the surface by the aid of diamond-powder made into a paste with olive-oil. The tools are very simple, and adapted to produce the kind of abrasion wished for by the artist. When thus engraved the surface is polished with box-wood tools and rotten-stone. The ancient gems are remarkable for a higher and finer polish than is possessed by the generality of modern works, as well as for a more vigorous and sculpturesque effect.

The arts of incising a design upon a precious stone, and of sculpturing it in relief, originated with the nations of antiquity, and were practised by them with great success. Carnelian was their favourite stone for general use, but they also worked on onyx, chalcedony, jasper, and blood-stone. They frequently used the various tints of the stone to heighten the effect of their work, and produce *relief*. The ancients have preserved the names of many of the early Greek gem engravers who have never been surpassed for ability. One of their most celebrated works is the sardonyx of three strata, which formed part of the cabinet of gems of the Empress Josephine, and which represents the busts of Ptolemy Philadelphus (B.C. 285 to 258) and his queen Arsinœ. Its shape is an obtuse oval, measuring 6¼ inches by 5. Another with the same heads is preserved in the Imperial Cabinet at Vienna, measuring 4½ inches each way. But the largest and most important of these antique works is the apotheosis of Augustus, preserved in the Royal Cabinet of France, which measures 8 inches by 9, and represents more than twenty figures of men and deities, a wonderful monument of patient labour and artistic power. So fond were the ancients of these costly and beautiful works, that the Emperor Heliogabalus is recorded to have covered his shoes with engraved gems. They were also used to adorn coffers and other luxurious articles of furniture, as well as drinking vessels, patera, &c.—*Fairholt.*

ENLEVAGE. The discolouring or discharging style in calico-printing.

ENSTATITE. A name now applied to those varieties of bronzite which contain little or no iron. Enstatite is the chief constituent of the French rock called *Lherzolite*, and it has been also found in certain meteorites. The name, derived from ἐνστάτης (*enstates*), 'an opponent,' refers to the refractory behaviour of the mineral before the blowpipe.

ENTOZOA. Those animals which live *within* the bodies of other animals.

ENTRESOL. A floor between other floors; a low set of apartments placed above the first floor. The Quadrant, Regent Street, has a good example of the entresol. In Italy the term *Mezzanino*, or 'little middle floor,' is used to indicate the same arrangement.

ENVELOPES. The manufacture of envelopes has so largely increased, that the old method of folding them by means of a *bone folding stick*, although a good workman could thus produce 3,000 a day, was not capable of meeting the demand; hence the attention of several was turned to the construction of machines for folding them. Amongst the most successful are the following:—

Envelope folding.—In the envelope-folding machine of Messrs. De La Rue & Co., each piece of paper, previously cut by a fly-press into the proper form for making an envelope (and having the emblematical stamp or wafer upon it), is laid by the attendant on a square or rectangular metal frame or box, formed with a short projecting piece at each corner, to serve as guides to the paper, and furnished with a moveable bottom which rests on helical springs. A presser at the end of a curved compound arm, which moves in a vertical plane, then descends, and presses the paper down into the box,—the bottom thereof yielding to the pressure; and thereby the four ends or flaps of the piece of paper are caused to fly up; the presser may be said to consist of a rectangular metal frame, the ends of which are attached to the outer part of the curved arm, and the sides thereof to the inner portion of the arm; so that the ends and sides of the presser can move independently of each other. The ends of the presser then rise, leaving the two sides of it still holding down the paper; two little lappet pieces next fold over the two side flaps of the envelope; and immediately a horizontal arm advances, carrying a V-shaped piece charged with adhesive matter or cement (from a saturated endless band), and applies the same to the two flaps. A third lappet presses down the third flap of the envelope upon the two cemented flaps, and thereby causes it to adhere thereto; and then a pressing piece, of the same size as the finished envelope, folds over the last flap and presses the whole flat. The final operation is to remove the envelope, and this is effected by a pair of metal fingers, with India-rubber ends, which descend upon the envelope, and, moving sideways, draw the envelope off the bottom of the box (the pressing piece having moved away and the bottom of the box risen to the level of the platform of the machine) on to a slowly-moving endless band, which gradually carries the finished envelopes away. A fresh piece of paper is laid upon the box or frame, and the above operations are repeated. This machine makes at the rate of 2,700 envelopes per hour.

Another machine for the same object was invented by Mr. A. Remond, of Birmingham, and is that employed by Messrs. Dickinson & Co. The distinguishing feature of this arrangement is the employment of atmospheric pressure to feed in the paper which is to form the envelope, and to deflect the flaps of the envelope into inclined positions, to facilitate the action of a plunger, which descends to complete the folding. The pieces of paper, cut to the proper form, are laid on a platform, which is furnished with a pin at each corner, to enter the notches in the pieces of paper, and retain them in their proper position, and such platform is caused alternately to rise and bring the upper piece of paper in contact with the instrument that feeds the folding part of the machine, and then to descend until a fresh piece is to be removed. The feeding instrument consists of a hollow horizontal arm, with two holes in the under side, and having a reciprocating movement. When it moves over the upper piece of paper on the platform, a partial vacuum is produced within it, by a suitable exhausting apparatus, and the paper is thereby caused to adhere to it at the holes in its under surface by the pressure of the atmosphere. The instrument carries the paper over a rectangular recess or box; and then, the vacuum within it being destroyed, it deposits the paper between four pins, fixed at the angles of the box, and returns for another piece of paper. As the paper lies on the top of the box, the flap which will be undermost in the finished envelope is pressed by a small bar or presser on to the upper edge of two angular feeders, communicating with a reservoir of cement or adhesive matter, and thereby becomes coated with cement; and at the same time, the outermost or seal flap may be stamped with any required device, by dies, on the other side of the machine. A rectangular frame or plunger now descends and carries the paper down into the box; the plunger rises, leaving the flaps of the envelope upright; streams of air, issuing from a slot in each side of the box, then cause the flaps to incline inwards: and the folding is completed by the plunger again descending; the interior and under surface of such plunger being formed with projecting parts, suitable for causing the several flaps to hold in proper superposition. The bottom of the box (which is hinged) opens, and discharges the envelope down a shoot to a table below; the feeding instrument then brings forward another piece of paper; and a repetition of the above movements takes place.

EPHESITE. A micaceous mineral accompanying the emery of Gummach-Dagh, near Ephesus. It has been described by Dr. J. L. Smith.

EPIDERMIS. The outer covering or scarf-skin. The fibrous horny coating of some shells which sometimes are used in the arts.

EPIDOTE. A complex mineral silicate, usually containing alumina, peroxide of iron, lime, magnesia, and protoxide of iron. It crystallises in the oblique or monoclinic system, often in long well-shaped glassy crystals. The colour is generally some shade of green, often of a characteristic pistachio green, but sometimes passing into black.

Epidote is not uncommon in granite, and other crystalline rocks; whilst it forms the main constituent of a rock known as *Epidosite* or *Epidote-rock*. The first crystals occur in limestone, in trappean rocks, and in deposits of iron ore. The name (ἐπίδοσις, *epidosis*, increase) was originally proposed by Haüy on crystallographic considerations, but has since been much extended, and the species now includes a large number of varieties, the more important of which will be noticed under their respective names.

EPIZOA. Those animals which live parasitic *upon* other animals. See Entozoa.

EPSOMITE. Native Epsom salts, or sulphate of magnesia.

EPSOM SALTS. A sulphate of magnesia, consisting of magnesia 16·26, sulphuric acid 32·52, water 51·22. It derives its name from a mineral spring containing the salt at Epsom. It is largely manufactured by the evaporation of sea-water, after crystallisation of the common salt; or by precipitating the magnesia from sea-water by means of lime, and then dissolving this precipitate in sulphuric acid. It may also be prepared from carbonate of magnesia, or from magnesian limestone (dolomite). See Magnesia, Sulphate of.

EQUISETACEÆ. (*Equus*, a horse, *seta*, a hair.) A group of plants commonly called 'horse-tails.' The species of equisetum grow very abundantly in ditches, lakes, and rivers, in this and other parts of the world. The stems are striated, hollow, articulated, usually branched, having no true leaves, but in their place green-jointed branches arranged in whorls at the articulations of the stem. In South America they grow to a large size. The stems usually contain a great deal of silica in their composition, and the *Equisetum hyemale*, or Dutch rush, finds its use in the arts on this account. See Dutch Rush.

EQUISETUM. A genus of Equisetaceæ.

EQUIVALENTS, CHEMICAL. By this term is understood the proportions in which substances combine with each other to form definite compounds. These proportions are referred to the common standard, hydrogen, which is taken as unity. The limits of this work preclude the possibility of entering into the history of the steps by which the doctrine of equivalents was gradually developed; but it is proper that we should indicate some of the methods by which the equivalents of elements and compounds are ascertained and demonstrated to be correct. But before proceeding, it is necessary to define the term 'equivalent.' This is not easy to do, because the theoretical ideas of all chemists are not the same. Suppose, for example, the constitution of water were to be taken as the starting point. On submitting it to the action of the pile, it is immediately observed that the ratio of the two gases evolved is as 1 to 2. One chemist will at once assume that water is a simple binary compound of one equivalent of each of its constituents. But this involves the assumption that the gaseous volume of the equivalent of hydrogen is twice that of oxygen. The other chemist assuming that one volume of a gas represents an equivalent, considers water to be a ternary compound, having the formula H^2O. It is plain that the atom of hydrogen will have only half the value on the second hypothesis that it will on the first, or, what comes to the same thing, the atom of oxygen will be twice as great. If, with some chemists, we consider the volumes of the gases to represent atoms or equivalents, then, water consisting of two volumes of hydrogen and one volume of oxygen, and as by weight water contains 8 parts of oxygen to 1 part of hydrogen, it is plain that 8 parts of oxygen by weight will represent 1 equivalent, and 1 part by weight of hydrogen will represent 2 equivalents. Consequently 1 equivalent of hydrogen will weigh ·5. But to avoid fractional numbers it will (on these assumptions) be more convenient to write the equivalent of hydrogen = 1, and oxygen 16. In this country it has, until recently, been usual to consider the atom of hydrogen as occupying twice the space in the gaseous state of that of oxygen. The atomic weights being, therefore, oxygen 8 and hydrogen 1.

We have said that it is by no means easy to define an equivalent. The difficulty arises not merely from the different aspects under which theoretical chemists regard the elements and their compounds, but also from the practical difficulties attending the determination of the true constitution of some substances. Thus the equivalent of bismuth is assumed by some to be 71 and by others 213; the oxide in the one case becomes BiO, in the other BiO^3; the first equivalent being only one-third as great as the second. But, it is to be observed, the variations in the theoretical views of chemists are of no consequence, so long as we clearly comprehend the nature of those variations. The *relative* values or proportions are the same in all cases. It is, in fact, somewhat the same as if one class regarded the avoirdupois pound as made up of 16 ounces, each ounce weighing 437·5 grains, and the other considered it as consisting of 8 ounces, each ounce containing 875·0 grains.

In order to clearly understand the nature of the equivalents as received in this country, it is necessary to remember that there are three relations of volume amongst gases, namely, one, two, and four volumes. The first relation applies solely to elementary gases. The two others apply to elements and compounds. [It is true that the vapour-densities of pentachloride of phosphorus, chloride of ammonium, and, perhaps, one or two other substances, appear to differ from this rule, but it is probable that, like sulphur, the vapour densities require to be determined under special conditions of temperature or pressure.] In the table of equivalents the density of the vapours of those substances which are capable of assuming the gaseous states are so placed that the number obtained by experiment may be compared with that deduced from theoretical considerations. In the following table the vapour-volumes or combining measures of some of the more important elements are given. We shall see presently the practical value of the information contained in it:—

Element	Combining Measure	Element	Combining Measure
Hydrogen	two volumes	Oxygen	one volume
Chlorine	do.	Sulphur	do.
Bromine	do.	Selenium	do.
Iodine	do.	Phosphorus	do.
Fluorine (*hypothetical*)	do.	Arsenic	do.
Nitrogen	do.	Carbon	do.

It must be remembered that all volatile compounds possess four-volume formulæ, except a few, which in this country are always written as if possessing a condensation to two volumes; such are carbonic acid, carbonic oxide, sulphurous acid, &c. With the above information it will be easy for any person to calculate the density of any vapour or gas by the aid of the following directions:—

To obtain the density of any vapour or gas having a condensation to four volumes, such as most organic or inorganic compounds.—Multiply half the density of hydrogen by the atomic weight of the vapour or gas. Example:—Find the density of the vapour of hydrobromic acid. The atomic weight of hydrobromic acid is 81. The density of hydrogen is 0·0692, half of which is 0·0346. Then 0·0346 × 81 = 2·8026. Experiment gave 2·73.

To obtain the density of any vapour or gas having a condensation to two volumes.—Multiply the density of hydrogen by the atomic weight of the gas or vapour. Example:—Find the density of chlorine gas. The atomic weight of chlorine being 35·5, and the density of hydrogen 0·0692, we have by the rule, 0·0692 × 35·5 = 2·4566. The density by experiment is 2·44.

To obtain the density of any vapour or gas having a condensation to one volume.—Multiply twice the density of hydrogen by the atomic weight of the gas or vapour. Example:—Find the density of the vapour of oxygen. The atomic weight of oxygen being 8, and twice the density of hydrogen being 0·1384, we have 0·1384 × 8 = 1·1072. Experiment has yielded 1·1056.

The above methods of calculating the densities of vapours and gases are those always employed by the writer of this article, and will be found incomparably shorter and more convenient than any other.

It is perfectly plain that, by a simple inversion of the above rules, it is equally easy from the known density of a gas or vapour to calculate its atomic weight. Nevertheless, for the sake of those who are unaccustomed to calculations of this kind, we append the following rules:—

To calculate the atomic weight of any gas or vapour having a condensation to four volumes.—Divide the density of the gas by half the density of hydrogen. Example: —Find the atomic weight of hydrobromic acid gas, the density of which is 2·8026; $\frac{2{\cdot}8026}{0{\cdot}0346} = 81{\cdot}000$.

To calculate the atomic weight of any gas or vapour having a condensation to two volumes.—Divide the density of the gas by the density of hydrogen.

To calculate the atomic weight of any gas or vapour having a condensation to one volume.—Divide the density of the gas by twice the density of hydrogen.

It is plain, then, that if we are in possession of the atomic weight and vapour-volume of any substance, it is easy to determine the density of its vapour or gas. Also, that having the density of the vapour and the vapour-volume, it is easy to calculate the atomic weight. If we consider for an instant what is meant by the term 'density of a vapour or gas,' it will appear equally easy to find, from the density of the gas, the weight of 100 cubic inches at the standard temperature and pressure. By the density of a gas is meant the number expressing how much it is heavier or lighter, bulk for bulk, than air. If, therefore, we multiply the density of a gas by the weight of 100 cubic inches of air, at the standard temperature and pressure (= 30·00 grains), we immediately find the number required. Example:—The density of hydrogen is 0·0692 and 0·0692 × 30 = 2·0760, or the weight of 100 cubic inches of hydrogen, at a temperature of 60° Fahr., and 30 inches of the barometer.

From what has been said, it is evident that no difficulty exists in determining the equivalents of bodies which can be obtained in a gaseous state. Where the equivalent of a fixed body is to be ascertained, or where it is desired to proceed in a different manner, the method employed must depend upon the nature of the substance. We shall consider three of the most simple and general cases, namely, an acid, an alkali, and a neutral body.

1. *Mode of determining the equivalent of an acid.*—For this purpose it is necessary to analyse a salt, the constitution of which is known. If the base or metallic oxide in the salt is one of which the atomic weight is well established, it is very easy to determine the combining proportion of the acid. We say, as the percentage of oxide is to the percentage of acid, so is the atomic weight of the oxide to the atomic weight of the acid. Example:—Butyrate of silver has the following composition:—

Oxide of silver	59·487
Butyric acid	40·513
	100·000

We therefore say:—

$$\underbrace{59{\cdot}487}_{\text{Percentage of oxide of silver.}} : \underbrace{40{\cdot}513}_{\text{Percentage of acid.}} :: \underbrace{116}_{\text{Equivalent of oxide of silver.}} : \underbrace{79{\cdot}000}_{\text{Equivalent of the acid.}}$$

It must be remembered that the atomic weight so obtained is that of the anhydrous acid, so that one equivalent of water must be added to find the atomic weight of the acid in its ordinary condition. If the equivalent desired be that of a hydrogen acid, the method of proceeding must be slightly modified, but the details need not be given, as they are self-evident.

2. *Mode of determining the equivalent of an alkali.*—Several methods present themselves, each possessing certain advantages. Most alkalis, organic and inorganic, form salts well adapted for enabling their atomic weight to be ascertained by analysis. We shall select as an example ammonia, and the salt employed to settle the atomic weight will be the sulphate, which contains—

Oxide of ammonium	39·40
Sulphuric acid	60·60
	100·00

In the same way that an oxide of known composition is the datum employed to determine the equivalent of an acid, so, on the other hand, an acid, the formula of which is well established, serves to enable the formula of an alkali to be deduced. We therefore say:—

$$\underbrace{60\cdot60}_{\text{Percentage of acid.}} \quad : \quad \underbrace{39\cdot40}_{\text{Percentage of alkali.}} \quad :: \quad \underbrace{40\cdot00}_{\text{Equivalent of the acid.}} \quad : \quad \underbrace{26\cdot00}_{\text{Equivalent of the alkali.}}$$

Most alkalis, especially those derived from the organic kingdom, form well-defined and easily crystallisable compounds with some of the metallic chlorides, especially those of gold, platinum, and palladium. These salts are well adapted for enabling atomic weights to be fixed.

3. *Mode of determining the equivalent of a neutral substance.*—Neutral bodies are formed upon so many models or types that no general method can be given for the required purpose. If volatile at moderate temperatures, the density of the vapour can be ascertained, and this is generally sufficient. Salts have their equivalents found by determining the percentage composition, and proceeding as in Examples 1 and 2. The equivalent of a metal is found by forming a compound with some substance, the atomic weight of which is well known, such as oxygen or sulphur. The compound is then carefully analysed. Example:—It has been found that 100 parts of oxide of copper contain—

Copper	80·00
Oxygen	20·00
	100·00

We therefore say:—

$$\underbrace{20\cdot00}_{\text{Percentage of oxygen.}} \quad : \quad \underbrace{80\cdot00}_{\text{Percentage of copper.}} \quad :: \quad \underbrace{8\cdot00}_{\text{Equivalent of oxygen.}} \quad : \quad \underbrace{32\cdot00}_{\text{Equivalent of copper.}}$$

A precisely analogous mode of proceeding may be adopted with chlorides, iodides, &c.—C. G. W.

It is important to clearly separate the idea of *chemical equivalence* from that of *atomic weight.* Two elements can be strictly called equivalent to each other only when one is capable of being substituted for the other in chemical combination. Thus 35·5 parts of chlorine (its atomic weight) are strictly equivalent to 1 part of hydrogen; but 16 parts of oxygen (its modern atomic weight) are equivalent to 2 parts of hydrogen; 14 parts of nitrogen usually to 3 of hydrogen; 12 of carbon to 4 of hydrogen; and so on. Hence the idea of chemical equivalence is by no means the same as that of atomic weight; the atom of one element not being necessarily equivalent to another in its combining power. For the modern doctrine of equivalence, see Watts's 'Dictionary of Chemistry,' and in this work, the articles Atomicity and Atomic Weights.

ERASINE. See Abietene.

ERBIUM. The metallic radicle of Erbia, one of the earths associated with yttria. It was discovered by Mossander in 1842. Salts of erbia give characteristic absorption-spectra exhibiting dark bands. See Watts's 'Dictionary of Chemistry.'

EREMACAUSIS,—*slow combustion.* This term has been applied to that constant combination of oxygen with carbon and hydrogen, to form carbonic acid and water, which is unceasingly going on in nature, as in the decay of timber or the 'heating' of hay or grain put together in a moist state. Perfect dryness, and a temperature below freezing, stop this eremacausis, or slow combustion.

ERGOT OF RYE. Diseased grains of rye ('spurred rye') which become elongated and curved in shape, and of a jet-black colour, by the attack of a fungus called *Cordyceps purpurea.* In this state the rye is highly poisonous. The ergot of rye has been employed in medicine.

ERINITE. A hydrous arsenate of copper.

ERMINE. The Ermine, *Mustela Erminea,* is one of the weasel tribe. This little animal is most destructive, destroying a considerable quantity of game. It is upwards of 9½ inches long, exclusive of the tail which measures 3½ inches more. In the winter the fur becomes quite white, except the tip of the tail which always remains black. In the summer it is of a fine chestnut colour, and the fur is then known by the furriers as Roselet. It is a native of northern countries. It is especially abundant in Russia, Siberia, Kamtschatka, Lapland, and Norway. It is found occasionally in Scotland. See Fur.

ERRATIC BLOCKS. Rounded and weather-worn fragments of the harder rocks, which are found very widely scattered, at great distances from the places whence they were originally derived. They are generally supposed to have been removed by the transporting power of icebergs and fields of ice.

ERUBESCITE. A name for purple copper-ore, or 'horse-flesh ore.' See Copper.

ERYTHRIC ACID. The colorific principle of Angola and Madagascar Orchilla weeds. By macerating the lichen in milk of lime, Stenhouse obtained 12 per cent. of crude erythric acid. It yields red compounds with ammonia, and also in its reaction with hypochlorite of lime. See Lichen; Orchilla.

ERYTHRINE or **ERYTHRITE.** A hydrous arsenate of copper, known also as cobalt-bloom. See Cobalt.

ERYTHROXYLON COCA. The coca. This shrub is a native of Peru, and is cultivated extensively in the Andes. The dried leaves, mixed with finely-powdered chalk, are chewed by the Peruvians. This peculiar stimulant brings on a condition of apathy. It prevents hunger and retards sleep, so that the natives who work in the mines will sometimes, under its influence, labour from twenty to thirty hours at a stretch. The continued use of coca is more injurious than that of opium or tobacco. See Coca.

ESCARPMENT. A word which has long been in use in geological works; and by the earlier writers it was employed to denote any hill that had a sharp slope or scarp, but of late years it has acquired a more restricted meaning, and it is now applied only to hills of one particular kind. 'It may be defined,' says Mr. Whitaker 'as the boundary ridge of a formation or bed, that is to say, the ridge along which a formation or bed is cut off, and beyond which it does not extend, except in the form of outliers; it follows the line of the strike.'—*Geology of the London Basin.*

ESCHALOT (*Échalote,* Fr.), commonly Shallot. A small kind of onion. *Allium ascalonicum.*

ESCULIN. A substance found in the inner white bark of the horse-chestnut tree, remarkable for its fluorescent power. See Fluorescence.

ESPARTO, or *Spanish Grass,* as its name denotes, is imported from Spain, where it is indigenous in certain mountains and uncultivated districts on the Mediterranean coast. It is also produced on the north coast of Africa, where it is called by the Arabs *alfe, alfa,* or *alva.* It appears to have been used by the Romans for cordage, and called by them *Spartium.*

This plant, classed as a sedge by botanists (and by them denominated *Lygeum Spartum* and *Stipa tenacissima*), grows in tufts and bunches similar to the rushes in this country; it varies from 2 to 4 feet in height, and consists of a long flat lanceolated leaf or blade, which, as the sap descends and the plant ripens, takes a cylindrical form. It is pulled up from the roots, exposed to the sun, and, when dry, laid in small bundles, and these again, for facility of carriage, into larger ones, which are transported in carts, or more generally on donkeys' backs (both Spain and Africa, in the uncultivated and wild districts of the country where the plant exists, being, comparatively speaking, without roads) to the port of shipment.

The plant being now imported to the extent of 30,000 to 40,000 tons yearly, was selling at the commencement of the year 1862 at 5*l.* per ton; but owing to the reduction in the price of rags, and to the general stagnation of trade caused by the American war, this price has been latterly reduced.

Numerous patents have (as might naturally be expected) been taken out for the treatment of this plant; those by Mr. Routledge would appear, from the increasing employment of this material, to be the most useful, effectual, and economical. Mr. Routledge represents, indeed, that the cost of production either in the condition of half stuff or paper, is below that of rags to produce a similar quality of paper, and the power required for reducing much less. Judging from the specimens of paper exhibited by Mr. Routledge in 1862, manufactured by him at his mills at Eynsham, in Oxfordshire, exclusively from esparto, as well as from the other specimens of paper manufactured at various other mills employing his process, in which esparto is used as a blend with the ordinary rag material, the results are very satisfactory, demonstrating that a new material has at length been brought into use meeting this long-desired requirement, both as regards quality and economy.

One satisfactory feature in Mr. Routledge's process is the fact that no material alteration in existing machinery or appliances is required; no higher pressure boiling in expensive vessels is necessitated; the silica, always more or less combined with a coating of raw fibres, is got rid of, and the gummo-resinous matter neutralised, permitting the fibres to be eliminated and drawn out by the ordinary pulping engine, as now practised with rags. The assurance of a successful result appears to be dependent on the proper adjustments of the proportions of the chemicals employed; this secured, and the process is extremely simple, the issue appears to be reliable, and, what is of no little importance, invariable and constant.

The fibres produced from esparto are specifically lighter than those from any other paper-making material in use; their mechanical structure, moreover, admits of minute subdivision, without destroying the feathery or mossy arrangement which facilitates the intimate felting or blending of the ultimate fibres on the endless wire of the Fourdrinier machine; then, esparto paper, in consequence of this peculiarity, feels thicker in the hand, and takes a finer surface than that made from cotton rags, and, in proportion to the blend or admixture with other rag or paper-making material, imparts these advantageous characteristics. It is to be remarked, however, that its introduction generally into the trade being only, comparatively speaking, of recent date, it has not yet arrived at full development, its employment being hitherto limited to common and ordinary printing papers and cartridges, and in the unbleached state to brown and cap papers.

Our Imports for the last five years have been as follow:—

Places	1868		1869		1870		1871		1872	
	Tons	Value	Tons	Value	Tons	Value	Tons	Value	Tons	Value
From		£		£		£		£		£
Spain .	92,927	599,213	82,355	494,133	72,835	529,200	80,472	729,163	55,909	468,199
Algeria .	2,762	15,483	3,487	19,970	29,500	215,385	45,371	364,667	28,068	198,053
Other parts	139	895	494	2,961	1,126	7,825	18,568	145,351	20,621	137,144
Total .	95,828	615,591	86,336	517,064	103,461	752,410	144,411	1,239,181	104,621	803,396

ESSENCE D'ORIENT, the name of a pearly-looking matter procured from the blay or bleak, a fish of the genus *Cyprinus*. This substance, which is found principally at the base of the scales, is used in the manufacture of artificial pearls. A large quantity of the scales being scraped into water in a tub, is there rubbed between the hands to separate the shining stuff, which subsides on repose. The first water being decanted, more is added with agitation till the essence is thoroughly washed from all impurities, when the whole is thrown upon a sieve; the substance passes through, but the scales are retained. The water being decanted off, the essence is procured in a viscid state, of a bluish-white colour, and a pearly aspect. The intestines of the same fish are also covered with this beautiful glistening matter. Several other fish yield it, but in smaller proportion. When well prepared, it presents exactly the appearance and reflections of the real pearl, or the finest mother-of-pearl; properties which are probably owing to the interposition of some portions of this same substance between the laminæ of these shelly concretions. Its chemical nature has not been investigated; it putrefies readily when kept moist, an accident which may however be counteracted by water of ammonia. See Pearls.

ESSENCE OF SPRUCE is prepared by boiling the young tops of the *Abies nigra*, or black spruce, in water, and concentrating the decoction by evaporation in a water-bath. With a duty of 10*l.* per cent. ad valorem—imposed August 20, 1852—we received:

in 1871, from all countries to the value of 10*l.* only; and
„ 1872, „ „ „ 21*l.* „

ESSENCES. See Perfumery.

ESSENTIAL OILS. See Oils, Fixed and Essential, and Otto.

ESSONITE. A lime-alumina garnet, of brownish-red colour, known also as *cinnamon-stone*. It comes chiefly from Ceylon, and is cut as a gem-stone, being indeed sometimes mistaken for the hyacinth or jacynth.

ETCHING ON GLASS. See Glass, and Engraving on Glass.

ETCHING VARNISH. (*Aetzgrund-Deckfirniss*, Ger.) Though the practice of the elegant art of etching does not come within the scope of our Dictionary, the preparation of the varnishes, and of the biting menstrua which it employs, legitimately belongs to it.

The varnish of Mr. Lawrence, an English artist resident in Paris, is made as follows: Take of virgin wax and asphaltum, each two ounces, of black pitch and burgundy-pitch, each half an ounce. Melt the wax and pitch in a new earthenware glazed pot, and add to them, by degrees, the asphaltum, finely powdered. Let the whole boil till such time as that, taking a drop upon a plate, it will break when it is cold, on bending it double two or three times betwixt the fingers. The varnish, being then enough boiled, must be taken off the fire, and after it cools a little, must be poured into warm water, that it may work the more easily with the hands, so as to be formed into balls, which must be kneaded, and put into a piece of taffety for use.

Care must be taken, first, that the fire be not too violent, for fear of burning the ingredients, a slight simmering being sufficient; secondly, that whilst the asphaltum is being put in, and even after it is mixed with the ingredients, they should be stirred continually with the spatula; and, thirdly, that the water into which this composition is thrown should be nearly of the same degree of warmth with it, in order to prevent a kind of cracking that happens when the water is too cold.

Preparation of the hard varnish used by Callot, commonly called the Florence Varnish.—Take four ounces of fat oil very clear, and made of good linseed oil, like that used by painters; heat it in a clean pot of glazed earthenware, and afterwards put to it four ounces of mastic well powdered, and stir the mixture briskly till the whole be well melted, then pass the mass through a piece of fine linen into a glass bottle with a long neck, that can be stopped very securely; and keep it for the use that will be explained below.

Method of applying the soft varnish to the plate, and of blackening it.—The plate being well polished and burnished, as also cleansed from all greasiness by chalk or Spanish white, fix a hand-vice on the edge of the plate where no mark is intended to be, to serve as a handle for managing it when warm; then put it upon a chafing-dish, in which there is a moderate fire, and cover the whole plate equally with a thin coat of the varnish; and whilst the plate is warm, and the varnish upon it in a fluid state, beat every part of the varnish gently with a small ball or dauber made of cotton tied up in taffety, which operation smooths and distributes the varnish equally over the plate.

When the plate is thus uniformly and thinly covered with the varnish, it must be blackened by a piece of flambeau, or of a large candle which affords a copious smoke; sometimes two or even four such candles are used together for the sake of despatch, that the varnish may not grow cold, which if it does during the operation, the plate must be heated again, that it may be in a melted state when that operation is performed; but great care must be taken not to burn it, which, when it happens, may be easily perceived by the varnish appearing burnt and losing its gloss.

The menstruum used and recommended by Turrell, an eminent London artist, for etching upon steel, was prepared as follows:—

Take Pyroligneous acid	4 parts by measure,
Alcohol	1 part, mix, and add
Nitric acid	1 part.

This mixed liquor is to be applied from 1 to 15 minutes, according to the depth desired. The nitric acid was employed of the strength of 1·28—the double aqua-fortis of the shops.

The *eau forte* or menstruum for copper, used by Callot, as also by Piranesi, with a slight modification, is prepared with 8 parts of strong French vinegar,

4	parts of	verdigris,
4	,,	sea salt,
4	,,	sal-ammoniac,
1	,,	alum,
16	,,	water.

The solid substances are to be well ground, dissolved in the vinegar, and diluted with the water; the mixture is now to be boiled for a moment, and then set aside to cool. This method is applied to the washed, dried, and varnished plate, after it has suffered the ordinary action of aqua-fortis, in order to deepen and finish the delicate touches. It is at present called the *eau forte à passer*.

ETHENE. See Olefiant Gas.

ETHER, $C^8H^{10}O^2$ ($\mathbf{C^4H^{10}O}$). *Syn. Sulphuric ether, Oxide of ethyl, Ethylic* or *Vinic ether*, &c. &c. By this term is known the very volatile fluid produced by the action on alcohol of substances having a powerful affinity for water, such as sulphuric acid.

Preparation on small scale.—A capacious retort with a moderate-sized tubulature is connected with an efficient condensing arrangement. Through the tubulature passes a tube connected with a vessel full of spirit, sp. gr. 0·83. The tube must have a stopcock to regulate the flow. A mixture being made of five parts of alcohol of the density given above, and nine parts of oil of vitriol, it is to be introduced into the retort, and a lamp-flame is to be so adjusted as to keep the whole gently boiling. As soon as the ether begins to come over, the stopcock connected with the spirit reservoir is to be turned sufficiently to keep the fluid in the retort at its original level.

Preparation on large scale.—The apparatus is to be arranged on the same principle, but, for fear of fracture, may be constructed of cast iron, lined with sheet lead in the part containing the mixture. The chief disadvantage of this arrangement is its opacity, whereby it becomes impossible to see the contents of the retort, and therefore not so easy to keep the liquid at its original level. In this case the quantity distilling over must be noted and the flow of spirit into the retort regulated accordingly. The most convenient mode of proceeding is to have a large stone bottle with a tubulature at the side near the bottom (like a water filter) to hold the spirit. A tube passes from the bottle to the retort. It has at the end, near the retort or still, a bend downwards leading into the tubulature. If a glass still be used, it must for safety be placed in a sand-bath. The distillate obtained, either on the large or small scale, is never pure ether, but contains sulphurous and acetic acids, besides water and alcohol. To remove these, the distillate is introduced, along with a little cream of lime, into a large separating globe, such as that mentioned under BROMINE. The whole is to be well agitated, and the lime-solution then run off by means of the stopcock. The purified ether still contains alcohol and water, to remove which it should be rectified in a water-bath. The fluid will then constitute the ether of commerce. If the second distillation be pushed too far the ether will, if evaporated on the hand, leave an unpleasant after-smell, characteristic of impure ether. If wished exceedingly pure, it must be shaken up in the separating globe, with pure water. This will dissolve the alcohol, and leave the ether, contaminated only by a little water, which may be removed by digestion with quicklime and redistillation at a very low temperature on a hot water-bath.

Pure ether is a colourless mobile liquid, sp. gr. 0·71. It boils at 95° F. The density of its vapour is 2·56 (calculated). Gay-Lussac found it 2·586.

The word 'ether,' like that of alcohol, aldehyde, &c., is now used as a generic term to express a body derived from an alcohol by the elimination of water. Many chemists write the formula C^4H^5O, and call it oxide of ethyl in the same manner as they regard alcohol as the hydrated oxide of the same radical. But there is no just reason for departing from the law we have laid down with reference to the formulæ of organic compounds. We shall therefore write ether $C^8H^{10}O^2$ ($\mathbf{C^4H^{10}O}$). This view has many advantages. We regard, with Gerhardt and Williamson, ether and alcohol as derived from the type water. Alcohol is two atoms of water in which one equivalent of hydrogen is replaced by ethyl; ether is two atoms of water in which both atoms of hydrogen are replaced by that radical. But there are a large class of compound ethers procurable by a variety of processes. These ethers were long regarded as salts in which oxide of ethyl acted the part of a base. Thus, when butyrate of soda was distilled with alcohol and sulphuric acid, the resulting product was regarded as butyrate of oxide of ethyl. The compound ethers are regarded as two atoms of water in which one equivalent of hydrogen is replaced by the radical of an alcohol, and the other by the radical of an acid. In addition to those, there are others more closely resembling the simple ethers. They are founded also on the water type, both atoms of hydrogen being replaced by alcohol radicals, but by different individuals. They are called mixed ethers. The following formulæ show the chemical constitution of all these varieties placed for comparison in juxtaposition with their type:—

$$\underbrace{\left.\begin{matrix}H\\H\end{matrix}\right\}O^2}_{\text{Water (2 eqs.)}} \qquad \underbrace{\left.\begin{matrix}C^4H^5\\C^4H^5\end{matrix}\right\}O^2}_{\text{Common ether.}} \qquad \underbrace{\left.\begin{matrix}C^4H^5\\C^2H^3\end{matrix}\right\}O^2}_{\text{Methylo-ethylic ether.}} \qquad \underbrace{\left.\begin{matrix}C^4H^5\\C^8H^7O^2\end{matrix}\right\}O^2}_{\text{Butyric ether.}}$$

$$\left.\begin{matrix}\mathbf{H}\\\mathbf{H}\end{matrix}\right\}\mathbf{O} \qquad \left.\begin{matrix}\mathbf{C^2H^5}\\\mathbf{C^2H^5}\end{matrix}\right\}\mathbf{O} \qquad \left.\begin{matrix}\mathbf{C^2H^5}\\\mathbf{C\,H^3}\end{matrix}\right\}\mathbf{O} \qquad \left.\begin{matrix}\mathbf{C^2H^5}\\\mathbf{C^4H^7O}\end{matrix}\right\}\mathbf{O}$$

In the above formulæ the first represents the type water. The second common ether, the two equivalents of ethyl replacing the two of hydrogen. In the third, we have a mixed ether, one of the equivalents of hydrogen being replaced by ethyl and the other by methyl. The fourth illustration is that of a compound ether: one of the hydrogens is there replaced by ethyl, and the other by the oxidised radical of butyric acid.

Ether is largely used in medicine and chemistry. In small doses it acts as a powerful stimulant. Inhaled in quantity it is an anæsthetic. It is a most invaluable solvent in organic chemistry for resinous, fatty, and numerous other bodies.—C. G. W. See Watts's 'Dictionary of Chemistry.'

ETHER, ACETIC, is used to flavour silent corn spirits in making imitation brandy; it requires therefore some additional notice beyond the other ethers. It may be prepared by mixing 20 parts of acetate of lead, 10 parts of alcohol, and 11½ of concentrated sulphuric acid; or 16 of the anhydrous acetate, 5 of the acid, and 4½ of absolute alcohol; distilling the mixture in a glass retort into a very cold receiver, agitating with weak potash-lye the liquor which comes over, decanting the supernatant ether, and rectifying it by re-distillation over magnesia and ground charcoal.

Acetic ether is a colourless liquid of a fragrant smell and pungent taste, of specific gravity 0·866 at 45° F., boiling at 166° F., burning with a yellowish flame, and disengaging fumes of acetic acid. It is soluble in 8 parts of water.

Acetic ether may be economically made with 3 parts of acetate of potash, 3 of very strong alcohol, and 2 of the strongest sulphuric acid, distilled together. The first product must be re-distilled along with one-fifth of its weight of sulphuric acid; as much ether will be obtained as there was alcohol employed.

ETHER, SULPHURIC, NITRIC, CHLORIC, &c. The stronger mineral acids etherify the alcohols directly, and the names of the resulting ethers are derived from the acid employed. (See Watts's 'Dictionary of Chemistry.') A duty of 1*l*. 5*s*. per gallon was fixed on sulphuric ether on the 25th September 1862. We imported in 1871, 4,001 gals., of the value of 1,874*l*.; and in 1872, 2,246 gals., of the value of 1,791*l*.

ETHIOPIAN PEPPER. The fruit of the *Xylopia* (*Uvaria*) *aromatica*, which is much used as pepper in Africa. This is one of the *Anonaceæ* or Custard Apple family. The wood of one species, *Anona palustris*, is so soft that it is used instead of corks to stopper bottles with. The lancewood is obtained from another species, *Duguetia quitarensis*.

ETHIOPS was the name given by the alchemists to certain black metallic preparations. *Martial ethiops* was the black oxide of iron; *mineral ethiops*, the black sulphuret of mercury; and *ethiops per se*, the black oxide of mercury.

ETHYL. The radical of ordinary alcohol and ether. See Watts's 'Dictionary of Chemistry.'

ETHYLAMINE, C^4H^7N ($\mathbf{C^2H^7N}$). An exceedingly volatile base, discovered by Wurtz. It is produced in a great number of reactions. Several alkaloïds existing in the animal and vegetable kingdoms afford ethylamine on distillation with potash. Its density at 476° is 0·964. It boils at 66° Fahr. It is regarded as ammonia in which an equivalent of hydrogen is replaced by ethyl.—C.G.W.

ETHYLENE. Olefiant gas; bicarburetted hydrogen gas. See OLEFIANT GAS.

ETIOLATION. Deprived of colour by being kept in the dark. Celery, sea-kale, and other plants are purposely *blanched* or etiolated by excluding the light, this exclusion preventing the formation of *chlorophyll*, the green colouring matter of leaves.

EUCALYN. An unfermentable sugar separated during the fermentation of melitose, which is a sugar obtained from certain species of Tasmanian *Eucalyptus*.

EUCALYPTUS. The gum-tree of the New Hollanders. Mr. Backhouse says: 'We often find large cavities between the annual concentric circles of the trunk filled with a most beautiful red or rich vermilion-coloured liquid gum, which flows out as soon as the saw has afforded it an opening.' Several varieties of the Eucalyptus yield essential oils by distillation, which may be used for scenting soap, &c. There was a large collection shown at the Exhibition in 1862, in the Australian section. The gum yielded by the *Eucalyptus resinifera* is considered by druggists as not in the least inferior to the kind which the *Pterocarpus* or red saunders wood of India produces. This species yields, on incision, an astringent substance known as 'Botany-Bay Kino,' which contains a principle called *Eucalyptine*. A saccharine substance, known as 'Australian manna,' is derived from another species, *E. mannifera*. Many of the Australian Eucalypti are called 'Stringy-bark trees,' in consequence of the fibrous layers in their bark. The bark of several species has been used in tanning and in paper-making. Some of the Eucalypti are so rich in oil that it is said one of the towns on the Australian gold-fields was for a time lighted by gas extracted from eucalyptus leaves. The ashes of the wood are peculiarly rich in potash. Much attention has been lately called to the extraordinary influence of *E. globulus* in improving the climatic condition of marshy districts, whence it has been called the 'fever-destroying tree.' This species, known as the Blue-gum tree, is a native of Tasmania, but has been successfully cultivated in Southern Europe, Algeria, Natal, the West Indies, &c. It is said that at the Cape the cultivation of this tree has completely changed the unhealthy character of parts of the colony. The bark and leaves of this species are reputed to possess febrifugal properties.

EUCHROITE. A hydrous arsenate of copper, occurring in green crystals, of the rhombic system, at Libethen in Hungary.

EUCLASE. A silicate of alumina and beryllia, allied to the emerald. It crystallises usually in small colourless crystals belonging to the oblique system, and exhibiting highly perfect cleavage. The stone is sufficiently hard to be cut and polished, but is of no value to the jeweller in consequence of its extreme brittleness; indeed, this fragility suggested the name to Haüy (εὐ, *eu*, perfect; κλάω, *klao*, to cleave). The euclase is found in Brazil and in the Ural Mountains.

EUDIOMETER is the name of any apparatus subservient to the chemical examination of the atmospheric air. It means a *measure of purity*, but it is employed merely to determine the proportion of oxygen which it may contain. The explosive eudiometer—in which about two measures of hydrogen are introduced into a graduated glass tube containing five measures of atmospheric air, and an electric spark is passed across the mixture—is the best of all eudiometers; and of these, the siphon form proposed by Dr. Ure, in a paper published by the Royal Society of Edinburgh, in 1819, is the most convenient.

EUGENIA. A genus of plants of the order *Myrtaceæ*, called after Prince Eugène of Savoy. *Eugenia Pimenta* is the Allspice Tree. This tree is cultivated largely in the West Indies in regular walks, known as 'Pimento walks.' The Pimento is the dried unripe berries of the Pimenta. When the fruit has attained its full size, but is yet green, it is gathered and sun-dried. It is afterwards put in bags of one hundredweight each for the European market; some planters kiln-dry it. Pimento is imported almost entirely from Jamaica, hence it is sometimes called Jamaica pepper. See ALLSPICE; PIMENTO.

EUKAIRITE. An ore of silver found at the Skrikerum copper-mine in Sweden. According to Berzelius, it consists of selenium, 26·; silver, 38·93; copper 23·05; earthy matter, 8·90; carbonic acid, &c., 3·12.

EULYTINE. A silicate of bismuth, found in small tetrahedral crystals, with other bismuth ores, at Schneeberg, and at Bräunsdorf in Saxony.

EUPHORBIACEÆ. The Spurge family. Most of the plants of this order abound in a milky acrid juice in which the peculiar principle of the plant resides. It contains a great number of plants which are either useful or dangerous to man. The *Jatropha* yields the manihot or cassava. The *Ricinus* is the castor-oil tree; the *Croton*, *Cascarilla*, and *Box*, and the caoutchouc varieties, are included in this vast family of plants, which are found in all parts of the globe, and said to number 2,800 species.

EUPHORBIUM, commonly called from Euphorbius, is an acrid resin obtained from *Euphorbia officinarum* (Linn.), and imported from Western Africa. It is used only medicinally.

EUPHOTIDE. A rock composed mainly of saussurite and smaragdite, or some other variety of diallage. It has been cut and polished as an ornamental stone.

EUPIONE. A fluid first discovered by Reichenbach in wood-tar. All the properties of eupione agree with the indifferent hydrocarbons found in Boghead naphtha. Eupione is so indifferent to the action of acids, that it may be repeatedly treated with concentrated oil of vitriol, or fuming nitric acid, without any action taking place. Its density varies with the boiling point, from 0·633 to 0·740. It is said to be contained among the products of the distillation of rape-oil. There is no doubt that these hydrocarbons will, eventually, be of great value in the arts.—C.G.W. See NAPHTHA, BOGHEAD.

EURITE. A name applied to some felstones in consequence of their easy fusibility compared with hornstones, which they often greatly resemble in general characters.

EURYANGIUM SUMBUL. The Sumbul plant, a native of Bucharia. See SUMBUL.

EVANSITE. A hydrous phosphate of alumina from Hungary, named by Mr. D. Forbes after the late Mr. Brooke Evans, of Birmingham,

EVAPORATION (Eng. and Fr.; *Abdampfen*; *Abdünsten*, Ger.) is the process by which any substance is converted into, and carried off, in vapour. Though ice, camphor, and many other solids evaporate readily in dry air, we shall consider, at present, merely the vaporisation of water by heat artificially applied.

The vapour of water is an elastic fluid, whose tension and density depend upon the temperature of the water with which it is in contact. Thus the vapour rising from water heated to 165° F. possesses an elastic force capable of supporting a column of mercury 10·8 feet high; and its density is such that 80 cubic feet of the vapour contain one pound weight of water; whereas 32½ cubic feet of steam of the density corresponding to a temperature of 212° and a pressure of 30 inches of mercury, weigh one pound. When the temperature of the water is given, the elasticity and specific gravity of the vapour emitted by it may be found.

Since the vapour rises from the water only in virtue of the elasticity due to its gaseous nature, it is obvious that no more can be produced, unless what is already incumbent upon the liquid have its tension abated, or be withdrawn by some means. Suppose the temperature of the water to be midway between freezing and boiling, viz. 122° F., as also that of the air in contact with it to be the same, but replete with moisture, so that its interstitial spaces are filled with vapour of corresponding elasticity and specific gravity with that given off by the water, it is certain that no fresh formation of vapour can take place in these circumstances. But the moment a portion of vapour is allowed to escape, or is drawn off by condensation to another vessel, an equivalent portion of vapour will be immediately exhaled from the water.

The pressure of the air and of other vapours upon the surface of water in an open vessel, does not prevent evaporation of the liquid; it merely retards its progress. Experience shows that the space filled with an elastic fluid, as air or other gaseous body, is capable of receiving as much aqueous vapour as if it were vacuous, only the repletion of that space with the vapour proceeds more slowly in the former predicament than in the latter, but in both cases it arrives eventually at the same pitch. Dr. Dalton very ingeniously proved that the particles of aeriform bodies present no permanent obstacle to the introduction of a gaseous atmosphere of another kind among them, but merely obstruct its diffusion momentarily, as if by a species of friction. Hence, exhalation at atmospheric temperatures is promoted by the mechanical diffusion of the vapours through the air with ventilating fans or chimney draughts; though, under brisk ebullition, the force of the steam readily overcomes that mechanical obstruction.

The quantities of water evaporated under different temperatures in like times, are proportional to the elasticities of the steam corresponding to these temperatures. A vessel of boiling water exposing a square foot of surface to the fire, evaporates about 725 grains in the minute; the elasticity of the vapour is equivalent to 30 inches of mercury. To find the quantity that would be evaporated from the same surface per minute at a heat of 88° F.:—At this temperature the steam incumbent upon water is capable of supporting 1·21 inch of mercury; whence the rule of proportion is 30 : 1·28 :: 725 : 30·93; showing that about 31 grains of water would be evaporated in the minute. If the air contains already some aqueous vapour, as it commonly does, then the quantity of evaporation will be proportional to the difference between the elastic force of that vapour, and what rises from the water.

Suppose the air to be in the hygrometric state denoted by 0·38 of an inch of mercury, then the above formula will become 30 : 1·28 − 0·38 :: 725 : 21·41; showing that not more than 21½ grains would be evaporated per minute under these circumstances.

The elastic tension of the atmospheric vapour is readily ascertained by the old experiment of Le Roi, which consists in filling a glass cylinder (a narrow tumbler for example) with cold spring water, and noting its temperature at the instant it becomes so warm that dew ceases to be deposited upon it. This temperature is that which corresponds to the elastic tension of the atmospheric vapour.

Whenever the elasticity of the vapour, corresponding to the temperature of the water, is greater than the atmospheric pressure, the evaporation will take place not only from its surface, but from every point in its interior; the liquid particles throughout the mass assuming the gaseous form, as rapidly as they are actuated by the heat which subverts the hydrostatic equilibrium among them, to constitute the phenomena of ebullition. This turbulent vaporisation takes place at any temperature, even down to the freezing point, provided the pneumatic pressure be removed from the liquid by the air-pump, or any other means. Ebullition always accelerates evaporation, as it serves to carry off the aqueous particles not simply from the surface, but from the whole body of the water.

The vapours exhaled from a liquid at any temperature contain more heat than the fluid from which they spring; and they cease to form whenever the supply of heat into the liquid is stopped. Any volume of water requires for its conversion into vapour about *five times* as much heat as is sufficient to heat it from the freezing to the boiling temperature. The heat, in the former case, seems to be absorbed, being inappreciable by the thermometer; for steam is no hotter than the boiling water from which it rises. It has been therefore called by Dr. Black, *latent heat*; in contradistinction to that perceived by the touch and measured by the thermometer, which is called *sensible heat*. The quantity of heat absorbed by one volume of water in its conversion into steam, is about 1,000° F.; it would be inadequate to heat 1,000 volumes of water, one degree of the same scale. Were the vessel charged with water so heated, opened, it would be instantaneously emptied by vaporisation, since the whole caloric, equivalent to its constitution as steam, is present. When, upon the other hand, steam is condensed by contact with cold substances, so much heat is set free as is capable of heating about five times its weight of water from 32° to 212° F.

Equal weights of vapour of any temperature contain equal quantities of heat; for example, the vapour exhaled from one pound of water, at 77° F., absorbs during its formation, and will give out in its condensation, as much heat as the steam produced by one pound of water at 212° F. The first portion of vapour with a tension = 30 inches, occupies a space of 27·31 cubic feet; the second, with a tension of 0·92 inch, occupies a space of 890 cubic feet.[1] Suppose that these 890 volumes were to be compressed into 27·31 in a cylinder capable of confining the heat, the temperature of the vapour would rise from 77° to 212°, in virtue of the condensation, as air becomes so hot by compression in a syringe, as to ignite *amadou*. The latent heat of steam at 212° F. is $1180° - 180 = 1000$; that of vapour, at 77°, is $1183 - 45 = 1135$; so that, in fact, the lower the temperature at which the vapour is exhaled, the greater is its latent heat, as Joseph Black and James Watt long ago proved by experiments upon distillation and the steam-engine.

From the preceding researches it follows, that evaporation may be effected upon two different plans:—

1. Under the ordinary pressure of the atmosphere; and that either,

(A) By external application of heat to boilers, with (*a*) an open fire; (*b*) steam; (*c*) hot liquid *media*.

(B) By evaporation with air; (*a*) at the ordinary temperature of the atmosphere; (*b*) by currents of warm air.

2. Under progressively lower degrees of pressure than the atmospheric, down to evaporation in as perfect a vacuum as can be made.

It is generally affirmed, that a thick metallic boiler obstructs the passage of the heat through it so much more than a thin one as to make a considerable difference in their relative powers of evaporating liquids. Dr. Ure states that he made a series of experiments upon this subject. Two cylindrical copper pans, of equal dimensions, were provided; but the metal of the one was twelve times thicker than that of the other. Each being charged with an equal volume of water, and placed either upon the same hot plate of iron, or immersed, to a certain depth, in a hot solution of muriate of lime, he found that the ebullition was greatly more vigorous in the thick than in the thin vessel, which he ascribed to the conducting substance up the sides, above the contact of the source of heat, being 12 times greater in the former case than in the latter.

If the bottom of a pan, and the portions of the sides, immersed in a hot fluid medium, solution of caustic potash or muriate of lime, for example, be corrugated, so as to contain a double expanse of metallic surface, that pan will evaporate exactly double the quantity of water, in a given time, which a like pan, with smooth bottom and sides, will do immersed equally deep in the same bath. If the corrugations contain three times the quantity of metallic surface, the evaporation will be threefold in the above circumstances. But if the pan, with the same corrugated bottom and sides, be set over a fire, or in an oblong flue, so that the current of flame may sweep along the corrugations, it will evaporate no more water from its interior than a smooth pan of like shape and dimensions placed alongside in the same flue, or over the same fire. This curious fact Dr. Ure states he has verified upon models constructed with many modifications. Among others, he caused a cylindrical pan, 10 inches diameter, and 6 inches deep, to be made of tin-plate, with a vertical plate soldered across its diameter; dividing it into two equal semi-cylindrical compartments. One of these was smooth at the bottom, the other corrugated; the former afforded as rapid an evaporation over the naked fire as the latter, but it was far outstripped by its neighbour when plunged into the heated liquid medium.

If a shallow pan of extensive surface be heated over a subjacent fire, by a liquid medium, or a series a steam-pipes upon its bottom, it will give off less vapour in the same time when it is left open, than when partially covered. In the former case, the cool incumbent air precipitates by condensation a portion of the steam, and also opposes considerable mechanical resistance to the diffusion of the vaporous particles. In the latter case, as the steam issues with concentrated force and velocity from the contracted orifice, the air must offer less proportional resistance, upon the known hydrostatic principle of the pressure being as the areas of the respective bases of the communicating vessels.

In evaporating by surfaces heated with ordinary steam, it must be borne in mind

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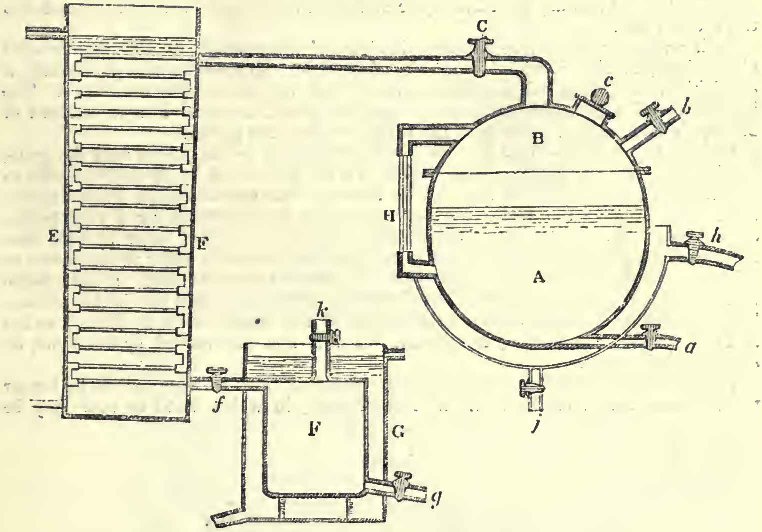
[1] One pound avoirdupois of water contains 27·72 cubic inches; one cubic inch of water forms 1696 cubic inches of steam at 212° F.: therefore one pound of water will form 27·31 cubic feet of such steam; and 0·93 : 30 :: 27·31 : 890 cubic feet.

that a surface of 10 square feet will evaporate fully one pound of water per minute, or 725 × 10 = 7250 gr., the same as over a naked fire; consequently the condensing surface must be equally extensive. Suppose that the vessel is to receive of water 2,500 lbs. which corresponds to a boiler 5 feet long, 4 broad, and 2 deep, being 40 cubic feet by measure, and let there be laid over the bottom of this vessel 8 connected tubes, each 4 inches in diameter and 5 feet long, possessing therefore a surface of 4·8 feet square. If charged with steam, they will cause the evaporation of half a pound of water per minute. The boiler to supply the steam for this purpose must expose a surface of 4·8 square feet to the fire. It has been proved experimentally that 10 square feet surface of thin copper can condense 3 lbs. of steam per minute, with a difference of temperature of 90 degrees Fahr. In the above example, 10 square feet evaporate 1 lb. of water per minute; the temperature of the evaporating fluid being 212° F., consequently $3 : 1 :: 90 : \frac{90}{3}$. During this evaporation the difference of the temperature is therefore = 30°. Consequently the heat of the steam placed in connection with the interior of the boiler, to produce the calculated evaporation, should be, $212 + 30 = 242°$, corresponding to an elastic force of 53·6 inches of mercury. Were the temperature of the steam only 224, the same boiler in the same time would produce a diminished quantity of steam, in the proportion of 12 to 30; or to produce the same quantity the boiler or tubular surface should be enlarged in the proportion of 30 to 12. In general, however, steam boilers employed for this mode of evaporation are of such capacity as to give an unfailing supply of steam.

838



We shall now illustrate, by some peculiar forms of apparatus, different systems of evaporation. *Fig.* 838 explains the principles of evaporating *in vacuo*. A B represents a pan or kettle charged with the liquor to be evaporated. The somewhat wide orifice *c*, secured with a screw-plug, serves to admit the hand for the purpose of cleaning it thoroughly out when the operation is finished; *h* is the pipe of communication with the steam boiler; *b* is a tube prolonged and then bent down with its end plunged into the liquor to be evaporated, contained in the charging back (not shown in the figure). H is a glass tube communicating with the vacuum pan at the top and bottom, to show by the height of the column the quantity of liquid within. The eduction evaporating pipe C is provided with a stop-cock to cut off the communication when required. *i* is a tube for the discharge of the air and the water from the steam-case or jacket; the refrigerator E is best formed of thin copper tubes about 1 inch in diameter, arranged zigzag or spirally like the worm of a still in a cylinder. The small air-tight condenser F, connected with the efflux-pipe *f* of the refrigerator, is furnished below with a discharge-cock *g*, and surrounded by a cooling case, for the collection of the water condensed by the refrigerator. In its upper part there is a tube *k*, also furnished with a cock, which communicates with the steam boiler, and through which the pan A B is heated.

The operation of this apparatus is as follows: after opening the cocks C, *f*, *g*, and before admitting the cold water into the condenser E, the cock of the pipe *k* is opened, in order that by injecting steam it may expel the included air; after which the cocks *k* and *g* are to be shut. The water must now be introduced into the condenser, and the cock *b* opened, whereon the liquid to be evaporated rises from the charging back, through the tube *b*, and replenishes the vacuum pan to the proper height, as shown by the register glass tube H. Whenever the desired evaporation or concentration is effected, the cock C must be closed, the pipe *k* opened, so as to fill the pan with steam, and then the efflux cock *a* is opened to discharge the residuary liquor. By shutting the cocks *a* and *k*, and opening the cock *b*, the pan will charge itself afresh with liquor, and the operation will be begun anew, after *b* has been shut and C opened.

The contents of the close water cistern F, may be drawn off during each operation. For this purpose, the cock *f* must first be shut, the cold water is to be then run out of the condenser G, and *k* and *g* are to be opened. The steam entering by *k* makes the water flow, but whenever the steam itself issues from the cock *g*, this orifice must be immediately shut, the cock *f* opened, and the cold water again introduced, whereupon the condensed water that had meanwhile collected in the under part of the refrigerator flows off into the condenser vessel F. Since some air always enters with the liquor sucked into the pan, it must be removed at the time of drawing off the water from the two condensers, by driving steam through the apparatus. This necessity will be less urgent if the liquor be made to boil before being introduced into the vacuum pan.

Such an apparatus may be modified in size and arrangement to suit the peculiar object in view, when it will be perfectly adapted for the concentration of extracts of every kind, as well as saline solutions containing vegetable acids or alkalis. The interior vessel A B should be made of tinned or plated copper. For an account of Howard's vacuum pan, made upon the same principle, see SUGAR.

When a boiler is set over a fire, its bottom should not be placed too near the grate, lest it refrigerate the flame, and prevent that vivid combustion of the fuel essential to the maximum production of heat by its means. The evil influence of leaving too little room between the grate and the copper may be illustrated by a very simple experiment. If a small copper or porcelain capsule containing water be held over the flame of a candle a little way above its apex, the flame will suffer no abatement of brightness or size, but will continue to keep the water briskly boiling. If the capsule be now lowered into the middle of the flame, this will immediately lose its brightness, becoming dull and smoky, covering the bottom of the capsule with soot; and, owing to the imperfect combustion, though the water is now surrounded by the flame, its ebullition will cease.

Fig. 839 is a section of two evaporating coppers *en suite*, so mounted as to favour the full combustion of the fuel. A is the hearth, in which wood or coal may be burned. For coal, the grate should be set higher and be somewhat smaller. *a* is the door for feeding the fire; *d*, an arch of fire-bricks over the hearth; *c*, a grate through which the ashes fall into the pit beneath, capable of being closed in front to any extent by a sliding door *b*. B and C are two coppers encased in brickwork; *f* the flue. At the end of the hearth near *m*, where the fire plays first upon the copper, the sole is made somewhat lower and wider, to promote the spreading of the flame under the vessel. The second copper C, receives the benefit of the waste heat; it may be placed upon a higher level, so as to discharge its concentrated liquor by a stop-cock or siphon into the first.

839

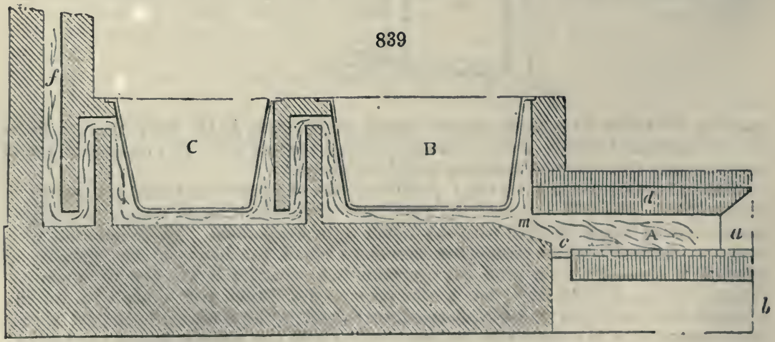


Fig. 840 represents a pan for evaporating liquids, which are apt, during concentration, to let fall crystals or other sediment.

These would be injured either by the fire playing upon the bottom of the pan, or, by adhesion to it, they would allow the metal to get red hot, and in that state run every risk of being burnt or rent on the sudden intrusion of a little liquor through the incrustation. When large coppers have their bottoms planted in loam, so that the flame circulates in flues round their sides, they are said to be *cold-set.*

A is a pear-shaped pan, charged with the liquid to be evaporated; it is furnished with a dome cover, in which there is an opening with a flange *f*, for attaching a tube, to conduct the steam wherever it may be required. *a* is the fire-place; *b*, the ash-pit. The conical part terminates below in the tube *g*, furnished with a stop-cock at its nozzle *h*. Through the tube *c d c′*, furnished above and below with the stop-cocks *c* and *c′*, the liquid is run from the charging back or reservoir. During the operation, the upper cock *c* is kept partially open, to replace the fluid as it evaporates; but the under cock *c′* is shut. The flame from the fireplace plays round the kettle in the space *e*, and the smoke escapes downwards through the flue *i* into the chimney. The lower cylindrical part *g* remains thus comparatively cool, and collects the crystalline or other solid matter. After some time, the under stop-cock *c′*, upon the supply-pipe, is to be opened to admit some of the cold liquor into the cylindrical neck. That cock being again shut, the sediment settled, and the large stop-cock (a horizontal side valve would be preferable) *h* opened, the crystals are suffered to descend into the subjacent receiver; after which the stop-cock *h* is shut, and the operation is continued. A construction upon this principle is well adapted for heating dyeing coppers, in which the sediment should not be disturbed, or exposed to the action of the fire. The fireplace should be built as for the brewing copper.

840

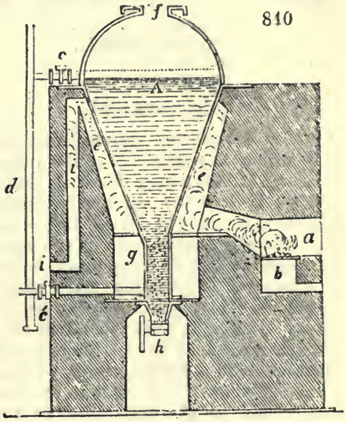
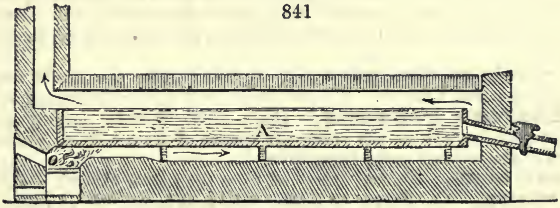


Fig. 841 represents an oblong evaporating pan, in which the flame, after beating along its bottom, turns up at its further end, plays back along its surface, and passes off into the chimney. A is a rectangular vessel, from 10 to 15 feet long, 4 to 6 feet broad, and 1 or 1½ foot deep. The fire-bricks, upon which the pan rests, are so arranged as to distribute the flame equally along its bottom.

841



Leidenfrost in 1756 ('*Annales de Chimie*') observed some remarkable facts connected with evaporation, which have since received some striking illustration from the experiments of M. Boutigny.

When water is thrown on a plate heated considerably above the boiling point of water, the liquid assumes a spheroidal form, and this condition has hence received the name of the *spheroidal state.* This water rolls about like melted crystal without any signs of ebullition, and it is dissipated but very slowly. The explanation usually given is as follows:—'The cause of the phenomena appears to be this: water exhibits an attraction for the surface of almost all solids, and wets them; fluid mercury exhibits the opposite property, or repulsion for most surfaces. The attraction of water for surfaces brings it into the closest contact with them, and greatly promotes the communication of heat by a heated vessel to the water contained in it. But heat appears to develope a repulsive power in bodies, and it is probable that, above a peculiar temperature, the heated metal no longer possesses this attraction for water. The water not being attracted to the surface of the hot metal, and induced to spread over it, is not rapidly heated, and therefore boils off slowly.'—*Graham.*

The explanation given by this excellent authority has been selected as representing fairly the prevailing view. It is not, however, satisfactory. The water is said to be at a sensible distance from the hot plate, and a layer of aqueous vapour of very high temperature is known to surround the water, and yet the *spheroidal* water does not acquire the boiling temperature. Here is evidence of some peculiar, and as yet unexplained condition, belonging, either to heat of a certain kind or degree, or to the molecules of the body under its influence.

Boutigny observed that water may pass into the *spheroidal state* when projected upon metal above the temperatures of 142°. Ether and alcohol pass into the *spheroidal state* between the temperatures 142° F. and 273° F. A thermometer being plunged in liquids while in the *spheroidal state*, indicated the following temperatures:—

Water	205·7° F.
Absolute alcohol	167·9
Ether	93·6
Hydrochloric ether	50·9
Sulphurous acid	13·1

All these being some degrees below the boiling temperature of those fluids.

Boutigny has shown that the vapour escaping from water in the *spheroidal state*, although it has a very elevated temperature, does not possess the usual elasticity of steam; it does not exert an expansive power. But if the vessel from which the vapour is forming is allowed to cool, to a certain point, a degree of elasticity equal to the elevated temperature of the vapour is suddenly exerted. This is supposed by Boutigny to explain many steam-boiler explosions.

Whenever evaporation takes place, it should be remembered, it produces cold—that is, it lowers the temperature of the body from which the evaporation is taking place. Leslie, by the evaporation of ether *in vacuo*, froze mercury. Thilorier solidified carbonic acid by the intense cold produced by its own evaporation. Boutigny froze water in a red-hot vessel, by the evaporation of sulphurous acid from the heated vessel in which the water is in the *spheroidal state*. Faraday froze mercury in a red-hot crucible by the evaporation of a mixture of solid carbonic acid and ether. But the lowest temperature yet reached has been in the experiments of Natterer, of Vienna, who obtained as low a temperature as − 220° F. by mixing liquid nitrous oxide with bisulphide of carbon, and evaporating this mixture *in vacuo*. Carré's freezing-machine depends for its action on the rapid evaporation of a solution of ammonia.

The *spheroidal condition* of fluids does not appear to be dependent entirely on heat. By dropping alcohol or ether on the surface of the same fluids, such *spheroidal drops* may be obtained; and water splashed upon water often assumes the same condition. Mr. Tomlinson has some curious experiments upon the formation of these varieties of spheroids.

Further remarks on these points will be found under the heads respectively of COAL; FREEZING; and VAPOUR. See also HEAT, in Watts's 'Dictionary of Chemistry.'

EVERLASTING FLOWERS. These dried flowers, largely used by the French as *Immortelles*, are for the most part species of *Gnaphalium*, *Helichrysum*, and other plants of the natural order *Compositæ*.

EVERNIC ACID. An acid extracted from the lichen *Evernia prunastri*.

EXANTHINE. The Purree or Indian yellow of India. See INDIAN YELLOW.

EXOGENS. A botanical term, applied to plants which grow by addition to the outer parts of the stem. Most British trees are Exogens. The correlative term *Endogens* is applied to plants which, like palms, appear to grow by addition to the inner parts of the stem. The stem varies in structure in four principal ways: it is either formed by successive additions to the outside of the wood, when it is called *exogenous*, or by successive additions to its centre, when it is called *endogenous*, or by the union of the bases of leaves, and the extension of the point of the axis, which is called *acrogenous*, or by simple elongation or dilatation where no leaves or buds exist, as among *Thallogens*.—*Lindley*.

EXOSMOSE and ENDOSMOSE. As some manufacturing processes involve the phenomena expressed by these two words, it appears necessary briefly to explain them.

When two liquids are separated by a porous sheet of animal membrane, unglazed earthenware, porous stone, or clay, these liquids gradually diffuse themselves; and supposing salt and water to be on one side of the division, and water only on the other, the saline solution passes in one direction, while the water, though with less intensity, passes in another.

Instead of the two words introduced by Dutrochet, Professor Graham proposed the use of the single term Osmose (from *ὠσμός*, impulsion).

It was supposed that there was, at the same time, an impulsive force acting from without and another acting from within; that there was indeed a current *flowing in*, and another *flowing out.* It appears, however, to be proved that the *osmose* between water and saline solutions, consists not in the passage of two liquid currents, but in the passage of particles of the salt in one direction, and of pure water in the other. Professor Graham observed that common salt diffuses into water through a thin membrane of ox-bladder deprived of its outer muscular coating, at the same rate as when no membrane is interposed. This force plays an important part in the functions of life, and it will be found to explain many of the phenomena associated with Dyeing, Tanning, &c. See OSMOSE FORCE.

EXPANSION (Eng. and Fr.; *Ausdehnung*, Ger.) is the increase of bulk experienced by all bodies when heated, unless a change in molecular arrangement takes place, as in the case of clays in the potter's kiln.

Table I. exhibits the linear expansion of several solids by an increase of temperature from 32° to 212° F.; Table II. exhibits the expansion in bulk of certain liquids.

TABLE I.—*Linear Dilatation of Solids by Heat.*

Dimensions which a bar takes at 212° whose length at 32° is 1·000000.

Substances	Authority	Dilatation in Decimals	Dilatation in Vulgar Fractions
Glass tube	Smeaton	1·00083333	
,,	Roy	1·00077615	
,,	Deluc's mean	1·00082800	$\frac{1}{1116}$
,,	Dulong and Petit	1·00086130	$\frac{1}{1148}$
,,	Lavoisier and Laplace	1·00081166	$\frac{1}{1122}$
Plate glass	,, ,,	1·000890890	$\frac{1}{1142}$
Crown glass	,, ,,	1·00087572	$\frac{1}{1114}$
,,	,, ,,	1·00089760	$\frac{1}{1090}$
,,	,, ,,	1·00091751	
,, rod	Roy	1·00080787	
Deal	Roy, as glass	—	
Platinum	Borda	1·00085655	
,,	Dulong and Petit	1·00088420	$\frac{1}{1131}$
,,	Troughton	1·00099180	
,, and glass	Berthoud	1·00110000	
Palladium	Wollaston	1·00100000	
Antimony	Smeaton	1·00108300	
Cast-iron prism	Roy	1·00110940	
Cast-iron	Lavoisier, by Dr. Young	1·00111111	
Steel	Troughton	1·00118990	
Steel rod	Roy	1·00114470	
Blistered steel	Phil. Trans. 1795, 428	1·00112500	
,,	Smeaton	1·00115000	
Steel not tempered	Lavoisier and Laplace	1·00107875	$\frac{1}{927}$
,, ,,	,, ,,	1·00107956	$\frac{1}{926}$
,, tempered yellow	,, ,,	1·00136900	
,, ,, ,,	,, ,,	1·00138600	
,, ,, ,, at a higher heat	,, ,,	1·00123956	$\frac{1}{807}$
Steel	Troughton	1·00118980	
Hard steel	Smeaton	1·00122500	
Annealed steel	Muschenbroek	1·00122000	
Tempered steel	,,	1·00137000	
Iron	Borda	1·00115600	
,,	Smeaton	1·00125800	
Soft iron, forged	Lavoisier and Laplace	1·00122045	
Round iron, wire drawn	,, ,,	1·00123504	
Iron wire	Troughton	1·00144010	
Iron	Dulong and Petit	1·00118203	$\frac{1}{846}$
Bismuth	Smeaton	1·00139200	
Annealed gold	Muschenbroek	1·00146000	
Gold	Ellicot, by comparison	1·00150000	
,, procured by parting	Lavoisier and Laplace	1·00146606	$\frac{1}{682}$
,, Paris standard, unannealed	,, ,,	1·00155155	$\frac{1}{645}$
,, ,, annealed	,, ,,	1·00151361	$\frac{1}{601}$

Substances	Authority	Dilatation in Decimals	Dilatation in Vulgar Fractions
Copper	Muschenbroek	1·0019100	
„	Lavoisier and Laplace	1·00172244	$\frac{1}{581}$
„	„ „	1·00171222	$\frac{1}{584}$
„	Troughton	1·00191880	
„	Dulong and Petit	1·00171821	$\frac{1}{582}$
Brass	Borda	1·00178300	
„	Lavoisier and Laplace	1·00186671	
„	„ „	1·00188971	
Brass scale, supposed from Hamburg	Roy	1·00185540	
Cast brass	Smeaton	1·00187500	
English plate-brass, in rod	Roy	1·00189280	
„ „ in a trough form	„	1·00189490	
Brass	Troughton	1·00191880	
Brass wire	Smeaton	1·00193000	
Brass	Muschenbroek	1·00216000	
Copper 8, tin 1	Smeaton	1·00181700	
Silver	Herbert	1·00189000	
„	Ellicot, by comparison	1·0021000	
„	Muschenbroek	1·00212000	
„ of cupel	Lavoisier and Laplace	1·00190974	$\frac{1}{524}$
„ Paris standard	„ „	1·00190868	$\frac{1}{524}$
Silver	Troughton	1·0020826	
Brass 16, tin 1	Smeaton	1·00190800	
Speculum metal	„	1·00193300	
Spelter solder; brass 2, zinc 1	„	1·00205800	
Malacca tin	Lavoisier and Laplace	1·00193765	$\frac{1}{516}$
Tin from Falmouth	„ „	1·00217298	$\frac{1}{462}$
Fine pewter	Smeaton	1·00228300	
Grain tin	„	1·00248300	
Tin	Muschenbroek	1·00284000	
Soft solder; lead 2, tin 1	Smeaton	1·00250800	
Zinc 8, tin 1, a little hammered	„	1·00269200	
Lead	Lavoisier and Laplace	1·00284836	$\frac{1}{351}$
„	Smeaton	1·00286700	
Zinc	„	1·00294200	
Zinc, hammered out ½ inch per foot	„	1·00301100	
Glass, from 32° to 212°	Dulong and Petit	1·00086130	$\frac{1}{1161}$
„ from 212° to 392°	„ „	1·00091827	$\frac{1}{1089}$
„ from 392° to 572°	„ „	1·000101114	$\frac{1}{987}$

The last two measurements by an air-thermometer.

TABLE II.—*Expansion of certain Liquids by being heated from 32° to 212°.*

Substances	Authority	Expansion in Decimals	Expansion in Vulgar Fractions
Mercury	Dulong and Petit	0·01801800	$\frac{1}{55·5}$
„ in glass	„ „	0·01543200	$\frac{1}{65}$
Water from its maximum density	Kirwan	0·04332	$\frac{1}{23}$
Muriatic acid (sp. gr. 1·137)	Dalton	0·0600	$\frac{1}{17}$
Nitric acid (sp. gr. 1·40)	„	0·1100	$\frac{1}{9}$
Sulphuric acid (sp. gr. 1·85)	„	0·6600	$\frac{1}{17}$
Alcohol (to its boiling point)?	„	0·1100	$\frac{1}{9}$
Water	„	0·0460	$\frac{1}{22}$
Water, saturated with common salt	„	0·0500	$\frac{1}{20}$
Sulphuric ether (to its boiling point)?	„	0·0700	$\frac{1}{14}$
Fixed oils	„	0·0800	$\frac{1}{12·5}$
Oil of turpentine	„	0·0700	$\frac{1}{14}$

If the density of water at 39° be called 1·00000,
at 212° it becomes . . . . . . 0·9548,
and its volume has increased to . . 1·04734;
at 77° it becomes . . . . . . 0·9973587,
and its volume has increased to only . 1·00265,
which, though one-fourth of the whole range of temperature, is only $\frac{1}{18}$ of the total expansion. Water at 60° F. has a specific gravity of . 0·9991253,
and has increased in volume from 39° to . 1·00008,
which is only about $\frac{1}{58}$ of the total expansion to 212°, with $\frac{1}{6\cdot4}$ of the total range of temperature.

All gases expand the same quantity by the same increase of temperature, which from 32° to 212° F. $=\frac{180}{480}=\frac{3}{8}$ of its initial volume, or 100 volumes become 1·375. For each degree of F. the expansion is $\frac{1}{480}$.

When dry air is saturated with moisture, its bulk increases, and its specific gravity diminishes, because aqueous vapour is less dense than air, at like temperatures.

The following Table gives the multipliers to be employed for converting one volume of moist gas at the several temperatures, into a volume of dry gas:—

Temperature	Multiplier	Temperature	Multiplier
53° F.	0·9870	64°	0·9799
54	0·9864	65	0·9793
55	0·9858	66	0·9786
56	0·9852	67	0·9779
57	0·9846	68	0·9772
58	0·9839	69	0·9765
59	0·9833	70	0·9758
60	0·9827	71	0·9751
61	0·9920	72	0·9743
62	0·9813	73	0·9735
63	0·9806		

Lavoisier and Laplace arrived, after an extensive series of experiments, at the two important conclusions following:—

1st. All solid bodies whatever, being gradually heated from the temperature of melting ice to that of boiling water, and then gradually cooled from the temperature of boiling water to that of melting ice, will be found to have exactly the same dimensions at the same temperature during the process of heating and cooling; the gradual diminution of bulk in cooling corresponding exactly with the gradual increase of bulk in heating.

2nd. Glass and metallic bodies gradually heated from the temperature of melting ice to that of boiling water, undergo degrees of expansion proportional to those of mercury at the same temperature; that is to say, between the limits just mentioned, the expansion of the solid corresponding to two degrees of the thermometer, is twice the expansion which corresponds to one degree, the expansion which corresponds to three degrees is three times the expansion which corresponds to one degree, and so on; the quantity of expansion being multiplied in the same proportion as the number of degrees through which the thermometer has risen is multiplied. See HEAT, Watts's 'Dictionary of Chemistry.'

Experiments by Fresnel, Forbes, Powell, Trevelyan, and Tyndall have a tendency to prove that heat occasions a repulsion between the particles of matter at small distances. If a heated poker is laid slantingly on a block of lead at the ordinary temperature, it will commence to vibrate, first slowly, and will increase with such rapidity as to produce a musical note, which continues for some time, usually changing to an octave at the termination. These results would appear to prove a movement amongst the particles constituting the bar.

Some remarkable examples of expansion are furnished by the influence of sunshine on the Britannia Tubular Bridge.

The most interesting effect is that produced by the sun shining on one side of the tube, or on the top, while the opposite side and bottom remain shaded and comparatively cool; the heated portions of the tube expand, and thereby warp or bend the tube towards the heated side, the motion being sometimes as much as 2½ inches vertically and 2½ inches laterally.

While the tubes were supported on the temporary piers on the beach, these motions were easily observed. An arm carrying a pencil was fixed on the south side of the tube, at the centre, and a board was fixed on a post independent of the tube, and at right angles to it; the pencil was pressed against the board by a spring, and the rise and fall, and the lateral motions of the tube, were consequently traced on the board. In this way a very interesting diagram was taken daily. The lowest part of each figure is the starting point, or normal position of the tube, to which the pencil always accurately returns during the night. As soon as the sun rises in the morning it starts towards the right hand, rising obliquely, the top and one side of the tube being warmed, and the bottom and opposite side remaining unaffected. It continues thus till one o'clock, when the sun, having ceased to shine on the southern side, begins to warm the northern side, the top still retaining its high temperature; the tube thus acquires a nearly horizontal motion towards the left hand, the slight descent in the line indicating the diminishing effects of the sun on the top as it gradually sinks. The greatest deflection to the left hand is not attained until sunset, after which the tube rapidly descends in a uniformly-curved line to its resting point. In the summer time this point is hardly attained before the rising sun compels it to commence its journey anew. When the sun is frequently obscured by passing clouds, very curious diagrams are obtained. During the absence of the sun the tube begins to cool rapidly, and to return to its normal position; every passing cloud is thus beautifully recorded.

The middle of the centre arch of Southwark Iron Bridge rises one inch in the height of summer. When great lengths of iron pipe are laid down for the conveyance of steam or hot water, sliding joints are necessary to prevent destruction either of the apparatus or of the building in which it is placed.

The practical applications made of the expansion and contraction of metals by heat are many. The tire of a wheel is put on hot, and by its contraction on cooling, firmly binds the other parts of the wheel together; boiler-plates are riveted with red-hot rivets; collars of metal are driven on while hot, and the like.

Mollard drew together the walls of a building that had bulged, by screwing up bars of iron tight to the walls while they were hot, and a similar process was adopted in the Cathedral of Armagh.

Playfair and Joule ('Chemical Society's Memoirs') have made a valuable series of researches on the expansion of bodies by heat, principally salts; these have not, however, any sufficient practical bearing to occupy our space.

EXPLOSIVE AGENTS. The peculiar characters of such explosive compounds as GUNPOWDER, GUN-COTTON, DYNAMITE, NITRO-GLYCERINE, and the like, will be found under those articles respectively. In this place it is intended to describe in a general way some explosive compounds which are less known, and which have not as yet been employed successfully.

Chlorate-of-Potash Compounds.—The peculiar powers of chlorate of potash, and its violent oxidising properties have led to many experiments. This salt has been mixed with the prussiates of potash, with sugar and with starch, and sometimes with the addition of sulphur. These gunpowder substitutes have been known as *white gunpowder*, *German gunpowder*, &c. Ingenious attempts have been made to reduce the dangerous nature of the chlorate-of-potash mixtures by combining them with inert materials. One kind consists of mixtures of the salt with organic substances containing, in addition to carbon, a considerable proportion of hydrogen, such as powdered nut-galls, tannin, and resins. Horsley's powder was somewhat of this character, with the addition of some nitro-glycerine. That of Messrs. Hochstäder, which was introduced in 1860, and subsequently modified by M. Reichen, was somewhat similar. Strips of blotting-paper were soaked in a pasty mass consisting essentially of a mixture of chlorate of potash, saltpetre, charcoal (and small quantities of other readily oxidisable substances), together with a little gum or other binding material dissolved in water. The paper becomes coated with the explosive mixture, and at the same time impregnated with the oxidising salts, of which it absorbs a part of the solution; the strips are rolled up tightly while wet, and when dry they become hard and compact cylindrical masses, which are violently explosive when confined, but resist detonation when submitted to percussion or friction. One of these *white gunpowders* was recommended for its safety; the chlorate of potash and the other ingredient being kept separately until required for use.

Tutonite is a blasting agent of this class. It has the peculiarity of being made up in the form of hard pellets or disks, instead of being in a granulated form or in powder.

Safety Powder was a blasting agent devised by Mr. Kellow, and manufactured at the works at South Down, opposite to Devonport. It consisted of spent tan and sawdust, saturated with saltpetre or nitrate of soda, and a little chlorate of potash; the compound being subsequently crudely mixed with sulphur. (The manufacture was abandoned, the works having been destroyed by fire.)

Pyrolithe is the name of a blasting powder very nearly resembling that of Mr. Kellow's.

Poudre Barytique or *Saxifragine* is of a similar character. It is the invention of a Belgian officer, Captain Wynants, and consists of a mixture of charcoal and nitrate of baryta, with a small proportion of saltpetre. The baryta-powder is comparatively very slow burning; and its special characters are such that its application could not but remain limited to ordinary mining and quarrying uses.

Picric Acid or *Carbazotic Acid.*—Among the numerous products obtained by the action of nitric acid upon materials of organic origin, one of the earliest discovered possessing explosive properties is the product known as picric acid, which is furnished in that way by indigo, &c. Picric acid was discovered in 1788, and prepared in small quantities. It is now readily manufactured from the coal-tar product known as carbolic acid, and is now an article of commerce as a cheap and brilliant yellow dye. See Picric Acid. This, when mixed with saltpetre or chlorate of potash, particularly with the latter, furnishes products which in violence of action more nearly resemble gun-cotton and nitro-glycerine preparations than does any other readily explosive agent. Both mixtures are susceptible of detonation by friction, and especially that containing chlorate of potash, which is indeed inapplicable to practical purposes on account of its dangerous nature.

M. Designolle has produced safer mixtures of picrate of potash for artillery, small arms, and for blasting purposes. One of these consisting of picrate of potash, saltpetre, chlorate of potash, and charcoal gave satisfactory results. Mr. Abel informs us that the picrate of ammonia incorporated with saltpetre furnishes one of the safest explosive mixtures of a violent character yet produced.

Colonia Powder is a modified gunpowder saturated with nitro-glycerine.

Dualine is Schultze's sawdust powder impregnated with nitro-glycerine.

Glyoxiline consists of a mixture of gun-cotton pulp and saltpetre converted into porous pellets, which are saturated with nitro-glycerine, and afterwards coated with varnish to protect it from damp.

Lithofracteur.—Lieutenant Trauzl, in his 'Explosive-Nitrilverbindungen,' describes this preparation as simply a dynamite, in which an imperfect kind of gunpowder has been substituted for a proportion of the siliceous earth; and he gives the following as the approximate percentage composition of the material: nitro-glycerine 52, siliceous earth and sand 30, powdered coal 12, nitrate of soda 4, and sulphur 2. It has not been found in practice equal to dynamite.

Fulminates of Mercury and Silver.—These violent explosive agents are used only in the preparation of percussion caps, and have not been applied to any other useful purpose.

Iodide of Nitrogen and *Chloride of Nitrogen* will be described under their respective heads.

The following remarks on the 'Development of Force from Explosive Agents' are abstracted from Mr. Abel's paper read before the Institution of Civil Engineers in 1873.

'The character of explosion and the mechanical force developed, within given periods, by the metamorphoses of explosive mixtures, such as gunpowder, is subject to modifications, and even the most violent explosive compounds known (the mercury and silver fulminates, and the chloride and iodide of nitrogen) behave in different ways under the operation of heat or other disturbing influences, according to the circumstances which attend the metamorphosis of the explosive agent (*e.g.* the position of the source of heat with reference to the mass of the substance to be exploded, or to the extent of initial resistance opposed to the escape of the products of explosion). Thus chloride of nitrogen, when covered with a film of water, explodes with great violence when brought into contact with a decomposing agent; but if the covering of water is entirely removed, and the usual means are resorted to for causing the instantaneous decomposition of the liquid, its transformation into gases takes place with little or no explosive violence. Again, if a heap of fulminate of mercury be ignited at any portion of the exposed surface or immediately beneath it, the substance inflames into a dull explosion, and but little mechanical work is performed; but if the heap be ignited in the centre, or near the base, the explosion is very violent, and considerable shattering effect is produced. In these instances the covering of the water, on the one hand, and the external portions of the heap of fulminate on the other, perform the functions of the tamping in a blast-hole, or the walls of a shell, in determining accumulation of pressure and consequent development of violent explosion at the point of first ignition, which is then instantaneously transmitted through the mass. Applying this result to practical purposes, it is found that by igniting a charge of powder at or near the base in an ordinary blast-hole, considerable destructive force can be developed without the use of any tamping, as the upper portion of the charge acts itself as tamping to the part first ignited, and develops its violent explosion. The destructive action is, of course, still further increased, if tamping be employed under the above conditions.

'Nitro-glycerine and analogous explosive compounds which bear some relation to the chloride of nitrogen in their power of sudden explosion, require the fulfilment of special conditions for the development of their explosive force. Thus, the explosion of nitro-glycerine by the simple application of heat can only be accomplished if the source of heat be applied in such a way that chemical decomposition is established in some portion of the mass, and is formed by the continual application of heat to that part.

'The development of the violent explosive action of nitro-glycerine, freely exposed to air, through the agency of a detonation, was for some time regarded as a peculiarity of that substance; it has, however, been demonstrated that gun-cotton and other explosive compounds and mixtures do not necessarily require confinement for the full development of their explosive force, but that this result is attainable (and very readily in some instances, especially in the case of gun-cotton), by means similar to those applied in the case of nitro-glycerine.

'The manner in which a detonation operates in determining the violent explosion of gun-cotton, nitro-glycerine, &c., has been made the subject of careful investigation. It has been demonstrated experimentally, that the result cannot be ascribed to the direct operation of the heat developed by the chemical changes of the charge of detonating material used as the exploding agent. An experimental comparison of the mechanical force exerted by different explosive compounds, and by the same compound employed in different ways, has shown that the remarkable power possessed by the explosion of small quantities of certain bodies (the mercury and silver fulminates) to accomplish the detonation of gun-cotton, while comparatively large quantities of other highly explosive agents are incapable of producing that result, is generally accounted for satisfactorily by the difference in the amount of force suddenly brought to bear in the different instances upon some portion of the mass operated upon. Most generally, therefore, the degree of facility with which the detonation of a substance will develop similar change in a neighbouring explosive substance may be regarded as proportionate to the amount of force developed within the shortest period of time by that detonation, the latter being, in fact, analogous in its operation to that of a blow from a hammer, or of the impact of a projectile.

'Several remarkable results of an exceptional character have, however, been obtained, which indicate that the development of explosive force under the circumstances referred to is not always simply ascribable to the sudden operation of mechanical force. These were especially observed in the course of a comparison of the conditions essential to the detonation of gun-cotton and of nitro-glycerine by means of particular explosive agents (chloride of nitrogen, &c.), as well as in an examination into the effects produced upon each other by the detonation of these two substances. In illustration, it may be instructive to give two examples. The detonation of compressed gun-cotton is accomplished by the explosion of 5 grains of confined fulminate of mercury, placed in contact with the mass, but it requires ten times that quantity of the violent explosive agent, chloride of nitrogen, also confined, to produce the same result. Again, the mechanical force exerted by the explosion of nitro-glycerine is fully equal to that developed by the fulminate of mercury, yet a quantity of nitro-glycerine about seventy times greater than the minimum of the fulminate required to detonate compressed gun-cotton, fails, when exploded in contact with the latter, to produce any other result than the complete mechanical disintegration of the mass.

'Instances of the apparently simultaneous explosion of numerous distinct and even somewhat widely-separated masses of explosive substances (such as simultaneous explosions in several distinct buildings at powder-mills) do not unfrequently occur, in which the generation of a disruptive impulse by the first or initiative explosion, which is communicated with extreme rapidity to contiguous masses of the same nature, appears much more likely to be the operating cause than that such simultaneous explosions should be brought about by the direct action of heat and mechanical force.

'It need scarcely be stated that the detonation of a large quantity of an explosive body is accomplished by the initiative detonation of a very small portion of the mass; this is the case even if the material is arranged in the form of a train of considerable length, the detonating fuze being applied at one extremity. Rows of gun-cotton disks, from 3 feet to 5 feet in length, with intervals of 0·5 inch and 1 inch between the individual masses, have been detonated in this way. There is, however, a limit to the distance to which a detonation will be transmitted along a row of spaced disks, the limit being determined by the particular weight of the masses employed; if it be exceeded, those masses which are at the further extremity will be inflamed and scattered, instead of being detonated. A few preliminary experiments have been made with the view of determining, by means of Noble's chronoscope, the rapidity with which detonation progresses along a row of gun-cotton disks. This will, no doubt, vary with the sizes of the masses. In an experiment with disks weighing 2 ounces each, placed in a row without intervals, it was found that the detonation extended to 3 feet in about one five-thousandth part of a second.'

EXPRESSED OILS. See OILS.

EXTRACT OF LEAD. A common name for the solution of acetate of lead, also called Goulard's Lotion.

EXTRACTS. (*Extraits*, Fr.; *Extracten*, Ger.) The older apothecaries used this term to designate the product of the evaporation of any vegetable juice, or infusion, or decoction; whether the latter two were made with water, alcohol, or ether; whence arose the distinction of aqueous, alcoholic, and etherous extracts.

Fourcroy made many researches upon these preparations, and supposed that they had all a common basis, which he called the *extractive* principle. But Chevreul and other chemists have since proved that this pretended principle is a heterogeneous and very variable compound. By the term *extract* therefore is now meant merely the whole of the soluble matters obtained from vegetables, reduced by careful evaporation to either a pasty or solid consistence. The watery extracts, which are those most commonly made, are as various as the vegetables which yield them; some containing chiefly sugar or gum in great abundance, and are therefore innocent or inert; while others contain very energetic impregnations. The conduct of the evaporating heat is the capital point in the preparation of extracts. They should be always prepared, if possible, from the juice of the fresh plant, by subjecting its leaves or other succulent part, to the action of a powerful screw, or hydraulic press; and the evaporation should be effected by the warmth of a water-bath, heated not beyond 100° or 120° Fahr. Steam heat is now applied advantageously in some cases, where it is not likely to decompose any of the principles of the plant. But by far the best process for making extracts is *in vacuo*, upon the principles explained in the article EVAPORATION. It is much easier to fit up a proper apparatus of this kind than most practical men imagine. The vacuum may either be made through the agency of steam, as there pointed out, or by means of an air-pump. One powerful air-pump may form and maintain a good vacuum under several receivers, placed upon the flat ground flanges of so many basins, each provided with a stop-cock at its side for exhaustion. The airless basin containing the juice being set on the shelf of a water-bath, and exposed to a proper temperature, will furnish in a short time a large quantity of medicinal extract, possessing the properties of the plant unimpaired.

For exceedingly delicate purposes, the concentration may be performed in the cold, by placing saucers filled with the expressed juice over a basin containing sulphuric acid, putting a glass receiver over them, and exhausting its air.

The use of the air-pump for evaporating such chemical substances as are readily injured by heat, has been very common since Professor Leslie's discovery of the efficacy of the combined influence of rarefied air and an absorbing surface of sulphuric acid in evaporating water at low temperatures. It has been supposed that the virtues of narcotic plants in particular might be better obtained and preserved by evaporation *in vacuo* than otherwise, as the decomposing agency of heat and atmospheric oxygen would be thereby excluded. There is no doubt that extracts thus made from the expressed juices of fresh vegetables possess, for some time at least, the green aspect and odour of the plants in far greater perfection than those usually made in the air, with the aid of artificial heat. Dr. Meurer has endeavoured to show that the colour and odour are of no use in determining the value of extracts of narcotics, that the albumen left unchanged in the extracts made *in vacuo*, tends to cause their spontaneous decomposition, and that the extracts made with the aid of alcohol, as is the practice in Germany, are more efficacious at first, and much less apt to be injured by keeping. M. Baldenius has detailed experiments to prove that the juices of recent plants mixed with alcohol, in the homœopathic fashion, are very liable to spontaneous decomposition. To the above expressed juice, the Germans add the alcoholic tincture of the residuary vegetable matter, and evaporating both together, prepare very powerful extracts.

Extracts of bark and other vegetable substances to be used in tanning or dyeing are made in the countries in which the plants grow. The operation is very roughly performed, and the imported extracts are usually very full of impurities.

In 1872 we imported of *Extracts unenumerated* as follows, the values only being given:—

	Value
From Belgium	£5,265
„ France	4,043
„ United States of America	6,853
„ British North America	4,400
„ Other Countries	1,253
	21,814

Of extracts of bark and other vegetable substances used for tanning or dyeing we exported in the same year to the value of 8,794*l*., of unenumerated extracts to the value of 3,089*l*., and of extract of malt to the value of 25*l*.

EXUVIÆ. Cast skins, shells, or coverings of animals which are shed or cast off, as the skins of serpents or caterpillars, the shells of lobsters, and the like. In geology, the shells and other similar remains of animals found in the rocks.

F

FACETTING. The process of cutting faces upon ornamental articles. Steel jewellery, such as beads, studs, buttons, the ornaments on the hilts of dress-swords and similar objects, are ground on horizontal laps with fine emery. Facets on gold and silver are cut and polished on revolving wheels, after the same general method as that pursued by the lapidary for cutting facets on stones.

FACTORY. In the sense in which this term is introduced here, it is contracted from 'manufactory;' meaning the place where workmen are employed in fabricating goods. To describe all the various factories would be to describe all the different manufactures, or at least, the arrangements of the machines by which the raw material is converted into marketable goods. The arrangements of a cotton factory fairly represent all the arrangements for other branches of textile manufactures. Under SILK, WOOL, &c., will be found particulars of the machines used and their general arrangements in these factories respectively. See COTTON FACTORY.

FÆCULA. See FECULA.

FAHLERZ, FAHLITE, or **FAHL-ORE.** A mineral known also as *Grey Copper ore*, and *Tetrahedrite*; the latter name referring to the common occurrence of this ore in tetrahedral crystals belonging to the cubic system. The chemical composition of fahlerz varies greatly in different specimens, but, speaking broadly, it may be said to be a double sulphide of copper and antimony; the antimony, however, may be replaced to a greater or less extent by the isomorphous elements—arsenic and bismuth, whilst the copper may be replaced in like manner by iron, zinc, silver, or mercury. We may thus recognise an antimonial series and an arsenical series, these being connected by an arsenio-antimonial and a bismutho-arsenico-antimonial series. Many varieties of fahlerz contain sufficient silver to render them important as silver ores, and these argentiferous varieties have been described under the names of *Polytelite* and *Freibergite*. The following analyses are selected with the view of showing some of the variations presented in the composition of different forms of fahlerz:—

	I	II	III	IV
Sulphur . . .	25·77	22·53	27·48	21·17
Antimony . . .	23·94	19·34	24·85	24·63
Arsenic . . .	2·88	2·94	...	...
Bismuth . . .	...	0·81	...	...
Copper . . .	37·98	35·34	22·62	14·81
Iron	0·86	0·87	4·80	5·98
Zinc	7·29	0·69	4·65	0·99
Silver	0·62	...	13·57	31·29
Mercury . . .	...	17·27	...	...
Lead	...	0·21	1·43	...

I. From Kapnik, in Transylvania; by H. Rose. II. From Kotterbach, near Iglo; by Vom Rath. III. From Foxdale silver-lead mine, Isle of Man; by David Forbes. IV. From the Habachtfund mine, Freiberg, Saxony; by H. Rose. See COPPER.

FAHLUNITE. An altered form of the mineral called *Iolite* or *Dichroite*.

FAÏENCE or **FAYENCE.** An old French term, nearly corresponding in meaning with our household word 'crockery.' It is now commonly applied by collectors to all the finer kinds of earthenware. Some authorities maintain that the word is derived from the town of Faenza, near Bologna. It is known that Majolica or Raffaelle ware was made at an early date at Faenza, and hence Majolica is sometimes distinguished as 'Faenza' ware. But this is a very different material from what is now commonly called Faïence. See MAJOLICA.

FAIKES or **FAKES.** A *miner's term* in Scotland for fissile sandy shales, or sandstone possessing a shale-like structure. Dark bituminous shales are called *blaes*, and the two varieties are thus distinguished.

FAINTS is the name of the impure spirit which comes over first and last in the distillation of whiskey; the former being called the *strong*, and the latter which is much more abundant, the *weak* faints. This crude spirit is much impregnated with fetid essential oil (fusel oil); it is therefore very unwholesome, and must be purified by rectification.

FAIRY-STONE. A name given in the south of England to the fossil sea-urchins found in the chalk. They are sometimes called 'fairy loaves.'

FALLING STONES. A name given to meteoric stones. See METEORIC STONES.

FALSE SILVER. A term applied by the ancients, in all probability, to zinc. Strabo, in a passage quoted in Watson's 'Chemical Essays,' speaks of false silver, with the addition of copper, making orichalcum, or brass.

FALSE TOPAZ. A light yellow pellucid variety of quartz crystal. It may be distinguished from yellow topaz, for which, when cut, it is frequently substituted, by its difference of crystalline form, the absence of cleavage, inferior hardness, and lower specific gravity. Found in the Brazils, &c.

FAMP is a siliceous bed, composed of very fine particles. This term is confined chiefly to the North of England. Famp possesses little cohesion, and when exposed to the action of the air it crumbles into a sandy kind of clay. Beds of 'famp' often separate the hard 'posts' of sandstone; they also contain more mica than the sandstone rocks among which they are interspersed. See POST.

FAN (*Eventail*, Fr.; *Fächer*, Ger.) is usually a semi-circular piece of silk or paper, pasted double, enclosing slender slips of wood, ivory, tortoise-shell, whalebone, &c., arranged like the tail of a peacock in a radiating form, and susceptible of being folded together and expanded at pleasure. This well-known hand ornament is used by ladies to cool their faces by agitating the air. Fans made of feathers, like the wing of a bird, have been employed from time immemorial by the natives of tropical countries.

Fan is also the name of the apparatus for winnowing corn, for urging the fires of furnaces, and for purposes of ventilation. For an account of the powerful blowing and ventilating fan machines, see IRON MANUFACTURE and VENTILATION OF MINES.

FANG, *a mining term.* A niche cut in the side of an adit or shaft to serve as an air-course. Sometimes the term *a fanging* is applied to a main of wood-pipes.

FAREWELL ROCK. The name given in South Wales to the Millstone Grit, because no coal is found worth working after this rock has been reached.

This rock is much used for the hearths of furnaces, its power of resisting the most intense heat being remarkable.

FARINA (*Farine*, Fr.; *Mehl*, Ger.) is the flour of any species of corn, or starchy root, such as potato, arrow-root, &c. See BREAD and STARCH.

FASSAITE. A variety of augite containing alumina, lime, magnesia, and iron. It occurs in the Fassathal, in Piedmont.

FATS (*Graisses*, Fr.; *Fette*, Ger.) occur in a great number of the animal tissues, being abundant under the skin in what is called the cellular membrane, round the kidneys, in the folds of the omentum, at the base of the heart, in the mediastinum, the mesenteric web, as well as upon the surface of the intestines, and among many of the muscles. Fats vary in consistence, colour, and smell, according to the animals from which they are obtained; thus, they are generally fluid in the cetaceous tribes, soft and rank-flavoured in the carnivorous, solid and nearly scentless in the ruminants, usually white and copious in well-fed young animals; yellowish and more scanty in the old. Their consistence varies also according to the organ of their production; being firmer under the skin and in the neighbourhood of the kidneys than among the moveable viscera. Fat forms about one-twentieth of the weight of a healthy animal. But as taken out by the butcher it is not pure; for being of a vesicular structure, it is always enclosed in membranes, mixed with blood, blood-vessels, lymphatics, &c. These foreign matters must first be separated in some measure mechanically, after the fat is minced small, and then more completely by melting it with hot water, passing it through a sieve, and letting the whole cool very slowly. By this means a cake of cleansed fat will be obtained.

Braconnot and Raspail have shown that solid animal fats are composed of very small microscopic, partly polygonal, partly reniform particles, which are connected together by very thin membranes. These may be ruptured by mechanical means, then separated by triturating the fresh fats with cold water, and passing the unctuous matter through a sieve. The particles float in the water, but eventually collect in a white granular crystalline appearance, like starch. Each of them consists of a vesicular integument, of the nature of stearine, and an interior fluid like elaine, which afterwards exudes. The granules float in the water, but subside in spirits of wine. When digested in strong alcohol, the liquid part dissolves, but the solid remains.

These particles differ in shape and size, as obtained from different animals; those of the calf, ox, sheep, are polygonal, and from $\frac{1}{50}$th to $\frac{1}{350}$th of an inch in diameter; those of the sow are kidney-shaped, and from $\frac{1}{50}$th to $\frac{1}{100}$th; those of man are polygonal, and from $\frac{1}{50}$th to $\frac{1}{600}$th; those of insects are spherical, and at most $\frac{1}{500}$th of an inch.

Fats all melt at a temperature much under 212° F. When strongly heated with contact of air, they diffuse white pungent fumes, then blacken, and take fire. When subjected to distillation they afford a changed fluid oil, carburetted hydrogen, and the other products of oily bodies. Exposed for a certain time to the atmosphere they become rancid, and generate the same fat acid as they do by saponification. In their fresh state they are all composed principally of stearine, margarine, and oleine, with a little colouring and odorous matter; and in some species, hircine, from the goat; phocenine, from the dolphin; and butyrine from butter. By subjecting them to a great degree of cold, and compressing them between the folds of blotting-paper, a residuum is obtained, consisting chiefly of stearine and margarine; the latter of which may be dissolved out by oil of turpentine.

Beef and Mutton Suet.—When fresh, this is an insipid, nearly inodorous fat, of a firm consistence, almost insoluble in alcohol, entirely so, if taken from the kidneys and mesenteric web of the ox, the sheep, the goat, and the stag. It varies in whiteness, consistence, and combustibility, with the species and health of the animals. They may all be purified in the manner above described. Strong sulphuric acid developes readily the acid fats by stirring it through melted suet. Alkalis, by saponification, give rise to one of the three acids, the stearic, margaric, or oleic. Beef suet consists of stearine, margarine, and oleine; mutton and goat suet contain a little hircine. The specific gravity of the tallow of which common candles are made is, by Ure's experiments, 0·936. The melting point of suet is from 98° to 104° F. The proportion of solid and fluid fat in it is somewhat variable, but the former is in much larger proportion. Mutton suet is soluble in 44 parts of boiling alcohol, of 0·820; beef suet in 44 parts. Marrow fat consists of 76 of stearine, and 24 of oleine; it melts at 115° F.

Hog's lard is soft, fusible at 81° F, convertible, by an alkaline solution, into a stearate, margarate, oleate, and glycerine. Its sp. grav. is 0·938, at 50° F. It consists of 62 of oleine, and 38 of stearine, in 100 parts.

Goose-fat consists of 68 oleine and 32 stearine.

Butter, in summer, consists of 60 of oleine and 40 of stearine; in winter, of 35 of oleine and 65 of stearine; the former substance being yellow and the other white. It differs, however, as produced from the milk of different cows, and also according to their pasture.

Chevreul investigated with great care the composition of fats. He has shown that they are mixtures of simple fats as oleine, stearine, and margarine. For his investigations, see those articles in Watts's 'Dictionary of Chemistry.'

The following statement is given on the authority of Braconnot:—

	Oleine	Stearine		Oleine	Stearine
Hog's lard . . .	62	38	Duck-fat . . .	72	28
Ox marrow . . .	24	76	Ox tallow . . .	25	75
Goose-fat . . .	68	32	Mutton suet. . .	26	74

The late Dr. Robert Dundas Thomson gave the following list of animal fats and their melting points:—

Badger-fat . . .	86°	Pheasant	109°
Beef tallow . . .	98½	Turkey.	113
Calf	136·8	Stearine (human) . . .	120
Camel	131	„ (sheep) . . .	109
Cochineal fat . . .	104	„ (oxen) . . .	111
Cow's butter . . .	79·7	„ (hog) . . .	109
Duck-fat	77	„ (duck) . . .	109
Dog	79¾	Cetine	120
Fox	129	Chlorestine	278
Hare.	117½	Cantharides fat . . .	93½
Hog's lard. . . .	80·5	Margarine (butter) . .	105
Horse grease . . .	140	Palmitine	115
Human fat . . .	77		

The purification and decoloration of fats have been the object of many patents. One of the best is to mix 2 per cent. of strong sulphuric acid with a quantity of water, in which the tallow is heated for some time with much stirring; to allow the materials to cool, to take off the supernatant fat, and to re-melt it with abundance of hot water. More tallow will thus be obtained, and that considerably whiter and harder than is usually procured by the melters.

Dr. Ure stated that he found that chlorine and chloride of lime did not improve, but rather deteriorated, the appearances of oils and other fatty bodies. According to Appert, minced suet subjected to the action of high-pressure steam in a digester, at 250° or 260° F., becomes so hard as to be sonorous when struck, whiter, and capable, when made into candles, of giving a superior light. A convenient mode of *rendering* minced tallow, or melting it, is to put it in a tub, and drive steam through it from numerous orifices in ramifying pipes placed near the bottom. Mr. Watts's plan of purifying fats, patented in March 1836, has been successful. He employs dilute sulphuric acid, to which he adds a little nitric acid, with a very small quantity of bichromate of potash to supply oxygen, and some oxalic acid These are mixed with the fat in the steaming tub. When the lumps of it are nearly dissolved, he takes for every ton of fat, one pound of strong nitric acid, diluted with one quart of water; to which he adds two ounces of alcohol, naphtha, sulphuric ether, or spirits of turpentine; and after introducing this mixture, he continues the boiling for half an hour. The fat is finally washed.

Others have proposed to use vegetable or animal charcoal first, especially for rancid oils, then to heat them with a solution of sulphate of copper and common salt, which is supposed to precipitate the fetid albuminous matter.

Mr. Prynne obtained a patent in March 1840, for purifying tallow for the candlemaker, by heating it along with a solution of carbonate of potash or soda for 8 hours, letting the whole cool, removing the tallow to another vessel, heating it by means of steam up to 206° F., along with dry carbonate of potash (pearlash): letting this mixture cool very slowly; and finally removing the tallow to a vessel inclosed in steam, so as to expel any subsidiary moisture.

A patent for a like purpose was obtained in June 1842, by Mr. H. H. Watson. He availed himself of the blanching power of oxygen, as evolved from permanganate of potash (chameleon mineral), in the act of its decomposition by acids, while in contact with the melted fat. He prescribed a leaden vessel (a well-joined wooden tub will also serve) for operating upon the melted tallow with one-twentieth of its weight of the manganate dissolved in water, and acidulated to the taste. The whole are to be well mixed, and gradually heated from 150° up to 212° F., and maintained at that temperature for an hour. On account of the tendency of the dissolved manganate to spontaneous decomposition, it should be added to the dilute acid, mixed with the fat previously melted at the lowest temperature consistent with its fluidity.

Mr. Wilson, of Vauxhall, has applied centrifugal action to the separation of the liquid from the more solid parts of fatty matters, employing in preference the *hydro-extractors* used by Seyrig and Co. for drying textile fabrics. Mr. Wilson applies a stout cotton twill in addition to the wire-grating; and in order to avoid the necessity of digging the concrete parts, and to prevent them from clogging the interstices for the discharge of the oily matter, he places the whole in a bag 8 inches in diameter, and of such length that when laid on the rotating machine against the grating the two ends will meet. The speed of the machine must be kept below that at which stearic acid or stearine would pass: which is known by the limpidity of the expressed fluid. To take advantage of the liquefying influence of heat, he keeps the temperature of his own room about 2° F. above that of the substances under treatment.

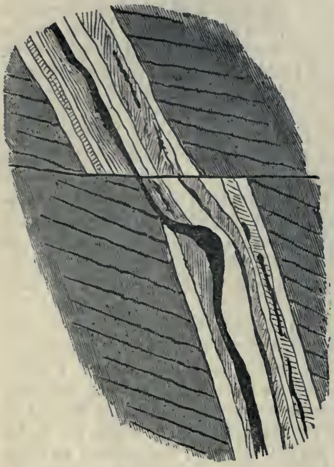
The chemistry of fat will be found in Watts's 'Dictionary of Chemistry.' For *Imports*, &c., see TALLOW.

See also GLYCERINE; MARGARINE; OLEINE; SOAP; STEARINE.

FAULTS (*Failles*, Fr.), in mining, are disturbances of the strata, the name being derived from the circumstance that these movements interrupt the miner's operations, and render it difficult to discover where the vein of ore or bed of coal has been '*thrown*' by the disturbance producing the fault. Any fissure in a rock accompanied by a displacement of any kind is called a 'fault.' By a movement of the earth a crack may be produced, but, if there has not been a movement, it is simply a fissure; while, if the rock on either side of the crack has been moved, it becomes a *fault*.

A mineral vein may be regarded as a fissure formed during the consolidation of the rocks in which it exists, or by some movement of the entire mass, producing these cracks at right angles to the line of greatest mechanical force; these have been eventually filled in with the mineral or metalliferous matter which we find in them. After this has taken place, there has sometimes been a movement of a portion of the ground, and the mineral vein, or lode, has been fractured. A simple illustration of this is the following, *fig.* 842, where we have the mineral vein dislocated, and subsequently to the dislocation there has been a formation of a string of spathose iron, following the bendings of a crack formed by the movement, which, in this case, has been less than the width of the lode. In the large majority of examples the 'heave' or 'throw' of the lode has been very considerable. It is usual to speak of a *fault* as if the fissure had actually moved the lode. It should be understood that an actual movement of great masses of the solid earth is implied, and consequently, the *lode* having been formed before the movement, it is moved with the rock in which it is enclosed. *Fig.* 844 is the plan of veins 1, 2, 3, 4, and an elvan course *a a*, which have been dislocated along the line *b*, *c*, and all the lodes and the elvan course moved. In this case the movement has probably taken place from the North towards the South. This disturbance will be continued to a great depth, and in *fig.* 843 is a section showing the dislocation of a lode into three parts. In this case the movement has probably been the subsidence of that portion of the ground containing the lode *b*, and the further subsidence of that portion containing the lode *a*; the condition of the surface being subsequently altered by denudation. The inclination of a lode is frequently changed by these movements, thus *fig.* 845 supposes *c d* to represent the original condition of the lode; by a convulsion, the portion *a b* has fallen away leaving a chasm between, and the 'dip' or inclination of the lode is therefore materially changed. The direction of the lode is frequently altered by these movements. Many lodes in Cornwall have a direction from the N. of E. to the S. of W. up to a fault, on the other side of which the direction is changed from the S. of E. to the N. of W. Where these disturbances are of frequent occurrence, the difficulties of mining are greatly increased.

842



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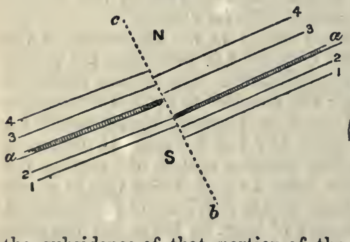

845

The dislocations and obstructions found in coal-fields, which render the search for coal so difficult, and its mining so laborious and uncertain, are the following:—

1. *Dykes.* 2. *Slips.* 3. *Hitches.* 4. *Troubles.*

The first three infer dislocation of the strata; the fourth, changes in the bed of coal itself.

1. A *dyke* is a wall of extraneous matter, which divides all the beds in a coal-field.

Dykes extend not only in one line of bearing through coal-fields for many miles, but run sometimes in different directions, and have often irregular bendings, but no sharp angular turns. When from a few feet to a few fathoms in thickness, they occur sometimes in numbers within a small area of a coal-basin, running in various directions, and even crossing each other. *Fig.* 846, represents a ground plan of a coal-field, intersected with greenstone dykes. A B and C D are two dykes standing parallel to each other; E F and G H are cross or oblique dykes, which divide both the coal-strata and the primary dykes A B and C D.

2. *Slips* run in straight lines through coal-measures, and at every angle of incidence to each other. *Fig.* 847 represents a ground plan of a coal-field, with two slips A B and C D, the line of bearing of the planes of the strata, which throw them down to the outcrop. This is the simplest form of a slip. *Fig.* 848, exhibits part of a coal-field intersected with slips, like a cracked sheet of ice. Here A B is a dyke; while the narrow lines show faults of every kind, producing dislocations varying in amount of slip from a few to a great many fathoms. The faults at the points *a, a, a* vanish; and the lines at C denote four small partial slips called *hitches*.

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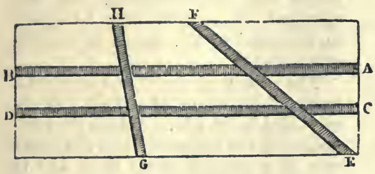

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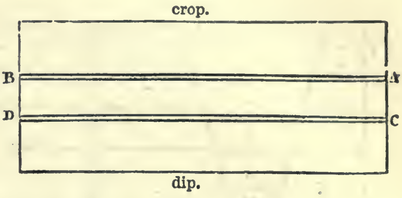
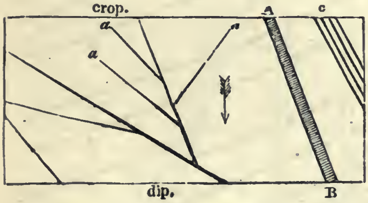


The effects of slips and faults—whether produced by dykes, or otherwise—on the coal-strata appear more prominently when viewed in a vertical section, than in a ground plan, where they seem to be merely walls, veins, or lines of demarcation. *Fig.* 849 is a vertical section of a coal-field, from dip to rise, showing three strata of coal *a, b, c.* A B represents a dyke at right angles to the plane of the coal-beds. This rectangular wall merely separates the coal-measures, without affecting their line of rise; but further to the rise, the oblique dyke C D interrupts the coals *a, b, c,* and not only disjoins them, but has produced a movement which has thrown them and their concomitant strata greatly lower down; but still, with this depression, the strata retain their parallelism and general slope. Nearer to the outcrop, another dyke, E F, interrupts the coals *a, b, c,* not merely breaking the continuity of the planes, but throwing them moderately up, so as to produce a steeper inclination, as shown in the figure. It sometimes happens that the coals in the compartment H, betwixt the dykes C and E, may lie nearly horizontal, and the effect of the dyke E, F, is then to throw out the coals altogether, leaving no vestige of them in the compartment K.

848



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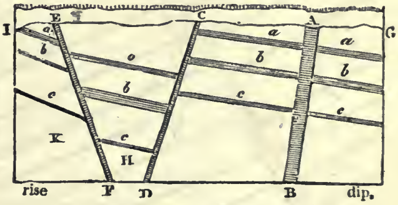
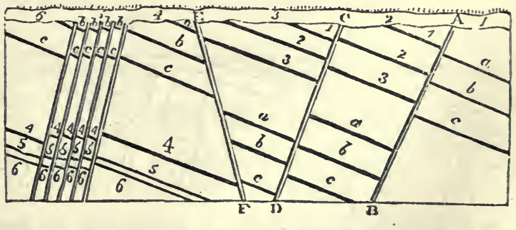


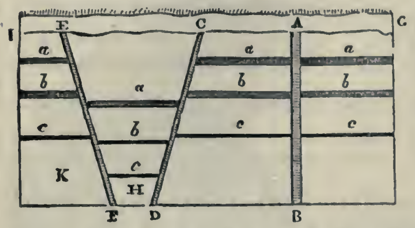
The effect of slips on the strata is also represented in the vertical section, *fig.* 850, where *a, b, c* are coals with their associated strata, A B is an intersecting slip, which throws all the coals of the first compartment much lower, as is observable in the second, No. 2; and from the amount of the slip, it brings in other coal-seams, marked 1, 2, 3, not in the compartment No. 1. C D, is a slip producing a similar result, but not of the same magnitude; E F represents a slip across the strata, reverse in direction to the former; the effect of which is to throw up the

850



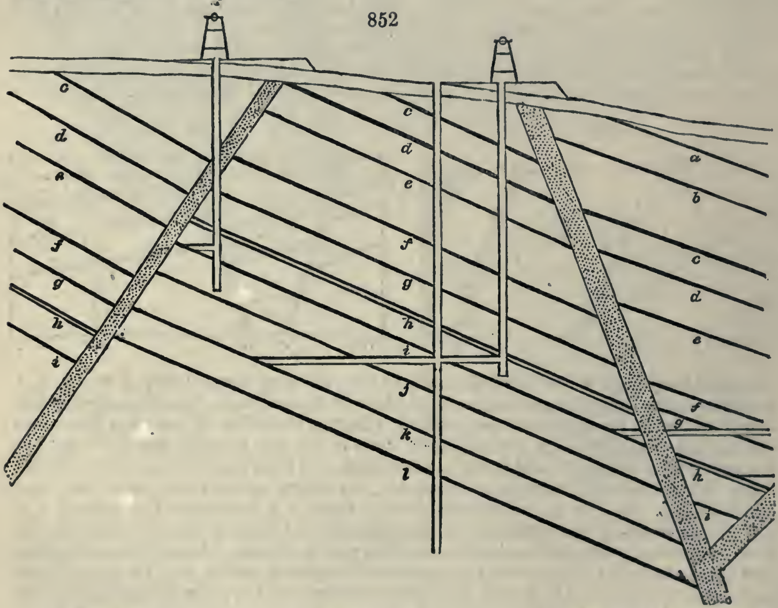
coals as shown in the area No. 4. Such a slip occasionally brings into play seams seated under those marked *a*, *b*, *c*, as seen at 4, 5, 6; and it may happen that the coal marked 4 lies in the prolongation of a well-known seam, as *c*, in the compartment No. 3, when the case becomes puzzling to the miner. In addition to the above varieties, a number of slips or hitches are often seen near one another, as in the area marked No. 5, where the individual displacements are inconsiderable, but the aggregate dislocation may be great, in reference to the seams of the 6th compartment.

851



The results of dykes and slips on a horizontal portion of a field are exemplified in *fig.* 851. Where the coal-measures are horizontal, and the faults run at a greater angle than 45° to the line of bearing, they are termed 'dip' and 'rise' faults, as A B, C D, E F. The following *fig.* 852, which is an accurate section of the Mostyn coal-field, Flintshire, will show the amount to which those disturbances are experienced. The letters mark with sufficient distinctness the beds on either side of the faults.

852



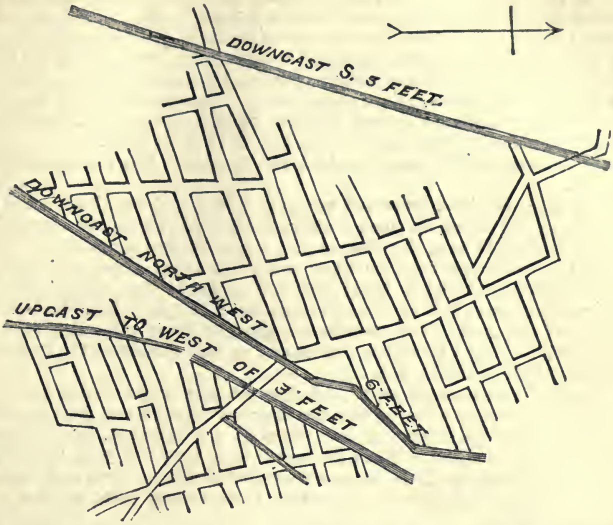
a. Worked out.
b. Ditto.
c. 5 yd. coal worked out.
d. 3 yd. ditto.
e. Inferior coal.
f. Ditto.
g. Yard coal worked out.
h. 4 ft. coal (tolerable).
i. Main coal, 6 ft. (very good).
j. 5 ft. coal.
k. Stone coal.
l. 3 ft. coal.

853

Fig. 853 gives a true section of a portion of the North Staffordshire Coal-field, showing the dislocations which have been produced, and the mechanical force exerted by the movements which have taken place.

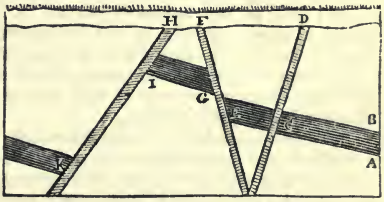
Fig. 854 shows a colliery in plan, and the amount of the movement produced by the dislocations.

854



Coal viewers or engineers regard the dislocations now described as being subject in one respect to a general law, which may be thus explained:—Let *fig.* 855 be a portion of a coal-measure; A being the pavement and B the roof of the coal-seam. If, in pursuing the stratum at C, a dyke D occurs, standing at right angles with the pavement they conclude that the dyke is merely a partition-wall between the beds by its own thickness, leaving the coal-seam undisturbed on either side; but if a dyke F forms, as at E, an obtuse angle with the pavement, they conclude that the dyke is not a simple partition between the strata, but has thrown up the several seams into the predicament shown at G. Finally, should a dyke H make at I an acute angle with the pavement, they conclude that the dyke has thrown down the coal-measures in the position of K.

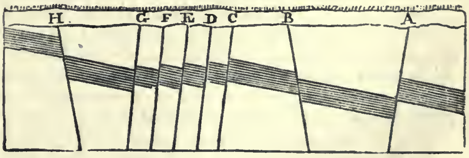
855



Dykes and faults are denominated upthrow or downthrow, according to the position they are met with in working the mine. Thus, in *fig.* 849, if the miner is advancing to the rise, the dyke A B obviously does not change the direction; but C D is a downthrow dyke of a certain number of fathoms towards the rise of the basin, and E F is an upthrow dyke likewise towards the rise. On the other hand, when the dykes are met with by the miner in working from the rise to the dip, the names of the above dykes would be reversed; for what is an upthrow in the first case becomes a downthrow in the second, relative to the mining operations.

3. *Hitches* are small and partial slips, where the dislocation does not exceed the thickness of the coal-seam; and they are often correctly enough called *steps* by the miner. *Fig.* 856 represents the operation of the *hitches* A, B, C, D, E, F, G, H, on the coal-measures. Though observed in one or two seams of a field, they may not appear in the rest, as is the case with dykes and faults.

856



Troubles are smaller, but often numerous faults, by which the beds of coal are disturbed, and as these greatly interfere with the progress of the miner, he regards them as *troubles*, and hence their name.

In the above description the language of the mine has been retained, but in the case of the dyke, as of the *fault-proper*, it is not that the dyke has lifted the coal-bed up or down, but during the convulsive movements of the earth, when those trap dykes were being forced from below, great movements were produced on either side of the fissures through which the molten matter ascended, and hence the alteration in the position of the beds, which were previously, perhaps, nearly in a horizontal plane. See Dyke.

FEATHERS. (*Plumes*, Fr.; *Federn*, Ger.) 'The most beautiful, the most complex, and the most highly elaborated of all the coverings of animals, due to the development of the epidermal system, is the plumage of birds.'—*Owen*.

A feather consists of the *quill*, the *shaft*, and the *vane*. The vane consists of *barbs* and *barbules*.

The *quill* is pierced by a lower and an upper orifice, and contains a series of light, dry, conical capsules, fitted one upon another, and united together by a central pedicle.

The *shaft* is slightly bent, the concave side is divided into two surfaces by a middle longitudinal line continued from the upper orifice of the quill, the convex side is smooth. Both sides are covered with a horny material similar to that of the quill, and they enclose a peculiar white, soft, elastic substance, called the *pith*. The *barbs* are attached to the sides of the shaft. The *barbules* are given off from either side of the barbs, and are sometimes similarly barbed themselves, as may be seen in the barbules of the long feathers of the peacock's tail.

The barbules are commonly short and close set, and curved in contrary directions, so that the two adjoining series of barbules interlock together and form the mechanism by which the barbs are compacted into the close and resisting vane of the quill, or 'feather,' properly so called. When the barbules are long and loose, they characterise that form of the feather which is properly called a 'plume,' and such are the most valuable products of the plumage of birds in a commercial point of view, as *e.g.* the plumes of the ostrich.

The Down.—The lower barbs in every kind of feather are usually loose, forming the down, which is increased in most birds by what is called the 'accessory plume.' This is usually a soft downy tuft, but varies in different species, and even in the feathers of different parts of the body of the same bird. The value of feathers for bed stuffing depends upon the proportion of loose soft down that enters into their composition; and as the 'accessory plume' in the body feathers of the swans, geese, and ducks, is almost as long as the feather from which it springs, hence arises the commercial value of the feathers of those aquatic birds.—*Owen*.

The first covering of the young bird is a down. In most birds a certain portion of the down feathers is retained with the true feathers, and this proportion is usually greatest in the aquatic birds.

It is most remarkable in the eider duck (*Anas mollissima*). 'The down of the eider combines, with its peculiar softness, fineness, and lightness, so great a degree of elasticity that the quantity of this beautiful material which might be compressed and concealed between the two hands of a man will serve to stuff the coverlet of a bed.'—*Owen*.

Feathers constitute the subject of the manufacture of the *Plumassier*, a name given to the artisan who prepares the feathers of certain birds as ornaments for ladies and for military men, and to him also who combines the feathers in various forms. We shall content ourselves with describing the method of preparing ostrich feathers, as most others are prepared in the same way.

Several qualities are distinguished in the feathers of the ostrich; those of the male, in particular, are whiter and more beautiful. Those upon the back and above the wings are preferred; next those of the wings, and lastly, of the tail. The down is merely the feathers of the other parts of the body, which vary in length from 4 to 14 inches. This down is black in the males, and grey in the females. The finest white feathers of the female have always their ends a little greyish, which lessens their lustre, and lowers their price. These feathers are imported from Algiers, Tunis, Alexandria, Madagascar, and Senegal; this being the order of their value.

The *scouring process* is thus performed:—4 ounces of white soap, cut small, are dissolved in 4 pounds of water, moderately hot, in a large basin; and the solution is made into a lather by beating with rods. Two bundles of the feathers, tied with packthread, are then introduced, and are rubbed well with the hands for five or six minutes. After this soaping, they are washed in clear water, as hot as the hand can bear.

The whitening or bleaching is performed by three successive operations.

1. They are immersed in hot water mixed with Spanish white, and well agitated in it; after which they are washed in three waters in succession.

2. The feathers are azured in cold water containing a little indigo tied up in a fine cloth. They should be passed quickly through this bath.

3. They are sulphured in the same way as straw hats are (see SULPHURING); they are then dried by hanging upon cords, when they must be well shaken from time to time to open the fibres.

The ribs are scraped with a bit of glass cut circularly, in order to render them very pliant. By drawing the edge of a blunt knife over the filaments they assume the curly form so much admired.

Those feathers which are of a dingy colour are dyed black. For 20 pounds of feathers, a strong decoction is made of 25 pounds of logwood in a proper quantity of water. After boiling it for 6 hours, the logwood is taken out, 3 pounds of copperas are thrown in, and, after continuing the ebullition for 15 or 20 minutes, the copper is taken from the fire. The feathers are then immersed by handfuls, thoroughly soaked, and worked about, and left in two or three days. They are next cleansed in a very weak alkaline lye, and soaped three several times. When they feel very soft to the touch, they must be rinsed in cold water, and afterwards dried. White feathers are very difficult to dye a fine black.

For dyeing other colours, the feathers should be previously well bleached by the action of the sun and the dew; the end of the tube being cut sharp like a toothpick, and the feathers being planted singly in the grass. After fifteen days' exposure, they are cleared with soap as above described.

Rose colour or *pink*, is given by safflower and lemon-juice.

Deep red, by a boiling-hot bath of brazil-wood, after aluming.

Crimson. The above deep-red feathers are passed through a bath of cudbear.

Prune de Monsieur. The deep-red is passed through an alkaline bath.

Blues of every shade, are dyed with the indigo vat.

Yellow, after aluming, with a bath of turmeric or weld.

Other tints may be obtained by a mixture of the above dyes.

Feathers supply us with a soft elastic down on which we can repose our wearied frames, and enjoy sweet slumbers. Such are called *bed* feathers.

Goose feathers are most esteemed. There is a prejudice that they are best when plucked from the living bird, which is done thrice a year, in spring, midsummer, and the beginning of harvest. The qualities sought for in bed feathers are softness, elasticity, lightness, and warmth. Their only preparation when cleanly gathered is a slight beating to clear away the loose matter, but for this purpose they must be first well dried either by the sun or stove; stoving or hot air being also necessary to remove any animal matter liable to putrefy.

The feathers of the eider duck, *Anas mollissima*, called eider-down, possess in a superior degree all the good qualities of goose-down. It is used only as a covering to beds, and never should be slept upon, as it thereby loses its elasticity.

Quills for writing.—These consist usually of the feathers plucked out of the wings of geese. Dutch quills have been highly esteemed, as the Dutch were the first who hit upon the art of preparing them well, by clearing them both inside and outside from a fatty humour with which they are naturally impregnated, and which prevents the ink from flowing freely along the pens made with them. The Dutch for a long time employed hot cinders or ashes to attain this end; and their secret was preserved very carefully, but it at length transpired, and the process was then improved. A bath of very fine sand must be kept constantly at a suitable temperature, which is about 140° F.; into this the quill-end of the feather must be plunged, and left in it a few instants. On taking the feathers out they must be strongly rubbed with a piece of flannel, after which they are found to be white and transparent. Both carbonate of potash in solution and dilute sulphuric acid have been tried to effect the same end, but without success. The yellow tint which gives quills the air of age, is produced by dipping them for a short time in dilute muriatic acid, and then making them perfectly dry. But this process must be preceded by the sand-bath operation.

Quills are dressed by the London dealers in two ways: by the one, they remain of their natural colour; by the other, they acquire a yellow tint. The former is called the Dutch method, and the principal workman is called a Dutcher. He sits before a small stove fire, into which he thrusts the barrel of the quill for about a second, then lays its root quickly below his blunt-edged knife, called a hook, and, pressing this firmly with the left hand, draws the quill briskly through with his right. The bed on which the quill is laid to receive this pressure is called the plate. A skilful workman can pass 2,000 quills through his hands in a day of ten hours. They are next cleansed by being scrubbed by a woman with a piece of rough dog-fish skin, and then tied up in bundles.

In the goose's wing, the five exterior feathers only are valuable for writing; the first is the hardest and roundest of all, but the shortest; the next two are the best of the five. The heaviest quills are generally the best.

Our recent *Imports* have been as follow:—

	1868		1869		1870	
	Imports	Value	Imports	Value	Imports	Value
Feathers for Beds:	cwts.	£	cwts.	£	cwts.	£
from Russia . .	3,457	32,266	3,378	31,529	4,219	39,368
„ Hamburg or Germany .	5,446	45,746	3,633	30,518	3,925	32,071
„ France . .	1,544	12,969	1,720	14,448	2,842	23,873
„ Spain or Italy .	...	...	...	...	911	7,653
Other parts . .	458	3,846	451	3,785	548	4,640
Total . .	10,905	94,827	9,182	80,280	12,445	108,505
Ostrich Feathers:	lbs.	£	lbs.	£	lbs.	£
White . . .	16,156	68,855	26,002	86,918	26,710	111,505
Black . . .	44,556	73,767	38,157	58,319	39,353	65,292
Other sorts of feathers .	42,205	38,073	61,684	61,729	81,367	73,834
Ornamental feathers .	...	...	...	...	...	...

	1871		1872	
	Imports	Value	Imports	Value
Feathers for Beds:	cwts.	£	cwts.	£
from Russia	4,993	27,493	5,783	38,978
„ Hamburg or Germany . . .	...	...	4,767	25,661
„ France	2,986	11,059	3,960	12,785
„ Spain or Italy	...	...	186	1,562
Other parts	7,521	38,522	1,268	7,643
Total	15,500	76,074	15,964	86,629
Ostrich Feathers:	lbs.	£	lbs.	£
White	...	...	...	...
Black	...	...	...	...
Other sorts of feathers	172,402	378,119	...	...
Ornamental feathers	...	...	177,102	449,783

FEATHER ALUM or *Hair-Salt.* A hydrous sulphate of alumina, resulting from volcanic action, and from the decomposition of iron pyrites, especially in the coal-measure shales. See ALUM.

FEATHER ORE, *Plumosite,* or *Heteromorphite.* A sulphide of antimony and lead, allied to *Jamesonite.* Its composition is, sulphur 19·2, antimony 31·0, lead 49·8. It is sometimes found in capillary forms and like a cobweb, but it is also found massive.

FECULA (*Fécule,* Fr.; *Stärkmehl,* Ger.) sometimes signifies corn-flour, sometimes starch, from whatever source obtained; and it is also applied to chlorophyll, the green matter of plants. The term is applied to any pulverulent matter obtained from plants by simply breaking down the texture, washing with water, and subsidence.

FEEDER, *a mining term.* A small lateral lode falling into the main lode or mineral vein.

FELL. The hide of an animal.

FELL-MONGER. The business of the fell-monger is to separate the wool from the skin. The wool is sold to the wool-stapler, and the stripped skins sent to the leather-dressers or parchment-makers.

FELSITE or **FELSTONE.** A compact rock, composed mainly of felspar, with more or less quartz. It has been shown that most felsites contain the elements of granite in a compact instead of a crystalline form. See FELSPATHIC ROCKS.

FELSPAR or **FELDSPAR** (*Feldspath,* Fr. and Ger.) Under the name of *felspar,* the mineralogist associates a number of important rock-forming minerals, which, from the many characters they possess in common, were formerly confounded together, and are with difficulty distinguished from one another by mere inspection; but which, nevertheless, are sufficiently distinct, both in chemical composition, and in crystalline form, to admit of division into several well-defined species. The felspars are, in all cases, anhydrous double silicates, consisting of a silicate of alumina, combined with a silicate of a protoxide which may be either potash, soda, or lime; but as these oxides are capable of mutually replacing each other, it commonly happens that two or even more of them coexist in the same species. In all the members of the felspar-group, there exists the simple relation of one atom of the sesquioxide, alumina, to one of the protoxide base or bases; but the proportion of silica varies considerably in the different species. The amount of silica bears a definite relation to the geological character of the rock in which the felspar occurs, and to the minerals with which it is associated; the highly-silicated species, as orthoclase, albite, and oligoclase, occurring in granites, trachytes, and other so-called acid rocks; whilst the less silicated felspars, as labradorite, are confined to basalts, certain lavas, and other basic rocks.

Exposed to a high temperature, the felspars fuse, with greater or less difficulty, to a vitreous enamel possessing considerable hardness, a property which has led to their use in glazing porcelain. All the felspars are sufficiently hard to scratch glass, but are themselves scratched by quartz; and this hardness, combined with their crystalline form, often serves to distinguish them from other minerals. Their specific gravity varies from about 2·5 in orthoclase to upwards of 2·7 in labradorite; and by its constancy in the different species, becomes a useful characteristic. The lustre is commonly vitreous, passing into pearly on the more perfect cleavage planes; whilst certain of the rarer varieties enjoy peculiar opalescent and iridescent properties, of which the jeweller takes advantage, to a limited extent. With the exception of labradorite, all the felspars are either unacted, or imperfectly acted, on by acids.

According to the nature of their basic constituents, the felspars admit of classification into four groups, viz.:—

I. Potash-felspar (often containing soda); *orthoclase* or *common felspar*; and *sanidine*, or *glassy felspar*.

II. Soda-felspar (often containing potash); *albite*, and *oligoclase*, or *soda-spodumene*.

III. Soda-lime-felspar (often containing potash); *labradorite*, or *labrador-felspar*; and *andesine*.

IV. Lime-felspar; *anorthite*.

With regard to this arrangement it may be remarked that some of the species here enumerated appear to shade insensibly one into another, so that doubts have not unnaturally been entertained by certain mineralogists as to the real specific distinctions between such minerals. Of late years, Tschermak, an Austrian mineralogist, has specially applied himself to this question, and has arrived at the conclusion that there are only three really distinct species: namely, a potash-felspar (*orthoclase*), a soda-felspar (*albite*), and a lime-felspar (*anorthite*); all the other so-called species being merely mixtures in various proportions of these three extreme types. But as orthoclase crystallises in the monoclinic, or singly-oblique system, whilst albite and anorthite crystallise in the triclinic, or doubly-oblique system, it is difficult to conceive how orthoclase can be isomorphous with the other felspars. Hence Tschermak has been led to recognise two distinct kinds of mixed felspars; those that contain both potash and soda being regarded as mechanical mixtures of orthoclase and albite, like *perthite*, whilst those containing both soda and lime are true isomorphous mixtures of albite and anorthite. Although much theoretical interest attaches to these views, it will be convenient in this place to adhere to the old-established classification cited above.

I. ORTHOCLASE (*Orthose*, Fr.; *Orthoklas*, Ger.; *Ortosa*, Ital.) This is the most ordinary species, and that which in popular language is called simply 'felspar.' It occurs as a colourless, grey, or flesh-red mineral, crystallising in oblique rhombic prisms, and frequently presenting the peculiar forms called twin-crystals. The crystals always exhibit two well-marked directions of cleavage at right angles to each other, whence the name of the species (ὀρθὸς, straight; κλάω, to cleave). Orthoclase is a potash-felspar, of which the following is an analysis from the Baveno granite: silica, 65·72; alumina, 18·57; potash, 14·02; soda, 1·25; lime, 0·34; magnesia, 0·10; = 100 (*Abich*). This mineral is an important constituent of granite, gneiss, syenite, pegmatite, felstone, and trachyte: of granite it ordinarily composes from 40 to 45 per cent. The species orthoclase has been subdivided into a great number of varieties, frequently founded on very insufficient grounds. The purest and most transparent varieties are distinguished as *adularia;* and when exhibiting a faint bluish opalescence are used in jewellery under the name of *Moon-Stone.* Other opalescent varieties are the *microcline*, from the zircon-syenite of Norway; and the *Murchisonite* from Dawlish, and from Heavitree, near Exeter—a mineral named after the late Sir R. Murchison. A bright green orthoclase, coloured by a trace of oxide of copper, occurs near Lake Ilmen, in Siberia, and is employed for ornamental purposes under the name of *Amazon-stone*, from having been first found in the River Amazon. *Erythrite* is a flesh-coloured felspar, from Kilpatrick, containing 3 per cent. of magnesia; whilst the felspar called *hyalophane* is notable for containing a large percentage of baryta. *Loxoclase* and *Chesterlite*, are American varieties of orthoclase; whilst *Valencianite* is the name given to a Mexican adularia.

Sanidine, or *glassy felspar*, is a transparent potash-soda-felspar, regarded often as a distinct species. It occurs in tabular, vitreous crystals, embedded in trachyte and other volcanic rocks; and much resembles the artificial felspar obtained in certain metallurgical operations. The well-known glassy felspar from the Drachenfels consists of silica, 66·6; alumina, 18·5; potash, 8·0; soda, 4·0; lime, 1·0; peroxide of iron, 0·6; = 98·7 (*Berthier*). *Rhyacolite* is a name proposed by Rose for a Vesuvian variety of glassy felspar, which appears, however, to be only a mixture of felspar and nepheline. The transparent felspars occurring in the lavas of Vesuvius are sometimes termed *ice-spar.*

II. Albite, or *Cleavelandite*—known also as *pericline* and *tetartine*—is a soda-felspar first described by G. Rose. It consists of silica, 68·75; alumina, 18·79; soda, 10·90; potash, 1·21; lime, 0·51; magnesia, 0·09; peroxide of iron, 0·54; = 100·79 (*Weiss*). Albite differs from orthoclase in the form of its crystals, which are much less symmetrical, and belong to an essentially distinct system (triclinic). It was at one time supposed to be a frequent constituent of granite, and syenite, but it is now known that much of the felspar formerly mistaken for albite is really oligoclase. *Peristerite* is a Canadian albite, remarkable for the beauty of its opalescence.

Perthite is a flesh-red potash-soda-felspar from Perth in Canada East, notable for being a mixed mineral made up of alternating bands of orthoclase and albite.

Oligoclase, or *soda-spodumene*, is composed of silica, 62·54; alumina, 22·49; soda, 7·84; potash, 4·54; lime, 2·18; magnesia, 0·41; = 100 (*Deville*). This is an analysis of the mineral from Teneriffe, where it occurs in trachyte; but it is found also in granite, syenite, serpentine, and basalt. The name *sun-stone*, occasionally applied to certain varieties of orthoclase, is properly restricted to a Norwegian oligoclase, presenting an aventurine appearance, which has been referred to the presence of minute crystals of either specular iron, or göthite.

III. Labradorite, or *Labrador felspar*, is a soda-lime-felspar, consisting of silica, 55·75; alumina, 26·50; lime, 11·0; soda, 4·0; peroxide of iron, 1·25; water, 0·50; = 99 (*Klaproth*). This beautiful mineral was first observed by the Moravian missionaries, on the shores of St. Paul's Isle, off the coast of Labrador, where it occurs associated with hypersthene, hornblende, and magnetic iron-ore. It forms a common constituent of most basalts and melaphyres, and occurs also in many recent lavas, as well as in certain meteoric stones.

From the beautiful chatoyant reflections which this mineral exhibits when polished, it is highly valued for purposes of ornament. The parts exhibiting the play of colours are disposed in irregular spots and patches, and the same spot, held in different positions, displays various tints. The cause of this play of colours has not been satisfactorily determined, but it is commonly supposed to proceed from minute internal fissures or cleavage-planes in the stone; whilst the aventurine-like appearance is due to certain microscopic embedded crystals, regarded variously as göthite, specular iron ore, or magnetic pyrites. See Labradorite.

Delesse has applied the name of *Vosgite* to a French labradorite. rendered hydrous by partial alteration.

Andesite is a felspar occurring in the trachyte of the Andes, in the Vosges and elsewhere. Its composition is silica, 60·26; alumina, 25·01; soda, 7·74; lime, 6·87; potash, 0·84; magnesia, 0·14; = 100·86 (*Rammelsberg*).

IV. Anorthite, a lime-felspar, composed of silica, 43·96; alumina, 35·30; lime, 18·98; soda, 0·47; magnesia, 0·45; potash, 0·39; peroxide of iron, 0·63; = 100·18 (*Abich*). It occurs in the ejected limestone-blocks on Monte Somma; and has been found also in the island of Procida, in the Bay of Naples; and in the syenite of Carlingford, in Ireland.

Amphodelite is a Scandinavian anorthite, whilst *Thiorsaurite* is an Icelandic variety. *Barsowite* and *Bytownite* are two closely allied minerals; the former from Siberia, and the latter from Canada. In the species called *Danburite*—a mineral frequently classed with the lime-felspars—a large proportion of the silica is replaced by the analogous compound, boric acid.

Although in many cases it is by no means easy to distinguish the several species of felspar one from another, yet a broad distinction may be readily drawn between those felspars which crystallize in the *monoclinic* (singly-oblique) and those which crystallize in the *triclinic* (doubly-oblique) system. The former present two cleavage planes at right angles to each other, and are hence called *orthoclastic*; whilst the latter have their directions of cleavage oblique to each other, and are therefore called *plagioclastic* felspars. The triclinic or plagioclastic species are characterised by fine striæ on the cleavage planes, indicating the junction of twin-crystals; transparent microscopic sections viewed under polarised light, exhibit coloured bands corresponding with these twin-lamellæ. The plagioclases comprise all species of felspar, except orthoclase and sanidine.

The principal economic value of the felspathic minerals depends on their application to porcelain manufacture, partly as a constituent of the paste itself, but chiefly as a glaze. From the decomposition of the felspar in certain granites, the well-known kaolin, or China clay, is commonly supposed to result. The felspathic minerals are also employed as manures, the alkalis present rendering them especially valuable. See CLAY; POTTERY; MANURES.

FELSPATHIC. Of or belonging to felspar.

FELSPATHIC ROCKS. (*Roches feldspathiques*, Fr.; *Feldspathgesteine*, Ger.) Rocks in which felspar forms an essential and frequently the principal constituent. *Felstone*, *felsite*, or *cornean*, is a rock consisting almost exclusively of a compact orthoclase, associated with a small amount of free silica, and much resembling in its general characters certain forms of quartz, whence it has unfortunately been termed *petrosilex*. From all varieties of quartz, it may however be readily distinguished by its fusibility, and hence it was called by Werner *fusible hornstone*. A felstone occurring with the magnetic iron-ore of Dannemora retains its Swedish name of *Hälleflinta;* and the *leelite* of Dr. Clarke appears to be a very similar rock. The name of *adinole* has been applied by Beudant to a rock closely related to felstone, but consisting of compact albite-felspar. When distinct felspar-crystals are developed in a compact base of felstone, the rock becomes a *felspar-porphyry;* and when these are accompanied by quartz it forms a *quartziferous-porphyry* or *elvanite*. Of these rocks, formed of mixtures of felspar and quartz, several varieties are recognised; such as *eurite*, *aplite*, *granulite*, and *leptynite*. *Pegmatite* is a very similar rock, often known as *graphic granite* from the peculiar disposition of the quartz-crystals in the felspar-base. Such a rock may be termed a *binary granite*, since it requires only the addition of some micaceous mineral to convert it into a true *granite*. The granitic rocks have been divided into numerous varieties founded either on peculiarities of texture, such as *gneiss*, which is commonly regarded as a schistose granite; or on variations in composition, arising generally from the presence of certain accessory minerals: thus, the *beresite* from Bersof in the Ural Mountains is a granite containing iron-pyrites. In certain granitic rocks, the mica is replaced by other minerals giving rise to several distinct varieties: in the Cornish *luxullianite*, for example, it is replaced by schorl, and in the so-called *protogine* of the Alps by talc; whilst in *syenite* its place is supplied by hornblende. In the *zircon-syenite* of Norway, zircon occurs as an accessory constituent; and to this rock the Siberian *miascite* is closely related. On the disappearance of the quartz in syenite, a rock is obtained consisting of felspar and hornblende, and commonly termed *greenstone;* of which rock *diorite*, *aphanite*, *timazite*, and *amphibolite*, may be mentioned as varieties. A singular concretionary greenstone from the Island of Corsica is known as *Napoleonite* or *orbicular diorite*, and sometimes very improperly as *Corsican granite*.

The rocks passing under the names of *basalt*, *dolerite*, *anamesite*, and *melaphyre*, all bear a greater or less resemblance to greenstone, but are distinguished by containing the more basic felspars, labradorite or oligoclase, associated always with augite, and often with various other minerals, such as olivine, magnetic iron-ore, &c. Many of these rocks are popularly united under the general name of *trap*.

Another series of felspathic rocks is formed by those volcanic products of which *trachyte* is the type. This rock consists almost exclusively of felspar, and often becomes porphyritic by the presence of crystals of sanidine. Among the varieties of trachyte may be noticed the *andesite* of the Andes, and the *domite* of the Puy-de-Dôme. *Rhyolite* is a highly-silicated trachytic rock. A compact fissile rock allied to trachyte is termed *phonolite* or *clinkstone*, in allusion to the ringing sound which it emits on being struck.

When trachytic rocks have been completely fused they pass into a vitrified condition, forming a variety of *obsidian* or *volcanic glass*. A capillary form of obsidian from the Sandwich Islands is known as *Pélé's hair*. When obsidian loses its vitreous texture it passes into *pitchstone;* and when presenting a concretionary structure it is termed *pearlstone*. *Pumice* is simply a cellular or fibrous form of felspathic lava.

Special descriptions of such felspathic rocks as are of any practical importance will be found under their respective headings.

FELT. (*Feutre*, Fr.; *Filz*, Ger.) A material formed by working into a sheet, wool or hair, upon the principle of their matting together.

FELTING (*Feutrage*, Fr.; *Filzen*, Ger.) is the process by which loose flocks of wool, and hairs of various animals, as the beaver, rabbit, hare, &c., are mutually interlaced into a compact textile fabric. The first step towards making felt is to mix, in the proper proportions, the different kinds of fibres intended to form the stuff; and then, by the vibratory strokes of the bowstring, to toss them up in the air, and to cause them to fall as irregularly as possible, upon the table, opened, spread, and scattered. The workman covers this layer of loose flocks with a piece of thick blanket stuff slightly moistened; he presses it with his hands, moving the hairs backwards and forwards in all directions. Thus the different fibres get interlaced, by their ends pursuing ever tortuous paths; their vermicular motion being always, however, root foremost. As the matting gets denser, the hand pressure should be increased, in order to overcome the increasing resistance to the decussation.

A first thin sheet of soft spongy felt being now formed, a second is condensed upon it in like manner, and then a third, till the requisite strength and thickness be obtained. These different pieces are successively brought together, disposed in a way suitable to the wished-for article, and united by continued dexterous pressure. The felt must be next subjected to the fulling mill. See Hat Manufacture, and Kamptulicon.

FENKS. The refuse of whale blubber. It is used as a manure, and has been employed in the manufacture of Prussian blue.

FENNEL. The *Anethum Fœniculum*, a plant yielding an aromatic oil. The leaves are used for making sauce; the seeds are carminative.

FENUGREEK. The *Trigonella Fœnum-Græcum*, an herb cultivated throughout Greece and the East as an article of food. The seeds, which alone are used, are eaten, both boiled and raw, mixed with honey. The *Trigonella cærulea* is a native of Switzerland and Bohemia. The flowers are of a delicate blue colour, and have an odour like that of Balsam of Peru. This odour increases by drying, and the Italian perfumers use it extensively. The Swiss use it to flavour some of their cheeses.

FER ACIEREUX. Steely iron produced by the Catalan process. See Iron.

FERMENT (Eng. and Fr.; *Hefe*, Ger.) is the substance which, when added in a small quantity to vegetable or animal fluids, tends to excite those intestine motions, or changes, which accompany fermentation. It seems to be the result of an alteration which vegetable albumen and gluten undergo with contact of air amidst a fermenting mass. The precipitates or lees which fall down, when fermentation is finished, consist of a mixture of the fermenting principle with the insoluble matters contained in the fermented liquor, some of which, like *hordeine*, existed in the worts, and others are probably generated at the time.

To prepare a pure ferment, or at least a compound rich in that principle, the precipitate separated during the fermentation of a clear infusion of malt, commonly called yeast or barm, is made use of. This pasty matter must be washed in cold distilled water, drained and squeezed between the folds of blotting-paper. By this treatment it becomes a pulverulent mass, composed of small transparent grains, yellowish grey when viewed in the compound microscope. It contains much water, and is therefore soft, like moist gluten and albumen. When dried it becomes, like these bodies, translucid, yellowish brown, horny, hard, and brittle. In the soft humid state it is insipid, inodorous, insoluble in water and alcohol. If in this state the *ferment* be left to itself, at a temperature of from 60° to 70° F., but not in too dry a situation, it putrefies with the same phenomena as vegetable gluten and albumen, and leaves, like them, a residuum resembling old cheese. See Fermentation and Yeast.

FERMENT OILS. Volatile oils produced by the fermentation of plants, and not originally contained in them. These were the *quintessences* of the alchemists. In most cases they are obtained by placing the leaves of the flowering plant in water, and allowing them to ferment; after which the liquid is distilled, and the ferment oil usually separated by means of ether. The following ferment oils are described in Watts's 'Dictionary of Chemistry':—

Ferment oil of *Chærophyllum sylvestre.* Wild Chervil. Common parsley.
,, *Chelidonium majus.* The larger celandine.
,, *Conium maculatum.* Common hemlock.
,, *Erythræa centuarium.* Little centuary.
,, *Echium vulgare.* Vipers' bugloss.
,, *Erica vulgaris.* Common heath.
,, *Marrubium vulgare.* White horehound.
,, *Achillea millefolium.* Common yarrow.
,, *Plantago.* The plantain.
,, *Quercus robur.* Oak.
,, *Salix pentandra.* The willow.
,, *Salvia pratensis.* Meadow sage.
,, *Trifolium fibrinum.* The clover.
,, *Tussilago farfara.* Colt's foot.
,, *Vitis vinifera.* The vine.
,, *Urtica urens.* The nettle.
,, *Diseased apples.*

FERMENTATION. (*Fermentation*, Fr.; *Gährung*, Ger.) A change which takes place, under the influences of air and moisture at a certain temperature, in the constituent particles of either vegetable or animal substances. This change is indicated by a sensible internal motion—the development of heat—the evolution of gaseous products. Fermentation may be divided into several kinds, as—

Saccharine,
Acetic,
Alcoholic or Vinous,
Putrefactive,
Butyric,
Glyceric,
Lactic,
Mucous.

Of the latter examples but a brief notice is required. *Mucous fermentation* is established when the juice of the beetroot or carrot is kept at a temperature of 100° for some time, when a tumultuous decomposition takes place. All the sugar disappears, and the liquor is found to contain a large quantity of gum, and of mannite with lactic acid.

Lactic Fermentation.—If a solution of one part of sugar in five parts of water be made to ferment, by the addition of a small quantity of cheese or animal membrane, at a temperature of 90° or 100°, lactic acid is formed, which may be separated by adding a little chalk, the lactate of lime depositing in crystalline grains. In lactic fermentation *mannite* invariably is produced as a secondary product, the formation of which is not explained. It has been suggested that the formation of mannite is connected with the production of succinic acid, which Schmidt, in a letter to Liebig, stated that he had found in fermenting liquids containing sugar. He suggested the following equation (Schmidt's formulæ are retained):—

$$\underbrace{C^8H^9O^8}_{\text{Mannite.}} + \underbrace{C^4H^3O^4}_{\text{Succinic acid.}} = \underbrace{C^{12}H^{12}O^{12}}_{\text{Grape sugar.}}$$

Glyceric Fermentation.—When glycerine is mixed with yeast, and kept in a warm place for some weeks, it is decomposed and converted into *metacetonic acid.* This fermentation resembles the last named. The glycerine, $C^6H^7O^5$, forming metacetonic acid, $C^6H^5O^4$, as sugar, $C^6H^6O^6$, does lactic acid, $C^6H^5O^5$, by loss of the elements of water.—*Kane.*

Butyric Fermentation.—If the lactic fermentation is allowed to proceed beyond the point indicated for the formation of lactate of lime, the precipitate in part redissolves with a very copious evolution of hydrogen gas and carbonic acid, and the liquor contains butyrate of lime. In this action two atoms of lactic acid, $C^{12}H^{10}O^{10}$, produce butyric acid, $C^8H^7O^3$, carbonic acid, and hydrogen gas.

Putrefactive Fermentation. See PUTREFACTION.

The three first-named kinds of fermentation demand a more especial attention from their importance as processes of manufacture. Under the heads respectively of ACETIC ACID, BEER, BREWING, DISTILLATION, MALT, and WINE, will be found everything connected with the practical part of the subject; we have therefore only now to deal with the chemical and physical phenomena which are involved in the remarkable changes which take place. When vegetable substances are in contact with air and moisture, they undergo a peculiar change (*decomposition*). Oxygen is absorbed and carbonic acid and water are given off, while there is a considerable development of heat. This may take place with greater or less rapidity, and thus *eremacausis*, fermentation, or combustion, may be the result; the spontaneous ignition of hay (as an example) being the final action of this absorption of oxygen.

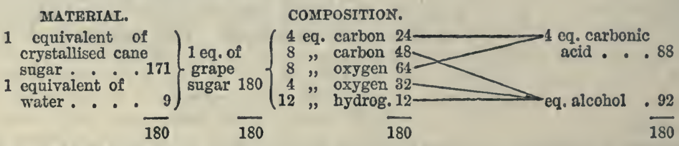
Saccharine Fermentation.—If starch, $C^{12}H^9O^9 + 2HO$, be moistened with an infusion of pale malt, it is rapidly converted into dextrine, $C^{12}H^{10}O^{10}$, and hence into grape sugar, $C^{12}H^{12}O^{12}$; this is especially called the saccharine fermentation, since sugar is the result.

Acetic and Alcoholic Fermentation.—If sugar is dissolved in water, it will remain perfectly unaltered if the air is excluded; but if exposed to the air, a gradual decomposition is brought about, and the solution becomes brown and sour. Oxygen has been absorbed, and *acetic acid* produced. If, however, the sugar is brought into contact with any organic body which is in this state of change, the particles of the sugar participate in the process, carbonic acid is evolved, and *alcohol* produced. There are some substances which are more active than others in producing this change. *Yeast* is the most remarkable; but blood, white-of-egg, glue, and flesh, if they have begun to putrefy, are capable of exciting fermentation; vegetable albumen and gluten being, however, more active. Vegetable albumen, gluten, and legumin differ from most vegetable bodies in the large quantity of nitrogen which they contain. These substances exist in all fruits; and hence, when fruit is crushed, the sugar of the juices in contact with the albumen or gluten being then exposed to the air, oxygen is rapidly absorbed, the nitrogenous body begins to putrefy, and the sugar passes into fermentative activity. The necessity for oxygen is at the commencement of the decomposition; when the putrefaction of the albumen or gluten has once begun, it extends throughout the mass without requiring any further action of the air. These may be regarded as natural ferments. Yeast is an artificial one. This body will be more particularly described. See Yeast.

To produce a vinous liquid, it is necessary that there shall be present sugar, or some body, as starch or gum, capable of conversion into sugar, a certain portion of water, and some ferment—for all practical purposes, *yeast*; and the temperature should be steadily maintained at about 80° Fahr. Both cane and grape sugar yield alcohol by fermentation; but Liebig considered that cane sugar, before it undergoes vinous fermentation, is converted into grape sugar by contact with the ferment, and that, consequently, it is grape sugar alone which yields alcohol and carbonic acid.

Grape sugar, as dried at 212°, contains exactly the elements of two atoms of alcohol and four of carbonic acid; as $2(C^4H^6O^2)$ and $4CO^2$ arise from $C^{12}H^{12}O^{12}$.

Cane sugar takes an atom of water to form grape sugar. It follows therefore that cane sugar should in fermenting yield more than its own weight of carbonic acid and alcohol; and it has been ascertained by experiment that 100 parts actually give 104, whilst by theory 105 should be produced, consisting of 51·3 of carbonic acid, and 53·7 of alcohol.—(*Kane.*) Dr. Pereira has given the following very intelligible arrangement to exhibit these changes:—



These facts will sufficiently prove that vinous or alcoholic fermentation is but a metamorphosis of sugar into alcohol and carbonic acid.

Such are the generally-received views. We find, however, some other views promulgated which it is important to notice.

The following remarks on the Fermentation of Worts, as coming from the hands of a practical brewer, are of considerable value:—

As to the theories respecting the causes of fermentation that have for some time past engaged the attention of the highest scientific talent of the present day, it would be premature, and, perhaps, somewhat to be deprecated, to attempt in an article of this kind to establish either the one theory or the other; it is sufficient to the purposes of the brewer's art to know the general principles that affect fermentation, more particularly the alcoholic fermentation of beer-wort, and a long-past experience has taught us that these can be reckoned up and controlled with all the precision attainable in ordinary chemical manipulations.

The ferment, under the names of Yeast, Barm, Store, or Must, when examined under a tolerably powerful microscope, in physical appearance seems to be composed of innumerable spherical forms, semi-opaque, and somewhat of a cream colour, varying according to the shade imparted to the malt in the process of drying. Perhaps the best way to conduct the examination is as follows:—Select a well-distended bubble of yeast, just touch it with a glass plate, immediately transfer it to the microscope and commence the examination, directing the light from the reflector underneath, so that it shall pass upward through the glass plate. The thin film of yeast adhering to it will then be in a very convenient form for careful examination; it will then at once be seen that the spherules are agglomerated together with just the same accident that would occur with ordinary soap-bubbles, no appearance of any regular organised arrangement being evinced. As the yeast dries, these individual spheres or spherules burst in like manner to the soap-bubble alluded to, and the substance of which it was composed falls on the spot to which it had become fixed; it would appear to have contained gas only, for neither internal structure nor even liquid is discoverable. Now take a drop of the beer-wort in a state of active fermentation, place it on the glass plate support of a microscope, and hold it up to the eye, allowing a sufficiently strong light to pass through it. If the microscope be now rolled round after the manner of an ordinary kaleidoscope, the spherules will be seen to roll about the fluid in exactly the same manner that shot would in the latter instrument; but of course allowance must be made for the difference in their specific gravities respectively, and the density of the medium enveloping each. If some of the bottom yeast be now examined in the like manner, it will appear to have amongst it quantities of these spherules in a ragged condition. In addition to the spherical forms just described, there may be seen extremely minute black specks, having somewhat the shape of a four-rayed rhomboidal star: it is difficult to determine what these may be; their opacity almost precludes the idea of their being of organic origin; perhaps they may be a particle of the lime-salts in an insoluble state, originally contained in the water from which the beer was brewed; many of them are attached to spherules of yeast, after the manner that an air-bubble is sometimes seen to suspend small particles of solid substances.

It often happens that, mixed with the yeast proper, there may be other ferments, and these, so far as science has lent us aid, it is desirable to describe. The lactic ferment is of the most common occurrence. M. W. Schultze is very definite in his description of it. He says: 'When completely developed, it presents an appearance of minute, translucent strips, in four divisions, slightly drawn together in the middle; in its early stages, it only presents a quantity of small specks moving around each other. It refracts light strongly, has a peculiar mild brilliancy, and the contents of the exterior membrane cannot be seen.' M. Pasteur says the diameter of this parasite is about one fifteen-thousandth of an inch, and that by its physical appearance it is most easily distinguished from yeast ferment.

The ordinary atmosphere contains an abundance of germs of ferment, and M. Schultze affirms that the motes floating in the air are, by the spores which they contain, capable of aiding the development of lactic fermentation in worts. M. Hoffman assures us of their presence upon grain and the stalks of grapes; and it is suspected that the dust adhering to grain, and even malt, may be a means of developing lactic fermentations; and, in the same way that yeast multiplies itself in sweet wort, the lactic ferment may also propagate itself, and, independently of the original lactic fermentation, produce what is commonly designated secondary fermentation. M. Schultze says that lactic fermentation requires a supply of nitrogen, and its presence, duration, and force depend on the quantity present of that element. The heating of wort from 140° to 149° appears to oppose the development of the cellules of lactic ferment; a little below 140° its production is slow and not abundant; between 120° and 70° it becomes rapid and energetic; the temperature most favourable to its production being between 95° and 113°. When lactic acid is present in a wort it appears to check a further production of it, but if the free acid be neutralised with soda a fresh formation commences at once. Whenever a wort has become sour, the lactic ferment is always to be found in it, more abundantly in proportion to the amount of spontaneous fermentation that has occurred; therefore spontaneous fermentation is judged to be of lactic origin, and, indeed, is lactic fermentation which has passed its ordinary limits. Experienced chemists also affirm that in the fermentation of beer with yeast, if the temperature is allowed to attain 89° alcohol ceases to be produced, but that the fermentation degenerates into the lactic condition, and lactic acid is the product of it.

Butyric Ferment.—There is another kind of ferment which it is very important to describe, and which, probably, is without exception the most troublesome and deadly of the brewer's enemies; this is the butyric ferment: it appears to originate principally from organic impurities in the water, but it is asserted also to be produced in the ordinary fermentation of beer, if such fermentation be allowed to attain a temperature above 84°; in all cases diarrhœa is produced when it is drunk whether in beer or water; in beer it may be suspected when there is odour of pine-apple, especially if the beer has the character of soon producing headache. Mr. Charles Heisch is of opinion that it is to be found in all water that has become contaminated with sewage, even to the smallest amount; the brewer will do well to make himself acquainted with Mr. Heisch's researches upon this particular subject. It may be briefly stated that the conclusions he appears to have arrived at are: First, that where this ferment is found in water, be the amount of it ever so small, that water must not be used for food purposes till the ferment is thoroughly eradicated from it, for they increase so rapidly under favourable circumstances, that they must ultimately prove injurious to health; Secondly, in any dilute solution of sugar they quickly betray their presence by a turbidity accompanied eventually by the butyric odour. He describes them as minute spherical cells, with, in most cases, a very bright nucleus. Their vitality is in no way destroyed even by half-an-hour's boiling; ordinary filtration, even through the finest Swedish filter-paper, does not remove them; filtering through a good bed of animal charcoal, frequently dried, appears to remove them effectually: the softer the water the more quickly they grow; in hard water they appear at first to form small clots, consisting of cells mixed with crystals of carbonate of lime. The addition of nitrates or ammoniacal salts to the water does not seem to accelerate their growth. By permitting the action of these germs on sugar to go on, at a temperature between 60° and 70°, they present uniformly the following appearances:—The cells generally group together in bunches like grapes, quite differently from the ordinary yeast globules; they next spread out into strings, with a wall surrounding and connecting the cells; the original cell-walls then seem to break, and leave apparently tubular threads branched together.

The following experiment with malt and some very hard water, shows a permanent hardness of 40° and an ordinary hardness of 59°, with so little as only ·010 of free ammonia and ·003 of albuminoidal ammonia, to the 100,000 grains of water. Half-a-pint of this water was placed in a clean glass beaker and covered; it was crystal bright, and remained so for at least three weeks, depositing only carbonate salts as the water evaporated. Ten corns of malt were then put into the water and the beaker replaced in the window, that it should be subjected to as much light as possible. The corns eventually sank, and about 48 hours afterwards the water had attained quite a milky turbidity, bubbles of gas were continually being evolved from the corns, and a distinct and very unpleasant odour arose from the fermentation that was evinced, and which most certainly had not any alcoholic odour about it. Upon examination with the microscope, the minute spherical forms in common with yeast were distinctly to be seen, and where there was room for locomotion many of them appeared to be disporting themselves, very much after the fashion of midges in the air, or the little water-beetle seen so commonly on the surface of a stream on a summer day; amongst them there were also the little specks of opaque substance, already noticed in the microscopical examination of ordinary fermentation with yeast. With only a cursory glance, the observer might easily have been led to suppose that these movements were accidental, but after attentive observation it became quite evident that it was organised work with a definite purpose, which appeared to be to form strings of about five globules, not always straight, and, when these strings were completed, they remained at rest.

Now with these facts before us, let us try to mark out a safe line of conduct for the guidance of the brewer; and the first step is, undoubtedly, to obtain the alcoholic ferment in a state of great purity, and to maintain it in full health and vital energy. Experience proves that these latter qualifications are best secured by allowing the yeast to have contact only with a cold and still atmosphere; and the more intense the cold in contact with it, the more satisfactory will be the result of its application to the purpose of fermentation, as the most intense cold does not even impair the energy of the ferment. Careful selection and cultivation are the principal means to adopt to preserve or obtain yeast in a state of purity; and if it be kept from air currents, there is less danger of infection from the mischievous germs that are always present in the common atmosphere. If grape-juice be introduced into a number of phials, with long, upright, straight necks at the top, thereby giving to the atmosphere free admission to the liquid contained, in process of time spontaneous fermentation generally sets in; but if the necks be bent short round, and turned downwards, fermentation seldom sets in. This is obviously from the increased difficulty the circulating atmosphere has in depositing the germs of lacteous ferment upon the fluid. The knowledge of these facts is valuable, for it shows to us a simple mechanical arrangement by which we may successfully resist the inoculation of our fresh yeast and sound beer-worts from the atmosphere. The means may be thus described:—First, the yeast-safe must be provided with a means of refrigeration, that the progress of fermentation shall be completely arrested; secondly, the circulation of the atmosphere that has actual contact with the yeast must be obstructed as much as possible. Antiseptics must not be resorted to, for whatever will destroy the vitality of either lacteous or butyric ferment, will also have the like effect upon yeast ferment. Neither should it be attempted to decrease acid tendency by the use of neutralising agents, for the door is thus opened for the advancement of the acetic change; and this is why, in the manufacture of lactic acid, that, as the fermentation advances or proceeds, and lactic acid is produced, it is found necessary to continually make to it additions of carbonate of lime, that the existing acid may be taken up; for, if this is not done, the lactic product ceases to be formed before the fermentation is completed.

By the aid of scientific investigations prosecuted to the present time, we are enabled to arrange the different kinds of fermentation and their products. When a glucose solution comes in contact with yeast, about 95 per cent. of it is changed into alcohol and carbonic acid gas, the remaining portion into glycerine, succinic acid, and other compounds; if in the progress of the fermentation, the heat be allowed to rise considerably, some of the alcohol present becomes oxidised, and acetic acid is the result; the germs of lacteous ferment also increase rapidly (being already present in the solution), for it is practically impossible to prepare a saccharine wort that shall be entirely free from them; any breath of air that passes over it, the vessel that contains it, or any substance whatever that touches the liquid, may be the medium of their introduction and incorporation with it; and, being there, it is only a question of circumstance and time, when they will assert their presence, lactic acid and mannite being the products of the fermentation induced by them. If this lactic fermentation be allowed to spend itself, the ferment appears to degenerate into the butyric form, and butyric acid is the product, carbonic anhydride and hydrogen being evolved.

Respecting the temperatures adjudged to be the best for favouring alcoholic fermentation, this is a subject to which we must give the most patient reasoning; for, although brewing is an art known and practised throughout the world from time immemorial, it is a curious circumstance, that in no part of the manipulation is there so much diversity of opinion as upon this one point—temperature; but it is not to be wondered at, when we take into consideration that it is upon the particularly nice attainment of a peculiar flavour, that one beer is appreciated by some, and a totally different one by others; so we see that the 'right flavour' varies with the palate of the consumer, and that for its attainment we have to rely almost entirely upon the due proportion of the various products of fermentation. This no doubt explains to some extent the cause of the different temperatures that are in favour with different brewers. But there is another circumstance that it will be well to consider. It is, perhaps, much to be regretted that the chemists who have given us the results of their researches have not considered it necessary to state the bulk of the material upon which they operated in the prosecution of their experiments, for undoubtedly this circumstance has an important effect upon the temperature indicated; the rate at which the heat is generated, is transmitted by the vessel containing the fermenting wash, and is absorbed or carried off by the surrounding medium, must have its effect upon the thermometer's indications, and upon the resulting products of the fermentation. In conducting a mash, we know that for the complete transformation of the starch in a small mash, a considerably higher mashing-temperature is required than is necessary for a large mash; and by the same rule, fermentations must be conducted in small vessels with a higher temperature than is required for larger vessels. But in proportion as the yeast is subjected to the higher temperatures, or prolonged exposure, so it degenerates both in vitality and character; therefore it is best to maintain a uniformly low temperature, and give the required impetus by an allowance of a larger quantity of yeast. It would have been of considerable advantage to us as brewers, if those gentlemen to whom we are so much indebted had stated the particular kinds of ferment that appeared to be mostly developed by the influence of the temperature and time attendant on the fermentations which were the subject of their researches; but their investigations have, however, proved to us thus much:—

1. That alcoholic fermentation with ordinary brewer's yeast may be conducted with a temperature so low even as 40° Fahr.

2. That alcohol in the presence of gluten or yeast at temperatures above 52° is liable to become acetic.

3. That at temperatures above 61° the germs of lacteous ferment begin to show vitality.

4. That at temperatures above 84° alcoholic fermentation ceases, and lactic fermentation degenerates into the butyric formation.

In apportioning the quantity of yeast to a brewing, the gravity of the wort must be a first consideration.

In practice we find that with different gravities it does not answer to apportion yeast by the rule of proportion, taking gravity for the data of calculation, for the higher gravities require a higher percentage to be allowed them than the lower gravities; this arises from two causes:

1st. It is self-evident that, as soon as fermentation commences, the amount of alcohol manufactured in a certain bulk of wort of a high gravity must bear a greater proportion to that bulk than would the alcohol produced from the same bulk of wort at a low gravity; and it is found that the presence of alcohol in a wort has the power of arresting the progress of fermentation, the more effectually as the quantity present bears a higher proportion to the bulk. Of course, therefore, this is more easily accomplished in worts of high gravities; and, in order to carry on the attenuation in such worts, an extra quantity of yeast must be allowed to meet this emergency.

For this reason it is sometimes found necessary to supplement the first addition of yeast to a brewing by another portion to be added when the fermentation appears sluggish, before the full amount of attenuation is reached; and it is a good plan at this time to freshen up the vitality of the ferment by a slight addition of *malt meal* well whisked up with it.

2nd. If worts of different gravities be examined thirty-six hours after the setting-on has occurred, it will be found that each pound of yeast added will have done the work of attenuation at a greater rate in the lighter gravities than will be the case with the heavier worts. This undoubtedly arises in a great measure from the presence in the lighter worts of the larger proportion of albuminous constituents, and this condition adds considerably to the energy of the fermentation. The increased percentage of the albuminoids occurring in worts of light gravities, arises simply from the fact that for them the exhaustion of the malt is usually carried as far as possible; the stronger worts consequently consisting of the more soluble saccharine constituents.

From the foregoing remarks it will be seen that there is great difficulty in the way of an attempt to give a reliable rule for apportioning the quantity of yeast to a brewing, for there are many points to consider. These it will be well to recapitulate:—

1. The temperature at which it is intended to conduct the fermentation; the lower this is the more yeast must be used.

2. The specific gravity of the ale to be fermented; the higher this is, the greater must be the percentage of the yeast apportioned.

3. The extent to which the exhaustion of the malt has been carried; the more so that this has been permitted, the less yeast must be used and the more slowly must the fermentation be conducted.

The extent to which granulation of the malt has occurred in the process of crushing; the more it has been pressed, the less yeast must be used, and the more slowly must the fermentation be conducted.

The character of the water used in the process of brewing, undoubtedly has its effect, though it is but seldom taken into account; the harder the water is, the more yeast by a considerable proportion must be allowed. This latter consideration leads us on to a subject, the importance of which cannot be over-estimated, however some may assume to deride it; but it does not require any elaborate reasoning to show that quality in the water is an advantage almost equal to quality in the malt and hops. It cannot be denied that the practical dyer must be master of the constituents contained in the water he uses in his processes, before he can hope for unvarying success; neither can we disregard the well-known effect of drinking water in its hard state; and recent researches bear testimony to how small a quantity of organic impurity in any water makes it extremely prejudicial as an article of food. These facts speak for themselves, and point to the necessity there is that every brewer should have the means of readily ascertaining the quality of the water he brews with. Amongst the most successful of the trade this necessity is acknowledged and met as well as possible by a frequent analysis of the waters supplied to the brewery; but the ordinary brewer has very seldom the time, the means, or the requisite ability to make a complete analysis of the water; but he may make an approximate analysis with rapidity and great advantage, much oftener than is customary. Let him study the use of permanganate of potash in the volumetric analysis for organic matter described in Mr. Sutton's 'Volumetric Analysis.' The ordinary and permanent hardness can also be easily tested, as also the presence of ammonia-compounds, and these are perhaps the facts which require watching in the waters supplied to breweries.

In conducting a healthy alcoholic fermentation, the following general rules should be observed:—The wort should be purified as much as possible from gross constituents and acetic tendency, first by using in its manufacture a water the lime-salts of which will aid in their precipitation. (Of the beneficial influence of the hard waters favoured by the brewer, Dr. Hassall suggests a theory which appears very satisfactory. He says: 'During ebullition, the excess of carbonic acid in the water, by which the carbonates of lime and magnesia are retained in solution, is expelled, and those salts are precipitated. Again, the alkaline phosphates present in malt have the power of converting the sulphate of lime into phosphate, which is thrown down; an alkaline sulphate, which is soluble, being synchronously formed. The greater part of the phosphate of lime produced, is re-dissolved in the acid generated during fermentation; consequently, the water, from being hard, thus becomes soft, and in this state is well suited for extracting the active properties of the malt and hops.') Secondly. The wort should be cleared by every means that care and mechanical ingenuity can provide.

The yeast for setting-on should be selected with every care, freed as much as possible from the gross flocks accruing in preceding manipulations, from tannic and gallic acids (the product of the hop), from atmospheric contaminations, and from acetic and butyric germs. It should be as virgin as possible, and the lower the temperature at which it was produced the better it will be. When about to be applied, the wort with which it is to be mixed should be of such a temperature as to induce immediately an active fermentation; this temperature must of course vary according to the gravity and bulk of the wort, say for bulks of about 25 barrels of a gravity of 22 lbs. per barrel; the temperature for stone squares may be from 67° to 70°, and for wood rounds from 64° to 67°. Let the yeast be added as soon as the wort begins to run into the fermenting utensil, and decrease the temperature by the subsequent running down, and the whole should be most thoroughly roused many times during the process of filling.

As to temperature, avoid extremes, and especially dangerously high ones; rather employing an extra quantity of yeast than a high temperature; and the less heating that is attempted, in the progress of the fermentation, by the means of attemperaters, the better. The fermentation should be expedited by all safe means available, for either heat or protracted working diminish the alcoholic excellence and tend to impair the flavour, in proportion as they have been permitted to affect the process.

When the desired amount of attenuation is obtained, no time should be lost in freeing the alcoholised product from degeneracy by contact with the yeast, and preserving by refrigeration as much as possible of the alcohol and carbonic acid gas that have been generated. To this end it is best to draw off the alcoholised product as quietly as possible into a clean settling back provided with a means of refrigeration, and when it has become sufficiently bright, rack and store at once; great experience and judgment are a necessity in determining this last point, and no amount of theory can supply the lack of them. Peculiarities of water, modes of mashing and fermentation, character of the barley season and malting, state of the weather, gravity of the wort, and peculiarities of the market for which the beer is brewed, are all points which have to be carefully attended to, or the previous management and care will result only in bitter disappointment. On the care with which the settling and racking have been conducted depend the flavour, brilliancy, and briskness of the product. Finings of any sort are of very little avail, and if their effects were more generally known, they would be but very seldom used; for, chemically, they must be injurious both to the beer and the consumer, and practically they prove so both to the cask and its contents. If they meet with either acids or alkalis, acetic and lactic tendencies are generated in the alcoholic solution with which they are mixed, and by their decay butyric decomposition is generated. If they are rendered insoluble, they become indigestible, and this latter result is found to be the effect of bisulphate of lime. All finings, be they soluble or insoluble, flatten the beers when mixed by the amount of agitation they require to make them take effect; thereby much of the carbonic acid gas (which is the product that gives to beers that brilliancy, sparkle, and pungency so grateful to the consumer's palate) is liberated and lost, and this also diminishes the keeping ability of the beer.

Liebig calls *putrefactive fermentation* every process of decomposition which, caused by external influences in any part of an organic compound, proceeds through the entire mass without the further co-operation of the original cause. *Fermentation*, according to Liebig's definition, is the decomposition exhibited in the presence of putrefying substances or ferments, by compounds nitrogenous or non-nitrogenous, which alone are not capable of putrefaction. He distinguishes, in both putrefaction and fermentation, processes in which the oxygen of the atmosphere continually co-operates, from such as are accomplished without further access of atmospheric air.

Liebig opposes the view which considers putrefaction and fermentation as the result of vital processes, the development of vegetable formations or of microscopic animals. He adduces that no trace of vegetable formations are perceptible in milk which is left for some time in vessels carefully tied over with blotting-paper, not even after fermentation has regularly set in, a large quantity of lactic acid having been formed. He further remarks of fermentative processes, that alcoholic fermentation having been observed too exclusively, the phenomena have been generalised, while the explanation of this process ought to be derived rather from the study of fermentative phenomena of a more general character.

Blondeau propounds the view that every kind of fermentation is caused by the development of fungi. Blondeau states that alcoholic fermentation is due to a fungus which he designates *Torula cerevisiæ;* whilst another, *Penicillium glaucum*, gives rise to lactic fermentation. The latter fermentation follows the former in a mixture of 30 grm. of sugar, 10 grm. of yeast, and 200 c. c. of water, which has undergone alcoholic fermentation at a temperature of about 20°, being terminated in about two days. Beer yeast, when left in contact with water in a dark and moist place, contains, according to Blondeau, germs both of *Torula cerevisiæ*, and of *Penicillium glaucum;* the former can be separated by a filter, and will induce alcoholic fermentations in sugar-water, whilst the latter are extremely minute, and pass through the filter; the filtrate, mixed with sugar-water, gives rise to lactic fermentation. Acetic fermentation is due to the development of *Torula aceti;* sugar is converted into acetic acid without evolution of gas, if 500 grm. dissolved in a litre of water be mixed with 200 grm. of casein, and confined in contact for a month at a temperature of about 20°. The conversion of nitrogenous substances into fat—for instance, of casein, in the manufacture of Roquefort cheese; of fibrin under similar circumstances, which Blondeau designated by the term fatty fermentation (*fermentation adipeuse*)—is caused by *Penicillium glaucum* or *Torula viridis;* and the former fungus is stated to act likewise in butyric and in urea fermentation (conversion of the urea into a carbonate of ammonia).

Opposed to this view Schubert has published an investigation upon yeast. In order to prove that the action of yeast is due merely to its porosity, he founds his investigation upon some experiments of Brendecke (particularly in reference to the statement that fermentation taking place in a solution of sugar in contact with porous bodies is due to an impurity of sugar); according to which various porous bodies, such as charcoal, paper, flowers of sulphur, &c., to which some bitartrate of ammonia is added, are capable of inducing fermentation in a solution of raw sugar. His observations are also based upon some experiments of his own, which seem to indicate that porous bodies, even without the addition of a salt, are capable of exciting fermentation in a solution of (pure?) cane-sugar. Whatever may be the means whereby alcoholic fermentation is induced, he states it to be indispensable that the body in question should be exposed for some time to the influence of air, and that oxygen and carbonic acid are absorbed by the ferment. Both oxygen and carbonic acid, being electro-negative substances, stand in opposition to the electro-positive alcohol, and therefore predispose its formation, but only when they are highly condensed by the powerful surface-attraction of the yeast, or of any porous body. The electrical tension, he states, may be increased by many salts, provided that the latter do not at the same time chemically affect either the sugar or the ferment.

C. Schmidt has communicated the results of his experiments to the '*Annal. Chem. Pharm.*' After stating numerous experiments, he continues: 'Nor are fungi the *primum movens* of saccharine fermentation; the clear filtrate obtained by throwing almonds crushed in water upon a moist filter, soon induces fermentation in a solution of urea and of grape-sugar; in the latter case, no trace of ferment-cells can be discovered under the microscope, not even after fermentation is fully developed. If the solution, still containing sugar, is allowed to stand eight days or a fortnight after fermentation has ceased, an exuberant development of cellular aggregations is observed, but no putrefaction ensues; the fungi, well washed and introduced into a fresh solution of grape-sugar, continue to grow luxuriantly, inducing, however, if at all, but very weak fermentation, which rapidly ceases; hence the growth of fungi during fermentative processes is but a secondary phenomenon. The increase of the residuary ferment, which occurs after yeast has been in contact with sugar, arises from a development of ferment cellulose, which probably takes place at the expense of the sugar. If muscle, gelatine, yeast, &c., in a very advanced state of putrid decomposition be introduced into a solution of 1 sugar in 4 water, all phenomena of putrefaction disappear; after a few hours, active fermentation sets in, ferment-cells being formed, and the liquid contains alcohol, but no mannite. The inactivity of crushed yeast is due, not to the destruction of the fungi, but to the chemical changes which are induced in yeast during the considerable time necessary for complete comminution. The crushed cells, introduced into sugar-water, give rise to the production of lactic acid, without evolution of gas.' Schmidt is of opinion that fermentation is a process analogous to the formation of ether. He believes that one of the constituents of yeast, together with the elements of grape-sugar, gives rise to the formation of one or several compounds, which are decomposed *in statu nascenti* (like sulpho-vinic acid), splitting into alcohol and carbonic acid.

We believe that the preceding paragraphs fairly represent the views which have been promulgated upon the phenomena of change, which are in many respects analogous to those of combustion and of vitality, presented in the fermentative processes. Much has been done, but there are still some points which demand the careful attention of the chemist.

In a practical point of view, the question which arises from the alteration in the specific gravity of the fluid by fermentation is a very important one, a knowledge of the original gravity of beer being required to fix the drawback allowed upon beer when exported, according to the terms of 10 Vict. c. 5. By this act a drawback is granted of 5*s.* per barrel of thirty-six gallons upon beer exported, of which 'the worts used *before fermentation* were not of less specific gravity than 1·054, and not greater specific gravity than 1·081,' and a drawback of 7*s.* 6*d.* per barrel upon beer of which 'the worts used *before fermentation* were not of less specific gravity than 1·081.' The brewer observes the original gravity of his worts by means of some form of the hydrometer, and preserves a record of his observation. The revenue officer has only the beer, from which he has to infer the original gravity. From the great uncertainty which appeared to attend this question, Professors Graham, Hofmann, and Redwood were employed by the Board of Inland Revenue to discover how the original gravity of the beer might be ascertained most accurately from the properties of the beer itself. When worts are fermented, the sugar passes into alcohol, and they lose in density, and assume as beer a different specific gravity.

The gravity of the wort is called the *original gravity*—that of the beer, *beer-gravity.* The report of Graham, Hofmann, and Redwood, upon 'original gravities,' may be supposed to be in the hands of every brewer; but as some of the points examined materially explain many of the phenomena of vinous fermentation, we have transferred a few paragraphs to our pages:—

'As the alcohol of the beer is derived from the decomposition of saccharine matter only, and represents approximately double its weight of starch-sugar, a speculative original gravity might be obtained by simply increasing the extract-gravity of the beer by that of the quantity of starch-sugar known to be decomposed in the fermentation. The inquiry would then reduce itself to the best means of ascertaining the two experimental data, namely, the extract-gravity and the proportion of alcohol in the beer, particularly of the latter. It would be required to decide whether the alcohol should be determined from the gravity of the spirits distilled from the beer; by the increased gravity of the beer when its alcohol is evaporated off; by the boiling-point of the beer, which is lower the larger the proportion of alcohol present; or by the refracting power of the beer upon light—various methods recommended for the valuation of the spirits in beer.

'Original gravities so deduced, however, are found to be useless, being in error and always under the truth, to an extent which has not hitherto been at all accounted for. The theory of brewing, upon a close examination of the process, proves to be less simple than is implied in the preceding assumption; and other changes appear to occur in worts, simultaneously with the formation of alcohol, which would require to be allowed for before original gravities could be rightly estimated. It was found necessary to study the gravity, in solution of each by itself, of the principal chemical substances which are found in fermented liquids. These individual gravities defined the possible range of variation in original gravity, and they brought out clearly for the first time the nature of the agencies which chiefly affect the result.

'The use of cane-sugar is now permitted in breweries, and the solution of sugar may be studied first as the wort of simplest composition. The tables of the specific gravity of sugar solutions, constructed by Mr. Bate, have been verified, and are considered entirely trustworthy. The numbers in the first and third columns of Table I., which follow, are however, from new observations. It is to be remarked that these numbers have all reference to weights, and not to measures. A solution of cane-sugar, which contains 25 grains of sugar in 1000 grains of the fluid, has a specific gravity of 1010·1, referred to the gravity of pure water taken as 1000; a solution of 50 grains of cane-sugar in 1000 grains of the fluid, a specific gravity of 1020·2, and so on. The proportion of carbon contained in the sugar is expressed in the second column; the numbers being obtained from the calculation that 171 parts by weight of cane-sugar ($C^{12}H^{11}O^{11}$) consist of 72 parts of carbon, 11 parts of hydrogen, and 88 parts of oxygen; or of 72 parts of carbon combined with 99 parts of the elements of water. It is useful to keep thus in view the proportion of carbon in sugar solutions, as that element is not involved in several of the changes which precede or accompany the principal change which sugar undergoes during fermentation, and which changes only affect the proportion of the oxygen and hydrogen, or elements of water, combined with the carbon. The proportion of oxygen and hydrogen in the altered sugar increases or diminishes during the changes referred to; but the carbon remains constant, and affords, therefore, a fixed term in the comparison of different solutions.

TABLE I.—*Specific gravity of solutions of Cane-sugar in water.*

Cane-sugar, in 1000 parts by weight	Carbon in 1000 parts by weight	Specific Gravity
25	10·53	1010·1
50	21·05	1020·2
75	31·58	1030·2
100	42·10	1040·6
125	52·63	1051
150	63·16	1061·8
175	73·68	1072·9
200	84·21	1083·8
225	94·73	1095·2
250	105·26	1106·7

'When yeast is added to the solution of cane-sugar in water, or to any other saccharine solution, and fermentation commenced, the specific gravity is observed to fall, owing to the escape of carbonic acid gas, and the formation of alcohol, which is specifically lighter than water; 171 grains of sugar, together with 9 grains of water, being converted into 92 grains of alcohol and 88 grains of carbonic acid ($C^{12}H^{11}O^{11}+HO=2C^{4}H^{6}O^{2}+4CO^{2}$). But if the process of fermentation be closely watched, the fall of gravity in cane-sugar will be found to be preceded by a decided increase of gravity. Solutions were observed to rise from 1055 to 1058, or 3 degrees of gravity, within an hour after the addition of the yeast, the last being in the usual proportion for fermentation. When the yeast was mixed in minute quantity only, such as $\frac{1}{300}$ of the weight of the sugar, the gravity of the sugar solution rose gradually in four days from 1055 to 1057·91, or also nearly 3 degrees; with no appearance, at the same time, of fermentation or of any other change in the solution. This remarkable increase of density is owing to an alteration which takes place in the constitution of the cane-sugar, which combines with the elements of water and becomes starch-sugar: a change which had been already proved by H. Rose and by Dubrunfaut to precede the vinous fermentation of cane-sugar. The same conversion of cane-sugar into starch-sugar, with increase of specific gravity, may be shown by means of acids as well as of yeast. A solution of 1000 parts of cane-sugar in water, having the specific gravity 1054·64, became with one part of crystallised oxalic acid added to it 1051·7; and, being afterwards heated for twenty-three hours to a temperature not exceeding 128° Fahr., it was found (when cooled) to have attained a gravity of 1057·63—an increase again of nearly 3 degrees of gravity.'

The difference between the gravities of solutions of cane-sugar and starch-sugar are of great practical value, but these must be studied in the original; the result, however, being 'that the original gravity of a fermented liquid or beer must be different, according as it was derived from a wort of cane-sugar or of starch-sugar.'

The gravity of malt wort was determined to be intermediate between that of pure cane-sugar and starch-sugar, and solutions containing an equal quantity of carbon exhibited the following gravities:—

Cane-sugar – 1072·9 Pale malt – 1074·2 Starch-sugar – 1076·0

Two other substances were found to influence the original gravity of the wort: dextrin, or the gum of starch, and caramel. Tables are given of the specific gravities of these, from which the following results have been deduced:—

Starch-sugar	1076
Dextrin	1066·9
Caramel	1062·3

Caramel is stated to interfere more than dextrin in giving lightness or apparent attenuation to fermented worts, without a corresponding production of alcohol.

'Another constituent of malt wort, which should not be omitted, is the soluble azotised or albuminous principle derived from the grain. The nitrogen was determined in a strong wort of pale malt with hops, of the specific gravity 1088, and containing about 21 per cent. of solid matter. It amounted to 0·217 per cent. of the wort, and may be considered as representing 3·43 per cent. of albumen. In the same wort, after being fully fermented, the nitrogen was found to amount to 0·134 per cent., equivalent to 2·11 per cent. of albumen. The loss observed of nitrogen and albumen may be considered as principally due to the production and growth of yeast, which is an insoluble matter, at the cost of the soluble albuminous matter. Solutions of egg-albumen in water, containing 3·43 and 2·11 per cent. respectively of that substance, were found to have the specific gravities of 1004·2 and 1003·1. Hence a loss of density has occurred during fermentation of 1·1 degree on a wort of 1088 original gravity, which can be referred to a change in the proportion of albuminous matter. It will be observed that the possible influence of this substance and of the greater or less production of yeast during fermentation, upon the gravity of beer, are restricted within narrow limits.'

The reporters proceed:—

'The process required for the determination of the original gravity of beer must be easy of execution, and occupy little time. It is not proposed, in the examination of a sample, to separate by chemical analysis the several constituents which have been enumerated. In fact, we are practically limited to two experimental observations on the beer, in addition to the determination of its specific gravity.

'One of these is the observation of the amount of solid or extractive matter still remaining after fermentation, which is always more considerable in beer than in the completely-fermented wash of spirits. A known measure of the beer might be evaporated to dryness, and the solid residue weighed; but this would be a troublesome operation, and could not indeed be executed with great accuracy. The same object may be attained with even a more serviceable expression for the result, by measuring exactly a certain quantity of the beer, such as four fluid ounces, and boiling it down to somewhat less than half its bulk in an open vessel, such as a glass flask, so as to drive off the whole alcohol. The liquid when cool is made up to four fluid ounces, or the original measure of the beer, and the specific gravity of this liquid is observed. It has already been referred to as to the extract-gravity of the beer, and represents a portion of the original gravity. Of a beer of which the history was known, the original gravity of the malt wort was 1121, or 121°; the specific gravity of the beer itself before evaporation, 1043; and the extract-gravity of the beer 1056·7, or 56·7°.

'The second observation which can be made with sufficient facility upon the beer, is the determination of the quantity of alcohol contained in it. This information may be obtained most directly by submitting a known measure of the beer to distillation, continuing the ebullition till all the alcohol is brought over, and taking care to condense the latter without loss. It is found in practice that four ounce-measures of the beer form a convenient quantity for the purpose. This quantity is accurately measured in a small glass flask, holding 1750 grains of water when filled up to a mark in the neck. The mouth of the small retort containing the beer is adapted to one end of a glass tube-condenser, the other end being bent and drawn out for the purpose of delivering the condensed liquid into the small flask previously used for measuring the beer. The spirituous distillate should then be made up with pure water to the original bulk of the beer, and the specific gravity of the last liquid be observed by the weighing bottle, or by a delicate hydrometer, at the temperature of 60° Fahr. The lower the gravity the larger will be the proportion of alcohol, the exact amount of which may be learned by reference to the proper tables of the gravity of spirits. The spirit-gravity of the beer already referred to proved to be 985·25; or it was 14·05° of gravity less than 1000, or water. The "spirit-indication" of the beer was therefore 14·05°; and the extract-gravity of the same beer 56·7°.

'The spirit-indication and extract-gravity of any beer being given, do we possess data sufficient to enable us to determine with certainty the original gravity? It has already been made evident that these data do not supply all the factors necessary for reaching the required number by calculation.

'The formation of the extractive matter, which chiefly disturbs the original gravity, increases with the progress of the fermentation; that is, with the proportion of alcohol in the fermenting liquor. But we cannot predicate from the theory any relation which the formation of one of these substances should bear to the formation of the other, and are unable, therefore, to say beforehand that because so much sugar has been converted into alcohol in the fermentation, therefore so much sugar has also been converted into the extractive substance. That a uniform, or nearly uniform relation, however, is preserved in the formation of the spirits and extractive substance in beer brewing, appears to be established by the observations which follow. Such an uniformity in the results of the vinous fermentation is an essential condition for the success of any method whatever of determining original gravities, at least within the range of circumstances which affect beer brewing. Otherwise two fermented liquids of this class, which agree in giving both the same spirit-indication and the same extractive gravity, may have had different original gravities, and the solution of our problem becomes impossible.'

The following table, one of several of equal value, gives the results of a particular

TABLE II.—*Fermentation of Sugar-Wort of original gravity* 1055·3.

I Number of Observation	II Period of Fermentation		III Degrees of Spirit-Indication	IV Degrees of Extract-Gravity	V Degrees of Extract-Gravity *lost*
	Days	Hours			
1	0	0	0	55·30	0
2	0	6	1·59	52·12	3·18
3	0	12	2·57	47·82	7·48
4	0	19	3·60	43·62	11·68
5	0	23	4·33	40·13	15·17
6	1	5	5·31	35·50	19·80
7	1	12	6·26	31·39	23·91
8	1	19	7·12	27·63	27·67
9	2	11	8·59	20·26	35·04
10	3	11	9·87	13·40	41·90
11	5	12	10·97	7·60	47·70
12	6	12	11·27	4·15	51·15

fermentation of cane-sugar. 'Fifteen and a half pounds of refined sugar were dissolved in 10 gallons of water, making $10\frac{7}{8}$ gallons of solution, of which the specific gravity was 1055·3 at 60°; and after adding three fluid pounds of fresh porter yeast, the specific gravity was 1055·95. The original gravity may be taken as 1055·3 (55·3°).

'Columns III. and V. respectively exhibit the spirit which has been produced, and the solid matter which has disappeared; the first in the form of the gravity of the spirit, expressed by the number of degrees it is lighter than water, or under 1000, and the second by the fall in gravity of the solution of the solid matter remaining below the original gravity 1055·3. This last value will be spoken of as "degrees of gravity lost;" it is always obtained by subtracting the extract-gravity (column IV.) from the known original gravity. To discover whether the progress of fermentation has the regularity ascribed to it, it was necessary to observe whether the same relation always holds between the columns of "degrees of spirit-indication" and "degrees of gravity lost." It was useful, with this view, to find what degrees lost corresponded to whole numbers of degrees of spirit-indication. This can be done safely from the preceding table, by interpolation, where the numbers observed follow each other so closely. The corresponding degrees of spirit-indication and of gravity lost, as they appear in this experiment upon the fermentation of sugar, are as follow:—

TABLE III.—*Fermentation of Sugar-Wort of original gravity* 1055·3.

Degrees of Spirit-Indication	Degrees of Extract-Gravity lost	Degrees of Spirit-Indication	Degrees of Extract-Gravity lost
1	1·71	7	27·01
2	4·74	8	31·87
3	9·26	9	37·12
4	13·48	10	42·55
5	18·30	11	47·88
6	22·54		

'In two other fermentations of cane-sugar, the degrees of gravity lost, found to correspond to the degrees of spirit-indication, never differed from the numbers of the preceding experiment, or from one another, more than 0·9° of gravity lost. This is a sufficiently close approximation.

'The following table is of much importance:—

TABLE IV.—STARCH-SUGAR.

Degrees of Spirit-Indication, with corresponding degrees of gravity lost.

Besides the degrees of gravity lost corresponding to whole degrees of spirit-indication, the degrees of gravity lost corresponding to tenths of a degree of spirit-indication are added from calculation.

Degrees of Spirit-Indication	·0	·1	·2	·3	·4	·5	·6	·7	·8	·9
0	...	·2	·3	·5	·7	·9	1·0	1·2	1·4	1·6
1	1·9	2·1	2·4	2·7	3·0	3·3	3·6	3·9	4·2	4·6
2	5·0	5·4	5·8	6·2	6·6	7·0	7·5	8·0	8·5	9·0
3	9·5	9·9	10·3	10·7	11·2	11·6	12·0	12·4	12·8	13·3
4	13·8	14·2	14·6	15·0	15·5	15·9	16·3	16·7	17·2	17·7
5	18·3	18·7	19·1	19·5	19·9	20·3	20·8	21·2	21·7	22·2
6	22·7	23·1	23·5	23·9	24·4	24·7	25·2	25·6	26·1	26·6
7	27·1	27·6	28·1	28·6	29·1	29·6	30·0	30·5	31·0	31·5
8	32·0	32·5	33·0	33·5	34·0	34·5	35·0	35·5	36·0	36·6
9	37·2	37·7	38·2	38·7	39·2	39·7	40·3	40·8	41·3	41·8
10	42·4	42·9	43·4	44·0	44·5	45·0	45·6	46·1	46·6	47·2
11	47·7									

'It is seen from this table that for 5° of spirit-indication, the corresponding degrees of gravity lost are 18·3°. For 5·9° of spirit-indication, the corresponding degrees of gravity lost are 22·2°.

'This table is capable of a valuable application, for the sake of which it was constructed. By means of it, the unknown original gravity of a fermented liquid or beer from cane-sugar may be discovered, provided the spirit-indication and extract-gravity of the beer are observed. Opposite to the spirit-indication of the beer in the table, we find the corresponding degrees of gravity lost, which last, added to the extract-gravity of the beer, gives its original gravity.

'Suppose the sugar beer exhibited an extract-gravity of 7·9° (1007·9), and spirit-indication of 11°. The latter marks, according to the table, 47·7° of gravity lost, which added to the observed extract-gravity, 7·9°, gives 55·6° of original gravity for the beer (1055·6).'

Similar tables are constructed for starch-sugar, and for various worts with and without hops.

After explaining many points connected with the problem, as it presented itself under varied conditions as it respected the original worts, the Report proceeds:—

'The object is still to obtain the spirit-indication of the beer. The specific gravity of the beer is first observed by means of the hydrometer or weighing bottle. The extract-gravity of the beer is next observed as in the former method; but the beer for this purpose may be boiled in an open glass flask till the spirits are gone, as the new process does not require the spirits to be collected. The spiritless liquid remaining is then made up to the original volume of the beer as before. By losing its spirits, the beer of course always increases in gravity, and the more so the richer in alcohol the beer has been. The difference between the two gravities is the new spirit-indication, and is obtained by subtracting the beer-gravity from the extract-gravity, which last is always the higher number.

'The data in a particular beer were as follow:—

Extract-gravity	1044·7
Beer-gravity	1035·1
Spirit-indication	9·6°

'Now the same beer gave by distillation, or the former method, a spirit-indication of 9·9°. The new spirit-indication by evaporation is, therefore, less by 0·3° than the old indication by distillation. The means were obtained of comparing the two indications given by the same fermented wort or beer in several hundred cases, by adopting the practice of boiling the beer in a retort, instead of an open flask or basin, and collecting the alcohol at the same time. The evaporation uniformly indicated a quantity of spirits in the beer nearly the same as was obtained by distillation, but always sensibly less, as in the preceding instance. These experiments being made upon fermented liquids of known original gravity, the relation could always be observed between the new spirit-indication and the degrees of specific gravity lost by the beer. Tables of the degrees of spirit-indication, with their corresponding degrees of gravity lost, were thus constructed, exactly in the same manner as the tables which precede; and these new tables may be applied in the same way to ascertain the original gravity of any specimen of beer. Having found the degrees of spirit-indication of the beer by evaporation, the corresponding degrees of gravity lost are taken from the table; and adding these degrees to the extract-gravity of the beer, also observed, the original gravity is found. Thus the spirit-indication (by the evaporation method) of the beer lately referred to, was 9·6°, which mark 43° of gravity lost in the new tables. Adding these to 1044·7, the extract-gravity of the same beer, 1087·7 is obtained as the original gravity of the beer.'

The results of the extensive series of experiments made, were, that the problem could be solved in the two extreme conditions in which they have only to deal with the pure sugars entirely converted into alcohol.

'The real difficulty is with the intermediate condition, which is also the most frequent one, where the solid matter of the beer is partly starch-sugar and partly extractive; for no accurate chemical means are known of separating these substances, and so determining the quantity of each in the mixture.

'But a remedy presented itself. The fermentation of the beer was completed by the addition of yeast, and the constituents of the beer were thus reduced to alcohol and extractive only, from which the original gravity, as is seen, can be calculated.

'For this purpose, a small but known measure of the beer, such as four fluid ounces, was carefully deprived of spirits by distillation, in a glass retort. To the fluid, when cooled, a charge of fresh yeast, amounting to 150 grains, was added, and the mixture kept at 80° for a period of sixteen hours. Care was taken to connect the retort, from the commencement, with a tube condenser, so that the alcoholic vapour which exhaled from the wash during fermentation should not be lost. When the fermentation had entirely ceased, heat was applied to the retort to distil off the alcohol, which was collected in a cooled receiver. About three-fifths of the liquid were distilled over for this purpose; and the volume of the distillate was then made up with water to the original volume of the beer. The specific gravity of the last

TABLE V.—To be used in ascertaining Original Gravities by the Distillation Process.

Degrees of Spirit-Indication with corresponding degrees of gravity lost in Malt-Worts.

Degrees of Spirit-Indication	·0	·1	·2	·3	·4	·5	·6	·7	·8	·9
0	...	·2	·6	·9	1·2	1·5	1·8	2·1	2·4	2·7
1	3·0	3·3	3·7	4·1	4·4	4·8	5·1	5·5	5·9	6·2
2	6·6	7·0	7·4	7·8	8·2	8·6	9·0	9·4	9·8	10·2
3	10·7	11·1	11·5	12·0	12·4	12·9	13·3	13·8	14·2	14·7
4	15·1	15·5	16·0	16·4	16·8	17·3	17·7	18·2	18·6	19·1
5	19·5	19·9	20·4	20·9	21·3	21·8	22·2	22·7	23·1	23·6
6	24·1	24·6	25·0	25·5	26·0	26·4	26·9	27·4	27·8	28·3
7	28·8	29·2	29·7	30·2	30·7	31·2	31·7	32·2	32·7	33·2
8	33·7	34·3	34·8	35·4	35·9	36·5	37·0	37·5	38·0	38·6
9	39·1	39·7	40·2	40·7	41·2	41·7	42·2	42·7	43·2	43·7
10	44·2	44·7	45·1	45·6	46·0	46·5	47·0	47·5	48·0	48·5
11	49·0	49·6	50·1	50·6	51·2	51·7	52·2	52·7	53·3	53·8
12	54·3	54·9	55·4	55·9	56·4	56·9	57·4	57·9	58·4	58·9
13	59·4	60·0	60·5	61·1	61·6	62·2	62·7	63·3	63·8	64·3
14	64·8	65·4	65·9	66·5	67·1	67·6	68·2	68·7	69·3	69·9
15	70·5									

TABLE VI.—To be used in ascertaining Original Gravities by the Evaporation Process.

Degrees of Spirit-Indication with corresponding degrees of gravity lost in Malt-Worts.

Degrees of Spirit-Indication	·0	·1	·2	·3	·4	·5	·6	·7	·8	·9
0	...	·3	·7	1·0	1·4	1·7	2·1	2·4	2·8	3·1
1	3·5	3·8	4·2	4·6	5·0	5·4	5·8	6·2	6·6	7·0
2	7·4	7·8	8·2	8·7	9·1	9·5	9·9	10·3	10·7	11·1
3	11·5	11·9	12·4	12·8	13·2	13·6	14·0	14·4	14·8	15·3
4	15·8	16·2	16·6	17·0	17·4	17·9	18·4	18·8	19·3	19·8
5	20·3	20·7	21·2	21·6	22·1	22·5	23·0	23·4	23·9	24·3
6	24·8	25·2	25·6	26·1	26·6	27·0	27·5	28·0	28·5	29·0
7	29·5	30·0	30·4	30·9	31·3	31·8	32·3	32·8	33·3	33·8
8	34·3	34·9	35·5	36·0	36·6	37·1	37·7	38·3	38·8	39·4
9	40·0	40·5	41·0	41·5	42·0	42·5	43·0	43·5	44·0	44·4
10	44·9	45·4	46·0	46·5	47·1	47·6	48·2	48·7	49·3	49·8
11	50·3	50·9	51·4	51·9	52·5	53·0	53·5	54·0	54·5	55·0
12	55·6	56·2	56·7	57·3	57·8	58·3	58·9	59·4	59·9	60·5
13	61·0	61·6	62·1	62·7	63·2	63·8	64·3	64·9	65·4	66·0
14	66·5	67·0	67·6	68·1	63·7	69·2	69·8	70·4	70·9	71·4
15	72·0									

spirituous liquid was now taken by the weighing bottle. To obtain a correction for the small quantity of alcohol unavoidably introduced by the yeast, a parallel experiment was made with that substance. The same weight of yeast was mixed with water, and distilled in another similar retort. The volume of this second distillate was also made up by water to the beer volume; its specific gravity observed, and deducted from that of the preceding spirituous liquid. This alcohol was added to that obtained in the first distillation of the beer, and the weight of starch-sugar corresponding to the whole amount of alcohol was calculated. This was the first result.

'For the solid matter of the beer: the spiritless liquid remaining in the retort was made up with water to the beer volume, and the specific gravity observed. A correction was also required here for the yeast, which is obtained by making up the water and yeast distilled in the second retort, to the original volume of the beer, and deducting the gravity of this fluid from the other. The quantity of starch-sugar corresponding to this corrected gravity of the extractive matter was now furnished by the table. This was the second result.

'The two quantities of starch-sugar thus obtained were added together. The specific gravity of the solution of the whole amount of starch-sugar, as found in the table, represented the original gravity of the beer.

'This method must give an original gravity slightly higher than the truth, owing to the circumstance that the dextrin, albumen, and salts, which are found among the solid matters dissolved in beer, are treated as having the low gravity of extractive matter, and accordingly amplified by about one-sixth, like that substance, in allowing for them ultimately as starch-sugar. The error from this source, however, is inconsiderable. It is to be further observed, that the error from imperfect manipulation, of which there is most risk in the process, is leaving a little sugar in the extractive matter from incomplete fermentation. This accident also increases the original gravity deduced. The process has given results which are remarkably uniform, and is valuable in the scientific investigation of the subject, although not of that ready and easy execution which is necessary for ordinary practice, and which recommends the former method.'

The following is a statement by M. L. Pasteur of a new process for making beer so as to render it unchangeable:—

'Every one knows that beer is very liable to change; during the summer it will deteriorate in a month or six weeks.

'The wort used in the preparation of beer is very difficult to preserve. At a high temperature the wort of beer, in the course of a few hours, especially in stormy weather, will go through a great many different alterations. The alterations in the wort of beer have such an influence in the making of this drink, that it becomes absolutely necessary for the brewer to use the greatest precautions to guard against its disastrous effects. A low temperature is essential to the preservation of the wort of beer, and sometimes ice is employed. What, then, are these alterations which rule over the process of fermentation, and why should not means for combating them be found, more simple and more economical than those already in use? I have devised a new process of cooling and of fermentation, and the following are some of the results of my work:—

'1. The changes in beer are due to the development and the multiplication of microscopical organisms which I will call *sick fermentation*.

'2. The germs of this fermentation are carried by the air, and by the utensils in use, &c.

'3. Whenever the beer does not contain these living germs, which are the cause of its deterioration, it becomes unchangeable, at whatever temperature it is made.

'4. I can show that by the employment of certain processes in brewing, all the malt, all the yeast, and all the beer receive the germs of diseases proper to these substances.

'Let us take a beer that has been made according to the usual process employed in England, France, or Germany. Let us expose it in closed bottles at a temperature of from 15° to 25° C. It constantly happens that this beer in the course of a few weeks will be unfit for use. Its preservation is only possible, in some exceptional cases, by the addition of a quantity of hops superior to those generally used. At the time that the change is taking place, the microscopical organisms will make their appearance and multiply. What gives birth to these organisms?

'My studies have proved that the most changeable organic liquids, such as blood, the juice of the grape, &c., can be preserved indefinitely, without any change whatever, when exposed to the ordinary air, but air deprived of those particles of dust which it always carries about, and which are deposited on the surface of all the objects of nature. The contradiction that this proposition has raised will soon be overcome by a simple experiment which I have often shown before the Academy, and which consists in shutting up the liquids in vessels, having an opening placed at the end of a winding-tube, but so far removed from the liquid contained in the vessels that the particles of dust held in suspension in the air cannot come in contact with the liquid.

'That settled, let us prepare a series of vessels where the wort of beer may be perfectly preserved for weeks, months, or years; then, by a very simple process, which is the employment of a second tube like that of which I have spoken, let us introduce separately in each of these a drop from all the beers of commerce. As the clearest beer always contains some globules of yeast in suspension, the alcoholic fermentation will be established, and the wort of beer contained in each of them will in a few days undergo some transformation. Or, if the experiment be carried on in a stove at summer heat, and allowed to remain some weeks, the globules of ordinary alcoholic yeast will soon be associated, in numbers more or less considerable, with the *sick fermentation* of which I have before spoken. The germs of this fermentation exist in all the beers of commerce. This interpretation of facts is confirmed by the following results:—

'If a beer deprived of all the germs of disease is prepared, and wort that has not undergone any change is then added, a beer is obtained, in all cases, that will be perfectly healthy and free from any living organisms excepting those which constitute the globules of the alcoholic yeast. This experiment proves the correlation that exists between the changes in beer and microscopical organisms.

'From my studies on wine I have deduced that wine is not a liquid that changes of itself; the same thing is true of beer. The causes of the changes come from without. The only modifications that are spontaneous are the changes of a chemical order, sometimes from contact with oxygen, or from the effects of growing old, and a reaction taking place between the constituent elements.

'These changes in the nature of a liquid have nothing to do with disease. When any change takes place in beer, such as becoming *thin*, *putrid*, *sour*, strange organisms are developed in it, and these organisms would not be there unless the germs had existed originally in the liquid mass. Beer might be carried into the hottest countries if these germs of disease did not exist in it.

'Nothing can better demonstrate that the changes in the wort of beer are due to microscopical organisms, than the fact that if this wort has been previously boiled, or any other means used to destroy the germs of vitality, no change whatever takes place when the wort is brought into contact with the air.

'Concerning the yeast of beer, the facts do not present themselves with such simplicity as when dealing with the wort or the beer. The latter are dead substances; the yeast, on the contrary, is living. Very skilful botanists, amongst whom are M. Turpin, M. Hoffmann, and M. Trécul, have arrived at the conclusion from their own observations, that the yeast of beer gives birth to different mildews, amongst others the *Penicillium glaucum*.

'It is well known that the yeast of beer is liable to great changes, and these changes are always accompanied by the development of microscopical organisms. From whence do these organic productions come? Are they a modification of the cellules of the yeast in the conditions of the new life, or do the organisms find their origin in the dust from the objects with which the yeast has been in contact?

'I prepared some yeast deprived of all germs foreign to its own nature, and I can therefore give an account of the changes it underwent when brought in contact with the pure air. In this condition the yeast appeared perfectly inert, like a mineral substance, giving rise to no fermentation whatever; it did not even give birth to the *Mycoderma vini*, which is so like the yeast in its structure, its form, and mode of development.

'If one understands the preceding principles, it is easy to see that beer, which is no longer exposed to changes, may be made at any temperature.

'We must consider, first, that the beer is forced to come to a state of ebullition when it is still in the form of extract of malt with hops; during this process all the germs of disease are destroyed. The hot wort is enclosed in a vat, and then cooled either by contact with the air or by a current of water. The germs can be easily kept out during the process of cooling, by allowing carbonic acid gas to enter one of the tubes, while the other tube allows the excess of gas to escape. It must then be put to the operation of fermentation, as much as possible sheltered from the common air, and using a yeast that is perfectly pure. Where is this pure yeast to be found?

'I have observed that even in the best breweries the yeasts are always impure, because this impurity is due to the processes now in use. The employment of impure yeast renders the making of beer in closed vessels impossible, and even exaggerates the defects of the present process, if closed vessels are employed.

'The physiological difference between yeast and the *sick fermentation* is worthy of attention. While the yeast of beer lives and multiplies in contact with the air more rapidly than in the presence of carbonic acid gas, the germs of disease, on the contrary, are cramped in their life by the presence of oxygen gas. The result is, when the operations are carried on, sheltered from the air, the accessory fermentations develop with facility, while the alcoholic fermentation is slackened, because the yeast of beer cannot spread in contact with the oxygen—a new source of activity. All the attempts to make beer in closed vessels have failed up to the present time. But these effects arise from the impurity of the yeast commonly used by brewers. For if the yeast does not contain germs foreign to its nature, they can neither appear spontaneously nor by a transformation in the yeast. Such are the principal motives for the employment of a pure yeast, especially in my process. Several methods can be employed for the production of pure yeast, but it would take too long to explain the means I have adopted; it will suffice to say that the difference of the action of the oxygen of the air on the yeast and on the sick fermentation should be profited by.

'I put then into the wort pure yeast; the fermentation takes place, and being effected, sheltered from the air, or in the presence of limited quantities of pure air, it does not give alien fermentations, because the yeast of beer only was sown; and whatever is advanced on the subject of possible transformation of yeast into *Mycoderma aceti*, common mildews, &c., or *vice versâ*, is erroneous. Lastly, when the beer is finished, it can be treated in the ordinary manner, without any fear of the contact with the air producing any serious inconveniences, because the beer finished or on the point of being finished, does not offer favourable conditions for receiving the germs of disease; at least, those which do not want the oxygen of the air to live and multiply. As to the others, which are the *Mycoderma aceti* and the *Mycoderma vini*, simple precautions enable them to be easily avoided.

'Beer made under the conditions I have shown, and placed according to custom in casks recently tarred, or put in bottles, may be preserved for an indefinite time, even in a stove of from 20° to 25° C. Far from suffering any change by time, it appears rather to become softened by the effect of old age, in the same manner as wines which can be preserved without deteriorating. One can now understand the possibility of suppressing the use of ice during and after the fermentation, since the new process is applicable in all temperatures. The temperature of the cellars where the beer is preserved should be not lower than 10° to 12° C.; a temperature that can be obtained, even in summer, in temperate climates, by having the cellars a moderate depth.'

FERMENTATION PANARY. See Bread.

FERRIC ACID. (FeO^3.) This compound having been prescribed as a source of supplying oxygen to persons confined in diving-bells and in mines, by M. Payerne, claims notice in a practical work. M. Frémy is the discoverer of this acid, which he obtains in the state of ferrate of potash, by projecting 10 parts of dry nitre in powder upon 5 parts of iron filings, ignited in a crucible; when a reddish mass, containing much ferrate of potash, is formed. The preparation succeeds best when a large crucible, capable of holding about a pint of water, is heated so strongly that the bottom and a couple of inches above it, appear faintly, but distinctly red, in which state the heat is still adequate to effect due deflagration without decomposition. An intimate mixture of about 200 grains of *dried* nitre with about one-half its weight of the finest iron filings, is to be thrown at once upon the side of the crucible. The mixture will soon swell and deflagrate. The crucible being taken from the fire, and the ignited mass being cooled, is to be taken out with an iron spoon, pounded, and immediately put into a bottle, and excluded from the air, from which it would speedily attract moisture, and be decomposed. It is resolved by the action of water, especially with heat, into oxygen gas, peroxide, and nitrate of iron. This acid has not been obtained in a free state; it appears indeed to be scarcely capable of existing alone, decomposing, as soon as liberated, into oxygen and ferric oxide.—*Graham.*

Mr. J. D. Smith prepares the ferrate of potash by exposing to a full red heat a mixture of finely-powdered peroxide of iron with four times its weight of dry nitre. It has an amethyst hue, but so deep as to appear black, except at the edges. Oxygen is rapidly evolved by the action of sulphuric or nitric acid upon its solution. He considers the atom of iron to exist in this compound associated with 3 atoms of oxygen, or double the proportion of that in the red oxide. Hence 52 grains of pure ferric acid should give off 12 grains of oxygen, equal to about 35 cubic inches; but how much of the ferrate of potash may be requisite to produce a like quantity of oxygen cannot be stated, from the uncertainty of the operation by which it is produced.

FERRICALCITE. A term sometimes applied to those limestones which contain a large percentage of oxide of iron. The iron ore—'Red ore,' of the Churnet Valley, North Staffordshire—may be regarded as a striking example.

FERRIC SALTS. Salts of ferric oxide, or peroxide of iron. Thus the sulphate of sesquioxide of iron may be called ferric sulphate.

FERROCYANIDES. The compounds of the radical ferrocyanogen. The latter radical is bibasic; when, therefore, it combines with hydrogen to form ferrocyanic acid, it takes up two atoms. These two atoms of hydrogen can be replaced by metals as in ferrocyanide of potassium or prussiate of potash, as it is commonly called. See Prussiate of Potash. Ferrocyanogen consists of C^6N^3Fe, which may also be written Cy^3Fe, or, for brevity's sake, Cfy.

The modes of preparing the ferrocyanides differ, according as the resulting substance is soluble or insoluble in water. The soluble salts, such as those with alkalis, are prepared either by neutralising hydroferrocyanic acid with the proper metallic oxide, or by boiling prussian blue with the oxide, the metal of which it is intended to combine with the ferrocyangen. Other methods may also be adopted in special cases. The processes for preparing the ferrocyanides of the alkali-metals on the large scale will be described in the article Prussiate of Potash.

When the ferrocyanide is insoluble in water, it may be prepared by precipitating a salt of the metal with ferrocyanide of potassium. Thus, in the preparation of the reddish or purple ferrocyanide of copper,

$$2(CuO,SO^3) + K^2Cfy = Cu^2Cfy + 2(KO,SO^3).$$

The above equation written in full becomes:—

$$2(CuO,SO^3) + K^2C^6N^3Fe = Cu^2C^6N^3Fe + 2(KO,SO^3).$$

$$\mathbf{2(CuSO^4) + K^4C^6N^6Fe = 2(K^2SO^4) + Cu^2C^6N^6Fe.}$$

Ferrocyanide of potassium is much used as a test for various metals, in consequence of the characteristic colours of the precipitates formed with many of them. The principal ferrocyanides, with their colours and modes of preparation, will be found in the following list:—

Ferrocyanide of aluminium.—An instable compound formed by digesting hydrate of alumina with ferroprussic acid.

Ferrocyanides of antimony and arsenic.—Neither of these salts is known in a state of purity.

Ferrocyanide of barium.—This salt may be prepared by boiling prussian blue in slight excess with baryta-water, and evaporating to crystallisation.

Ferrocyanide of bismuth.—When a solution of ferrocyanide of potassium is added to a solution of a salt of bismuth, a yellow precipitate is obtained. It becomes of a greenish tint on keeping for some time.

Ferrocyanide of cadmium may be obtained as a white precipitate on adding a solution of ferrocyanide of potassium to a soluble salt of cadmium.

Ferrocyanide of calcium may be prepared in the same manner as that of barium, but, owing to the sparing solubility of lime in water, we must substitute cream of lime for baryta-water.

Ferrocyanide of cerium is a white salt only slightly soluble in water. Its properties are very imperfectly known.

Ferrocyanide of chromium.—The protochloride of chromium gives a yellow precipitate with ferrocyanide of potassium.

Ferrocyanide of cobalt.—Salts of cobalt give a pale blue precipitate with ferrocyanide of potassium. It appears to decompose on keeping, as its colour becomes altered.

Ferrocyanide of copper.—When ferrocyanide of potassium is added to a solution of subchloride of copper, a white precipitate appears, which, on exposure, becomes converted into a purplish red substance, apparently identical with the ordinary ferrocyanide of copper which falls down on the admixture of salts of the protoxide of copper with solutions of ferrocyanide of potassium.

Ferrocyanide of glucinum may be obtained, according to Berzelius, under the form of an amorphous varnish, by decomposing ferrocyanide of lead with a solution of subsulphate of glucina.

Ferrocyanide of hydrogen constitutes ferroprussic acid.

Ferrocyanide of iron, or *prussian blue.*—This salt exists in several conditions, according to the mode of preparation. The ordinary salt is formed by adding a solution of ferrocyanide of potassium to a solution of a persalt of iron.

Ferrocyanide of lead is procured as a white precipitate by adding a solution of ferrocyanide of potassium to a salt of lead.

Ferrocyanide of magnesium is probably best prepared by neutralising ferroprussic acid with magnesia or its carbonate. It forms a pale yellow salt.

Ferrocyanide of manganese may be obtained as a white precipitate, on adding ferrocyanide of potassium to a solution of pure protochloride or protosulphate of manganese.

Ferrocyanide of mercury.—This compound cannot be obtained in a state of purity by precipitation. It has not been sufficiently examined.

Ferrocyanides of molybdenum.—Molybdinous salts give, with ferrocyanide of potassium, a dark brown precipitate, soluble in excess of the precipitant.

Ferrocyanide of nickel is obtained under the form of a pale apple-green precipitate, on addition of prussiate of potash to a salt of nickel.

Ferrocyanide of silver.—Ferrocyanide of potassium gives a white precipitate with silver salts.

Ferrocyanide of sodium may be formed by the action of caustic soda on prussian blue.

Ferrocyanide of strontium can be procured precisely in the same manner as the corresponding barium salt.

Ferrocyanide of tantalum has probably never been obtained pure. Wollaston found that tantalic acid (dissolved in binoxalate of potash) gave a yellow precipitate with prussiate of potash.

Ferrocyanide of thorium.—A white precipitate is produced by the action of solution of prussiate of potash on salts of thorium.

Ferrocyanide of tin.—Pure salts of tin, whether of the per- or prot-oxide, give white precipitates with ferrocyanide of potassium.

Ferrocyanides of titanium.—Solutions of titanates give a golden brown precipitate when treated with solution of ferrocyanide of potassium.

Ferrocyanides of uranium.—The protochloride gives a pale, and the perchloride a dark reddish brown precipitate with ferrocyanide of potassium.

Ferrocyanide of vanadium.—Salts of vanadic oxide give pale yellow, and of vanadic acid rich green precipitates with prussiate of potash.

Ferrocyanide of zinc cannot be prepared by precipitation. It may be obtained in the form of a white powder by the action of oxide or carbonate of zinc on ferroprussic acid.—C.G.W. See Watts's 'Dictionary of Chemistry.'

FERROCYANOGEN, a compound radical, in which the metallic iron is an important constituent. See previous article, and Watts's 'Dictionary of Chemistry.'

FERROUS SALTS. Salts of ferrous oxide or protoxide of iron. Thus green vitriol may be called ferrous sulphate, instead of sulphate of protoxide of iron. In like manner ferrous chloride is synonymous with protochloride of iron.

FERRUGINOUS QUARTZ. A quartz stained by iron, an intermediate state between quartz and jasper. See JASPER.

FETT-STEIN, Ger. (*Fat Stone.*) A variety of Nepheline, one of the Scapolite family, so called from its resinous lustre.

FEVERFEW. The popular name of the *Pyrethrum Parthenium*, much used amongst the peasantry as a remedy for fevers. It contains some tannic acid, and has been employed in Germany in tanning and currying leather. The *Pyrethrum officinale* is the Pelletory of Spain. See PYRETHRUM.

FIBRES, or **FIBROUS BODIES.** From time to time numerous grasses, fibrous barks, and other substances of a similar character, have been introduced into commerce; a few of these only have been found available for manufacture. It is, however, deemed of interest to describe briefly some of these. Some of the more important vegetable fibres will be fully noticed under their respective heads. (See COIR; ESPARTO; FLAX; HEMP; PHORMIUM, &c.)

China Grass.—This fibre is obtained from *Urtica* (*Bœhmeria*) *nivea*, which grows abundantly in China, and in various parts of our Indian empire. The samples which have been imported are principally obtained from Canton and Hong-Kong. In 1849, Messrs. Wright and Co. obtained a patent for the preparation of this fibre. Their process consisted essentially of boiling the stems in an alkaline solution, after they had been previously steeped for 24 hours in cold water, and for 24 hours in water at 90° Fahr. The fibre is then thoroughly washed with pure water, and finally subjected to the action of a current of high-pressure steam till nearly dry.

Callooee Hemp or Rhea.—This fibre is usually confounded with China grass; but there is little doubt they are obtained from two different kinds of urtica; the China grass from the *Urtica nivea* of Willdenhow; the Callooee Hemp, *Kalmoi*, or *Rami*, of Sumatra, and the *Rhea*, from the *Urtica tenacissima* of Roxburgh. The plant producing the Callooee hemp was introduced from Bencoolen to Calcutta in 1803, where, under the care of Dr. Roxburgh, it was for many years cultivated in the Botanic Gardens. In 1814, a quantity of the Callooee hemp was imported into England, and properly tested; its practical value was thought so highly of, that the Society of Arts awarded a silver medal to Capt. James Cotton, of the East India Company, who introduced it. 'The chief obstacle which interfered, however, with its use, was the difficulty which was found to exist in the preparation of the fibre from the stems of the plants; none of the processes usually adopted with flax or hemp were found to be at all suitable to them; and the rude, wasteful, and imperfect means employed by the natives in preparing the fibre for the manufacture of twine, thread, and fishing nets, by the mere process of scraping, were wholly inapplicable on a large scale, and gave besides only a very inferior result. When macerated or retted in water, it was found that the fibre itself was more easily destroyed than the glutinous matter of the stem. During the last forty years, various attempts have been made to devise a good and cheap process for preparing this fibre, but hitherto without much success; and consequently, till quite recently, the cost of the fibre was such as to preclude its being brought into the market as a substitute for flax. But recent investigations have shown that the *Urtica tenacissima* and the *U. heterophylla* may be obtained in almost unlimited quantities in various parts of India; and a process which has been lately patented appears, to a very great extent, to have removed the practical difficulties which previously stood in the way of its employment by manufacturers; so that in a few years it is probable that the Callooee hemp will constitute an important addition to the fibrous materials employed in the arts.'—*Jurors' Report, Great Exhibition,* 1851.

Neilgherry Nettle (*Urtica heterophylla*).—This nettle appears to be remarkable beyond all others for its stinging properties. It is abundant in Mysore, flourishing in Alpine jungles. The Todawars prepare the fibre of this plant by boiling the stems in water, after which they readily separate it from the woody parts and then spin it into a coarse but very strong fibre. The Malays simply steep the stems in water for ten or twelve days, after which they are so much softened that the outer fibrous portion is easily peeled off.

Yercum Nar.—This is the native name of the fibres of the *Calotropis* (*Asclepias*) *gigantea*, a plant which grows wild, abundantly, in various parts of the Bengal and Madras Presidencies, and is used by the natives in the manufacture of cord called *Lamb-dore*, or *Tondee Coir*.

Aloe fibre, or *Nar*, the produce of the *Agave vivipara*, and other allied species. This is often called the *Silk grass fibre*.

Pine-apple fibre, sometimes called *Ananas flax*. This has been prepared in Java and at Travancore. Many fine specimens have been brought to this country.

Plantain fibre.—In the Government establishments of Ceylon this is extensively employed. Canvas and ropes are made of it. It is obtained from the *Musa textilis*. It is calculated that 8 cwt. per acre of this excellent fibre might be obtained.

Mahant bark.—Employed at St. Vincent's in the manufacture of fishing nets, common cord, and coarse lines for fishing.

New Orleans moss (*Tillandsia usneoides*), a substitute for horse-hair as a stuffing material for upholsterers. Sometimes the fibrous husk of the Indian corn is used for the same purpose, but it is more brittle than the moss.

Palm-tree fibre. These fibres are obtained from many varieties of the palm.

Grass fibre.—Many of the grasses are now being used in the manufacture of paper, and for other purposes.

The following tables by Dr. Roxburgh and Dr. Wright, afford much information as to the relative strengths of different kinds of fibrous substances. The first table gives experiments made by Dr. Roxburgh in 1804; some of the fibres were, however, probably imperfectly prepared:—

Common Name	Botanical Name	Breaking Weight
		lbs.
1. Hemp (English)	*Cannabis sativa*	105
2. Murga (Sanseviera)	*Alectris nervosa*	120
3. Aloe	*Agave Americana?*	110
4. Ejoo	*Saguerus Rumphii*	96
5. Donsha	*Æschynomone cannabina*	88
6. Coir	*Cocos nucifera*	87
7. Hemp (Indian)	*Cannabis sativa*	74
8. Woollet comal	*Abroma Augusta*	74
9. ———?	*Banhinia*	69
10. Sunn	*Crotolaria juncea*	68
11. Bunghi paat	*Corchorus olitorius*	68
12. Ghu nala paat	„ *capsularis*	67
13. ———?	*Hibiscus manihot*	61
14. Flax (Indian)	*Linum usitatissimum*	39

In 1808, Dr. Roxburgh made another series of experiments, of which the following table gives the result:—

Common Name	Botanical Name	Breaking Weight
		lbs.
1. Bowstring hemp	*Asclepias Sp.*	248
2. Callooee hemp	*Urtica tenacissima*	240
3. ———?	*Corchorus capsularis*	164
4. Sunn	*Crotolaria juncea*	160
5. Hemp (Indian)	*Cannabis sativa*	158
6. Donsha	*Æschynomone cannabina*	138
7. ———?	*Hibiscus strictus*	128
8. Musta paat	„ *cannabinus*	115
9. Bunghi paat	*Corchorus olitorius*	113
10. Plantain	*Musa*	79

Experiments were made some years ago by Dr. Wright on several well-known vegetable fibres when made into ropes. The following were the results:—

Common Name	Botanical Name	Breaking Weight
		lbs.
1. Yercum nar	*Calotropis gigantea*	552
2. Janapum	*Crotolaria juncea*	407
3. Cutthalay nar	*Agave Americana*	362
4. Cotton	*Gossypium herbaceum*	346
5. Maroot	*Sansevicra zeylanica*	316
6. Pooley mungu	*Hibiscus cannabinus*	290
7. Coir	*Cocos nucifera*	224

The defect of all these fibres is, as it regards their use in weaving, that they break the knot, and in all weaving processes the fibres require frequent joining.

FIBRE, VEGETABLE, called also LIGNINE (*Ligneux*, Fr.; *Pflanzenfaserstoff*, Ger.), is the most abundant and general ingredient of plants, existing in all their parts, the root, the leaves, the stem, the flowers, and the fruit; amounting in the compact wood to 97 or 98 per cent. It is obtained in a pure state by treating sawdust successively with hot alcohol, water, dilute muriatic acid, and weak potash-lye, which dissolve, first, the resinous; second, the extractive and saline matters; third, the carbonate and phosphate of lime; and, lastly, any residuary substances. Ligneous fibres, such as sawdust, powdered barks, straw, hemp, flax, linen, and cotton cloth, are convertible by the action of strong sulphuric acid into a gummy substance analogous to *dextrine*, and a sugar resembling that of the grape.

Much attention has of late years been directed to the conversion of vegetable fibre into paper. See PAPER.

'*Recognition of vegetable and animal fibres in spun and woven tissues.*—Kopp has lately examined the chemical behaviour of animal and vegetable fibres with a view to their detection in mixed fabrics. Cellulose (vegetable tissue of whatsoever origin) resists boiling aqueous solutions of an alkali, but is readily attacked by sulphuric, nitric, and hydrochloric acids. Cotton can be soaked without material injury in cold water containing 5 to 10 per cent. of acid; but, if heated, the cotton is disintegrated, and rapidly converted into gum and sugar. Fuming nitric acid and mixtures of concentrated sulphuric and nitric acids do not dissolve cellulose, but convert it into gun-cotton. Ammonia has no action on cotton and hemp at any temperature. The cuprate of ammonia, an ammoniacal solution of copper, sometimes spoken of as 'Schweitzer's test,' dissolves cotton, hemp, and flax. Vegetable fibre has but little affinity for artificial colours. If steeped in their solutions, it takes merely a stain, which is easily removed by soap. Cellulose is not easily destroyed by chlorine or the hypochlorites. If burnt, it yields no particular smell. Wool, on the other hand, resists acids, even when strong and hot, but is dissolved by alkalis. As it contains sulphur, sulphide of sodium is found on steeping it in soda, which gives a black precipitate with the acetate of lead. Nitric acid turns it yellow. The effect of chlorine and the hypochlorites is very similar. Schweitzer's test has no action in the cold, but dissolves it when hot. If burnt, it gives off the well-known smell of burnt horn. The affinity for artificial colours is very great, even without the aid of mordants. Silk, if burnt, smells like wool. It is attacked by strong and hot acids more readily than wool. Nitric acid turns it yellow. Dilute acids have little immediate action. Alkalis dissolve it; but, as no sulphur is present, there is no formation of a sulphide, and the acetate of lead does not yield a black precipitate. Dilute alkalis affect it, but without solution. Ammonia has no action. In Schweitzer's test it dissolves like cotton. Its affinity for colours is like that of wool. To detect cotton, hemp, flax, and jute in mixture with wool and silk, boil the sample in an aqueous solution of soda containing 10 per cent. of hydrate of soda. Wool and silk dissolve, while the vegetable fibres remain unacted upon. The whole is thrown upon a cotton filter, and the undissolved matter is then washed with hot water, and afterwards with water acidulated with 5 per cent. of hydrochloric acid, to which, if the residue is black or dark-coloured, a few drops of chlorine-water are added. Meantime, the original alkaline filtrate can be tested for wool with the acetate of lead. If a white precipitate is formed, which dissolves on stirring, silk alone is present. A black precipitate indicates wool. The nitro-peroxide of sodium gives a violet colour if wool be present. If the tissue is deeply coloured it may be cut up and steeped for fifteen to twenty minutes in a mixture of two measures of concentrated sulphuric and one of fuming nitric acid. Wool, silk, and colouring matters are destroyed, while the cellulose is converted into gun-cotton. White and pale mixed tissues may be tested by their affinity for colours. Cleanse and rinse thoroughly in water to remove starch and similar dressings; boil for ten minutes in water containing 2 per cent. carbonate of soda and a little soap; then rinse in hot water; steep five to ten minutes in water at 50° to 60° C., containing 2 per cent. sulphuric acid, and wash again. In the meantime prepare the colour-bath by dissolving a few decigrammes of magenta in 28 to 30 cubic centimeters of water; heat to boiling, and during ebullition add to it, drop by drop, caustic soda till a pale rose colour only remains in the liquid; take off the fire, and put in the sample; after some minutes take out to dry. Silk and wool are dyed while the vegetable fibres remain colourless. Wool may be detected in silk by the presence of sulphur: if it is immersed for a short time in plumbate of soda, the silk will be colourless and the wool black. Or a piece of the tissue, two centimeters square, may be boiled in 10 to 12 cubic centimeters of Schweitzer's test: in five to ten minutes the silk will be dissolved. If the silk is black add double the volume of Schweitzer's test, and soak ten to twelve minutes; after taking out the undissolved wool the liquid, quickly neutralised with nitric acid, gives no precipitate if silk is only present, but cellulose is precipitated.'

FIBRIN. Recent researches have shown that the substance known as *animal fibrin* is formed by the union of two distinct albuminous principles, termed, by A. Schmidt, the *fibroplastic* and *fibrinogenous substances.* Fibrin may be obtained in a pure state by agitating or beating new-drawn blood with a bundle of twigs, when it will attach itself to them in long reddish filaments, which may be deprived of colour by working them with the hands under a streamlet of cold water, and afterwards freed from any adhering grease by digestion in alcohol or ether.

Fibrin, thus obtained, is solid, white, flexible, slightly elastic, insipid, inodorous, denser than water, but containing $\frac{4}{5}$ths of its weight of it, and without action on litmus. When dried, it becomes semi-transparent, yellowish, stiff, and brittle: water restores its softness and flexibility. 100 parts of fibrin consist of 53·36 carbon, 19·68 oxygen, 7·02 hydrogen, and 19·31 nitrogen. As the basis of flesh, it is a very nutritious substance, and is essential to the sustenance of carnivorous animals.

Fibrin, Vegetable. A nitrogenous substance very similar to animal fibrin. It occurs in the gluten prepared from wheaten flour, and in most kinds of grain.

FIBROLITE. A silicate of alumina occurring in fibrous or columnar forms, associated with corundum, in the Carnatic. Many of the pre-historic stone celts found in Switzerland, France, and the Channel Islands, are said to be wrought in fibrolite.

FIBROUS RESIDUES. *New Process for separating the Animal from the Vegetable Ingredients.*—Mr. F. O. Ward was an exhibitor in 1862 of this process, which received the high approval ot the jury of Class II., to whose attention it was especially directed. Mr. Ward has been associated with Captain Wynants in carrying out this interesting and useful discovery. These gentlemen placed in the hands of Dr. Hofmann a concise description of their process, which we give in Mr. Ward's words:—

'There is a class of rags of intermediate character, neither wholly composed of vegetal matter, nor exclusively of animal origin. I allude to the residue of fabrics containing both these classes of materials interwoven.

'Such are the rags of so-called union fabrics, wool and cotton; of the silk and alpacas woven with a cotton warp; and of the numerous varieties of stuffs, merinos, &c., which are more and more extensively manufactured every year. Such also are the rags known technically as "seams;" being the clippings which fall from woollen rags under the scissors of the sorters, who prepare them for the machine by which they are torn into "rag-wool." These pieces are cut off and withheld from the tearing machine, precisely because they have a sewing thread running along them, or portions of cotton lining adherent, or other vegetal admixture. In rags of this class, each of the materials present interferes with the use, and diminishes the value, of the other. The paper-maker cannot advantageously work off the cotton because of the wool, which would sprinkle his sheets with coloured specks. The rag-wool manufacturer, on the other hand, cannot advantageously convert the wool to his purpose because of the cotton, which would show amidst the wool when dyed, as filaments of paler hue.

'To meet this difficulty two plans have been of late years proposed, viz., the disintegration of the cotton by means of dilute acid, in order to the separate recovery of the wool; and the dissolution of the wool by means of caustic alkali, in order to the separate recovery of the cotton.

'Both these plans, it will be observed, involve the sacrifice of one material for the recovery of the other; for its recovery in the case of the wool, much impaired in strength by acidulation: in the case of the cotton at a considerable expenditure of the alkaline solvent.

'The process now under review was devised in the year 1857, with special reference to this class of mixed rags; as also to the unsortable residuum which remains under the name of "land rags," after the sorting of a heap has been pushed as far as economically possible. The object kept in view was to turn to account not one only, but both the classes, animal and vegetable, of intermingled ingredients; and this result is accomplished by the new method without the aid of the acid or alkaline disintegrants heretofore employed; without, in fact, any chemical agency stronger or more costly than that of water, applied in the form of a high-pressure steam atmosphere. This process is so extremely simple that its nature, and the mode of practising it, can be explained in half a dozen sentences.

'The mixed rags, or other analogous mixed residue, are introduced into an ordinary autoclave digester, and there kept for about three hours (more or less) surrounded with an atmosphere of steam heated to a pressure of from three to five atmospheres. The exact pressure and temperature requisite vary with the materials under treatment; wool requiring a higher temperature than leather, for example, and silk than wool. The materials condense a proportion of the steam and absorb its heat. The joint action of the moisture and heat is to convert the animal matter into a friable substance, which, however, still retains its original form and aspect. Thus the wool of mixed rags retains after digestion the same fibrous appearance that it had before, though it crumbles to powder when handled. It will be understood that ordinary crushing and beating machinery readily reduces this brittle coal-like product to dust, and detaches it from the interwoven vegetable matter, which preserves its fibrosity unimpaired. The beater is provided with a sieve, which retains the vegetable fibre, but suffers the animal dust to fall through. Ultimately the vegetable fibre is projected from the machine as a paper-material ready for use; the animal dust, meanwhile, being propelled by an Archimedian screw, and raised by a Jacob's-ladder till it reaches the mouths of the sacks successively placed for its reception.

'In the details of this process, and in the fuel- and labour-saving arrangements for drying the rags and handling them in their passage through the several departments of the factory, there are peculiarities not bearing on the broad principles of the plan, though essential to its successful prosecution. Special precautions of this kind, as they are learned, point by point, by costly manufacturing experience, cannot, with propriety, be divulged; nor, indeed, would they interest any reader not specially charged with the conduct of the operation. I pass on, therefore, to a brief consideration of the products.

'The fibrous product, or paper-material, presents but few peculiarities for notice. It consists principally of cotton, but usually contains also a percentage of flax and hemp, which increase its tenacity and value. The fibre is, for the most part, set free in the form of long parallel threads, the warp of the fabrics treated; but it also presents many shreds of an ordinary rag—portions, doubtless, of the calico with which the stuffs were lined. As the cotton warps of union fabrics are usually dyed in fast colours, often black, and as they are apt to retain a small percentage of the altered wool-dust, they require to be boiled under somewhat higher pressure than ordinary coloured rags; with which, in other respects, they are pretty much on a par as paper-material. Until the right pressure for boiling them had been ascertained, it was found difficult to bleach them to perfect whiteness; and some early failures, thus occasioned, rendered the material unpopular among paper-makers. Nevertheless, when properly manipulated, this material produces excellent white paper, as the samples exhibited show.

'The animal product, being an entirely novel article, requires particular attention. It issues from the beating machine as a dark-coloured powder, intermingled with small lumps of the same substance, which lumps are sifted out and crushed. This powder, as practically produced, with the dust and grit of the rags in it, contains, on an average, nearly 12 per cent. of nitrogen; a proportion corresponding to 14·5 per cent. of ammonia. The nitrogen exists to a small extent as ready-formed ammonia held in combination with brown acids—ulmic and humic—developed during the process. The bulk of the nitrogen, however, is present, not in the form of ammonia, but as a constituent of the wool-product itself. This organic compound is partially soluble, and more so as more moisture is supplied to the rags during their digestion. As ordinarily produced, it is a manure of highly ammoniferous power, the whole of its nitrogen being liberated as ammonia, under the influences with which it meets in the soil. The rate of this development holds a happy medium between that of ordinary woollen rags, which are reckoned too "slow" a manure, and that of guano, which is often as much too "sudden." The farmer desires an equable as well as a copious development of ammoniacal plant-food, whereof abrupt and superabundant supplies are apt, as he expresses it, to "burn" the roots; which have, moreover, subsequently to endure privation of the very food thus worse than wasted.

'The new manure may, I think, be regarded as being for plants what moderately-cooked food is for animals; the artificial preparation being, in both cases, carried just far enough to leave Nature her appropriate share of the work. As, however, wool, leather, hair, silk, and the like, are not rich in phosphatic salts, an admixture of these, whether in the form of bone-ash, bone, or coprolitic superphosphate, Kouria Mouria guano, or the like, improves the manure; producing, in fact, a fertilising compost, which for general use leaves nothing to be desired. Of course, for soils specially deficient in any particular ingredient, and for crops requiring a more than average supply of some one element, special additions are made to the manure; which become thus turnip manure, cereal manure, bean manure, &c., as desired.

'Another property may also be mentioned here, as giving to this manure, in one particular, a considerable advantage over guano. It is that whereas guano is liable, while in store, to undergo spontaneous decomposition, whence arises the loss of much volatile alkali, the new wool-product, on the contrary, manifests no such tendency, but remains perfectly stable at all ordinary temperatures and in all states of the weather, an advantage which it doubtless owes to the high temperature at which it is made. This manure may, therefore, be warehoused for any length of time, and during any climatic vicissitudes to which it may be exposed either at home or in tropical regions.

'This product is distinguished in commerce as "Ulmate of Ammonia," a name which, though not perhaps strictly correct, serves to indicate two of its most notable constituents—acid and alkaline—in the combination which they really affect.

'Its analysis, by Professor Voelcker, of the Royal Agricultural College, Cirencester, is subjoined:—

Moisture	11·59
Organic matter[1]	73·89
Ammonia in state of ulmate	2·05
Oxides of iron and alumina and phosphoric acid	2·52
Carbonate of lime	2·22
Alkalis and magnesia	1·26
Insoluble siliceous matter	6·47
	100·00

'The relative proportion of the manurial and fibrous products resulting from the working of this process varies, of course, with the nature of the materials treated. Some mixed *dèbris* are rich in vegetal, others in animal, fibre. Average mixed rags, however, contain these ingredients in pretty equal proportions; and in all cases the sum of the weights of the two products, fibrous and pulverulent, equals the weight of the raw materials, so that the process involves no waste.

'The pecuniary profit of the operation is liable, of course, to vary from time to time with the cost price of the raw material, and labour employed, and the selling price of the products, as also with the varying activity of trade, and the intervals of commercial depression. On this point it may suffice to observe that a process founded on correct principles, and yielding, under skilful conduct, good chemical results, is generally found to succeed also, on the average, as a commercial enterprise, if it be soundly and vigorously administered. The new manufacture is carried on at large works, built expressly for the purpose, on the left bank of the Thames, at Grays, Essex, where machinery, adequate to treat about 12 tons of rags per diem, has been fitted up. A large paper-mill has also been erected on the opposite side of the river, at Dartford, to convert the fibrous product into paper. The ulmate is for the most part sold to manure manufacturers, who use it as the nitrogenous ingredient of their several fertilising composts. It is, therefore, employed by many farmers who are not aware of the fact.

'With reference to the origination of this process, the separability of animal from vegetal matters by the peculiar means indicated above, first occurred to the exhibitor, and was communicated by him to his friend Captain Wynants during the course of experiments carried on by them jointly for the attainment of a different end, viz. the total reduction to manure of certain forms of waste. The modified design thus originated was worked out by both conjointly; and it is the wish of the associates that any credit which an indulgent appreciation may connect with its success should be understood as attaching equally to both. Their highest ambition as to this process will be satisfied should the means employed therein be regarded as simple and cheap, yet efficacious to their appointed end; that end being the recovery, from

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[1] Containing—

Nitrogen	10·24
Corresponding to ammonia	12·43
Total quantity of nitrogen	11·93
Corresponding to ammonia	14·48

mixed fibrous residua, under somewhat difficult conditions, of unquestionably useful products.'

FICHTELITE. A resinous hydrocarbon occurring in fossil pine-wood from the Fichtelgebirge in Bavaria.

FICTILE MANUFACTURE. See Pottery, &c.

FICUS. The fig. The species of this genus are of considerable number, and all of them are inhabitants of warm countries. Most of the species yield a milky juice containing caoutchouc. The *Ficus elastica* is the India-rubber bearing tree; the *Ficus indica*, the banyan tree; the *Ficus religiosa*, the pippul tree or sacred fig of India; the *Ficus sycamoris*, an Egyptian tree, probably the sycamore of the Bible; and the *Ficus carica*, the common fig.

FID. A tapered wooden pin used by seamen in splicing large ropes. It is also the name of an iron support passed through a hole in the heel of a mast.

FIDDLE BLOCK. A block shaped like a fiddle. It has two sheaves, one over the other; the lower one smaller than the upper.

FIDDLE STRINGS. The catgut cords stretched across a violin; fastened at the ends and raised by the bridge. See Catgut.

FIDDLE WOOD. A West-Indian timber tree, the *Citharexylon melanocardium*, much used for mills, carriage-wheels, &c.

FIG-WORT. The fig-wort family (*Scrophulariaceæ*) form a natural order of dicotyledonous plants, the species belonging to which are herbs, abounding most in temperate climates, but also found both in tropical and arctic regions. The leaves are generally exstipulate, or the stipules are very small. The juice of these plants possesses very varied properties. In some it is watery. In others, as *Verbascum*, it is mucilaginous. In the *Veronicæ* it is bitter, as it is also in *Scrophularia* and some others. In the *Pediculariæ* and *Gratiolæ* it is astringent; and in *Digitalis* it is highly narcotic. The genus *Scrophularia* is the type, and contains numerous species, which are principally natives of temperate climates, more especially in the Mediterranean region.

The common fig-wort, *S. nodosa*, may be taken as the type: a common plant on ditch-sides, woods, and moist places. Its root is swollen and knotty, and it was supposed to resemble scrofulous tumours of the neck. As in former times it was pretty generally believed that Nature thus pointed out the proper remedies for different diseases, this plant was immediately supposed to possess great virtues in cases of scrofula, and was largely used for that purpose externally. Hence the name for the plant, which was afterwards adopted for that of the genus. At the present day it is said to be used on the Continent, in form of an infusion as a wash, in cases of itch. *S. canina*, a native of Italy, is used in like manner as a cure for the mange in dogs. The flowers of *S. nodosa* contain generally a quantity of honey, and are remarkably attractive in consequence to wasps and bees. 'Flores vesparum deliciæ,' says Linnæus.

FIGURE STONE. A stone used by the Chinese for carving small figures. Some of it is the mineral called *agalmatolite*, and some merely *steatite*, or soapstone.

FILBERTS. The nuts of a variety of the Hazel, or *Corylus Avellana*.

FILE (*Lime*, Fr.; *Feile*, Ger.) is a well-known steel instrument, having teeth upon the surface for cutting and abrading metal, ivory, wood, &c.

When the teeth of these instruments are formed by a straight sharp-edged chisel, extending across the surface, they are properly called files; but when by a sharp-pointed tool, in the form of a triangular pyramid, they are termed rasps. The former are used for all the metals, as well as ivory, bone, horn, and wood; the latter for wood and horn.

Files are divided into two varieties, from the form of their teeth. When the teeth are a series of sharp edges, raised by the flat chisel, appearing like parallel furrows, either at right angles to the length of the file, or in an oblique direction, they are termed *single cut*. But when these teeth are crossed by a second series of similar teeth, they are said to be *double cut*. The first are fitted for brass and copper, and are found to answer better when the teeth run in an oblique direction. The latter are suited for the harder metals, such as cast and wrought iron and steel. Such teeth present sharp angles to the substance, which penetrate it, while single-cut files would slip over the surface of these metals. The double cut file is less fit for filing brass and copper, because its teeth would be very liable to become clogged with the filings.

Files are also called by different names according to their various degrees of fineness. Those of extreme roughness are called rough; the next to this is the bastard cut; the third is the second cut; the fourth, the smooth; and the finest of all, the dead smooth. The very heavy square files used for heavy smith-work are sometimes a little coarser than the rough; they are known by the name of rubbers.

Files are also distinguished from their shape, as flat, half-round, three-square, four-square, and round. The first are sometimes of uniform breadth and thickness throughout, and sometimes tapering. The cross section is a parallelogram. The half-round is generally tapering, one side being flat, and the other rounded. The cross section is a segment of a circle varying a little for different purposes, but seldom equal to a semicircle. The three-square generally consists of three equal sides, being equilateral prisms, mostly tapering; those which are not tapering are used for sharpening the teeth of saws. The four-square has four equal sides, the section being a square. These files are generally thickest in the middle, as is the case with the smith's rubber. In the round file the section is a circle, and the file generally conical.

The heavier and coarser kinds of files are made from the inferior marks of blistered steel. Those made from the Russian iron, known by the name of old sable, called from its mark CCND, are excellent. The steel made from the best Swedish iron, called Hoop L or Dannemora, makes the finest Lancashire files for watch and clock makers.

The steel intended for files is more highly converted than for other purposes, to give them proper hardness. It should, however, be recollected, that if the hardness be not accompanied with a certain degree of tenacity, the teeth of the file break, and do but little service.

Small files are usually made of cast steel, which would be used for all other kinds, if it were not for its high price. It is much harder than the blistered steel, and from having been in the fluid state, is entirely free from those seams and loose parts which are common to blistered steel.

The smith's rubbers are generally forged in the common smith's forge, from the converted bars, which are, for convenience, made square in the iron before they come into this country. The files of lesser size are made from bars or rods, drawn down from the blistered bars, and the cast ingots, and known by the name of tilted steel.

The file-maker's forge consists of large bellows, with coke as fuel. The anvil-block, particularly at Sheffield, is one large mass of millstone grit. The anvil is of considerable size, set into and wedged fast into the stone; and has a projection at one end, with a hole to contain a sharp-edged tool for cutting the files from the rods. It also contains a deep groove for containing dies or bosses, for giving particular forms to the files.

The flat and square files are formed entirely by the hammer. One man holds the hot bar, and strikes with a small hammer. Another stands before the anvil with a two-handed hammer. The latter is generally very heavy, with a broad face for the large files. They both strike with such truth as to make the surface smooth and flat, without what is called hand-hammering. This arises from their great experience in the same kind of work. The expedition arising from the same cause is not less remarkable.

The half-round files are made in a boss fastened into the groove above mentioned. The steel, being drawn out, is laid upon the rounded recess, and hammered till it fills the die.

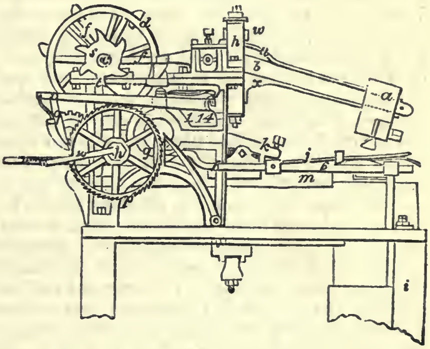
The three-sided files are formed similarly in a boss, the recess of which consists of two sides, with the angle downwards. The steel is first drawn out square, and then placed in a boss with an angle downwards, so that the hammer forms one side, and the boss two. The round files are formed by a swage similar to those used by common smiths, but a little conical.

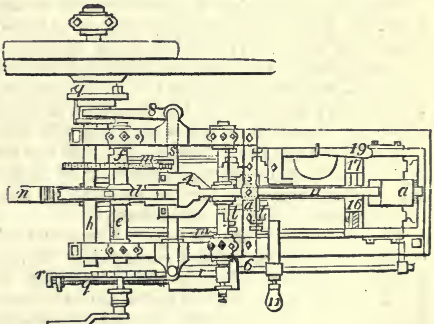
The file-cutter requires an anvil of a size greater or less, proportioned to the size of his files, with a face as even and flat as possible. The hammers weigh from one to five or six pounds. The chisels are a little broader than the file, sharpened to an angle of about 20 degrees. The length is just sufficient for them to be held fast between the finger and thumb, and so strong as not to bend with the strokes of the hammer, the intensity of which may be best conceived by the depth of the impression. The anvil is placed in the face of a strong wooden post, to which a wooden seat is attached, at a small distance below the level of the anvil's face. The file is first laid upon the bare anvil, one end projecting over the front, and the other over the back edge of the same. A leather strap now goes over each end of the file, and passes down upon each side of the block to the workman's feet, which, being put into the strap on each side, like a stirrup, holds the file firmly upon the anvil as it is cut. While the point of the file is cutting, the strap passes over one part of the file only, the point resting upon the anvil, and the tang upon a prop on the other side of the strap. When one side of the file is single cut, a fine file is run slightly over the teeth, to take away the roughness; when they are to be double cut, another set of teeth is cut, crossing the former nearly at right angles. The file is now finished upon one side, and it is evident that the cut side cannot be laid upon the bare anvil to cut the other. A flat piece of an alloy of lead and tin is interposed between the toothed surface and the anvil, while the other side is cut, which completely preserves the side already formed. Similar pieces of lead and tin, with angular and rounded grooves, are used for cutting triangular and half-round files.

Rasps are cut precisely in the same way, by using a triangular punch, instead of a flat chisel. The great art in cutting a rasp is to place every new tooth as much as possible opposite to a vacancy.

File-cutting machines have been from time to time invented. In 1778 M. de Montigny read a memoir before the Committee of Commerce, in which he mentioned the inventions for file-cutting in 1699 by Duverger, in 1725 by Fardouet, in 1740 by Thiout, in 1756 by Brachat and Gamain, and in 1778; since which, in 1800, Raoul invented a file-cutting machine; and in 1836 Ericsson introduced another. Sir John Robison, just before his death, invented a method for cutting curved files; and in 1843, Messrs. Johnson, Cammell, and Co. received the medal of the Scottish Society of Arts for perfecting Sir J. Robison's scheme. The accompanying woodcuts, which are representations of the file-cutting machine of Mr. W. Shilton of Birmingham, will show the general principle upon which those machines are constructed.

857





In order to render this invention better understood, two views of the apparatus for producing the crosscut or teeth of the files, are given.

Fig. 857 is an elevation of the upper part of the file-cutting machine, as seen on one side; *fig.* 858 is a plan or horizontal view, as the machine appears on the top.

a, is the head of the tilt hammer placed in the end of the lever *b*, which is mounted on an axle *c*, turning in proper bearings in the frame work of the machine; *d*, is the tilt wheel mounted on another axle *s*, also turning in bearings on the frame work of the machine, and having any required number of projections or tappets upon it for depressing the tail or shorter end of the hammer or tilt lever *b*.

The tilt wheel *d*, receives its rotatory motion from the toothed wheel *f*, mounted upon the same axle, and it takes into gear with a pinion *g*, upon the main shaft *h*, which is actuated by a band passed from any first mover to the rigger on its end, or in any other convenient manner. The bed upon which the blank piece of steel bears is marked *i*. This bed is firmly supported upon masonry placed upon proper sleepers: *j*, is one of the blank pieces of steel under operation, and is shown secured in the pair of jaws or holding clamps *k*, mounted on centre pins in the slide *l*, *fig.* 858, which slide is held down by a spring and slide beneath, and is moved backwards and forwards in the machine upon the (v) edges *m m*, of the frame, by means of the rack *n* and its pinion; the latter being mounted upon the axle of the ratchet wheel *p*, and which ratchet wheel is made to turn at intervals by means of the pall *q*, upon the end of the lever *r*, *fig.* 858. This lever is depressed, after every cut has been effected upon the blank by means of the teeth or tappets of the wheel *s*, coming in contact with the inclined plane *t*, upon the lever *r*. The tappet wheel *s*, is mounted upon the end of the axle *e*, of the tilt wheel, and consequently revolves with it, and by depressing the lever *r*, every time that a tooth passes the inclined plane *t*, the click *q*, is made to drive the ratchet wheel *p*, and thereby the advancing movement of the blank is effected after each blow of the tilt hammer.

There is a strong spring *u*, attached to the upper side of the tilt hammer, its end being confined under an adjustable inclined plane *v*, mounted in the frame *w*, which inclined plane can be raised or lowered by its adjusting screws as required, to produce more or less tension of the spring.

A similar spring is placed on the under side of the tilt hammer, to raise and sustain the cutter or tool clear of the bed after every blow, and, in conjunction with safety holders or catchers, to counteract any vibration or tendency the spring *u* may have to cause the hammer to reiterate the blow.

The end of the lower spring acts on an inclined plane, mounted in the frame *w*, which has an adjusting screw similar to *u*, to regulate the tension of the spring.

In case the under spring should raise, that is, return the hammer, with sufficient force or velocity to cause the top spring *u*, to reiterate the blow, the ends of the safety holders or catchers are made to move under and catch the tail of the lever *b*, immediately on its being raised by the under springs, which is effected by the following means:—The holders are mounted upon a plate or carriage 1, *fig.* 857, which turns upon a small pin or axle mounted in the ears of a cross bar; the upper ends of the holders are kept inclined towards the tail of the tilt hammer by means of a spring fixed to the cross bar, and which acts upon one end of the plate or carriage.

In order that the holders may be removed out of the way of the tail of the hammer *b*, when the tilt wheel is about to effect a blow, the tooth of the tilt wheel which last acted upon the hammer comes in contact with an inclined plane fixed on the plate or carriage 1, and, by depressing that end of the plate, causes the upper ends of the holders to be withdrawn from under the tail of the hammer *b*. The tilt wheel continuing to revolve, the next tooth advances, and depresses the tail of the hammer, but, before it leaves the tail of the hammer, the tooth last in operation will have quitted the inclined plane and allowed the spring to return the holders into their former position. After the tooth has escaped from the tail of *b*, the hammer will immediately descend and effect the blow or cut on the blank, and, as the tail of the hammer rises, it will come in contact with the inclined planes at the upper ends of the holders, and force them backwards; and, as soon as the tail of the hammer has passed the top of the holders, the spring will immediately force the holders forward under the tail of the hammer, and prevent the hammer rising again until the next tooth of the tilt wheel is about to depress the end of the hammer, when the same movements of the parts will be repeated, and the machine will continue in operation until a sufficient length of the blank of steel (progressively advanced under the hammer) has been operated upon, when it will be thrown out of gear by the following means:—

Upon the sliding bar 6, there is placed an adjustable stop, against which the foremost end of the slide *l l*, *fig.* 858, comes in contact as it is moved forward by the rack *n*, and its pinion. The sliding bar 6, is connected at its left end to the bent lever 8, the other end of this lever being formed into a forked arm, which embraces a clutch upon the main shaft, and, as the slide *l* continues to advance, it will come in contact with a stop; and when it has brought a sufficient length of the blank pieces of steel under the operation of the cutting tool, the slide *l*, in its progress, will have moved that stop and the bar 6 forward, and that bar, by means of the bent lever 8, will withdraw the clutch on the main shaft from locking into the boss of the fly-wheel, and consequently stop the further progress of the machine; the rigger and fly-wheel turning loosely upon the main shaft.

The cut file can now be removed from out of the clamps, and reversed to cut the other side, or another blank piece put in its place; and after throwing back the pall *q* of the ratchet wheel *p*, the slide *l*, and with it the fresh blank, may be moved back into the machine by turning the winch handle, on the axle of the ratchet wheel *p*, the reverse way, which will turn the pinion backwards, and draw back the rack *n*, without affecting any other parts of the machine; and on moving back the bar 6, by the handle 11, placed on the stop, the clutches will be thrown into gear again, and the machine proceed to cut the next blank.

When the blanks have been thus cut on one side, and are reversed in the machine to form the teeth upon the other side, there should be a piece of lead placed between the blank and the bed to protect the fresh-cut teeth.

It will be seen that the position of the stop upon the bar 6, will determine the length or extent of the blank piece of steel which shall be cut or operated upon; and in order that the progressive movement of the blanks under the cutting tool may be made to suit different degrees of fineness or coarseness of the teeth (that is, the distance between the cuts), there is an adjusting screw upon the lever *r*, the head of which screw stops against the under side of an ear projecting from the framework, and thereby determines the extent of the motion of the lever *r*, when depressed by the tappets of the wheel *s*, acting upon the inclined plane *t*, consequently determining the number of teeth the ratchet wheel *p* shall be moved round by the pall *q*; and hence the extent of motion communicated by the rack and pinion to the slide *l*, and the blank *j*, which regulates the distance that the teeth of the file are apart, and the lever *r* is forced upwards by a spring pressing against its under side.

It will be perceived that the velocity of the descent of the hammer, and consequently the force of the blow, may be regulated by raising or lowering the inclined plane *v* of the spring *u*; and in order to accommodate the bed upon which the blanks rest to the different inclinations they may be placed at, the part of the bed is formed of a semi-globular piece of hardened steel, which fits loosely into a similar concavity in the bed *r*, and is therefore capable of adjusting itself, so that the blanks shall be properly presented to the cutting tool, and receive the blow or cut in an equal and even manner; or the piece of steel may be of a conical shape, and fit loosely in a similar shaped concavity.

There are guides 16, placed on the top of the bed *i*, for the purpose of keeping the blanks in their proper position towards the cutting tool, and these can be regulated to suit blanks of any width, by turning the right and left handed screw 17. There is also another adjustable stop on the jaws or clamps *k* which serves as a guide when placing the blanks within the jaws: and 19 is a handle or lever for raising the clamps when required, which has a weight suspended from it for the purpose of keeping down the blanks with sufficient pressure upon the bed.

The cutting tool in the face of the hammer can be placed at any required angle or inclination with the blank, it being secured in the head of the hammer by clamps and screws. In cutting fine files a screw is employed in preference to the rack and pinion, for advancing the slide *l*, and the blank piece of steel in the machine.

Hardening the Files.—This is the last and most important part of file-making. Whatever may be the quality of the steel, or however excellent the workmanship, if it is not well hardened all the labour is lost.

Three things are strictly to be observed in hardening: first, to prepare the file on the surface, so as to prevent it from being oxidised by the atmosphere when the file is red-hot, which effect would not only take off the sharpness of the tooth, but render the whole surface so rough that the file would, in a little time, become clogged with the substance it had to work. Secondly, the heat ought to be very uniformly red throughout, and the water in which it is quenched, fresh and cold, for the purpose of giving it the proper degree of hardness. Lastly, the manner of immersion is of great importance, to prevent the files from warping, which in long thin files is very difficult.

The first object is accomplished by laying a substance upon the file, which, when it fuses, forms, as it were, a varnish upon the surface, defending the metal from the action of the oxygen of the air. Formerly the process consisted in first coating the surface of the file with ale grounds, and then covering it over with pulverised common salt (chloride of sodium). After this coating became dry, the files were heated red-hot, and hardened; after this, the surface was lightly brushed over with the dust of cokes, when it appears white and metallic, as if it had not been heated. This process has been improved, at least so far as relates to the economy of the salt, which from the quantity used, and the increased thickness, had become a serious object. Those who used the improved method are now consuming about one-fourth the quantity of salt used in the old method. The process consists in dissolving the salt in water to saturation, which is about three pounds to the gallon, and stiffening it with ale-grounds, or with the cheapest kind of flour, such as that of beans, to about the consistence of thick cream. The files required to be dipped only into this substance, and immediately heated and hardened. The grounds or the flour are of no other use than to give the mass consistence, and by that means to allow a larger quantity of salt to be laid upon the surface. In this method, the salt forms immediately a firm coating. As soon as the water is evaporated, the whole of it becomes fused upon the file. In the old method the dry salt was so loosely attached to the file, that the greatest part of it was rubbed off into the fire, and was sublimed up the chimney, without producing any effect.

The carbonaceous matter of the ale-grounds is supposed to have some effect in giving hardness to the file, by combining with the steel, and rendering it more highly carbonated. It will be found, however, upon experiment, that vegetable carbon does not combine with iron, with sufficient facility to produce any effect, in the short space of time a file is heating for the purpose of hardening. Some file makers are in the habit of using the coal of burnt leather, which doubtless produces some effect; but the carbon is generally so ill prepared for the purpose, and the time of its operation so short, as to render the result inconsiderable. Animal carbon, when properly prepared and mixed with the above hardening composition, is capable of giving hardness to the surface even of an iron file.

This carbonaceous matter may be readily obtained from any of the soft parts of animals, or from blood. For this purpose, however, the refuse of shoemakers and curriers is the most convenient. After the volatile parts have been distilled over, from an iron still, a bright shining coal is left behind, which, when reduced to powder, is fit to mix with the salt. Let about equal parts, by bulk, of this powder, and chloride of sodium be ground together, and brought to the consistence of cream by the addition of water. Or mix the powdered carbon with a saturated solution of the salt, till it becomes of the above consistence. Files which are intended to be very hard, should be covered with this composition, previous to hardening. All files intended to file iron or steel, particularly saw files, should be hardened with the aid of this mixture, in preference to that with the flour or grounds. Indeed, it is probable, that the carbonaceous powder might be used by itself, in point of economy, since the ammonia or hartshorn, obtained by distillation, would be of such value as to render the coal of no expense. By means of this method the files made of iron, which in itself is unsusceptible of hardening, acquire a superficial hardness sufficient for any file whatever. Such files may, at the same time, be bent into any form; and, in consequence, are particularly useful for sculptors and die-sinkers.

The next point to be considered is the best method of heating the file for hardening. For this purpose a fire, similar to the common smith's fire, is generally employed. The file is held in a pair of tongs by the tang, and introduced into the fire, consisting of very small cokes, pushing it more or less into the fire for the purpose of heating it regularly. It must frequently be withdrawn with a view of observing that it is not too hot in any part. When it is uniformly heated, from the tang to the point, of a cherry-red colour, it is fit to quench in the water. At present an oven, formed of fire-bricks, is used for the larger files, into which the blast of the bellows is directed, being open at one end, for the purpose of introducing the files and the fuel. Near to the top of the oven are placed two cross-bars on which a few files are placed, to be partially heating. In the hardening of heavy files, this contrivance affords a considerable saving, in point of time, while it permits them also to be more uniformly and thoroughly heated.

After the file is properly heated for the purpose of hardening, in order to produce the greatest possible hardness, it should be cooled as soon as possible. The most common method of effecting this is by quenching it in the coldest water. Some file-makers have been in the habit of putting different substances in the water, with a view to increase its hardening property. The addition of sulphuric acid to the water was long held a great secret in the hardening of saw-files. After all, however, it will be found that clear spring water, free from animal and vegetable matter, and as cold as possible, is the best calculated for hardening files of every description.

In quenching the files in water, some caution must be observed. All files, except the half-round, should be immersed perpendicularly, as quickly as possible, so that the upper part shall not cool. This management prevents the file from warping. The half-round file must be quenched in the same steady manner; but, at the same time that it is kept perpendicular to the surface of the water, it must be moved a little horizontally, in the direction of the round side, otherwise it will become crooked backwards.

After the files are hardened, they are brushed over with water and powdered cokes, when the surface becomes perfectly clean and metallic. They ought also to be washed well in two or three clean waters for the purpose of carrying off all the salt, which, if allowed to remain, would be liable to rust the file. They should moreover be dipped into lime-water, and rapidly dried before the fire, after being oiled with olive oil, containing a little oil of turpentine, while still warm. They are then finished.

FILIGREE (*Filigrane*, Fr.; *Filigran*, or *Feine Drahtgeflecht*, Ger.) is, as the last term justly expresses it, intertwisted fine wire, used for ornamenting gold and silver trinkets. The wire is seldom drawn round, but generally flat or angular; and soldered by gold or silver solder with borax and the blowpipe. The Italian word, *filigrana*, is compounded of *filum* and *granum*, or granular net-work; because the Italians, who first introduced this style of work, placed small beads upon it.

FILTRATION (Eng. and Fr.; *Filtriren*, Ger.) is a process purely mechanical, for separating a liquid from the undissolved particles floating in it, which liquid may be either the useful part, as in vegetable infusions, or of no use, as the washings of mineral precipitates. The filtering substance may consist of any porous matter in a solid, foliated, or pulverulent form; as porous earthenware, unsized paper, cloth of many kinds, or sand. The white blotting-paper sold by the stationers answers extremely well for filters in chemical experiments, provided it be previously washed with dilute muriatic acid, to remove some lime and iron that are generally present in it. Filter papers are first cut square, and then folded twice diagonally into the shape of a cornet, having the angular parts rounded off. Or the piece of paper, being cut into a circle, may be folded fan-like from the centre, with the folds placed exteriorly, and turned out sharp by the pressure of the finger and thumb, to keep intervals between the paper and the funnel into which it is fitted, to favour the percolation. The diameter of the funnel should be about three-fourths of its height, measured from the neck to the edge. If it be more divergent, the slope will be too small for the ready efflux of the fluid. A filter covered with the sediment is most conveniently washed by spouting water upon it with a little syringe. A small camel's-hair paint-brush is much employed for collecting and turning over the contents in their soft state. Agitation or vibration is of singular efficacy in quickening percolation, as it displaces the particles of the moistened powders, and opens up the pores which had become closed. Instead of a funnel, a cylindrical vessel may be employed, having its perforated bottom covered with a disc of filtering paper folded up at the edges, and made tight there by a wire ring. Linen or calico is used for weak alkaline liquors; and flannels, twilled woollen cloth, or felt-stuff for weak acid ones. These filter bags are often made conical like a fool's cap, and have their mouths supported by a wooden or metallic hoop. Cotton wool put loose into the neck of a funnel answers well for filtering oils upon the small scale. In the large way, oil is filtered in conical woollen bags, or in a cask with many conical tubes in its bottom, filled with tow or cotton wool. Stronger acid and alkaline liquors must be filtered through a layer of pounded glass, quartz, clean sand, or bruised charcoal. The *alcarrhazas* are vessels of porous biscuit stone-ware made in Spain, which are convenient for filtering water, as also is the porous filtering stone of Teneriffe, largely imported into England at one time, but now superseded in a great measure by the artificial filters patented under many forms, consisting essentially of strata of gravel, sand, and charcoal-powder.

It is convenient to render the filter self-acting by accommodating the supply of liquid to the rate of percolation, so that the pressure upon the porous surface may be always equally great. Upon the small scale, the lamp-fountain or bird's-glass form so generally used for lamps, will be found to answer.

Fig. 859 represents a glass bottle A, partly filled with the fluid to be filtered, supported in the ring of a chemical stand, and having its mouth inverted into the same liquor in the filter funnel. It is obvious, that whenever this liquor by filtration falls below the lip of the bottle, air will enter into it, let down a fresh supply to feed the filter, and keep the funnel regularly charged. If larger quantities are to be operated upon, the following apparatus may be employed. *Fig.* 860, A B, is a metallic vessel, which may be made air-tight; C is the under pipe provided with a stopcock R, for letting down the liquor into the filter *a b*. The upper pipe *t*, through which the fluid

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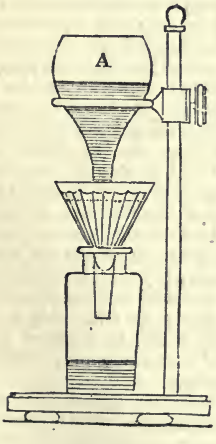

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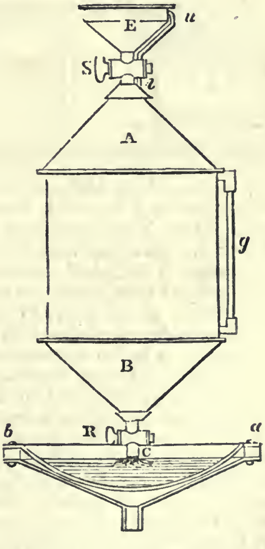

is poured by means of the funnel E, has also a stopcock which opens or shuts, at the same time, the small side tube *u t*, through which, during the entrance of the fluid, the air is let off from the receiver. A glass tube *g*, shows the level of the liquor in the body of the apparatus. In using it, the cock R must be first closed, and the cock S must be opened to fill the receiver. Then the filter is set a-going by reopening the cock R, so as to keep the fluid in the filter upon a level with the opening of the tube C. Both these pieces of apparatus are essentially the same.

In many manufactures, self-acting filters are fed by the plumber's common contrivance of a ball-cock in which the sinking and rising of the ball, within certain limits, serve to open or shut off the supply of liquor as it may be required or not. Dumont has adopted this expedient for his system of filtering syrup through a stratum of granularly ground animal charcoal or bone-black. *Fig.* 861 is a front view of this apparatus with 4 filters C; and *fig.* 862 is a cross section. The framework B supports the cistern A, in which the syrup is contained. From it the liquor flows through the stopcock *b*, and the connection-tube *a*, into the common pipe *c*, which communicates, by the short branch tubes *e*, with each of the four filters. The end of the branch tube, which is inside of the filter tub, is provided with a stopcock *d f*, whose opening, and thereby the efflux of the liquor from the cistern through the tube *a*, is regulated by means of the floating-ball *g*. Upon the brick-work D the filter tub stands, furnished at *h* with a false bottom of zinc or copper pierced with fine holes; besides which, higher up at *i* there is another such plate of metal furnished with a strong handle *k*, by which it may be removed, when the bone-black needs to be changed. In the intervening space *l*, the granular coal is placed. *o* is the cover of the filter tub, with a handle also for lifting it. One portion of it may be raised by a hinge, when it is desired to inspect the progress of the filtration within. *m m* is a slender vertical tube, forming a communication between the bottom part *h*, and the upper portion of the filter, to admit of the easy escape of the air from that space, and from among the bone-black as the syrup descends; otherwise the filtration could not go on. *p* is the stopcock through which the fluid collected in the space under *h* is let off from time to time into the common pipe *q*, *fig.* 861. *r* is a trickling channel or groove lying parallel to the tube *q*, and in which, by means of a tube *s*, inserted at pleasure, the syrup is drawn off in case of its flowing in a turbid state, when it must be returned over the surface of the charcoal.

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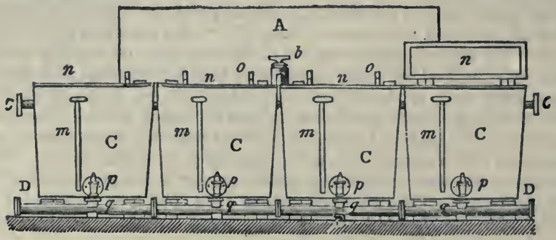

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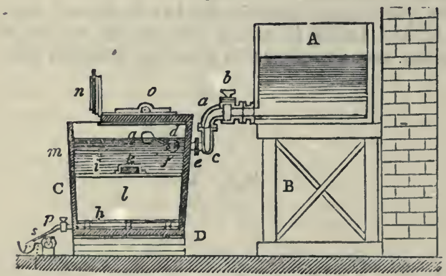

The celerity with which any fluid passes through the filter depends,—1, upon the porosity of the filtering substance; 2, upon the pressure exercised upon it; and 3, upon the extent of the filtering surface. Fine powders in a liquor somewhat glutinous, or closely compacted, admit of much slower filtration than those which are coarse and free; and the former ought, therefore, to be spread in a thinner stratum and over a more extensive surface than the latter, for equal effect: a principle well exemplified in the working of Dumont's apparatus, just described.

In many cases filtration may be accelerated by the increase of hydrostatic or pneumatic pressure. This happens when we close the top of a filtering cylinder, and connect it by a pipe with a cistern of fluid placed upon a higher level. The pressure of the air may be rendered operative also either by withdrawing it partially from a close vessel, into which the bottom of the filter enters, or by increasing its density over the top of the liquor to be filtered. Either the air-pump or steam may be employed to create a partial void in the receiver beneath the filter. In like manner, a forcing-pump or steam may be employed to exert pressure upon the surface of the filtering liquor. A common siphon may, on the same principle, be made a good pressure-filter, by making its upper leg trumpet-shaped, covering the orifice with filter-paper or cloth, and filling the whole with liquor, the lower leg being of such length as to create considerable pressure by the difference of hydrostatic level. This apparatus is very convenient either on the small or great scale, for filtering off a clear fluid from a light muddy sediment. The pressure of the atmosphere may be elegantly applied to common filters by the apparatus represented in *fig.* 863, which is merely a funnel enclosed within a gasometer. The case A B bears an annular hollow vessel *a b*, filled with water, in which receiver the cylindrical gasometer *d e f i* is immersed. The filter funnel C is secured at its upper edge to the inner surface of the annular vessel *a b*. In consequence of the pressure of the gasometer regulated by the weight *g*, upon the air enclosed within it, the liquid is equally pressed, and the water in the annular space rises to a corresponding height on the outer surface of the gasometer, as shown in the figure. Were the apparatus made of sheet iron, the annular space might be charged with mercury.

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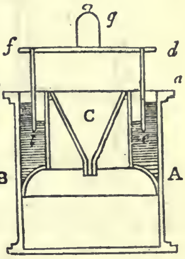

In general, relatively to the application of pressure to filters, it may be remarked, that it cannot be pushed very far, without the chance of deranging the apparatus, or rendering the filtered liquor muddy. The enlargement of the surface is, generally speaking, the safest and most efficacious plan of increasing the rapidity of filtration, especially for liquids of a glutinous nature. This expedient is well illustrated in the creased bag filter now in use in most of the sugar refineries of London. See SUGAR.

An improved method of rapid filtration has been introduced by Professor Bunsen. He facilitates the operation by filtering into a vessel from which the air has been partially exhausted by means of a water air-pump, on the principle of the Sprengel pump. The liquid undergoing filtration is thus forced, by the pressure of the atmosphere, through the pores of the filtering medium, and meets with but little resistance on the opposite side, where it passes into a rarefied atmosphere. Bunsen's paper on this subject has been translated in the 'Philosophical Magazine' for January 1869, p. 1. See ASPIRATOR.

In many cases it is convenient so to construct the filtering apparatus, as that the liquid shall not descend, but mount by hydrostatic pressure. This method has two advantages: 1. that without much expensive apparatus, any desired degree of hydrostatic pressure may be given, as also that the liquid may be forced up through several filtering surfaces placed alongside of each other; 2. that the object of filtering, which is to separate the particles floating in the fluid without disturbing the sediment, may be perfectly attained, and thus very foul liquids be cleared without greatly soiling the filtering surface.

Such a construction is peculiarly applicable to the purification of water, either alone, or combined with the downwards plan of filtration. Of the former variety an example is shown in *fig.* 864. The wooden or zinc conical vessel is provided with two perforated bottoms or sieves *e e*, betwixt which the filtering substance is packed. Over this, for the formation of the space *h h*, there is a third shelf, with a hole in its middle, through which the tube *d b* is passed, so as to be water-tight. This places the upper open part of the apparatus in communication with the lowest space *a*. From the compartment *h h* a small air-tube *l* runs upwards. The filtering substance consists at bottom of pebbles in the middle of gravel, and at the top of fine sand, which may be mixed with coarsely-ground bone-black, or covered with a layer of the same. The water to be filtered being poured into the cistern at top, fills through the tube *b d* the inferior compartment *a*, from which the hydrostatic pressure forces the water upward through the perforated shelf and the filtering materials. The pure water collects in the space *h h*, while the air escapes by the small tube *l*, as the liquid enters. The stopcock *i* serves to draw off the filtered water. As the motion of the fluid in the filter is slow, the particles suspended in it have time to subside by their own gravity; hence there collects over the upper shelf at *d*, as well as over the under one at *a*, a precipitate or deposit which may be washed out of the latter cavity by means of the stopcock *m*.

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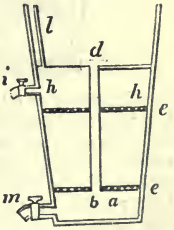

As an example of an upwards and downwards filter, *fig.* 865 may be exhibited. A B C D is a wooden or metallic cistern, furnished with the perforated shelf *c d* near its under part, upon which a vertical partition is fixed through the axis of the vessel. A semicircular perforated shelf is placed at *a*, and a second similar one at *b*. These horizontal shelves rest upon brackets in the sides of the cisterns, so that they may be readily lifted out. The space G is filled with coarse sand, J with moderately fine, and H with very fine. The foul water is poured into the chamber E, and presses through G J H and into the space F, whence it may be drawn by the stopcock *f*.

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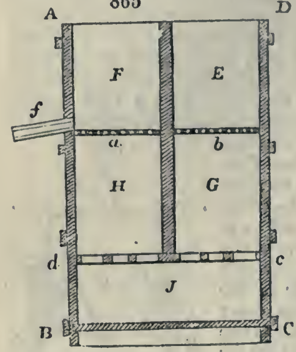
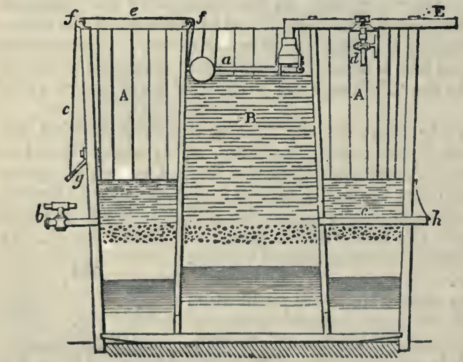


Fig. 866 represents in section a filtering apparatus, consisting of two concentric chambers; the interior being destined for downwards filtration, and the exterior for upwards. Within the larger cistern A, a smaller one B is placed concentrically, with its under part, and is left open from distance to distance, to make a communication between the interior cavity and the exterior annular space. These cavities are filled to the marked height with sand and gravel. The inner cylindrical space has fine sand below, then sharper sand with granular charcoal, next coarse sand, and lastly gravel. The annular space has in like manner fine sand below. The foul water is introduced by the pipe E, the orifice at whose end is acted upon by a ball-cock with its lever *a*; whereby the water is kept always at the same level in the inner vessel. The water sinks through the sand strata of the middle vessel, passes outwards at its bottom into the annular space, thence up through the sand in it, and, collecting above it, is let off by the stopcock on the pipe *b*. When a muddy deposit forms after some time, it may be easily cleared out. The cord *e*, running over the pulleys *f f*, being drawn tight, the ball lever will shut up the valve. The stopcock *d* made fast to the conducting tube E must then be opened, so that the water now overflows into the annular space at A; the tube *c*, in communication with the inner space B, being opened by taking out the stopper *h*. The water thereby percolates through the sand strata in the reverse direction of its usual course, so as to clear away the impurities in the space B, and to discharge them by the pipe *c h*. An apparatus of this kind of moderate size is capable of filtering a great body of water. It should be constructed for that purpose of masonry; but upon a small scale it may be made of stone-ware.

866



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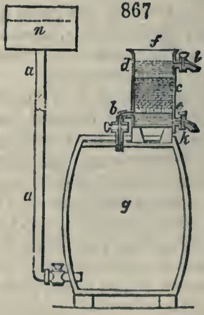


A convenient apparatus for filtering oil upwards is represented in *fig.* 867. *g* is an oil cask, in which the impure parts of the oil have accumulated over the bottom. Immediately above this, a pipe *a* is let in, which communicates with an elevated water-cistern *n*. *f* is the filter (placed on the lid of the cask), furnished with two perforated shelves, one at *e* and another at *d*, which divide the interior of the filter into three compartments. Into the lower space immediately over the shelf *e*, the tube *b*, furnished with a stopcock, enters, to establish a communication with the cask; the middle cavity *c* is filled with coarsely-ground charcoal or other filtering materials; and the upper one has an eduction-pipe *l*. When the stopcocks of the tubes *a* and *b* are opened, the water passes from the cistern into the oil cask, occupies from its density always the lowest place, and presses the oil upwards, without mixing the two liquids; whereby first the upper and purer portion of the oil is forced through the tube *b* into the filter, and thence out through the pipe *l*. When the fouler oil follows, it deposits its impurities in the space under the partition *c*, which may from time to time be drawn off through the stopcock *k*, while the purer oil is pressed upwards through the filter. In this way the different strata of oil in the cask may be filtered off in succession, and kept separate, if found necessary for sale or use, without running any risk of mixing up the muddy matter with what is clear. According to the height of the water-cistern *n* will be the pressure, and of course the filtering force. When the filter gets choked with dirt, it may be easily re-charged with fresh materials.

It has been for many years the custom of the Water Companies to send the water taken from the river through filter beds, prepared usually of sand and gravel. It was long thought that the effect of these filter beds was merely to separate the solid insoluble matters suspended in the water. It has, however, been shown by the investigations of the late Mr. Henry M. Witt (a chemist of peculiar promise, lost too soon to science, and ere yet the world could recognise his powers), that these filter beds had the power of separating many of the dissolved substances from the water; that, in fact, the soluble salts of lime, and the like, were removed by some peculiar physico-mechanical force, resident, as it appears, as a surface-force, in all porous masses. There are many very remarkable examples in nature of the operation of this power in producing beds charged with metalliferous matter, some of which will be described under the head of MINING.

Mr. H. M. Witt communicated to the 'Philosophical Magazine' for December, 1856, an account of some experiments on filtration, which are of much value. Many of his experiments were made at the Chelsea Water-works, and they appear of such interest that we quote the author's remarks to some extent:—

'The system of purification adopted by the Chelsea Water-works, at their works at Chelsea, consisted hitherto (for the supply has by this time commenced from Kingston) in pumping the water up out of the river into subsiding reservoirs, where it remained for six hours; it was then allowed to run on to the filter-beds. These are large square beds of sand and gravel, each exposing a filtering surface of about 270 square feet, and the water passes through them at the rate of about 6¼ gallons per square foot of filtering surface per hour, making a total quantity of 1687·5 gallons per hour through each filter.

'The filters are composed of the following strata, in a descending order:—

	ft.	in.
1. Fine sand	2	6
2. Coarser sand	1	0
3. Shells	0	6
4. Fine gravel	0	3
5. Coarse gravel	3	3

These several layers of filtering materials are not placed perfectly flat, but are disposed in waves, and below the convex curve of each undulation is placed a porous earthenware pipe, which conducts the filtered water into the mains for distribution. The depth of water over the sand was 4 feet 6 inches. The upper layer of sand is renewed about every six months, but the body of the filter has been in use for about twenty years.

'Samples of water were taken and submitted to examination:—

'1st, from the reservoir into which the water was at the time being pumped from the middle of the river.

'2nd, from the cistern, after subsidence and filtration.'

Experiments were made at different seasons of the year; but one of Mr. Witt's tables will sufficiently show the results.

	1 Originally present	2 After filtration	3 Amount separated	4 Percentage ratio of separated Matter
Total solid residue, including suspended matter	55·60	22·85	32·75	58·90
Organic matter	4·05	1·349	2·70	66·66
Total mineral matter	51·55	21·501	30·049	58·29
Suspended matter	28·93	2·285	26·645	92·10
Total dissolved salts	22·62	19·216	3·404	15·04
Lime	8·719	8·426	0·293	3·36

Col. 1 shows the quantities of the several substances originally present, represented in grains, in the imperial gallon (70,000 grains) of water.

2. The amount present after filtration.

3. The actual quantities separated in grains in the gallon of water.

4. The percentage ratio which the amounts separated bear to the quantities originally present.

'It has been assumed as a principle that sand-filtration can only remove bodies mechanically suspended in water, but I am not aware that this statement has been established by experiment; in fact, I am not acquainted with any published analytical examination of the effects of sand-filtration.

'These experiments supply the deficiency, and show, moreover, that these porous media are not only capable of removing suspended matter (80 to 92 per cent.), but even of separating a certain appreciable quantity of the salts from solution in water, viz. from 5 to 15 per cent. of the amount originally present, 9 to 19 per cent. of the common salt, 3 per cent. of the lime, and 5 of the sulphuric acid.

'Taking the purer water from Kingston, two experiments were made simultaneously with the same water, one filtration being through charcoal alone, and the other through sand alone; the sand filter having an area of 4 square feet, and consisting of the following materials:—

	ft.	in.
Fine sand	1	9
Shells		1½
Gravel		1½
Coarse gravel		9
	2	9

Results of Sand Filtration.

	Original Water used	After 23 hours' action			After 120 hours' action		
		Comparison	Amount separated	Percentage of Quantity separated	Comparison	Amount separated	ercentage ratio of Quantity separated
Total residue . .	24·578	23·87	0·708	2·88	23·60	0·888	3·613
Mineral salts . .	23·687	22·858	0·829	3·50	23·04	0·647	2·73
Organic matter .	0·8906	1·012	..	..	0·648	0·2426	..
Suspended matter .	3·509	2·663	0·846	24·109	..	..	..
Chlorine . . .	0·862	..	..	..	0·671	0·191	22·16
Chloride of sodium .	1·420	..	..	..	1·105	0·315	22·11

		After 240 hours' action			After 376 hours' action		
Total residue . .	24·578	22·534	2·044	8·316	22·507	2·071	8·426
Mineral salts . .	23·687	21·517	2·170	9·161	21·698	1·989	8·397
Organic matter .	0·8906	0·917	..	..	0·809	..	..
Suspended matter .	3·509	1·88	1·629	46·423	1·584	1·925	54·85
Chlorine . . .	0·862	0·674	0·188	21·8	..	..	..
Chloride of sodium .	1·420	1·110	0·310	21·8	..	..	..

Results of Charcoal Filtration.

	Original Water used	After 72 hours' action			After 120 hours' action		
		Comparison	Amount separated	Percentage ratio of Quantity separated	Comparison	Amount separated	Percentage ratio of Quantity separated
Total residue . .	24·578	22·13	2·448	9·906	21·644	2·934	11·93
Mineral salts . .	23·687	21·375	2·312	9·76	..	..	..
Organic matter .	0·8906	0·755	0·1356	15·22	..	..	..
Suspended matter .	3·509	..	..	..	3·06	0·449	12·79
Chlorine . . .	0·862	..	..	..	..	..	..
Chloride of sodium .	1·420	..	..	..	..	..	..

		After 240 hours' action			After 376 hours' action		
Total residue . .	24·578	20·821	3·757	15·28	21·374	3·204	13·03
Mineral salts . .	23·687	..	..	..	20·604	3·033	12·34
Organic matter .	0·8906	..	..	..	0·770	0·1206	13·54
Suspended matter .	3·509	2·79	0·719	20·48	..	..	..
Chlorine . . .	0·862	..	..	..	..	..	..
Chloride of sodium .	1·420	..	..	..	..	..	..

'Apart from its special interest, as compared with the following experiment, made simultaneously through charcoal, the following points are in themselves remarkable in the results obtained by this filtration through sand:—

'1st. That the filter continued increasing in efficacy even till the conclusion of the experiment, *i.e.*, for 376 hours, not having lost any of its power when the experiment was terminated.

'2nd. That no weighable quantity of dissolved organic matter was removed by the sand in this experiment; but it must be remembered that the quantity originally present was but small.

'3rd. Its power of removing soluble salts was considerable; as a maximum, 21 per cent. of the common salt being separated.'

On comparing this experiment with the preceding, the following point comes out as showing the difference between the effects of sand and charcoal as filtering media.

By the charcoal, speaking generally, a considerably larger quantity of the total residue contained in the water was removed than by the sand, their maximum results being respectively as follow:—

Amount originally present	Amount separated in Grains in the Gallon		Amount separated in Percentage of the Quantity present	
	By Sand	By Charcoal	By Sand	By Charcoal
24·578 grs. in the gallon	2·074	3·757	8·426	15·28

FIRE ANNIHILATORS. This name is given to a portable machine invented by Mr. Phillips, which is adjusted to produce the immediate production of steam, carbonic acid, and other gases, which could be at once directed on the burning mass. The machine is cylindrical in form, and slightly conical. For use it is charged with the following composition: charcoal 20 parts, nitrate of potash 60 parts, and gypsum 5 parts. These materials are boiled together in water, and afterwards dried in a stove at the temperature of 100°. The whole is moulded into the form of a brick, down the axis of which penetrates a hollow cavity for the reception of a bottle, which contains a mixture of chlorate of potash and sugar, surmounted by a globule of sulphuric acid. The charge so prepared is placed in a cylindrical vessel, perforated in many places, which is itself within another cylindrical vessel, also perforated for the passage of the gases; both these are contained in a double cylindrical receiver, the lower part of which contains a quantity of water. The apparatus is closed by two covers, in the outer of which is an opening for the escape of the vapour. In the centre of the cover is placed a spike, for the purpose of breaking the glass bottle deposited in the cavity of the charge. The spike being forced down breaks the bottle, and the sulphuric acid causes the instantaneous combustion of the chlorate of potash and sugar, which fires the charge. The gases now escape through the perforations, and heating the air in the water-chamber, and causing it to expand, forces the water up a tubular passage into the space between and around the cylindrical vessels placed each within each, and being thus converted into vapour, mixes with the gases, and escapes by the discharge-tube, forming a dense cloud, which rapidly extinguishes flame.

Many very successful experiments were made with these fire annihilators, but they have not been much used. There can be no doubt the principle is a correct one. Any arrangement for pouring carbonic acid upon flame would be certain of success, if the cost of production did not stand in the way. A patent was granted in 1873 to Mr. W. B. Dick, of Glasgow, for improvements in apparatus for extinguishing fires. Carbonic acid gas is generated by the action of sulphuric acid on bicarbonate of soda, and is dissolved in water; the solution is projected, by the expansive force of the gas, from a strong vessel through a regulator valve and delivery hose. The bottle of acid is held between a fixed bottom-support and a moveable cap, and is broken by striking an external cap. These 'extincteurs' have been recently supplied to some of the Government offices.

FIRE-ARMS, MANUFACTURE OF. This article belongs properly to a work on mechanical engineering. It cannot be extended as it should be without encroaching to too great an extent upon the space reserved for the articles which legitimately belong to this Dictionary. It has therefore been allowed to remain as it stood in the last edition: all the main principles connected with the construction of fire-arms being fully described.

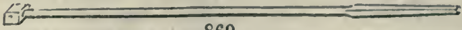
This art is divided into two branches: that of the metallic, and that of the wooden work. The first includes the barrel, the lock, and the mounting, with the bayonet and ramrod, for military arms. The second comprises the stock, and in fowling-pieces likewise the ramrod.

The Barrel.—Its interior is called the bore; its diameter, the calibre; the back end, the breech; the front end, the muzzle; and the closing of the back end, the breech pin or plug. The barrel is generally made of iron. Most military muskets and low-priced guns were formerly fashioned out of a long slip of sheet-iron folded together edge-wise round a skewer into a cylinder; they were then lapped over at the seam, and welded at a white heat. The most ductile and tenacious soft iron, free from all blemishes, must be selected for this slip. It is frequently welded at the common forge, but a proper air-furnace answers better, not being so apt to burn the iron, which should be covered with ashes or cinders. The shape of the bore is given by hammering the cylinder upon a steel mandril, in a groove of the anvil. Six inches of the barrel at either end are left open for forming the breech and the muzzle by a subsequent welding operation; the extremity put into the fire being stopped with clay, to prevent the introduction of cinders. For every length of two inches, there are from two to three welding operations, divided into alternating high and low heats; the latter being intended to correct the defects of the former. The breech and muzzle are not welded upon the mandril, but upon the horn of the anvil; the breech, being thicker in the metal, is more highly heated, and is made somewhat wider to save labour to the borer. The barrel is finally hammered in the groove of the anvil without the mandril, during which process it receives a heat every two minutes. In welding, the barrel extends about one-third in length; and for muskets, is eventually left from 3 to 3½ feet long; but for cavalry pistols, only 9 inches.

The best iron plates for gun-barrels are those made of *stub* iron; that is, of old horse-shoe nails welded together, and forged into thin bars, or rather narrow ribands. At one time *damascus* barrels were much in vogue; they were fashioned either as above described, from plates made of bars of iron and steel laid parallel, and welded together, or from ribands of the same damascus stuff coiled into a cylinder at a red heat, and then welded together at the seams. The best modern barrels for fowling-pieces and the modern rifles are constructed of stub nail-iron in this manner. The slip or fillet is only half an inch broad, or sometimes less, and is left thicker at the end which is to form the breech, and thinner at the end which is to form the muzzle, than in the intermediate portion. This fillet, being moderately heated to increase its pliancy, is then lapped round the mandril in a spiral direction till a proper length of cylinder is formed; the edges being made to overlap a little in order to give them a better hold in the welding process. The coil, being taken off the mandril and again heated, is struck down vertically with its muzzle end upon the anvil, whereby the spiral junctions are made closer and more uniform. It is now welded at several successive heats, hammered by horizontal strokes, called *jumping*, and brought into proper shape on the mandril. The finer barrels are made of still narrower stub-iron slips, whence they get the name of wire twist. On the Continent, some barrels are made of steel wire, welded together lengthwise, then coiled spirally into a cylinder. Barrels that are to be rifled, require to be made of thicker iron, and that of the very best quality, for they would be spoiled by the least portion of scale upon their inside. Soldiers' muskets are thickened a little at the muzzle, to give a stout holding to the bayonet.

The barrels thus made are annealed with a gentle heat in a proper furnace, and slowly cooled. They are now ready for the borer, which is an oblong square *bit* of steel, pressed in its rotation against the barrel by a lip of wood applied to one of its flat sides and held in its place by a ring of metal. The boring bench works horizontally, and has a very shaky appearance, in respect at least of the bit. In some cases, however, it has been attempted to work the barrels and bits at an inclination to the horizon of 30°, in order to facilitate the discharge of the borings. The barrel is held in a slot by only one point, to allow it to humour the movements of the borer, which would otherwise be infallibly broken. The bit, as represented in *fig.* 868, has merely its square head inserted into a clamp-chuck of the lathe, and plays freely through the rest of its length.

868



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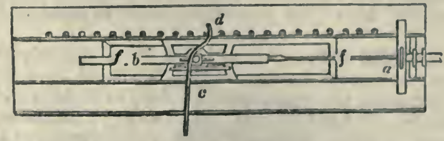

Fig. 869 represents in plan the *boring bench* for musket barrels; *f f* is the sledge or carriage frame in which the barrel is supported; *a* is the revolving chuck of the lathe, into which the square end of the bit, *fig.* 868, is inserted; *b* is the barrel, clamped at its middle to the carriage, and capable of being pressed onwards against the tapering bit of the borer, by the bent lever *c*, worked by the left hand of the operative against fulcrum knobs at *d*, which stand about two inches asunder. Whenever the barrel has been thereby advanced a certain space to the right, the bent end of the lever is shifted against another knob or pin. The borer appears to a stranger to be a very awkward and unsteady mechanism, but its perpetual vibrations do not affect the accuracy of the bore. The opening broach may be of a square or pentagonal form; and either gradually tapered from its thickest part, or of uniform diameter till within two inches of the end, whence it is suddenly tapered to a point.

A series of bits may be used for boring a barrel, beginning with the smallest and ending with the largest. But this multiplication of tools becomes unnecessary, by laying against the cutting part of the bit, slips of wood, called spales, of gradually increasing thickness, so that the edge is pressed by them progressively further from the axis. The bore is next polished. This is done by a bit with a very smooth edge, which is mounted as above, with a wedge of wood besmeared with a mixture of oil and emery. The inside is finished by working a cylindrical steel file quickly backwards and forwards within it, while it is revolving slowly.

In boring, the bit must be well oiled or greased, and the barrel must be kept cool by letting water trickle on it; for the bit, revolving at the rate of 120 or 140 times a minute, generates a great deal of heat. If a flaw be detected in the barrel during the boring, that part is hammered in, and then the bit is employed to turn it out.

Many sportsmen are of opinion that a barrel with a bore somewhat narrowed towards the muzzle serves to keep shot better together; and that roughening its inside with pounded glass has a good effect, with the same view. For this purpose, also, fine spiral lines have been made in their interior surface. The justness of the calibre of a fowling-piece or musket is tried by means of a truly-turned cylinder of steel, 3 or 4 inches long, which ought to move without friction, but with uniform contact from end to end of the barrel. Whatever irregularities appear must be immediately removed.

The outer surface of the barrel is commonly polished upon a dry grindstone, but it is better finished at a turning lathe with a slide-rest.

Rifle barrels have parallel grooves of a square or angular form cut within them, each groove being drawn in succession. These grooves run spirally, and form each an aliquot part of a revolution from the chamber to the muzzle. Rifles should not be too deeply indented, only so much as to prevent the ball turning round within the barrel; and the spires should be truly parallel, that the ball may glide along with a regular pace.

The Parisian gun-makers, who are reckoned very expert, draw out the iron for the barrels at hand forges, in fillets only one-ninth of an inch thick, one inch and a half broad, and four feet long. Twenty-five of these ribands are laid upon each other, between two similar ones of double thickness, and the bundle, weighing 60 lbs., bound with wire at two places, serves to make two barrels. The thicker plates are intended to protect the thinner from the violence of the fire in the numerous successive heats necessary to complete the welding, and to form the bundle into a bar two-thirds of an inch broad, by half an inch thick; the direction of the individual plates relatively to the breadth being preserved. This bar, folded flat upon itself, is again wrought at the forge, till it is only half an inch broad, and a quarter of an inch thick, while the plates of the primitive ribands are now set perpendicular to the breadth of the narrow fillet; the length of which must be 15 or 16 feet French (16 or 17 English), to form a fowling-piece from 28 to 30 inches long. This fillet, heated to a cherry red in successive portions, is coiled into as close a spiral as possible, upon a mandril about two-fifths of an inch in diameter. The mandril has at one end a stout head for drawing it out, by means of the hammer and grooves of the anvil, previous to every heating. The welding is performed upon a mandril introduced after each heat; the middle of the barrel being first worked, while the fillets are forced back against each other, along the surface of the mandril, to secure their perfect union. The original plates, having in the formation of the ultimate long riband become very thin, appear upon the surface of the barrel like threads of a fine screw, with blackish tints to mark the junctions. In making a double-barrelled gun, the two are formed from the same bundle of slips, the coils of the one finished fillet being turned to the right hand, and those of the other to the left.

The barrels forged, as above described, from a bundle of steel and iron plates laid alternately together, are twisted at the forge several times, then coiled and welded as usual. Fifteen workmen concur in one operation: six at the forge; two at the boring mill; seven at filing, turning, and adjusting; yet altogether make only six pairs of barrels per week. In the first instance, it will be understood, that, for the construction of the superior barrels, a bundle of horse-shoe nails is welded into a flat bar, similar bars of scrap steel are made, and these are made up into a bundle—a bar of iron, and a bar of steel—of eight or twelve bars. This is again welded into one bar, and the result is, when the surface is polished, that the difference in the texture of the two metals is distinctly visible. Now, if two bars of iron and one of steel, or two bars of steel and one of iron, or any other combination of the two, be adopted, there will be a variety in the pattern of the finished bar.

In constructing the barrel this bar may be twisted up singly, as described, or two bars differing in pattern may be welded together, and then twisted. It is usual to place two bars together, to twist one into a screw and leave the other plain, or to give one a right-handed twist and the other a left-handed one; or sometimes three bars are employed, and by twisting or otherwise previously to welding the bars together, and turning or twisting the compound bar into a cylinder, a great variety of patterns are produced on the finished barrel.

The breeching is of three kinds: the common; the chamber, plug, or mortar, *fig.* 870; and the patent, *fig.* 871. The common was formerly used for soldiers' muskets and inferior pieces. The second is a trifling improvement upon it. In the patent breeching, the screws do not interfere with the touch-hole, and the ignition is quicker in the main chamber.

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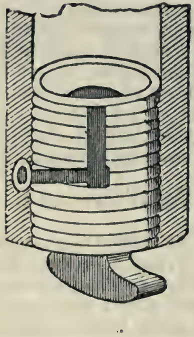

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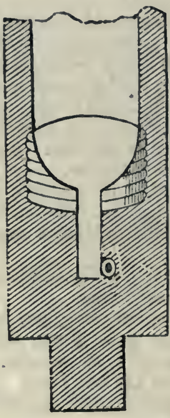

The only locks which it is worth while to describe are those upon the percussion principle, as flint locks have ceased to be employed. Forsyth's lock (*fig.* 872) was an ingenious contrivance. It has a magazine *a*, for containing the detonating powder, which revolves round a roller *b*, whose end is screwed into the breech of the barrel. The priming powder passes through a small hole in the roller, which leads to a channel in communication with the chamber of the gun.

The pan for holding the priming is placed immediately over the little hole in the roller. There is a steel punch *c*, in the magazine, whose under end stands above the pan, ready to ignite the priming when struck upon the top by the cock *d*, whenever the trigger is drawn. The punch, immediately after being driven down into the pan, is raised by the action of a spiral spring. For each explosion, the magazine must be turned so far round as to let fall a portion of the percussion powder into the pan; after which it is turned back, and the steel punch recovers its proper position for striking another blow into the pan.

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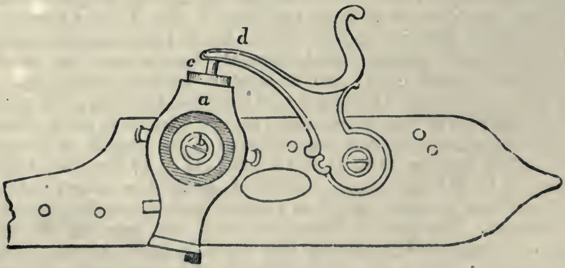

The invention of the copper percussion cap was another great improvement upon the detonating plan. *Fig.* 873 represents the ordinary percussion lock, which is happily divested of three awkward projections upon the flint lock, namely, the hammer, hammer spring, and the pan. Nothing now appears upon the plate of the lock, but the cock or striking hammer, which inflicts the striking blow upon the percussion cap. It is concave, with a small metallic ring or border, called a shield or fence, for the purpose of enclosing the cap, as it were, and preventing its splinters doing injury to the sportsman; as also protecting against the line of flame which may issue from the touch-hole in the cap-nipple. This is screwed into the patent breech, and is perforated with a small hole.

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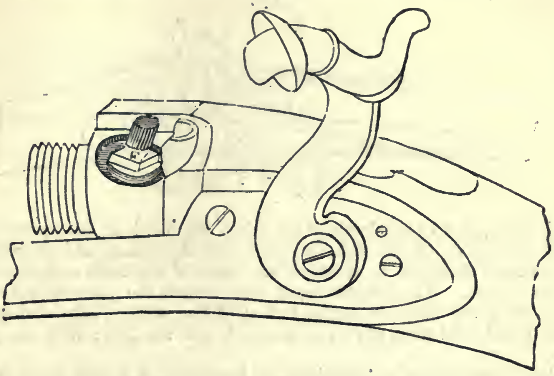

The safety lock of Dr. Somerville is, in its essential feature, a slide stop or catch, placed under the trigger, A, *fig.* 874. It is pulled forward into a notch in the trigger,

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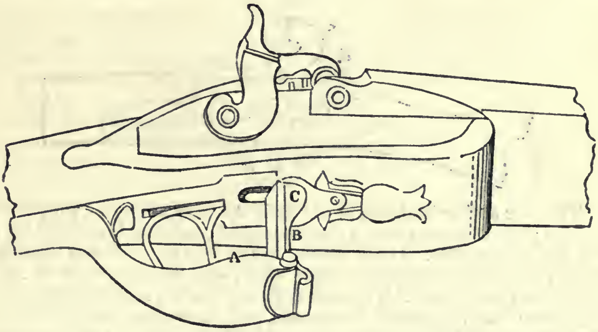

by means of a spring B, upon the front of the guard, which is worked by a key C, pressing upon the spring when the piece is discharged. In another safety plan there is a small moveable curved piece of iron, A, which rises through an opening B, in the lock-plate C, and prevents the cock from reaching the nipple, as represented in the figure, until it is drawn back within the plate of the lock when the piece is fired.

To fire this gun, two different points must be pressed at the same time. If by accident the key which works the safety be touched, nothing happens, because the trigger is not drawn; and the trigger touched alone can produce no effect, because it is locked. The pressure must be applied to the trigger and the key at the same instant, otherwise the lock will not work.

The old French musket is longer than the British, in the proportion of 44·72 inches to 42; but the French bayonet is 15 inches, whereas the British is 17.

	Eng. Dimensions	Fr. Dimensions
Diameter of the bore	0·75 in.	0·69 in.
Diameter of the ball	0·676	0·65
Weight of the ball in oz.	1·06	0·958
Weight of the firelock and bayonet in lbs.	12·25	10·980
Length of the barrel and bayonet . .	59·00	59·72

Within these few years a great many contrivances for fire-arms have been brought forward, and several have been patented. The first is that of Charles Random, Baron de Berenger. *Fig.* 875 shows the lock and breech of a fowling-piece, with a sliding protector on one of the improved plans; *a* is the hammer, *b* the nipple of the touch-hole, *c* a bent lever, turning upon a pin, fixed into the lock-plate at *d*. The upper end of this bent lever stands partly under the nose of the hammer, and while in that situation stops it from striking the nipple. A slider *g f h*, connected with the under part of the gun-stock, is attached to the tail of the bent lever at *i*; and when the piece is brought to the shoulder for firing, the hand of the sportsman pressing against the bent part of the slider at *g*, forces this back, and thereby moves the end of the lever *c* forwards from under the nose of the cock or hammer, as shown by the dotted lines. The trigger being now drawn, the piece will be discharged; and on removing the hand from the end *g*, of the slider *f*, the spring at *h*, acting against the guard, will force the slider forward, and the lever into the position first described.

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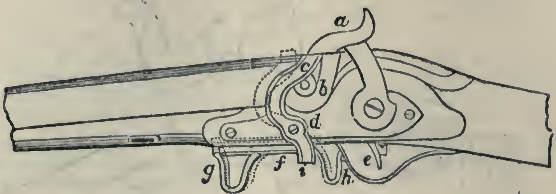

Mr. Redford, gun-maker, of Birmingham, introduced a modification of the lock for small fire-arms, in which the application of pressure to the sear spring for discharging the piece is made by means of a plug, depressed by the thumb, instead of the force of the finger exerted against the trigger. *Fig.* 876 represents a fowling-piece partly in action. The sear spring is shown at *a*. It is not here connected with the trigger, as in other locks; but is attached by a double-jointed piece to a lever *b*, which turns upon a fulcrum pin in its centre. At the reverse end of this lever an arm extends forwards, like that of an ordinary sear spring, upon which arm the lower end of the plug *c* is intended to bear; and when this plug is depressed by the thumb bearing upon it, that end of the lever *b* will be forced downwards, and the reverse end will be raised, so as to draw up the end of the sear spring, and set off the piece. For the sake of protection, the head of the plug *c* is covered by a moveable cap *d*, forming part of a slider *e*, which moves to and fro in a groove in the stock, behind the breech end of the barrel; this slider *e* is acted upon by the trigger through levers, which might be attached to the other side of the lock-plate; but are not shown in this figure to avoid confusion. When the piece is brought to the shoulder for firing, the fore-finger must be applied as usual to the trigger, but merely for the purpose of drawing back the slider *e*, and uncovering the head of the plug; when this is done, the thumb is to be pressed upon the head of the plug, and will thus discharge the piece. A spring bearing against the lever of the slider *e*, will, when the finger is withdrawn from the trigger, send the slider forward again, and cover the head of the plug, as shown.

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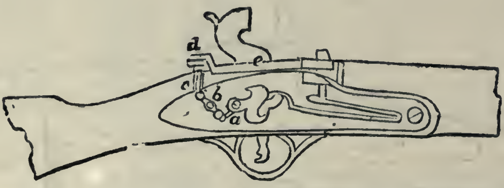

The Rev. John Somerville, of Currie, in April 1835, obtained a patent for a further invention to prevent the accidental discharge of fire-arms. It consists in hindering the hammer from reaching the nipple of a percussion lock, or the flint reaching the steel of an ordinary one, by the interposition of moveable safety studs or pins, which protrude from under the false breech before the hammers of the locks, and prevent them from descending to strike. These safety studs or pins are moved out of the way by the pressure of the right hand of the person using the gun only when in the act of firing; that is, when the force of the right hand and arm is exerted to press the butt-end of the stock of the gun against the shoulder while the aim is taken and the trigger pulled. In carrying the gun at rest, the proper parts of the thumb or hand do not come over Mr. Somerville's moveable buttons or studs.

Fig. 877 is a side view of part of a double percussion gun; and *fig.* 878 is a top or plan view, which will serve to explain these improvements, and show one out of many methods of carrying them into effect. A is the stock of the gun; B the barrels; C the breech; D the nipples; E the false breech, on the under side of which the levers which work the safety studs or pins are placed; F is the shield of the false breech; G triggers; H the lock-plate; and I the hammers: all of which are constructed as usual;

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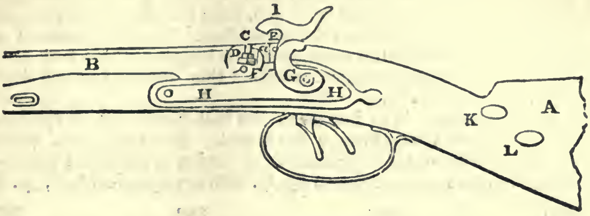

a a are the safety studs or pins, which protrude before the shield F, and work through guide pieces on the under side of the false breech. The button piece is placed

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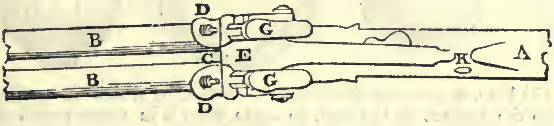

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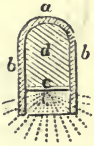

in the position for the thumb of the right hand to act upon it; but when the pressure of the ball of the right thumb is to produce the movement of the safety studs, it must be placed in or near the position K; and when the heel of the right hand is to effect the movement of the safety studs, the button piece must be placed at L, or nearly so.

In these last two positions, the lever (which is acted upon by the button piece to work the safety studs through a slide) would require to be of a different shape and differently mounted. When the hammers are down upon the nipples after discharging the gun, the ends of the safety pins press against the inner sides of the hammers. When this invention is adapted to single-barrelled guns, only one pin, *a*, one lever and button piece will be required.

Mr. Richards, gun-maker, Birmingham, patented a modification of the copper cap for holding the percussion powder, as represented in *fig.* 879; in which the powder is removed from the top of the cap, and brought nearer the mouth; *a* being the top, *b* the sides, and *c* the position of the priming. The dotted lines show the direction of the explosion, whereby it is seen that the metal case is opened or distended only in a small degree, and not likely to burst to pieces, as in the common caps, the space between *a* and *c* being occupied by a piece of any kind of hard metal *d*, soldered or otherwise fastened in the cap.

George Lovell, Esq., Director of the Royal Manufactory of Arms at Enfield, introduced an improvement upon the priming chamber. He forms it into a vertical double cone, joined in the middle by the common apex; the base of the upper cone, being in contact with the percussion cap, presents the most extensive surface to the fulminate upon the one hand, while the base of the under one, being in a line with the interior surface of the barrel, presents the largest surface to the gunpowder charge, upon the other. In the old nipple the apex of the cone being at its top, afforded very injudiciously the *minimum* surface to the exploding force.

Guns, Rifling of the Barrels.—The outside of rifle barrels is, in general, octagonal. After the barrel is bored, and rendered truly cylindrical, it is fixed upon the rifling machine. This instrument is formed upon a square plank of wood 7 feet long, to which is fitted a tube about an inch in diameter, with spiral grooves deeply cut internally through its whole length; and to this a circular plate is attached about 5 inches diameter, accurately divided in concentric circles, into from 5 to 16 equal parts, and supported by two rings made fast to the plank, in which rings it revolves. An arm connected with the dividing graduated plate, and pierced with holes, through which a pin is passed, regulates the change of the tube in giving the desired number of grooves to the barrel. An iron rod, with a moveable handle at the one end, and a steel cutter in the other, passes through the above rifling tube. The rod is covered with a core of lead one foot long. The barrel is firmly fixed by two rings on the plank, standing in a straight line on the tube. The rod is now drawn repeatedly through the barrel, from end to end, until the cutter has formed one groove of the proper depth. The pin is then shifted to another hole in the dividing plate, and the operation of grooving is repeated till the whole number of riflings is completed. The barrel is next taken out of the machine, and finished. This is done by casting upon the end of a small iron rod a core of lead, which, when besmeared with a mixture of fine emery and oil, is drawn, for a considerable time, by the workmen, from the one end of the barrel to the other, till the inner surface has become finely polished. The best degree of spirality is found to be from a quarter to half a revolution in a length of three feet.

Military Rifles.—An essential improvement in this destructive arm has been introduced into the British service.

The intention in all rifles is to impart to the ball a rotatory or spinning motion round its axis, as it passes out through the barrel. This object was attained, to a certain degree, in the rifles of the old pattern, by cutting seven spiral grooves into the inside of the barrel, in the manner shown by *fig.* 880, the spherical ball, *fig.* 881, being a little larger than the bore, was driven down with a mallet, by which the projecting ribs were forced into the surface of the ball, so as to keep it in contact with their curvatures, during its expulsion. Instead of this laborious and insecure process, the barrel being now cut with only two opposite grooves, *fig.* 882, and the ball being formed with a projecting belt, or zone, round its equator, of the same form as the two grooves, *fig.* 883, it enters so readily into these hollows, that little or no force is required to press it down upon the powder. So much more hold of the barrel is at the same time obtained, that instead of one *quarter* of a turn, which was the utmost that could be safely given in the old way, without danger of stripping the ball, a *whole* turn round the barrel in its length can be given to the two grooved rifles; whereby a far more certain and complete rotatory motion is imparted to the ball. The grand practical result is, that better practice has been performed by several companies of the Rifle Corps at 300 yards than could be produced with the best old military rifles at 150 yards; the soldier being meanwhile enabled to load with much greater ease and despatch. The belt is bevelled to its middle line, and not so flat as shown in the figure.

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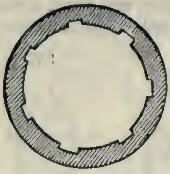

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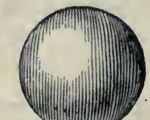

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This mode of rifling is not, however, new in England. In fact, it is one of the oldest upon record; and appears to have fallen into disuse from faults in the execution. The idea was revived within the last few years in Brunswick, and it was tried in Hanover also, but with a lens-shaped (*linsenformig*) ball. The judicious modifications and improvements it has finally received, have brought out all its advantages, and rendered it, when skilfully used, a weapon of unerring aim, even at the distance of 700 yards.

The locks, also, for the military service generally, are receiving important improvements. In Lovell's lock the action of the main spring is reversed, as shown by *fig.* 884; thus rendering the whole mechanism more solid, compact, and convenient;

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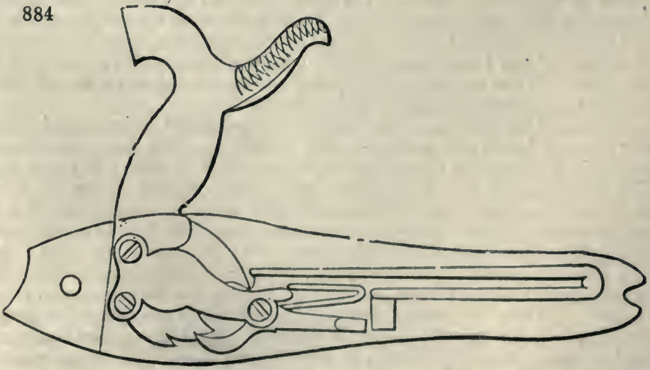

while the ignition of the charge is effected by percussion powders in a copper cap. Mr. Lovell, Inspector of Small Arms for Her Majesty's service, and Director of the Royal Manufactory, at Enfield Chase, directed his attention to the construction of a sure, simple, and strong musket, with which, under his superintendence, the whole of Her Majesty's soldiers were long provided. He has also furnished them with a short, but clear set of instructions for the cleaning and management of these excellent arms, illustrated by a series of wood engravings. From this little work the following notice is copied:—

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Fig. 885. The barrel, reduced to one-seventh size. *a*, the breech; *b*, the nipple-seat or lump; *c*, the back sight; *d*, the back loop; *e*, the middle loop; *f*, the swivel loop; *g* the front loop, with the bayonet-spring attached; *h*, the front sight; *i*, the muzzle.

Fig. 886. The breech-pin, half-size. *a* the tang; *b*, the neck; *c* the screw-threads; *d*, the face.

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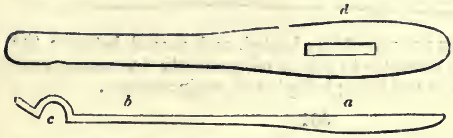

Fig. 887. The bayonet-spring, two ways, half size. *a*, the shank; *b*, the neck; *c*, the hook; *d*, the mortice.

Fig. 888. The nipple, full size. *a*, the cone; *b*, the squares; *c*, the shoulder; *d*, the screw-threads; *e*, the touch hole.

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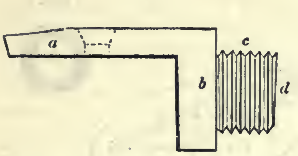

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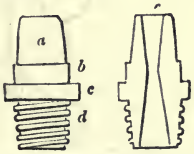

Fig. 889. The rammer reduced to one-seventh size. *a*, the head; *b*, the shaft; *c*, the screw-threads.

Fig. 890. The lock, outside, half size. *a*, the plate; *b*, the cock; *c*, the tumbler-pin; *d*, the hollow for the nipple seat.

Fig. 891. The lock, inside, half size, showing all the parts in their places with the cock down at bearer. *a*, the main-spring; *b*, the sear-spring; *c*, the sear; *d*, the tumbler; *e*, the bridle; *f*, the main-spring pin; *g*, the sear-pin; *h*, the sear-spring pin; *i*, the bridle-pin.

Barrel-welding by Machinery.—The barrels of muskets, birding-guns, &c., or what are called *plain*, to distinguish them from those denominated *stub* or twisted barrels, have of late years been formed by means of rolls: a process in which the welding is first effected on a short slab of thick iron, and then the barrel is brought down to its destined length and form, by repeatedly passing it between a pair of rolls, that have been previously grooved to the exact shape of the barrel intended to be made.

The iron, being thoroughly refined, and reduced into flat bars by the process described, is cut by the shears into slabs or lengths of 10 to 12 inches, and 10 to 10½ lbs. weight, or less, according to the description of gun-barrel that is intended to be made. These slabs are then heated, and bent in their whole length, by means of conveniently-grooved bending rolls, until they assume the form of rough tubes, of the kind of section shown by A, *fig.* 892. They are then placed on the hearth of the reverberatory furnace, and brought to a full welding-heat, and, as soon as the edges of a tube come to a semi-fluid state, it is taken out and passed between rolls having grooves somewhat smaller in diameter than the exterior of the tube, by which means the tube is perfectly welded from end to end; and if care be taken in the management of the heat, and the juncture be kept clear of dirt and cinders, the iron will be found perfectly homogeneous in every part, and there will be no appearance whatever of the seam where the edges came together. These tubes are repeatedly heated, and passed between the barrel rolls, which are of sufficient diameter to admit of gradually decreasing grooves, the whole length of the intended barrel being indented on their surfaces.

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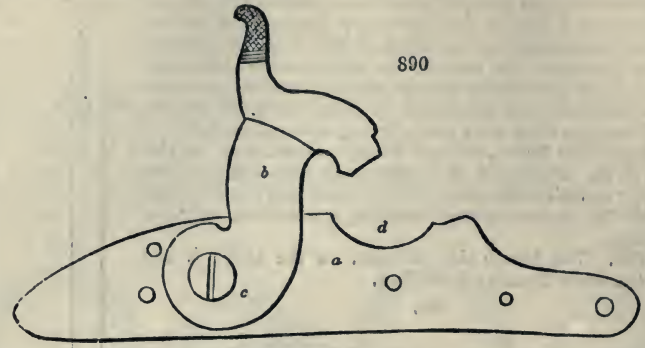

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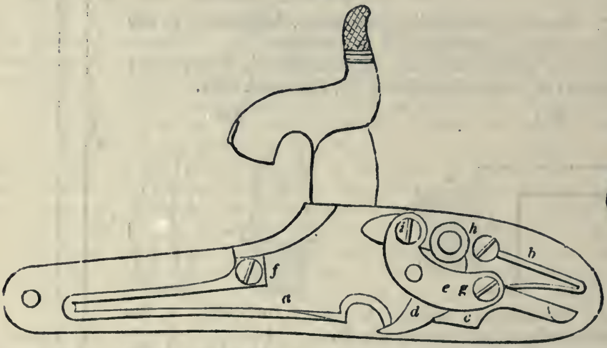

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To preserve the tubular form, and ensure regularity in the size of the bore during the welding process, they are taken out of the furnace, by thrusting into them a tool called a mandril, B, *fig.* 893, which consists of a long rod of iron, having a short steel treblett on its end, of the diameter that the bore of the barrel is meant to be. This rod is so adjusted by means of a strong iron plate C, near its handle, which is of wood, and long, that when passed with the heated tube on it between two transverse holding bars, the short steel treblett D shall be found exactly between the point of impact of the barrel rolls, E, E.

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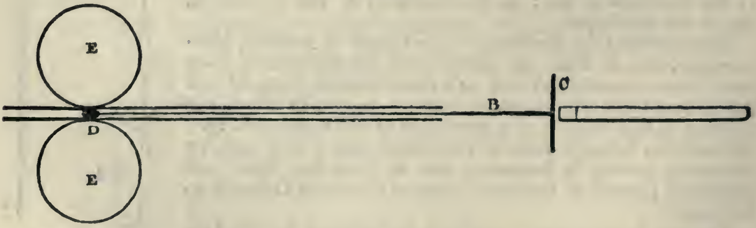

The adhesion of the hot iron to the surface of the rolls is strong enough to draw the tube off the mandril, which thus keeps the bore open from end to end; and by repeating the process through the whole series of grooves in the rolls, the barrel is gradually elongated, and brought down to the exact form required; any superfluous length at the muzzle is then cut off. The breech end is then adjusted by the hammer

—a triple-seat welded on by hand if it be intended for a percussion lock; and then the barrel is ready to go forward to the mill to be bored, turned, and finished.

Gun-barrels formed by this mechanical method are found to stand proof better than those worked by hand, because the heat is more equalised; and any imperfections in the original mass of iron are more dispersed over the whole extent of the tube.

Of late years large strides have been made towards increasing the efficacy of military fire-arms.

The first attempt to improve the rifle in use in the French army was that proposed by M. Delvigne, an officer of the royal ex-guard (*fig.* 894), in which the upper orifice of the chamber that contained the powder took the form of a cup, wherein the ball (somewhat wider in diameter) was received, and by two or three smart blows of a heavy-headed rammer (also cupped out for the purpose) became expanded laterally, and thus the rotatory motion was imparted to it by the spiral grooves of the barrel in passing out. Colonel Poncharra suggested the addition of a wood bottom or sabôt under the ball and a greased woollen patch; and Colonel Thouvesino proposed (*fig.* 895) a steel stem or pillar about 2 inches long inserted into the face of the breech-pin; round this pin the charge of powder was received, and the diameter of the ball, when resting on the top of the pin, was enlarged by the blows of the heavy-headed rammer, as suggested by Delvigne.

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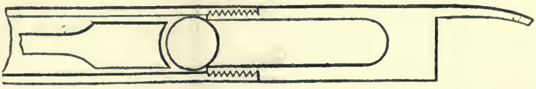

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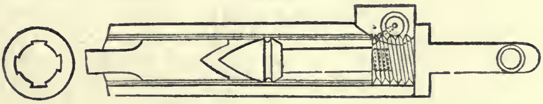

This system took the name of 'Carabine à Tige,' and has been very generally introduced for the service of fusilier battalions in Continental armies; very grave objections, however, have been found against it in use, from the impossibility of keeping the chamber (or part round the pin) clear; and from the severe labour to the soldier in ramming down and enlarging the diameter of the ball sufficiently to ensure the rotatory motion desired.

But if the ultimate results thus attained with spherical balls turned out not entirely satisfactory, it was made clearly manifest, in the course of the experiments carried on, that no insuperable difficulty stands in the way of rendering the fire of infantry very much more accurate and powerful, by the use of rifled barrels throughout the army, and thus leading to a verification of the prediction made by Robins above one hundred years ago, that 'whatever state shall thoroughly comprehend the nature and advantages of rifled barrel pieces, and, having facilitated and completed their construction, shall introduce into their armies their general use, with dexterity in the management of them, will by this means acquire a superiority which will almost equal any thing that has been done at any time.'

But besides smoothing the way to such an essential improvement, it has been elicited of late years, that when the accuracy of flight is secured by the rotatory motion derived from the rifling, the bullet, instead of being limited to the form of a sphere as heretofore, may, up to certain limits, be elongated with considerable increase of destructive effect; and with an augmentation of range very much beyond any thing that has hitherto been considered to lie within the reach of small arms—placing them, in fact, with reference to artillery and cavalry, in the first place instead of the last.

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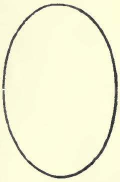

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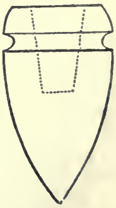

An immensely-extended field has thus been opened to experimenters. 1st. Mons Didion proposed a true oval (*fig.* 896) as the best form of bullet, so that, when shortened by the blows of the heavy rammer and widened in its diameter, it might be brought nearer to the spherical shape before leaving the barrel. 2nd. Mons. Delvigne took out a patent for a bullet (*fig.* 897) under the designation of 'Cylindro-Ogivale;' it had a conical opening behind, in which he imagined that the force of the powder would exert itself with sufficient energy to expand the lead permanently, and so make the ball take the rotatory movement derived from the rifling, without any fatigue to the soldier in loading: with this projectile, indeed, the operation is but slightly more difficult than with the ordinary cartridge and smooth barrels.

The bullet (*fig.* 898) of the 'Carabine à Tige' was called 'Cylindro-Conique,' and was said to possess this advantage over the preceding, that, being brought more to a point in front, it bored its way through the air with greater ease, and thus retained greater velocity, and of course, more extended range; and with this bullet it was that Mons. Tamisier introduced three sharp-edged channels round it, which he stated were necessary to keep its flight steady, by offering a resistance to the action of the air.

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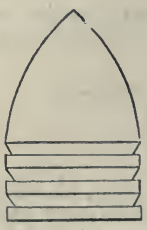

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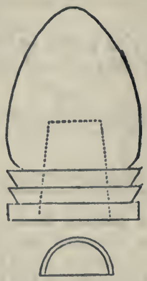

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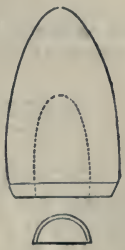


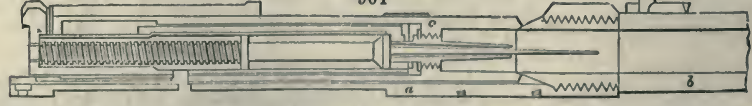
Finally, Mons. Minié, an officer of the French line, suggested (*fig.* 899) the addition of a dénoyau or culot to the hollow ball of Delvigne. This, in the form of a little cup made of sheet iron, is placed in the orifice of the conical hollow of the ball behind, and by the energy of the powder is driven into the ball, enlarging its diameter permanently, and thus giving all the accuracy of the rifle, with nearly the same facility of loading as with the plain barrel.

The principle of the invention, as thus developed, has, we learn, been adopted by our Government for the general use of the army, seeing that it offers so great advantages over the system of plain barrels, but the bullet (*fig.* 900), as modified by the Inspector of Small Arms, has on its exterior no channels, they being found not only useless as to steadying the flight of the projectile, but absolutely injurious in lowering its velocity. The bullet in its improved form too, being more truly balanced in its proportions, and made by mechanical means instead of by casting, has no tendency to the gyrations which appear to have so puzzled French artillerists, and for which they have invented the word 'derivation,' and wasted much learned disquisition.

But even if it were ever to happen, which is not likely, that these various projectors could be brought to agree as to the best form of projectile, they will then find out, that although by the general introduction of rifled and elongated bullets an immense advantage has been realised over plain barrels, their plans, based as they all are upon a system of *loading* at the *muzzle*, are at best but one step in advance; and that a good sound military fire-arm *loading* at the *breech* will, after all, remain the great desideratum —an arm that, without any less accuracy or power to reach masses of artillery or cavalry at a thousand yards' distance, will enable the soldier to triple the quantity of his fire at any moment that he may be called upon to repel a charge of cavalry, or attack or defend a breach at close quarters; of such simple construction, and so easily handled in every position of the body, that the soldier can pour every shot of his most murderous fire upon the enemy with unerring precision, whilst he himself may lie coolly behind a stone or in a ditch in entire security.

These are no longer wild imaginings, although so many hundreds of attempts towards the same object, from the earliest period to the present day, have been one after another seen invariably to fail. The Germans have been long and steadily pursuing the great object, until at length Herr Dreysa, of Sömmerda in Thuringia, has succeeded, after more than twenty years of continued labour, in establishing a musket, under the name of 'Zündnadelgewehr,' which, if not quite perfect, is so well adapted for the uses to which it is applied that the Prussians have armed the whole of their line and the Landwehr with this weapon.

901



The needle musket (*fig.* 901) consists of a strong socket *a*, open on the upper side and screwed on to the barrel *b*, which is rifled in the usual manner; within this socket is a slider *c*, which in fact constitutes the lock, as it contains the spiral spring and mechanism that produce ignition by percussion; it has a stout hebel, or handle, by which it is moved backwards and forwards freely. The cartridge (*fig.* 902) consists of the ball *a*, the sabot *b*, or bottom of hard paper, and holding the priming matter, and lastly the charge of powder *c*, the whole being made up in paper pasted together. In use, the slider being drawn back, the soldier puts the cartridge with the point of the ball in front into the open breech of the barrel, pushes the slider forward, and secures its close junction by a turn to the right against an inclined edge of the open socket. The spiral spring is then brought into action by pressing the spring case forward with the thumb.

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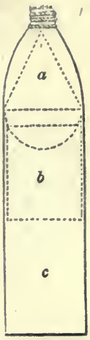


To Captain Drayson, R. A., we are indebted for the following. The Enfield rifle, which has lately been approved of for the use of the army, is constructed principally by machinery.

The factory at Enfield, at which this arm is manufactured, is considered one of the most complete establishments in the world.

The barrel, lock, wood-work, furniture, and bayonet are all constructed at Enfield, and, as each portion is made exactly of the same size and shape, a part of one rifle will fit into the same part of another.

The total length of this weapon, including bayonet, is 6 ft. 0½ in., and it weighs 9 lbs. 3 oz.; the barrel is 3 ft. 3 in. in length, and weighs 4 lbs. 2 oz.; the diameter of bore is ·577 inch. The bullet is elongated, and rotates on leaving the piece like a spherical bullet. The general figure of the bullet is cylindrical, but its front end is rounded, and its rear end has a conical-shaped cavity. In the Minié rifle, some of which were introduced into the service, a small iron cap was placed in the hollow at the rear end of the ball for the purpose of causing the bullet to expand, but in the Enfield rifle this opening is filled by a wooden plug instead. This diminishes the fouling of the bore, and answers all the purposes of expansion.

The bullet is ·568 inch, length 1·062 inch, weight 530 grains. The barrel is proved at Enfield, and when flaws are supposed to exist as much as 15 drams of powder have been fired, without bursting the barrel. The service charge is 2½ drams. The weight of 60 rounds of ammunition, including 75 caps, is 5 lbs. 8 oz.

The bore has three grooves; each groove forms a spiral of half a turn in 3 ft. 3 in. The rifle is sighted up to 900 yards, but an effective range may be obtained beyond that distance.

The system of rifling by grooves is the plan which has been generally employed, and many experiments with different numbers of grooves, some of varying depths, being deeper at the breech, and with different turns; some increasing towards the muzzle have been tried and thought advantageous, at various times. The Enfield rifle has three grooves, with a pitch of 6 ft. 6 in., so that the bullet receives half a turn round its axis while moving through the barrel, the length of which is 3 ft. 3 in. The bullet is cylindro-conchoidal; it is wrapped in paper, and made of such a diameter as to pass easily down the barrel. It requires very pure lead, to allow of its being properly expanded, or 'upset,' by the explosion, and is driven partly against the original portions of the bore, called the *lands*, and partly in the form of raised ribs, is forced into the grooves, whose spiral shape gives the required rotation. The Enfield bullet is shown in the annexed figure. It is conical in shape, and has its back end recessed for the insertion of a box-wood plug. This plug, driven forward at the first shock of the explosion of gunpowder, expands the lead until it fills the grooves at the breech. (*Fig.* 903.)

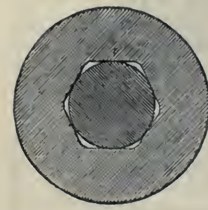
903

The prime cost of a finished Enfield rifle is stated to be about 2*l.* 5*s.*; and from 1,500 to 1,800 rifles per week are at present made at the Enfield rifle factory.

Since the remarkable proof, which has been obtained during the 'seven days' war,' of the advantages possessed by the Prussian needle-gun, our War Office has directed that all the fire-arms supplied to our army shall be breech-loaders, and the Enfield factory is now fully engaged in the conversion of the ordinary Enfield into this form of weapon.

Whitworth's Rifle.—This fire-arm, and the principles on which it is constructed, cannot be better described than by adopting, to a great extent, the words of the inventor: In the system of rifling which I have adopted, the interior of the barrel is hexagonal, and instead of consisting partly of non-effective *lands*, and partly of grooves, consists of effective rifling surfaces. The angular corners of the hexagon are always rounded, as shown in section, *fig.* 904, which shows a cylindrical bullet in a hexagonal barrel. The hexagonal bullet, which is preferred to the cylindrical one—although either may be used,—is shown in *fig.* 905. Supposing, however, that a bullet of a cylindrical shape is fired, when it begins to expand it is driven into the recesses of the hexagon, as shown in *fig.* 904. It thus adapts itself to the curves of the spiral, and, the inclined sides of the hexagon offering no direct resistance, expansion is easily effected. With all expanding bullets proper powder must be used. In many cases this kind of bullet has failed, owing to the use of a slowly-igniting powder, which is desirable for a hard metal projectile, as it causes less strain upon the piece; but is unsuitable with a soft metal expanding projectile, for which a quickly igniting powder is absolutely requisite to ensure a complete expansion, which will fill the bore: unless this is done the gases rush past the bullet, between it and the barrel, and the latter becomes foul, the bullet is distorted, and the shooting must be bad. If the projectile be made of the same hexagonal shape externally, as the bore of the barrel internally, that is, with a mechanical fit, metals of all degrees of hardness, from lead, or lead and tin, up to hardened steel, may be employed, and slowly-igniting powder, like that of the service, may be used. As we have already stated, the Enfield rifle has one turn in 6 ft. 6 in.; that is, the bullet rotates once on its axis in passing over this space. This moderate degree of rotation, according to Mr. Whitworth, only admits of short projectiles being used, as long ones turn over on issuing from the barrel; and, at long ranges, the short ones become unsteady. With the hexagonal barrel much quicker turns are used; and 'I can fire projectiles of any required length, as, with the quickest that may be desirable, they do not "strip." I made a short barrel, with one turn in the inch (simply to try the effect of an extreme velocity of rotation), and found that I could fire from it mechanically-fitting projectiles, made of an alloy of lead and tin; and with a charge of 35 grains of powder they penetrated through 7 inches of elm planks.'

904



905

'For an ordinary military barrel 39 inches long, I proposed a ·45-inch bore, with one turn in 20 inches, which is, in my opinion, the best for this length. The rotation is sufficient, with a bullet of the requisite specific gravity, for a range of 2,000 yards. The gun responds to every increase of charge, by giving better elevation, from the service charge of 70 grains up to 1,200 grains; this latter charge is the largest that can be effectually consumed, and the recoil then becomes more than the shoulder can conveniently bear with the weight of the service musket.'

The advocates of the slow turn of one in 6 ft. 6 in., consider that a quick turn causes so much friction as to impede the progress of the ball to an injurious, and sometimes dangerous, degree, and to produce loss of elevation and range; but Mr. Whitworth's experiments show the contrary to be the case. The effect of too quick a turn, as to friction, is felt in the greatest degree when the projectile has attained its highest velocity in the barrel, that is at the muzzle, and is felt in the least degree when the projectile is beginning to move, at the breech. The great strain put upon a gun at the instant of explosion is due, not to the resistance of friction, but to the *vis inertiæ* of the projectile which has to be overcome. In a long barrel with an extremely quick turn, the resistance offered to the progress of the projectile as it is urged forward becomes very great at the muzzle, and, although moderate charges give good results, the rifle will not respond to increased charges by giving better elevation. If the barrel be cut shorter, an increase of charge then improves the elevation.

There does not appear to have been, even yet, any thoroughly satisfactory experiments on the degree of motion which it is necessary to impart to the ball to ensure a flat trajection, and to overcome the different forces which are continually interfering with the correctness of aim, with even the best rifle. In the experiments with Armstrong's and Whitworth's cannon, some very satisfactory results have been obtained, and much information may be gained by studying the experiments quoted in the article on Artillery.

A professional writer, well qualified to judge of the matter on which he wrote, has made some striking remarks on the Whitworth rifle in the 'Mechanics' Magazine.' After pointing out the small importance of a high prime cost in the case of so durable a weapon as the rifle in question, he refers to the strength of the metal used.

In illustration of its great strength, this fact is quoted. Mr. Whitworth put into a rifle barrel, one inch in diameter at the breech, with a bore of 0·45 inch, a leaden plug 18 inches long, as tightly as it could be driven home upon the charge. It was fired with an ordinary charge of powder, and the leaden plug being expanded by the explosion remained in the barrel, the gases generated by the gunpowder all passing out through the touch-hole. With such strength great durability must of necessity co-exist, unless the quick turn of the rifling should tend to its rapid deterioration. But this is not the case. Mr. Longridge's elaborate investigations having proved that the amount of the force expended upon the rifling of the Whitworth rifle scarcely exceeds two per cent. of the total force of the powder.

Perhaps the most remarkable testimony which has been borne to the merits of this rifle is that of General Hay, the director of musketry instruction at Hythe. After admitting the superiority of the Whitworth to the Enfield in point of accuracy, General Hay said there was a peculiarity about the Whitworth small-bore rifles which no other similar arms had yet produced,—they not only gave greater accuracy of firing, but triple power of penetration. For special purposes, any description of bullet could be used, from lead to steel. The Whitworth rifle, with a bullet one-tenth of tin, penetrated 35 planks, whereas the Enfield rifle, with which a soft bullet was necessary, only penetrated 12 planks. He had found that at a range of 800 yards, the velocity added to the hardened bullet gave a power of penetration in the proportion of 17 to 4 in favour of the Whitworth rifle. This enormous penetration is of the highest importance in a military weapon, in firing through gabions, sandbags, and other artificial defences. Mr. Bidder, President of the Institution of Civil Engineers, says, the Whitworth small-bore rifle, fired with common sporting powder, would never foul so as to render loading difficult. He had himself fired 100 rounds one day, 60 rounds the next, then 40 rounds, and so on, and left the gun without being cleaned for ten days, when it fired as well as it did on the first day. The words of Mr. Whitworth as to the application of his principle to the Enfield weapon must be quoted in answer to the objections of cost, &c., urged against it. 'With regard to the cost of my rifled musket, which has been stated to be an impediment in the way of its adoption for the service, I may state that there would be no difficulty in adapting the machinery and plant already in operation at Enfield, or any requisite portion of it, for making rifles on my system. The change would not cause an increase in the manufacturing expenses; and, supposing the quality of the workmanship and the materials to remain the same, the advantages arising from the use of my bore and turn, and hard metal projectiles, would double the efficiency of the rifle without increasing the cost.'

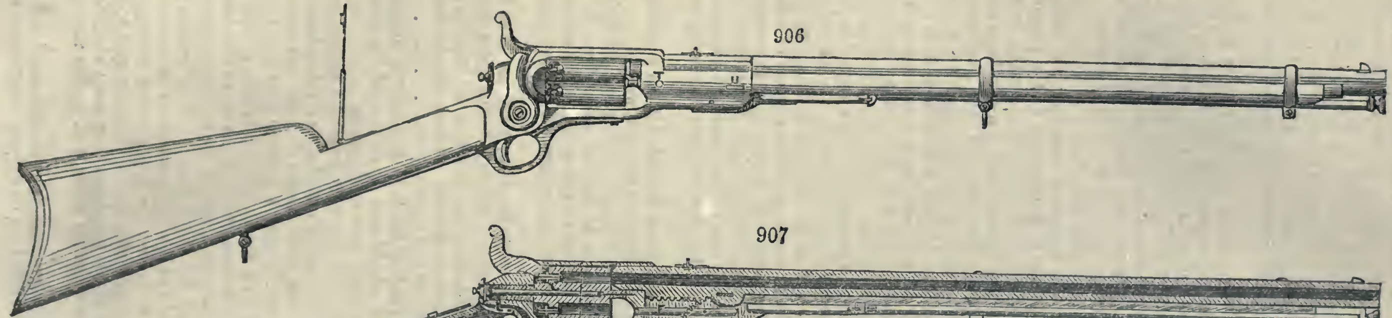
Amongst arms requiring some notice from us, the more remarkable, as involving some excellence in construction, or peculiarity in principle, are the following:—

Colt's Repeating Rifle.—This weapon is constructed mainly on the principle which was introduced by Colonel Colt, in his 'revolvers,' to be noticed presently. The Secretary of War of the United States reported as follows on this arm, which is shown in *fig.* 906, and in section *fig.* 907. *Fig.* 908 is a vertical section of the revolving barrels, and *fig.* 909 the wiping rod.

'The only conclusive test of the excellence of the arms for army purposes is to be found in the trial of them by troops in actual service. Colonel Colt's arms have undergone this test, and the result will be found, in some measure, by reports of General Harney and Captain Marcy, who used them in Florida against the Indians. These reports relate only to the *rifle*, but are clear and satisfactory. . . . . A board of officers recently assembled to consider the best mode of arming our cavalry, made a report, showing the present appreciation of the arm by officers of the army standing deservedly high for their services, experience, and intelligence.'

In its internal construction this rifle differs in some respects from the pistols and early revolving rifles. The catch which causes the breech cylinder to revolve, instead of acting against ratchet teeth, and on the cylinder itself, works in teeth cut on the circumference of the cylinder-end of the base-pin, in such a manner that the base-pin rotates with the cylinder itself, being locked by a small mortise in the cylinder; and the stop-bolt gears into corresponding notches, also cut in the end of the base-pin, and thus locks it when required. This is an improvement in the arrangement of these weapons, and by a simple arrangement the small spring catch, which, by means of a circular groove in the front end of the base-pin, keeps it in place, is immediately released by pressing on a small stud, and the cylinder can be instantaneously removed or replaced. Instead of the pin, which, in the pistol, is used to let the hammer down on, when carrying it, a small recess is cut between each nipple, in the cylinder itself, into which the hammer fits when let down, and makes security doubly secure.

The rifle is provided with two sights: the ordinary leaf-sight usually employed is also provided. The hinder sight is adjustable to suit long or varying ranges, and the



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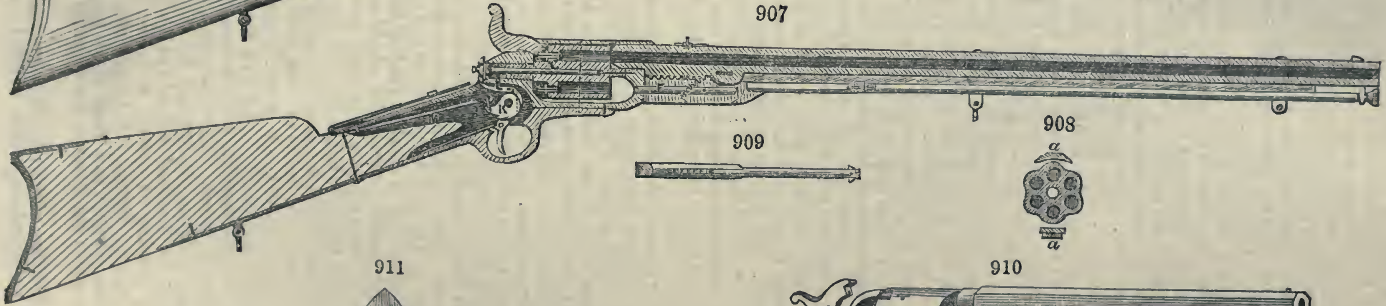

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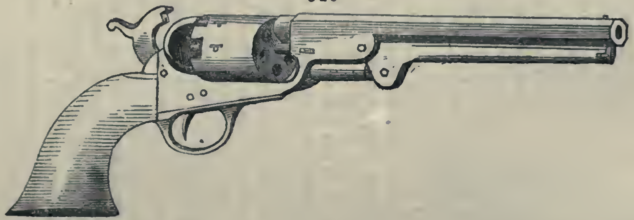

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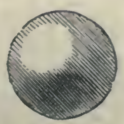

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front sight is that known as the bead-sight, which consists of a small steel needle, with a little head upon it, like the head of an ordinary pin, enclosed in a steel tube. In aiming with this sight, the eye is directed through a minute hole in the sliding piece of the hinder sight, to the small bead in the tube, which bead should cover the mark aimed at; and this sight affords great accuracy in shooting. The wiping rod, which occupies the position usually allotted to the ramrod, in muzzle-loaders, is ingeniously constructed so as to admit of being lengthened. In its interior, which is hollow, slides a slight steel rod, in the end of which a screw-thread is cut; on drawing out the rod, a turn or so of the hand in one direction enables this steel rod to be drawn out to a length as nearly as possible that of the outer case, and a few turns in the contrary direction fasten it firmly in its place; thus enabling it to be used with as much facility as if it were solid. When done with, the reversal of the former motions enables the rod to be restored to its original dimensions, and it can then be returned to its place. This weapon has a real business-like serviceable appearance, and its weight varies, according to the length of the barrel, from 8 lb. to 10 lb. each, with five and six shots.

Colonel Colt has introduced a new shot gun, which is adapted for being loaded alternately with shot and ball. This is adapted for colonists, enabling them to use the gun as an ordinary sporting weapon for birds, &c., or for more deadly purposes. The ball for Colt's rifle is shown by *figs.* 911, 912.

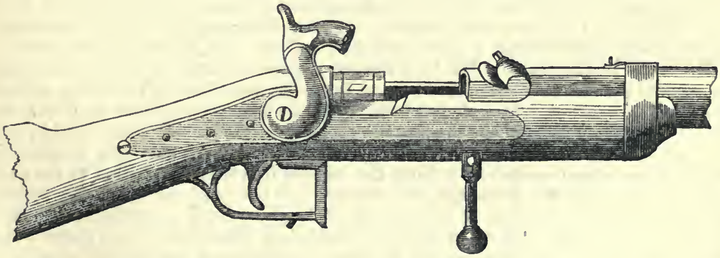
Lancaster's Elliptic Rifle.—So called, although the Elliptical rifle is very old. The bore in this rifle is slightly oblate; the twist found, by experience, to be most advantageous is one turn in 52 inches, the approved diameter of the bore ·498 inches, the length of the barrel being 32 inches. An eccentricity of ·01 inch in half an inch is found sufficient to make the bullet spin on its axis to the extreme verge of its flight. The length of the bullet found to answer best with these rifles is $2\frac{1}{4}$ diameters in length, with a windage of four or five thousandths of an inch.

Major Nuthall's Rifle.—In the ordinary mode of grooving rifles, sharp angles are left between the grooves and 'land' (those parts of the smooth bore left in their original state after the process of grooving has been completed). These create great friction with the projectile, both in loading and discharging. Major Nuthall removes these objections by rounding off the 'lands' into the grooves; that is, making them a series of convex and concave curves, the bore assuming a beautiful appearance to the eye, from the smoothness and evenness with which the lands and grooves blend into each other.

There are also General Boileau's rifle, and some others, which our space will not admit of our noticing.

Breech-loading Rifles have been introduced, and they prove so satisfactory that the principle of breech-loading is applied to ordinary fowling-pieces. Prince's breech-loader has been highly recommended. In this rifle, *fig.* 913, the barrel has attached to it a lever with a knob at its end, kept in its place and locked by a little bolt attached to the bow of the guard. In order to load, the stock being firmly grasped under the right arm, the catch is released, and the knob attached to the lever is drawn to the right, and almost simultaneously pushed forward. The lever being firmly connected with the breech-end of the barrel, the whole of the barrel is thus slipped forward in the stock, to the extent of about 3 inches, disclosing a steel cone, provided on either side with inclined planes, forming a segment of a screw, and locking tightly into slots at the breech-end of the barrel. The cartridge is dropped into the open space at the extremity of the cone, the lever is depressed, pulled backward, and then pushed into its place. The barrel and cone are thus tightly locked together, and until they are in this position the gun cannot possibly be fired. It is, therefore, obvious, that in strength and security this rifle is not inferior to any. At a

913



trial at Hythe, Mr. Prince fired 120 rounds in less than eighteen minutes, showing the rapidity of loading which this weapon admits of. The rifling preferred by the inventor is a five-grooved bore rather deeply cut, the twist being three quarters of a turn in three feet. The London gunmakers have certified to the great merits of Prince's breech-loading rifle.

Prince's cartridge is an ingenious invention; it can be used either with a muzzle or with a breech-loader. The cartridge is made of gun-paper, produced in the manner described for making gun-cotton. The spark fires this with the powder, and if the paper is pure there is no ash left from its combustion. Mr. Prince has brought out a new breech-loading rifle which is simpler than any yet produced. His practical experience in such matters, extending over more than a quarter of a century, combined with the success he has already attained, causes any fresh arm emanating from him to be regarded with considerable attention. The breech is opened by a half turn of a lever, and closed by a corresponding movement. Either common ammunition or a flask can be used in loading. The barrel is a fixture; a chamber being attached to the breech-end, so that existing muzzle-loaders may be readily converted. For cavalry a simple addition is made to the arm, so that the caps are placed on the nipple in the act of loading.

Terry's Breech-loading Rifle differs from Prince's in having the barrel fixed. There is an opening at the base of the breech, which being lifted by a lever discloses a receptacle for the cartridge.

Mr. Westley Richards, *Mr. James Leetch*, and some others have introduced breech-loading rifles. Of the former, Colonel Wilford says: 'The weapon manufactured by Mr. Westley Richards is a perfect wonder. I saw a small carbine, weighing only 5½ lbs., fire better at 800 yards than the long Enfield.'

In the rifle by Leetch the opening for the admission of the charge is in front of the chamber; consequently the shooter has all the security that the solidity of the breech can import.

Revolvers or Repeating Pistols.—The fame attached to Colt's revolvers, *fig.* 910, renders them so well known as to require but little introduction necessary. Although the invention of revolvers, of course, cannot be ascribed to Colonel Colt, their adaptation to modern requirements, and their general use, are undoubtedly due to his extreme energy, perseverance, and skill, and to him, therefore, every credit ought to be given. This make is now extensively used in the United States, and indeed in almost every corner of the world, and seems not to lose favour anywhere. In Turkey, Egypt, Brazil, Peru, Spain, Holland, Prussia, Russia, Italy, and Chili, as well as the United States, and our own country, they have been and are extensively used and approved; and we are given to understand that 40,000 of them have been supplied to our authorities, and have been served out and used in the Baltic, in the Crimea, in China, and in India, with the utmost effect. The shooting with Colt's arms is highly satisfactory. With Colt's revolver you can make first-rate shooting, and be perfectly satisfied with its action. As a proof that it is not liable to get out of repair, we need only state that the American Board of Ordnance had a holster pistol fired 1,200 times, and a belt pistol 1,500 times, without the slightest derangement. The penetration of the first-named was through 7 inches of board, and the second through 6 inches.

The barrel is rifle-bored. The lever ramrod renders wadding or patch unnecessary, and secures the charge against moisture, or becoming loose by rough handling or hard riding. The hammer, when at full cock, forms the sight by which to take aim, and is readily raised at full cock by the thumb, with one hand. It has been tested by long and actual experience, that Colt's arrangement is superior to those weapons in which the hammer is raised by pulling the trigger, in which, in addition to the great danger from accidental discharge, the strength of the pull necessary for cocking interferes with the correctness of aim, which is of so much importance. A very effectual provision is made to prevent the accidental discharge of this pistol whilst being carried in the holster, pocket, or belt. Between each nipple (the position of which secures the caps in their places) is a small pin, and the point of the hammer has a corresponding notch; so that if the hammer be lowered in the pin, the cylinder is prevented from revolving, and the hammer is not in contact with the percussion cap, so that, even if the hammer be struck violently by accident, it cannot explode the cap.

The movements of the revolving chamber and hammer are ingeniously arranged and combined. The breech, containing six cylindrical cells for holding the powder and ball, moves one sixth of a revolution at a time; it can only be fixed when the hammer and the barrel are in a direct line. The base of the cylinder being cut externally into a circular ratchet of six teeth (the lever which moves the ratchet being attached to the hammer); as the hammer is raised in the act of cocking, the cylinder is made to revolve, and to revolve in one direction only; while the hammer is falling the chamber is firmly held in position by a lever fitted for the purpose; when the hammer is raised the lever is removed, and the chamber is released. So long as the hammer remains at half-cock, the chamber is free and can be loaded at pleasure. Revolvers by Daw, by Adams and Dean, and others, have been introduced. They are all so similar in principle, that they need not be described.

FIRE-BLENDE. A rare mineral containing about 62 per cent. of silver, with sulphur and antimony. It is found at Andreasberg in the Hartz, at Freiberg in Saxony, and at Przibram in Bohemia.

FIRE-BRICKS. See Bricks.

FIRE-CLAY. Those clays which are termed *fire-clays* are such as are of a very refractory character—resisting the highest temperatures of the blast-furnace without melting. The conditions which are necessary for the production of a good fire-clay have rarely been sufficiently explained. The best fire-clays are hydrated silicates of alumina, not unfrequently containing silica uncombined; they should not contain soda, potash, or lime in any quantities, as those alkalis combine at high temperatures with the silica, and form glasses. The presence of iron is also exceedingly injurious to a fire-clay. Under the direction of Dr. Percy, an extensive series of analyses of fire-clays were made in the laboratory of the Museum of Practical Geology. From these, as published in Dr. Percy's 'Metallurgy,' the following more important have been selected :—

Places	SiO^3	Al^2O^3	KO	CaO	MgO	FeO	Fe^2O^3	Water combined	Water Hygroscopic
Stourbridge .	65·10	22·22	0·18	0·14	0·18	1·92	...	7·10	2·18
Corngreaves .	57·21	28·58	0·44	0·71	0·49	2·83	...	8·52	2·26
Brierley Hill .	51·80	30·40	...	...	0·50	4·41	...	...	13·11
Glascote, near Tamworth .	50·20	32·59	2·32	...	0·36	0·44	3·52	9·69	3·00
Stannington, near Sheffield	48·04	34·47	1·94	0·66	0·45	...	3·05	11·15	...
Newcastle .	55·50	27·75	2·19	0·67	0·75	...	2·01	10·53	...
Dowlais . .	67·12	21·18	2·02	0·32	0·84	...	1·85	4·82	1·39
Glasgow . .	66·16	22·54	...	1·42	...	5·31	...	3·14	...

See Clay.

FIRE-DAMP, the carburetted hydrogen of coal-mines, produced, in some cases, by the slow decomposition of the coal itself; in others, it is probably the result of the changes in the constitution of the vegetable matter of which the coal itself is formed, which has been confined under great pressure in the interstitial spaces of the coal or rocks immediately in connection with them. The accumulation of this gas in the 'goaf,' or waste spaces of a coal-mine, is probably due to the changes which the coal itself undergoes. The sudden outbursts of this gas, known as 'blowers,' are no doubt the result of the liberation of the gas by suddenly removing the pressure under which it has been confined. This gas is the constant product of the decomposition of carbonaceous bodies under water; it has hence been also called 'marsh gas.' It is a protocarburetted hydrogen, its formula being C^2H^4 (**CH^4**).

This carburetted hydrogen gas does not explode when mixed with air in a proportion much above or below the quantity necessary for complete combustion. With three or four times its volume of air it does not explode at all, with five and a half or six volumes of air it detonates feebly, and with seven or eight most powerfully. When mixed with fourteen volumes of air the mixture is still explosive, but with larger proportions of air the gas only burns about the flame of the taper. See Safety Lamp and Mining.

FIRE-DAMP INDICATOR. Fire-damp or *Grisou* of the French is a great source of danger to the coal-miner, for, when mixed with certain proportions of air, it forms a mixture which, meeting with a naked light, explodes, occasionally causing great destruction to life and property, while its products of combustion poison those who, although stunned by the concussion, would yet recover if conveyed into a pure atmosphere; therefore its presence is a twofold source of danger. To make these two sources of danger more easily comprehended, it may be explained that if fire-damp be present to a very large extent, it naturally reduces to such an amount the oxygen, because two substances cannot occupy the same space at one time, and oxygen being thus excluded leaves in its place fire-damp, which is not poisonous, but simply incapable of supporting life, that is of oxidising the blood, since life simply goes out. The other source of danger is, however, of a different character, for when an explosion of such a mixture takes place the carbon which is hidden in the compound called fire-damp or mine-gas becomes converted, by its combustion with oxygen, into carbonic acid or choke-damp, which is actually poisonous, so that if a man should breathe an atmosphere mixed with it, and be then removed into pure air, he would not be capable of resuscitation, for his life is gone; whereas in the case of suffocation by fire-damp it comes to be simply a case of suspended animation, for if the lungs be artificially inflated with pure air before a great expiration of time life may be saved, as in the case of persons who have been immersed in water; hence as a precautionary measure in all pits where fire- or choke-damp is known to occasionally or habitually be present, casks of lime-water should be placed at intervals, with coarse cloths suspended in them, so that men in the event of an explosion could seize a cloth as they run from their stall after an explosion, and holding this loosely to their mouths in the manner of a respirator they would find that the lime had removed the carbonic acid, and permitted only the remaining mixture of air and fire-damp to pass into their lungs; and these gases not being poisonous would enable the men to pass through the dangerous space occupied by the products of the explosion, and then to reach a place of safety; whereas if they should fall down and lie in the atmosphere of the explosion, the lime respirator would prevent them being poisoned, and when their bodies were reached by the searchers they would be removed, and the ordinary means of restoration being applied many would be recovered, while the searchers themselves would benefit by the aid of the respirators. If fire-damp to the extent of 5 per cent. be mixed with atmospheric air, and be long inhaled, it produces no remarkable effect, except perspiration, which becomes profuse if the amount of fire-damp reach 10 per cent.; if it still increase to 15 per cent., and be inhaled for half an hour, a peculiar bodily helpless feeling supervenes, which makes one feel disposed to lie on one's back, and the eyelids tingle and smart. These feelings pass off in a few minutes, if fresh air be breathed. In an atmosphere containing 22 per cent. of fire-damp a man may still breathe for some considerable time. The writer of this article remained in such an atmosphere for five minutes making experiments, without other inconvenience than a feeling of mental lassitude—other words do not convey the exact sensation; but in an atmosphere more fully charged with fire-damp, probably 33 per cent., he became helpless before he could determine the amount per cent. present, even in three attempts; that is, in shorter time than sixty seconds.

The physical characters of fire-damp vary greatly in different mines; in some cases, being present to exactly the same amount per cent., it will explode violently in the lamp with a click, in others quite quietly; the miners call it a 'sharp gas,' or a 'slow gas,' as the case may be. Its odour varies greatly; and a circumstance of much importance in another point of view is that its diffusion-rate as regards time varies in different pits; in one pit it will diffuse into a vessel in forty-five seconds, in another in fifty, while in a third it may take sixty seconds; the hygrometric state of the gas appears to cause these variations, for in dry pits the time is longer, or appeared to be so in these cases, than in pits whose atmosphere was at the dew point. The writer of this paper is of opinion that the circumstances attending the production of fire-damp in mines require investigation, as there are many points to be elucidated, by experiments to be made in the pits.

Fire-damp is a mechanical mixture of carburetted hydrogen, nitrogen, and carbonic acid, in varying proportions. The carburetted hydrogen is the only substance with which we have to deal in fire-damp, because it is this substance that, when mixed with atmospheric air, becomes explosive; in the act of combustion its carbon forming carbonic acid, and its hydrogen water, both of which at the moment of formation are gaseous, and being at a high temperature, they therefore occupy a larger space than was formerly occupied by the mixed gases: in other words, it explodes, and gives rise to all the phenomena so well known.

In speaking, then, in future of fire-damp, we allude only to the carburetted hydrogen, or marsh-gas, contained in the mixture, that alone being the combustible substance; a proposition to be noticed, because our figures will appear to be different from those obtained by some who have taken the compound substance. Fire-damp is a chemical compound, otherwise known by the name of mine-gas, or as marsh-gas, and is composed of one equivalent of carbon, with two equivalents of hydrogen; it is a light substance of specific gravity 0·559, air being 1·000, and, by its levity, has a tendency to rise to the uppermost part of a gallery. Notwithstanding the law of diffusion, the lower contain less than the upper strata in a chamber, but the writer found, in a return air-way in the Hetton colliery, a uniform atmosphere of 3 per cent. of fire-damp. It is combustible, forming carbonic acid and water.

In the same manner, while speaking of 'choke-damp,' 'after-damp,' 'black-damp,' 'dampie,' &c., we allude only to the carbonic acid which is contained in the compound which passes under so many names, according to the source whence it occurs, for in all cases it is a mixture of carbonic acid, watery vapour, and nitrogen, in varying proportions.

Carbonic acid gas is a chemical substance, composed of one equivalent of carbon and two equivalents of oxygen; it is a dense gas of a poisonous nature, having a specific gravity 1·524; its density causes it to flow to and accumulate upon the floor of a chamber. In an atmosphere, containing 10 per cent. of carbonic acid, life can be maintained for a short time only, and a candle for a still less time; indeed, Dr. Angus Smith has observed that 3 per cent. is fatal, if the amount of oxygen falls below 18 per cent. in the same atmosphere.

We have thus spoken of fire-damp and of carbonic acid, because we are about to explain Mr. Ansell's proposition for giving warning of the existence of these substances through the agency of *diffusion* by means of a simple system of telegraphy. Mr. George F. Ansell, late of the Royal Mint, in a recent lecture on this subject, said: 'Possessing this information, I visited some pits, that I might see the precise conditions to be met, and I placed before myself the problem, how to make known, by their own agency, the existence of substances so varying as carbonic acid and fire-damp; it was perfectly manifest that the specific gravity, as specific gravity which had been proposed by others, must fail, because of the dust and currents of air in the pits; but these thoughts developed the idea that specific gravity, as a diffusive agent, would be the plan, and I have up to this date been unable to improve the first-formed idea, although I have been enabled to greatly simplify the mode of operation. I felt all along that if the existence of dangerous gases could be made known to the master without the man's agency, then the servants would be more particular to observe the laws laid down by the master, and so conduce to the welfare of all.'

The diffusion of gases may be described as an intermingling of them when placed in such circumstances as to admit of the natural motion of their particles extending itself into space or into other gases; for this explanation, it is well to consider that matter in every form, whether solid, liquid, or gaseous, that is liquid in a higher sense, is formed of minute particles, just as the ocean is formed of drops of water. Those minute particles have been called atoms or molecules, and there are reasons for believing that these atoms have motion amongst themselves in either the solid, liquid, or gaseous form of matter. In the case of gases, the law governing one particular motion was eliminated by the late Mr. Thomas Graham, who demonstrated that gases diffuse into each other and into space in the inverse ratio to the square root of their densities; in other words, a light gas diffuses itself rapidly, while a dense gas diffuses itself slowly into space, or into another gas.

If we take the following substances, and compare them with atmospheric air, as the standard of specific gravity, they will illustrate our meaning, for—

	Specific gravity.	Cubic in.		Grains.
Air being taken as of	1·0000	100	will weigh	31·0117
Hydrogen being taken as of	0·0691	,,	,, ,,	2·1400
Marsh gas being taken as of	0·5590	,,	,, ,,	17·4100
Carbonic acid being taken as of	1·5240	,,	,, ,,	47·2600

The barometer registering 30 inches, and the thermometer 60° F. If, therefore, a vessel of a given capacity be filled with each of these different gases under precisely similar circumstances, and weighed carefully, the variations of weight would be as indicated above.

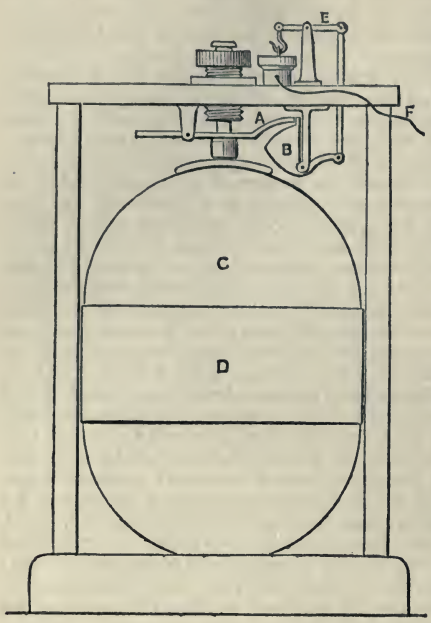
If, then, we imagine the containing vessel to be made of such a substance as will admit of diffusion, we should find that the gas would diffuse out of that vessel in a period of time relative to its specific gravity: hydrogen most quickly, marsh gas next in its place, air following, and lastly carbonic acid; each gas being replaced by its diffusion-equivalent of air; but in the case of air, although diffusion would take place, its amount would not be registered, because air would replace air, volume for volume.

To demonstrate this with one experiment, it will be sufficient to fill a glass tube, whose one end is closed by a plug of plaster of Paris, with coal-gas, and then to place its lower end in water, when the water will gradually rise in the tube, because the gas diffuses out into space, leaving a partial vacuum, while the atmosphere presses the water into that space.

But we find that the whole space is not exhausted, yet there is no gas remaining; for while the gas has diffused out, air has diffused into the tube (the gases have passed each other within the interstices of the plaster of Paris), and thus we come to the relative movement of gases under the circumstances of diffusion, or endosmose and exosmose, as it was formerly called.

The same gas, diffusing through different substances, occupies varying times, being quicker through unglazed pottery ware of Wedgwood than through Sicilian marble. The force or power of diffusion is considerable, as will be evident if the little apparatus about to be described be placed in an atmosphere of coal-gas. The instrument consists of a porous cell, surmounted by a cylinder, in which is placed a piston of brass, the piston being free to move, just as in the case of steam. Immediately that this instrument is placed in an atmosphere of coal-gas, diffusion commences; the gas passing into the porous cell through its walls more rapidly than the air passes out, causes an increase of volume, which exerts its pressure on the lower side of the piston and carries it up through the cylinder.

914



Fire-damp and choke-damp accumulate slowly under some conditions, and rapidly under others; there are, therefore, two main divisions to be met, and we will first explain how Mr. Ansell proposes to indicate the existence of a slowly-accumulating mass of gas in a goaf, or other place.

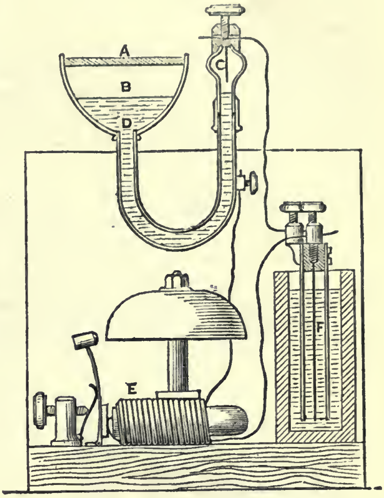
For the purpose of indicating by signal a slowly-accumulated mass of fire-damp, or of carbonic acid, he uses a balloon of thin India-rubber; for, singularly enough, he found that both these gases cause an *expansion* of the balloon. At first sight one can understand how marsh gas expands the balloon, by the law of diffusion; but that carbonic acid should also expand it, is so surprising, that the effect will require to be explained by a law not yet discovered.

The balloon is filled with atmospheric air, and its neck tied tightly with silk, or wax-end, and a piece of linen is bound round the equator of the balloon to prevent lateral expansion. The balloon C, *fig.* 914, so prepared, is placed under a small lever A upon a stand of wood, so that it exerts a gentle pressure on the lever; if now any fire-damp or carbonic acid accumulate round it, either of these gases passes through the substance of the India-rubber balloon, and, accumulating inside, causes it to expand, thus to press against the lever, and raising it releases a detent B, E, by which the terminal poles of a battery F are connected, whereby we get telegraphic communication with a distant place, or a warning on the spot at will. It must be stated that the temperature of a given place in a mine does not vary from year's end to year's end. The action of gases through India-rubber has been explained, by assuming that the gases dissolve in the outer coats of the India-rubber, and in solution pass through and evaporate from the inside. This proposition is rather fascinating, but Mr. Ansell refuses to regard it as the true explanation; he is, therefore, engaged in investigating the facts in a larger field, and at a future time hopes to discover the law which regulates the passage of gases through thin India-rubber.

These balloon instruments can be so arranged as to tell if the accumulation be still free from danger, or if it be explosive.

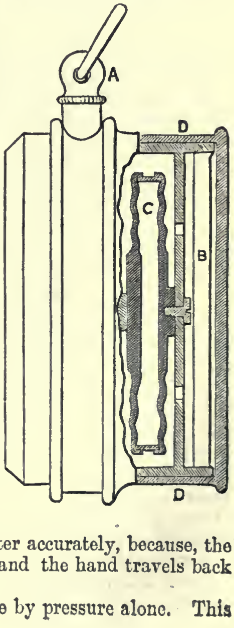
In the event of a sudden irruption of fire-damp, he applies the law of diffusion in all its simplicity; for by an instrument, *fig.* 915, he shows at once, if there be gas, no irruption can be so sudden that this instrument cannot tell of its approach—say, in from 5 to 10 seconds—according to the percentage of fire-damp contained in the dangerous rush. It may be so delicately set as to give warning if the mixture be still below the explosive point. The instrument consists of an iron funnel, B, whose stem is bent into a U, the funnel being closed with a plate, A, of unglazed Wedgwood ware (but, in his first experiments, he used a broken flower-pot), the stem being closed by a cap of brass, C, through which is passed a platinum-tipped copper-wire, capable of just dipping into the mercury, D, previously placed in the bend of the funnel. The distance between the platinum-pointed wire and the mercury regulates the point at which the indication shall be given as regards the irruption; that is to say, if a non-explosive mixture is to give its warning, the wire must be brought almost to touch the mercury; but if it be intended to give its alarm for an explosive amount, then it may stand a little farther off; but in no case to exceed the thickness of a shilling. If, when the instrument be ready, gas impinge on the porous tile diffusion takes place, and the pressure of the accumulating gas forces the mercury against the platinum-pointed wire, and the circuit being thus completed, telegraphic warning is given on the spot, as well as in the manager's room, if such be desirable, either by a needle or by a bell.

915



In the case of known accumulations, Mr. Ansell considered that, if the amount per cent. could be readily ascertained, measures in proportion could be taken to sweep out by ventilation such a dangerous mass. He tried instruments upon many systems, all acting by diffusion, and with many obtained splendid results, such, for instance, as with a column of water or of mercury; but in all cases temperature would be fatal, unless in the hand of a scientific man. Then, again, there is another action depending on the exchange of the proportions of the gases composing the atmosphere, which leads to errors; he has, therefore, been led to use the aneroid barometer, which, although far from a perfect instrument, is still reliable, and may be depended on till a better is discovered. In this place we may mention that Mr. Ansell is now at work at a most beautiful pocket indicator, which we have reason to believe will avoid all the difficulties of the aneroid, and be simply an indicator, not a compound instrument answering three purposes, as does the aneroid indicator. That marvellous arrangement, the Davy lamp, gives magnificent indications, and it may be asked, why try to go beyond it? Mr. Ansell says, 'I hope to supplement it by another indicator, for it must still be used with my proposed instrument; yet I am not without hope that I shall soon make my instrument self-registering; then I shall hope it will be even more useful than in its present form.'

916

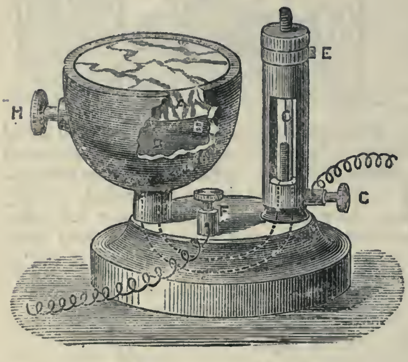


The instrument, *fig.* 916, about to be explained, is an aneroid barometer of the most delicate construction, the brass back of which has been removed, and its place occupied by a porous tile, B. There are besides one or two minor alterations, such, for instance, as a small valve, A, to be used at pleasure. This instrument acts by pressure on the outside of an aneroid chamber, C, which, by a system of levers, causes a hand to travel over a dial face, which is graduated in inches just as the ordinary aneroid, so that it can be used as a barometer, and as such can be relied upon. If we desire to experiment for fire-damp, or for choke-damp, by means of this indicator, it must be taken into the neighbourhood of the suspected atmosphere, and held by the ring handle, A, till it has become of the same temperature as the new place. It is absolutely necessary to follow these directions, because, when the valve is closed, the instrument is affected by temperature; when the temperature is equalised, which is usually in a short time, it may be known by the fact that the hand remains stationary after the valve is closed. The valve, which is simply a hole bored through the handle A, so that by turning the handle the atmosphere is admitted or excluded at will, is closed by screwing it tightly, and the position of the hand recorded. Then the brass cap D, which protects the porous tile, is removed, and the instrument held up into the suspected atmosphere, when in about 45 seconds the maximum effect is produced; at this time it is necessary to read the barometer accurately, because, the maximum point having been reached, effusion takes place, and the hand travels back to zero.

Effusion is the mechanical passage of gas through the tile by pressure alone. This action proceeds with the diffusion, hence we never obtain all the effect calculated upon; but directly diffusion ceases, effusion going on empties the chamber of gas, so that if the instrument be held long enough in the *same* atmosphere, the hand will return to zero, whence it started, and remain there till the instrument is taken into a purer atmosphere, or into one more fully charged. If into an atmosphere more fully charged, the barometer will rise, and this increased reading must be added to the other reading, so as to obtain the amount present at the new place. Thus in one reading it gives 3 per cent. of fire-damp; this atmosphere remains, and the hand returns to zero, but the instrument is placed in an atmosphere which gives 7 per cent. on its face, therefore the true reading is 7 + 3 = 10 per cent., which can be confirmed by taking the instrument into the intake gallery for a few minutes, and then putting on the cap; carry back the instrument to the suspected atmosphere, and it will at once indicate the 10 per cent.

Effusion has been a source of great trouble in the elimination of a suitable substance for a diffusion septum, but Mr. Ansell has just now happily found that Sicilian marble supplies his wants, for this substance permits *diffusion* to take place while it almost entirely arrests *effusion*. This will have a very important bearing on the indication of fire-damp, because it is now only necessary to fit a plate of Sicilian marble into the iron funnel of *fig.* 915 in the place of the porous tile A, and that instrument may be used instead of the delicate instrument shown at *fig.* 916, which, it must be admitted, is extremely delicate and liable to destruction. By regulating the thickness of the marble from one-eighth of an inch to one inch, Mr. Ansell meets the cases of the varying times required for the various rates at which gas accumulates. Instead, however, of using the instrument, *fig.* 915, which is proposed only as a means of warning to those on the spot, he wishes to place in the pits an instrument shown as *fig.* 917, which is about a third of the actual size. This is made of a thick cup of cast iron, screwed into a stand of the same metal, and from the other side of which an upright pillar rises to a height just above the top edge of the cup, as will be seen in the illustration. The top of the iron cup is closed by a solid disc of Sicilian marble three quarters of an inch thick, shown at A, where the iron is torn away for the sake of demonstration. The cup contains mercury as represented by D, while between B and A is a space B, occupied by atmospheric air. If the cup be examined it will be seen that the mercury D flows by a bent tube into the upright pillar where of course it assumes the same level as in the cup. In the event of fire-damp accumulating around the cup (and this instrument is to be placed near the roof at a fitting place in the pit) it at once diffuses through the marble, and by the law above explained accumulates in the space B, and thereby presses on the mercury D and causes it to flow and rise into the pillar till it touches the needle C, and thus to complete the circuit between the poles of a battery, and to ring a bell which may be placed miles or yards off in the viewer's office or in the lamp-cabin. The distance between the mercury and the needle C determines the point of mixture between the gases of which warning should be given; and this may be fixed at above or below the point of explosion at will, by regulating, by means of the screw which passes through the top, where a pin E is placed, to enable a man to regulate the distance in the dark by feeling the pin; H is a valve which should be securely closed as soon as the instrument has been steadily fixed in its proper position, while F and G are the wires which terminate in a cable going to the office, &c., so that twenty of these instruments communicate with the one bell, just as in the case of the telegraph bells at hotels, where the bell rings and a number drops to show which instrument is communicating the state of the pit.

917



All the time the valve A of the aneroid indicator is open, the instrument is a barometer, therefore it indicates change of altitude; at the spot one wishes to test the valve is closed; a knowledge of this will preclude the possibility of *mistaking change of altitude* for *gas*. It is well to remember that this instrument is not intended *to detect gas:* its inventor intends it to be used only to determine how much gas exists in any place where it has been shown to exist. A few intelligent observations will make any man as perfectly acquainted with the indicator as with his watch.

It is imperative that the instrument be held by the ring handle, else its action cannot be depended on. Mr. Ansell has found that the following figures are to be relied upon for fire-damp, and for carbonic acid :—

With Rising Barometer.

Fire-damp.

Per cent.	Inches.	
1 per cent.	=0·010	
3 ,,	=0·030	
5 ,,	=0·060	
7 ,,	=0·080	
7½ ,,	=0·090	explosive
10½ ,,	=0·130	
12½ ,,	=0·170	
15 ,,	=0·220	
20 ,,	=0·320	
50 ,,	=0·800	
100 ,,	=1·680	

With Falling Barometer.

Carbonic Acid.

Per cent.	Inches.
1 per cent.	=0·015
3 ,,	=0·050
5 ,,	=0·080
10 ,,	=0·160
15 ,,	=0·240
20 ,,	=0·330
50 ,,	=0·820
100 ,,	=1·640

Mr. Ansell was much assisted by Mr. Thomas W. Short (of the firm of Short and Mason, 62 Hatton Garden, E.C.), who practically realised the ideas Mr. Ansell conveyed to him, and so produced the apparatus in a simple and practical form.

The following actual experiments were made by Mr. Ansell in a coal-pit at the Ince Hall Colliery, on the 7th June, 1866, in the presence and with the assistance of some officials of the Ince Hall Colliery Company.

Two aneroid barometers were used, each with tiles of different thicknesses, with a view to determine the proper thickness. The instrument denoted by the * had the thinner tile.

Time occupied by experiments	Aneroid Barometer Indicator		Difference	Amount of gas indicated	Distance from floor	Davy Lamp giving to the Underviewer indications as follows—
	Before experiment	After experiment				
Seconds	Inches	Inches	Inches	Per cent.	Inches	
50	30·65	30·71	0·06	5·00	...	Small cap
*50	30·40	30·53	0·13	10·50	...	Very explosive
60	30·52	30·60	0·08	7·00	...	
*50	30·40	30·52	0·12	10·00	...	
50	30·57	30·62	0·05	4·50	24	
*50	30·40	30·50	0·10	8·00	24	Three-inch cap on flame
50	30·55	30·67	0·12	10·00	40	Lamp exploded sharply
*50	30·41	39·55	0·14	11·00	36	Lamp exploded sharply
50	30·50	30·65	0·15	11·50	24	Gas explosive at this point
50	30·60	30·65	0·05	4·50	6	One-inch top on flame
*50	30·44	30·50	0·06	5·00	12	Half-inch top on flame
*50	30·59	30·64	0·05	4·50	18	One-inch top on flame
	30·42	30·50	0·08	7·00	18	Three-quarter inch top on flame
60	30·61	30·65	0·04	4·00	...	
*60[1]	30·45	30·53	0·08	7·00	18	One-inch top on flame
60	30·56	30·66	0·10	8·00	18	One-inch top on flame
*50	30·42	30·56	0·14	11·00	24	Very explosive
60	30·59	30·70	0·11	8·50	24	Very explosive
*60	30·55	30·70	0·15	11·50	30	Over explosive point
50	30·40	30·59	0·19	13·50	30	Flame elongated in lamp, and gave evidence of going out
60	30·57	30·76	0·19	13·50	36	
*50	30·39	30·51	0·12	10·00	36	Very explosive
60	30·50	30·74	0·24	16·00	42	Lamp could not be held in this gas without fear of extinction
*50	30·41	30·62	0·21	14·50	42	

Note.—It was remarked by the underviewer, that the lamp indicated a varying amount of gas within a few seconds at the same place. These changes were attributed to the heat from our lamps and from our bodies; and it was found that the lamps and indicators most nearly agreed when both were taken into the gas at the same instant.

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[1] It was agreed that this was held 10 seconds too long, as the index-hand travelled backwards.

FIRE-OPAL or *Girasol.* A lustrous variety of opal. See OPAL.

FIRESTONE signifies a stone which will bear the heat of a furnace without injury. In geology the term is generally applied to the sandstone which occurs at the top of the Upper Greensand in the south of England, which, from its power of withstanding the effects of heat, is frequently used for lining kilns and furnaces. It is a greenish calcareous sandstone, soft, and easily worked in any direction when first taken from the quarry; but, on exposure, it becomes extremely hard and durable, and well suited for building purposes. Many of the older churches in Dorsetshire are built of this stone.—H.W.B.

FIRE-WORKS. See PYROTECHNY.

FIR-WOOD. The wood of several species of conifers, the most important of which are the Silver Fir, *Abies excelsa*, or the *Pinus abies* of Linnæus (*Sapin commun*, Fr.; *Weiss* or *Edel Tanne*, Ger.); and the Scotch Fir, *Pinus sylvestris* (*Pin d'Ecosse*, Fr.; *Kiefer*, or *Föhre*, Ger.). These are valuable as timber-trees, and for the resinous juices which exude from them. See ABIES; TURPENTINE.

FISCHERITE. A hydrous silicate of alumina, from Nischne-Tagilsk in the Urals.

FISH. Many of the parts of fish enter into manufactures, and, prepared, become articles of commerce. The 'sound' or swimming-bladder of the sturgeon yields isinglass, but the true isinglass is sometimes sophisticated by the gelatin of common fish. Fish-oil finds employment in many ways, and manures prepared from fish-offal are much used.

Owing to the arrangements made relative to our less important imports, it is not possible to give—as was given in the last edition—our importation of fish. See CAVAIRE; ISINGLASS; MANURE.

FISH-SKIN. The skin of the dog-fish, shark, and other ganoids, used occasionally in polishing and in cleaning rounded and irregular works in pattern making.

FISSURE. A crack or rent in rocks. See DYKE.

FIXED AIR. An old name for carbonic-acid gas.

FLAGSTONE. A stone which splits freely in a particular direction along the original lines of deposition of the rock. These are generally sandstones, and the splitting surfaces are frequently produced by thin laminæ of mica; but thin bedded limestones also furnish flagstones, of which some beds of Purbeck limestone and the Stonesfield slates are examples. Flagstones are also obtained from Lias limestones, which are, in fact, thin beds of indurated clay.—H.W.B.

Most of our common flagstones are micaceous sandstones from the coal-measures of Yorkshire.

FLAKE-WHITE. This name is applied indiscriminately to pure white lead, and to the trisnitrite of bismuth.

FLAME (*Flamme*, Fr. and Ger.), in the ordinary acceptation, is the combustion of a mixture of an inflammable gas or vapour with air. That it is not, as many suppose, combustion merely at the exterior surface where the gas and the air come in contact with each other, is proved by passing a fragment of phosphorus or sulphur into the centre of a large flame. Either of these bodies ignited in passing through the film of flame will continue to burn there with its peculiar light; thus proving that oxygen is mixed with the vapour in the interior. If we mix good coal-gas with as much atmospheric air as can convert all its carbon into carbonic acid, the mixture will explode with a feeble blue light; but if we mix the same gas with a small quantity of air, it will burn with a rich white flame: a knowledge of this fact has led to the practice, in many of our large gas-works, of pumping air into the gasometers with the coal-gas—a dishonest and a dangerous system. In the latter case, the carbonaceous particles are precipitated, as Sir H. Davy first showed, in the interior of the flame, become incandescent, and constitute *white light.* Towards the interior of the flame of a candle, a lamp, or a gas-jet, where the air is scanty, there is a deposition of solid charcoal, which, by its ignition, increases in a high degree the intensity of the light. If we hold a piece of fine wire gauze over a jet of coal-gas close to the orifice, and if we then kindle the gas, it will burn above the wire with its natural brilliancy; but if we elevate the gauze progressively higher, so as to mix more and more air with it before it reaches the burning point, its flame will become fainter and less white. At a certain distance it becomes blue, like that of the above explosive mixture. If a few platina wires be held in that dim flame they will grow instantly white hot, and illuminate the apartment. On reversing the order of this experiment, by lowering progressively a flat piece of wire gauze from the summit towards the base of a gas flame, we shall find no charcoal deposited at its top, because plenty of air has been introduced there to convert all the carbon of the gas into carbonic acid; but, as we descend, more and more charcoal will appear upon the meshes. At the very bottom, indeed, where the atmospheric air impinges upon the gauze, the flame is blue, and no charcoal can therefore be deposited.

The fact of the increase of the brilliancy and whiteness of flame by the development and ignition of solid matter in its bosom, illustrates many curious phenomena. We can thus explain why olefiant gas affords the most vivid illumination of all the gases; because, being surcharged with carbon, this is deposited in the middle of the flame, as it would be in an ignited porcelain tube, whereby its solid particles first get ignited to whiteness, and then burn away.

The explanation given above was originally advanced by Sir H. Davy, and has, until recently, been universally accepted by chemists and physicists. Dr. Frankland has, however, brought forward a body of evidence tending to show that the presence of incandescent solid particles is by no means essential to the luminosity of a flame. Indeed, many flames of high illuminating power cannot possibly contain solid particles; thus, when the vapour of bisulphide of carbon is burnt in nitric oxide gas, it produces a dazzling light, yet without the presence of any solid matter. Frankland maintains that the luminosity of a flame is directly connected with the density of the burning vapours. He finds that dense vapours and gases become luminous at much lower temperatures than do those of less density; and that a rare gas, when not luminous at a given temperature under ordinary atmospheric pressure, may become so when suddenly compressed. The passage of electric sparks through different gases produces an intensity of light varying with the density of the gas. With respect to ordinary flames, it is believed that glowing particles of precipitated carbon are not the true source of luminosity, and that soot is far from being a deposit of mere carbon. Frankland maintains that 'incandescent particles of carbon are not the source of light in gas and candle-flames, but that the luminosity of these flames is due to radiations from dense but transparent hydrocarbon vapours.'—*On the Source of Light in Luminous Flames*, *Proc. Roy. Inst.*, June 12, 1868.

In the blowpipe flame from an oil-lamp or a candle, the inner blue flame has the greatest heat, because there the combustion of the whole fatty vapour is complete. The feeble light of burning hydrogen, carbonic oxide, and sulphur, may, upon the principles above expounded, be increased by simply placing in them a few particles of oxide of zinc, slender filaments of amianthus, or fine platina-wire. It is now many years ago since Dr. Ure demonstrated, in his public lectures in Glasgow, that by narrowing the top of a long glass chimney over an argand flame either from oil or coal-gas, the light could be doubled, at the same cost of material. The very tall chimneys used by the lamp-makers are wasteful, as they generate a strong current of air, and the combustion of the solid matter is carried on with great rapidity. With a narrow chimney of half the length we can have nearly as good a light, and save 30 per cent. of the oil. See BLOWPIPE; LAMPS.

FLANDERS BRICKS, commonly called Bath bricks. These are made in large quantities at Bridgewater, from the silty clay deposited in the estuary, which contains a large proportion of fine sand. These bricks are much used for domestic purposes, also in making founders' cores, and for polishing some steel articles.

FLANNEL. A plain woollen stuff of a rather open and slight fabric.

Wales is the country in which flannel was originally made, and the Welsh flannel is still held in much estimation. Hand labour is rarely employed in the production of Welsh flannel; and, though it is not so cheap as some others, the quality and finish of this fabric generally cause it to be preferred for vests worn next the skin and similar purposes. Flannels are now made more extensively at Rochdale than in any other part of the world. In that neighbourhood the manufacturers produce the greatest variety of widths, finish, and substance, viz., the thin, the medium, the thick, double-raised, and swanskin. Saddleworth produces the so-called Saxony flannels, which are much admired; and some varieties are produced at Leeds, and finished the natural colour of the wool. In the West of England flannels are made, but not extensively; and in Ireland a few varieties of low flannels and coatings, called Galways, are manufactured from Irish-grown wool. See WOOLLEN MANUFACTURES.

FLASHINGS. Pieces of lead or other metal let into the joints of a wall so as to lap over the gutters, and prevent the splashings of rain from injuring the internal work. When glass is coated with a thin layer of coloured glass it is said to be 'flashed,' and the operation is called 'flashing.'

FLASK. In foundries, a shallow iron frame, without top or bottom, used for moulding. The lower flask is called a *drag*. See FOUNDING.

FLAT. The name of a river boat, usually flat-bottomed, and carrying from 80 to 120 tons. This term is also applied to baskets in which butter is now sent from all parts of the country to the London markets.

FLAT RODS. In *mining*, a series of rods for communicating motion from the engine, horizontally, to the pumps or other machinery in a distant shaft.

FLATS. *A mining term.* Flats are the decomposed parts of limestone strata, and often contain deposits of lead ore and other minerals, all of which are spread out horizontally. Similar horizontal beds occur in our tin mines, and they are sometimes very productive. The 'carbonas' of the tin mines near St. Ives are little more than flats. Hooson, in his 'Derbyshire Miner,' published in 1747, thus defines a flat:—'it is neither vein, pipe, rake, nor screw.'

FLATTING. The operation of finishing house-painting so as to prevent the unpleasant glare which arises from a surface left in simple oil colour. The flatting colour should be incorporated with a large quantity of spirits of turpentine. This drying leaves a dull surface, which is produced by the resin of the turpentine. Unfortunately, from the high price of turpentine, naphtha is now commonly employed. As naphtha contains no resin, the colour is not so permanently placed upon the surface; it washes off readily, and is liable, after a season, to fall off as dust. This substitution of naphtha should therefore never be allowed.

FLATTING MILL. A mill for rolling out metals into plates. Cylinders of great power are employed for this purpose.

FLAUGHTS. Tools for carding wool, used chiefly in Scotland.

FLAVIN. A yellow dye-stuff imported from America, and used as a substitute for quercitron bark. It is prepared by dissolving it in hot water, with which it makes a somewhat turbid solution. It should be used when newly dissolved, for if allowed to stand it deposits a brownish-yellow mass, in consequence of its not being all completely soluble in water. If boiled in distilled water until all the soluble matter is taken up, and the clear solution decanted, it soon yields a deposit. The colour produced by flavin is never good until raised. A colour dyed by it weakens gradually when a little sulphuric acid has been added; but what remains retains its brilliancy by raising, and in respect of this property it differs from bark.

Adolph Ott, of New York, makes the following remarks on Flavin in the 'American Chemist':—

'The flavine handed to me for examination came from the Stamford Manufacturing Company, 157 Maiden Lane, New York. It represented a light yellow powder, but sparingly soluble in hot water, and separating again on cooling. The supernatant liquid remained slightly coloured. Warm alcohol, even when diluted, dissolved it quickly; not so ether. Tartrate of potassa and copper was not reduced by an aqueous solution, showing the absence of sugar. The solution remained clear on adding a solution of glue, thus indicating the absence of tannin. Sodium-amalgam, when added to an alcoholic slightly-acidulated solution, gave rise to the well-known purple reaction indicative of quercetrin; this reaction was, by the way, also obtained with the deposit of a decoction of yellow bark. The watery solution of flavine decoloured permanganate of potassa, proving the presence of gallic acid (test of Monier). The absence of tannin and the presence of gallic acid are to be considered as proof that the alkaline decoction of the bark had been treated for some time with sulphuric acid.

'The above-mentioned tests satisfied me that the sample was a remarkably pure flavine.

'The late Professor Bolley, who first made us acquainted with the method of manufacture of flavine, discovered tannin and sugar in flavine analysed by him. My specimen was free from both, but contained gallic acid, the derivate of tannic acid. Since a solution of crude quercitrin assumes a beautiful yellow colour, when protochloride of tin is added, this being not the case with my flavine, I drew the conclusion it was free from quercitrin. This fact was also to be inferred from the presence of gallic acid.

'Prompted by the results of this investigation, I began to search whether there existed other analyses of flavine besides that given by Bolley. My researches in this direction remained without result; but I obtained, on the other hand, some notes which strikingly illustrate how slow industries sometimes progress when they are unaided by science. According to James Napier, who published a book on the art of dyeing in 1853, the flavine must have become a commercial commodity in or about the year 1850. Aside from describing its behaviour towards mordants and vegetable fibres, the author states that it contains 4·4 per cent. ashes. They consisted doubtless of sulphate of soda. Supposing that the dye-stuff had not been washed out, and that to make the decoction the same quantity of water had been employed as prescribed in the patent specification of Leeshing, it would be very easy to calculate how much soda was used. The quantity was doubtless very large. In 1856 ("Repertory of Patent Inventions") Leeshing, in Glasgow, secured a patent for the treatment of yellow bark, weld (the herb of *Reseda luteola*), and flavine, for the purpose of enhancing their colouring power. He terms "quercitrin," the material obtained from quercitron; "flavetin," the one obtained from flavine. His first process consists in boiling the pigment-yielding substance, either with dilute sulphuric or hydrochloric acid, and then washing it out with cold water; a second process consists in previously boiling the dye-woods or dye-stuffs in a weak soda-solution, saturating with sulphuric or hydrochloric acid, and boiling for half-an-hour. The inventor claims that the products thus obtained differ from the original substances in being free from tannin and lime (?), and in having acquired new properties, viz. a greater affinity for mordants and a more vivid and richer colour. Being less soluble in water, they are preferable for the dyeing of such tissues as require a boiling heat in the vat.

'Since particular stress is laid upon the increase of the intensity of the colour, it is to be assumed that the flavine contained then a larger proportion of quercitrin. Although the patentee fails to give hints with regard to this point, my supposition has been confirmed by the results of an examination of flavine imported in 1858 into Germany, made by Kœnig. I am unfortunately not in possession of the original paper, yet according to Gmelin, Kœnig obtained quercitrin in minute crystals by treating the flavine with very dilute boiling sulphuric acid, and by purifying the separated flocculent precipitate—the ordinary manner. However, it will always remain a disputed point whether Leeshing was or was not acquainted with the papers on quercitrin by Rigand, who first communicated the fact that this substance is split up if acted upon by dilute mineral acid. This paper appeared in the "Chemical Gazette," two years previous to the date of Leeshing's patent. I would remark that Rigand was well aware of the fact that mordanted cotton assumes a purer yellow when dyed with quercetin than when dyed with quercitrin.

'With regard to the process of Leeshing for enhancing the colouring power of the yellow oak, Bolley, in his "Chemische Technologie der Spinnfasern," says that it was not rational, the quercetin formed being deposited on the bark. But the learned technologist failed to consider that the process in question was also applied to flavine, which was already then a commercial commodity; and, moreover, we may well accept that it was not the intention of Leeshing to extract the colouring matter, partly because the weighty bark with enhanced colouring power brought a proportionally higher price than the pure dye-stuff, and partly because the demand for the latter (the flavine) was undoubtedly not yet sufficiently large. When considered in this light, the inventor certainly deserves credit. One of the processes is quite analogous to the preparation of garancine from madder. In both cases a substance combined with glucose must be set free to be converted into a dye-stuff. In short, the "quercitrin" of Leeshing is a technical product from quercitron.

'After the beautiful researches of Bolley and Rigand on quercitrin had already been published, it is incomprehensible that Muspratt (*vide* his "Chemistry applied to the Arts and Manufactures," edition of 1860), in treating of the above-mentioned dyes, states that their intensity was probably enhanced because the colouring matter had become more soluble in water. Yet on the very same page, in giving an abstract of the Patent Specification of Leeshing, he mentions that the derivates in question upon being treated with hot as well as cold water, yield much less colouring matter than the materials from which they had been produced. Schlumberger, according to Grothe, treats the bark of the yellow oak as follows:—100 kilos of the ground wood are mixed with 280 litres of water, acidulated with 25 kilos of oil of vitriol. This mixture is boiled for two hours, whereupon the bark is washed out, pressed and dried. For the same quantity of bark Schlumberger takes four times the quantity of acid (of only one-third the strength) of that of Leeshing, but extends the time of treatment to twice the length. These are the only points in which these two methods differ from each other. In speaking of this process, Grothe, in his "Katechismus der Bleicherei, Färberei, und des Zeugdrucks" (p. 103), remarks:—"All the tannin having been separated by treating the bark with sulphuric acid, the colours produced with *quercetin* are much purer and brighter than those obtained with flavine." I am at a loss to comprehend this, for it must be evident to every one that the ground bark, when directly treated with acids, must always contain a larger amount of intermediary products than flavine, even when this latter has not been washed out. Grothe, moreover, observes: "Dye-extracts from quercitron, which contain mainly quercitrin, yield with alum a beautiful yellow." I ask, how is it possible that extracts from quercitron, among which Grothe includes the flavine, dye a beautiful yellow, if yet containing tannin, which, according to Grothe, acts injuriously? And why have extracts of quercitron been produced "with a high percentage of quercitrin," since "recent investigations have demonstrated that they contain quercetin, which is principally effective?"

'Immediately after this, Grothe remarks:—"For this reason the quercetin is now especially made." If Grothe designates with this name the prepared bark of Schlumberger, he will excuse me for asking why it is that it is not preferable to produce the flavine, which, with regard to purity and intensity of colour, is to the yellow bark as the purpurine of Kopp to the madder of Alsace?

'With regard to the behaviour of the peculiar kind of tannic acid contained in the bark of *Quercus tinctoria*, many erroneous views seem still to exist. Bolley, in his above-mentioned treatise, observes, for instance, that it was probable that the flavine furnishes a purer yellow than the bark of quercitron, because it has been freed from the greater part of tannic acid. It appears to me that it would have been more correct to state that the flavine produces a purer colour because it consists chiefly of quercetin, as Bolley himself has demonstrated, while the bark contains only the less colouring quercitrin. It is, moreover, not quite clear to me in what manner the tannic acid referred to could act injuriously, since, for dyeing yellow, the goods are not mordanted with iron salts. Besides, the tannic acid from quercitron, according to Schlossberger, yields green, not black, when coming in contact with salts of peroxide of iron. This was already known by Dr. Bancroft when he wrote in his Patent Specification, bearing date of 1775:—"This species of bark may be distinguished from all others by its giving with alum a fine yellow colour, and not striking a black upon the addition of iron."

'According to Grothe ("Katechismus," &c., p. 103) flavine yields a dark, greenish-black precipitate with salts of protoxide of iron, and citron-yellow with salts of protoxide of tin. This can be comprehended only when it is known that Grothe compiled from the above-mentioned book of Napier, who evidently examined a kind of flavine containing much tannic acid. With salts of protoxide of iron, pure flavine yields a green colour with olive tint; with tin salt the liquid only assumes a brighter colour. A decoction of bark, however, from which quercitrin has already separated, produces, with salts of protoxide of iron, a greenish-black; with tin salt, a light yellowish precipitate. In this latter case the supernatant liquor grows reddish.

'In dyeing with a decoction of the bark, the brown colour discovered by Chevreul acts undoubtedly more injuriously than tannin does. If, therefore, one chooses, with Bolley, to ascribe the purer yellow of the flavine to the absence of a foreign substance, it would certainly be more correct to seek the cause of this fact in the absence of the brown colour of Chevreul. Every dyer knows that in dyeing with the bark of quercitron high temperatures are not desirable, the brown dye being then absorbed by the fibre, just as in dyeing with aniline violet the real colour contained therein is withdrawn at a high degree of heat.'

The quantity of colouring matter in flavin is very great, its value as compared with bark is 16 to 1, or one ounce of flavin is equal to one pound of quercitron bark. A portion burned left 4·4 per cent. of ash, and a solution of it gives the following reaction with salts:—

Persalts of iron	Orange black precipitate.
Protosalts of iron	Deep greenish black precipitate.
Protosalts of tin	Lemon yellow precipitate.
Persalts of tin	Orange yellow precipitate.
Alumina	A rich yellow precipitate.

Acids lighten the colour of the solution, and alkalis deepen it, rendering it redder.—*Napier.*

FLAVINDIN. A substance isomeric with indin and Indigo blue. It is produced by the action of potash on indin. Flavindin may be obtained in large quantities by continuing the ebullition of indin with solution of potash for a long time. It is purified by solution in water containing a few drops of ammonia, and precipitation with hydrochloric acid. Flavindin is of a pale yellow colour, and is sparingly soluble in alcohol. See Watts's 'Dictionary of Chemistry.'

FLAX (Latin, *linum;* French, *lin;* Italian and Spanish, *lino;* Portuguese, *linho;* German *Flachs;* Dutch *vlas*), the *Linum usitatissimum*, a plant of the class Pentandria, order Pentagynia, in the system of Linnæus, and the type of the order Linaceæ, in the natural system of Botany, largely cultivated for its fibre and seed, and, next to cotton, the most extensively used raw material for textile manufacture in the vegetable kingdom. This plant was primarily a native of Asia, and was introduced at an early period into Europe. Frequent mention is made of it in Scripture history, as grown both in Palestine and in Egypt, as well as of the fabrics manufactured from its fibre. It was probably introduced into Europe by the Phœnician traders, or the Greek colonists of Egypt and Syria. Homer alludes to the linen manufacture of Greece.

At the present day, the flax plant is grown for fibre alone, for seed alone, or for both products together, in many countries of the eastern, and in some of the western hemisphere. For seed alone, in Hindostan, Turkey, and the United States of America; for fibre and seed in Russia, Belgium, Holland, France, Germany, Scandinavia, Italy, Switzerland, the Iberian Peninsula, Great Britain, and Egypt; in Ireland, chiefly for the fibre, without utilising the seed.

The average annual production of fibre, in the chief countries where flax is grown, is as follows:—

	Tons
Russia	130,000
France	48,000
Belgium	18,000
Holland	9,000
Austria	60,000
Prussia	32,000
Ireland	35,000
Egypt	10,000

and adding all other countries, we may estimate the entire annual weight of fibre produced throughout the world, at 400,000 tons.

The quantity of seed may be taken at nearly 2,000,000 of quarters. At the average value of fibre and seed, the annual production in all countries, of the former, may be given in value at 20,000,000*l*., and of the latter at 5,000,000*l*., making in all, 25,000,000*l*. as the worth of the raw produce, before its conversion into woven fabrics and feeding-stuffs.

From all we can learn relative to the earliest annals of the flaxen trades of the United Kingdom, it would seem that the great object of those who took most interest in their progress was to secure ample supplies of raw material. Long before the manufacture of cotton gave such impulse to enterprise in Great Britain the governments of the day and the great landowners in each shire or county successively patronised the growth of flax. In many of the old English leases it was made a matter of actual covenant that farmers should every season set apart certain sections of land for that purpose, and at most of the country fairs there were premiums offered for the largest and best-finished parcels of flax. Two centuries ago, Scotland was especially famed for the production of the finest description of material to be found in either England or Ireland; and as she too had her Board of Trustees whose duty it was to encourage the growth as well as the manufacture of flax, a large quantity of that article was annually raised there. This system of home growth was kept up on both sides the Tweed until the last quarter of the past century, when the introduction of the Asiatic fibre, and the mechanical contrivances of Hargreaves, Crompton, and Arkwright, gave a new turn to British enterprise. In a few years the manufacture of cotton had extended so rapidly that it took the lead of all the clothing trades.

From that period demand for flax fell away, and English farmers, finding more difficulty in making sale of that variety of crop, ceased to grow it for fibre; but a few men in Dorset, Devonshire, and Somersetshire sow flax almost solely for seed. All that time, however, and on to the present, the Irish people, and especially Ulstermen, continued to grow the 'national fibre,' for although the cotton manufacture had made some progress there, the demand for linen rose rapidly and the cry for larger supplies of raw material was heard on all sides. The culture of flax in Ireland formed a large field of local enterprise at a very early period of that country's history. Cormac O'Conn, who reigned there in the third century, is described as wearing 'a girdle of fine flax;' and five hundred years afterwards, when Niall the Third was in power, exports of flax formed the most prominent features of Ireland's trade with England. During succeeding ages the Irish farmer seems to have forgotten his cunning, as in the days of Lord Strafford's vice-regal government in that island the growth of flax as well as the make of linen had degenerated very much. Whatever may have been the faults or failings of the unfortunate Earl, in other phases of his political career, the Irish linen trade owes more to him than to any other of the English deputies, not only of his own time, but of any that succeeded him. When Lord Strafford made his first tour of the Irish provinces, the average yield of the plantation acre, which in point of area was more than one and a half that of the English acre, did not exceed fifteen stones, and the length of fibre was about twelve inches. The Earl sent orders to Holland for supplies of seed in the spring of 1633, the year after his appointment, and he also brought over a number of Dutch farmers to teach Irishmen the most successful mode of cultivating the plant. These foreigners were kept at work for several seasons, and the result of their exertions was that in 1638 the turn-out was thirty stones to the acre, and the length of flax stem had increased to 2½ feet. Fifty years afterwards Arthur Dobbs wrote a history of Ireland's Commerce and Agriculture. There was then an area of thirty thousand acres under flax, and the yield had gone up to an average of forty-four stones to the Irish acre. We should here state that the settlement of the Huguenots in different parts of the island had by that time given powerful impetus to every branch of the linen trade. In nearly all the northern counties the culture of flax began to be studied as an art, and the more enterprising growers prided themselves very much on the quality of the article they were able to produce.

A board, consisting of nobles and gentry, was appointed to sit in Dublin, under the title of 'Trustees of the Linen and Hempen Manufactures,' and ample means were placed in the hands of members for the purpose of encouraging the trade. Five and twenty years afterwards a similar institution was established for Scotland; and in both cases much good was done, though the principle on which they were founded could scarcely be justified in rightly-regulated economy. Foreign flax seed was largely imported into Dublin and Dundee, and bounties awarded to growers of the largest and finest lots of fibres. But the breadth of lands under that crop north of the Tweed never exceeded 10,000 acres, or little more than one-fourth of the area sown at that time in Ireland. In 1809 there were only 5,000 acres in all Scotland against 35,000 acres in Ireland, but of that aggregate 23,000 acres were raised in Ulster. There were 148,000 acres sown in that county in 1815, and about the same extent of area in 1820, while in 1825 the sowing occupied 139,400 acres. After the dissolution of the Linen Board in 1828 no reliable record of crops was kept, and until 1847, when a regular system of agricultural statistics was got up in Ireland, all was left to mere conjecture. In the meantime the imports of foreign flax into the United Kingdom had been making enormous progress. We give the figures for different periods of the first half of the present century:—

Year	Cwts.
1801	273,720
1821	498,653
1831	936,440
1841	1,346,843
1851	1,194,184

Flax-spinning by machinery has accomplished wonders for flax-growers. Some attempts had been made to produce linen yarn by water-power in Lurgan, so early as 1717. A carpenter, Thomas Turner, of that town, who was much patronised by Louis Crommelin, invented a machine to spin flax and for which the Board of Trustees awarded him 100*l.*, but the death of the inventor took place before the work had been brought to perfection. Louis Paul, a Birmingham blacksmith, tried his hand at a machine in 1740, and John Kendrew and Thomas Porthouse of Darlington brought out in 1787 a still superior invention. But until John Marshall, son of a Leeds shopkeeper, took the matter in hand, all had proved complete failures. The Leeds mill was commenced about the close of the past century, and some time afterwards the trade was started in Dundee. These mills imported Irish flax very largely, and this gave fresh stimulus to growers in that island. Ireland had been trying the new principle of yarn spinning for some years, and although the Board of Trustees paid a premium of 30*l.* for every spindle erected, no permanent good resulted. The bounty system ceased in 1828, and two years afterwards T. and A. Mulholland, of Belfast, erected in that town their famous York-street mill, which, like that of the Marshalls of Leeds, gradually grew into gigantic proportions. In 1833 there were nine flax-spinning-mills at work in Belfast, thereby creating an immense increase in the consumption of raw material. Imports of foreign fibre were not keeping up to the requirements, and about that time a number of Belfast spinners and linen merchants began to feel that a famine in flax would arise if extra exertions were not made to extend home-growth. In 1841 a society was formed for that purpose, and so well did it do the work that the breadth of land which for that year was only 83,750 acres had been extended in 1844 to 122,680 acres. But the great good effected by the Flax Improvement Society did not end there. Besides that enlargement of area, the farmers were taught by experienced instructors better modes of preparing the soil and a more careful system of choosing seed. The effect of these lessons was to improve the skill of growers so much that the article produced was superior in quality and the yield equally improved.

A terrible prostration of energy in the ranks of Irish agriculturists followed the famine of 1847, and the breadth of flax lands was narrowed one-half. For some seasons afterwards this state of affairs continued, the total area in 1849 only extending to 60,070 acres. But, as better days set in, a great improvement took place in flax-growing, and in 1852 there were 137,000 acres under the crop; the succeeding season showed a much wider area, 174,529 acres having been sown. Then came a reaction, and in 1857 the breadth was only 97,720 acres. By this time the demand for first flax had been rendered still greater in consequence of the extension of spinning-mills in Dundee and Leeds; so that, besides the home requirements, Irish farmers had a stirring appeal for further supplies made to them from the sister isle. All this cry for more flax did not fall unheeded on the ears of the people engaged in the different departments of the trade. After the final suppression of the Sepoy mutiny, the tide of public interest had set strongly towards India, and much attention was aroused as to the best mode of turning to good account the immense capabilities of that magnificent appanage of the British Crown. The House of Commons, as the reflex of popular feeling outside, took up the subject, and a Select Committee was appointed to inquire into and 'take evidence on the Colonisation and Settlement of India.'

In course of that inquiry Mr. James Dewar, of the house of D. Dewar, Son, and Sons, Cheapside, London, stated, that of all Britain's possessions none equalled the land beyond the Ganges in the variety and value of its fibrous products. He said that in 1854 the Indian Government, at the suggestion of the Punjaub Agricultural Society, had induced the native farmers to cultivate 60,000 acres of land in flax; and so well did that crop succeed that in the following year 250,000 acres were sown. In 1858 Colonel Burnett brought over large lots of India-grown fibre, part of which, after having been examined and approved of by the Belfast Chamber of Commerce, was sold in that town at 45*l.* a ton. At a moderate computation of the average yield of the India flax lands, the value of the crop for 1855 was about 2,250,000*l.* In 1859 several of the leading linen merchants on both sides the Channel held conference as to the practical opening up of a field of industry beyond the Ganges, and ultimately Mr. James Dewar and other men in the trade formed 'The India Flax Company.' Ample means were subscribed to start the project of flax culture in the Punjaub on a scale of extended dimensions, and a large tract of land was acquired by the directors on very favourable terms. Practical instructors—men well schooled in the art of flax-growing—were sent out to watch over the preliminary proceedings, and teach the natives how to prepare the ground, sow the seed, and attend to the crop in every stage of its growth. For a few seasons the work went on favourably. In the south-east transept of the second Industrial Exhibition held at Kensington in 1862, several samples of Indian flax were shown, and these were considered as very hopeful evidences of what might be done in that phase of Indian enterprise. But from various causes, probably want of perseverance as the leading one, the India Flax Company was dissatisfied, and the whole affair was given up. There had, some time before, been much attention directed to Canada, where the prospects of abundant supplies were said to be most favourable. Some lots of flax grown in Ontario were sent to Belfast, some to Dundee, and some to Leeds, and in each case mill-owners were well pleased with the article; but after all the assertions made by sanguine projectors, Canada's flax culture has not done much for the spinning trade.

We have seen that England and Scotland have all but ceased to supply fibre for flax-spinning; to Ireland, therefore, and continental Europe, mill-owners must look for raw material. The uncertain nature of the crop and the very unfavourable state of the climate in some seasons cause great diversity of feeling among the Irish farmers as to the flax culture. A small extent of area marked the season of 1857, but in 1861 there were 147,950 acres sown; in 1862, 150,000 acres; in 1863, 214,000 acres; and in 1864, 301,942 acres, by far the widest area ever known. Of this last-noted total, Ulster alone had 278,254 acres, while Connaught had cultivated 8,688 acres; Leinster, 7,383 acres; and Munster, which for soil and climate could compete with Belgium itself, had only 7,620 acres. We hear much about utilising Ireland's resources, and of the necessity of creating more remunerative fields of enterprise for capitalists and work-people; but in the most fertile province of that nation, and where there might annually be produced some 250,000 acres of flax, we find that only a mere fractional part of such breadth had been thus occupied. And if so much had been sown every single pound weight of the entire crop would have been taken up by our mill-owners.

An unprecedented demand for flaxen products was created by the scarcity and dearth of cotton during the American War. Not only were the spindles of every mill in the kingdom taxed to their extreme power, but vast lots of French yarns were imported to meet the requirements of that time of extra activity. Of course there was great demand for flax, and fortunately the yield of 1864 was above the average. From that season, however, the growth of flax in Ireland declined. In 1865 there were 251,433 acres sown; in 1867, 253,257 acres; in 1869, 229,252 acres; and in 1871, 156,764 acres, or little more than one-half the breadth under flax in 1864. The yield of 1870 averaged about 40 stones of fibre to the acre, that of 1871 was less than 20 stones to the acre; but that year is well known as the most unfavourable of any season for the last sixty.

There were 430,000 spindles in England's flax mills in 1864, and 350,000 in Scotland; at the same time Ireland had 750,000 spindles set up in her mills. Very little change has since then taken place in the trade of Great Britain, while that of Ireland has increased to more than 900,000 spindles. Foreign supplies of raw material have been making up for defective produce in home lands, as will be seen by the annexed figures of imports:—

Year	Cwts.
1861	1,133,979
1865	1,913,132
1871	2,597,900

Some time after Sir Robert Peel's last accession to power, he proposed that duties should be thrown off all raw materials. Foreign flax then paid a tax of 10*l.* a ton, and when the minister mooted his intention to let such material come in free, a great outcry was raised against the proposition, which, it was said, would, if carried into law, ruin the Irish farmers. At that time (1842) milled flax sold at 5*s.* 6*d.* to 10*s.* 6*d.* the stone of 16½ lbs., and hand-scutched flax at 4*s.* 6*d.* to 6*s.* 6*d.* the stone. The average prices of flax for the first half of 1872 were 5*s.* 6*d.* to 8*s.* 6*d.* for hand-scutched, and 7*s.* to 12*s.* 6*d.* for milled, per stone of 14 lbs.

The flax plant has a single slender stem, varying from 2 to 4 feet in height, according to the nature of the soil and the season, with the difference of climate, and mode of culture. It has lanceolate, sessile leaves, of a rich green colour, and branches out, at the top, into two or more small stems, each of 2 or 3 inches in length, and bearing light blue flowers, succeeded by globular capsules, pointed at the apex, and bearing eight to ten seeds of a reddish brown, when ripe. The stem of the plant consists of an inner part, or core, sometimes hollow, but more frequently solid, composed of ligneous matter, surrounded with a bark of fibres, which are united to each other by a gum, the whole being sheathed in a fine epidermis. The plant arrives at maturity in fourteen or fifteen weeks after the seed is sown. It has then changed to a pale yellow or straw colour, and the seeds have become brown. The usual period of sowing, in European countries, is from March to May, although in some parts of the Continent the seed is put in the ground in autumn; but in this case nothing is gained, as the plant becomes mature very little earlier than when the sowing is done in spring. It is grown on a wide range of soils, sandy, calcareous, clay, loam, peaty, &c., but that best adapted to it is, either a deep, friable, clay loam, or the alluvial deposit of rivers, whether along their banks, their deltas, or where reclaimed from the sea, as in the case of the polders of Holland. Deep tillage, good drainage, and repeated pulverisation of the soil, are very requisite. The preparations for the crop are begun in winter, by ploughing the surface, and turning it up to the action of frost: they are completed in spring, by ploughing and harrowing. The seed is sown at the rate of 2½ bushels per statute acre, the best season being April. In the British Isles, Belgium, and Holland, the favourite seed is obtained from Russia, Riga being the port of shipment. Dutch seed is also extensively in use in Ireland, and a good deal of home-grown seed—the first year's growth from Riga seed (one year from the barrel), which is considered quite equal to the parent. No manure is used in Ireland, but in Belgium and France rape cake dissolved in urine is considered very useful. The seed is sown broadcast, and the soil is afterwards rolled. When the plant is a few inches high, weeds are carefully removed, and no further attention is necessary until the season of pulling. Flax is not cut with the scythe or sickle, but is pulled up by the roots. About the middle of August it is generally ready for pulling in the British Islands, but in Belgium and France it is in a fit state two to three weeks earlier.

The after treatment varies in different countries. In Russia, part of Belgium and Holland, and in France, the plant, after being pulled, is dried in the sun, being set up on the root end in two thin rows, the top interlacing in the form of the letter V inverted. The sun and air soon thoroughly dry the stems, and they are then made into sheaves, and the seed afterwards beaten off. The stems are steeped subsequently. Another mode, in general use in Ireland and in part of Flanders, is to steep the green stems immediately after they are pulled. In Flanders, the seed is invariably separated from the stems before the latter are immersed in water. In Ireland, although this is practised to some extent, yet the great bulk of the flax crop is put in the water at once, with the seed-capsules attached, and consequently there is a very considerable annual loss to the country by this waste of a most valuable product of the plant. In the Walloon country of Belgium, in its eastern provinces, and in the greater part of Germany, *dew-retting* is practised. That is, in place of immersing the stems in water, they are spread thinly on short grass, and the action of the dews and rains ultimately effects what immersion in a running stream or pool accomplishes in a much shorter time, namely, the decomposition of the gum which binds the fibres to the stem and to each other. Fibre obtained by this method is, however, of very inferior quality and colour.

If the fibre of flax be separated from the stem, without the decomposition of this matter, it is found to be loaded with impurities, which are got rid of afterwards in the wet-spinning, the boiling of the yarn, the subjection of the woven fabric to the action of an alkaline lye, and the action of the atmosphere—of rains and of alternate dippings in water, acidulated with sulphuric acid, and of a solution of chloride of lime, which are all required to perfect the bleaching. The great object, therefore, is to obtain the fibre as nearly free from all foreign substances as possible, and, consequently, the mechanical separation of it from the woody pith of the stem is not to be recommended.

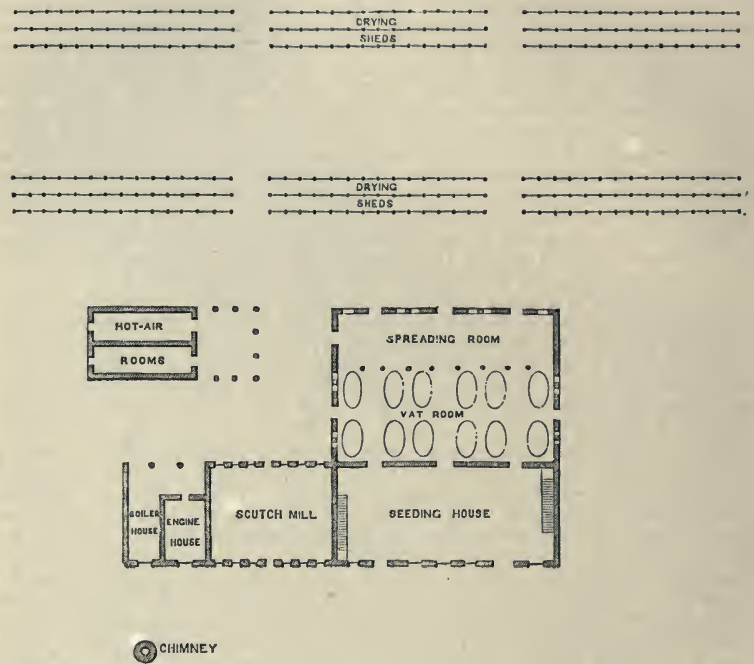
At various periods attempts have been made to prepare flax fibre without steeping. Weak acids, solutions of caustic potash, and of soda, soap lye, and lime, have all been tried, but have all been found objectionable. In 1815 Mr. Lee brought before 'the Trustees of the Linen and Hempen Manufactures of Ireland' his system of separating the fibre without steeping. He alleged that a large yield was thus obtained, that the colouring matter could afterwards be discharged by the most simple means, and that the fibre possessed greater strength. But it was found that the system was practically worthless. In 1816, Mr. Pollard, of Manchester, brought forward a plan of the same nature, and proposed to make an article from flax which could be spun on cotton machinery. This also fell to the ground. In France and Belgium, at different periods, similar projects were found equally impracticable. In 1850, and again in 1857, Mr. Donlau revived the same, but the same fatal objections prevented the success of the system. The fibre was loaded with impurities, and the apparently larger yield over steeped fibre consisted solely of these very impurities, which had to be got rid of in the after-processes of manufacture. At the same time it must be recognised that the 'dry separated' fibre can be rendered useful for one class of manufactures, viz., those where no bleaching is necessary, and its great strength is here an object. For ropes, rick-covers, tarpaulins, railway-waggon covers, &c., where pitch or tar is used to prevent the decomposing action of moisture and of atmospheric changes, this mode of obtaining flax fibre is highly useful.

The immersion of the flax stems in water, either as pulled full of sap, or after drying, appears, as yet, to be the best mode of effecting the decomposition of the gum, and obtaining the fibre pure, or nearly so. The water most suitable for this purpose is that obtained from surface-drainage, springs generally holding more or less of mineral matters in solution. Spring-water from a calcareous soil is peculiarly unsuitable, the carbonate of lime which it contains being adverse to the putrefactive fermentation of the vegetable extractive. In Russia, much of the flax grown is steeped in lakes. In Holland, it is always steeped in pools filled with the surface-drainage. In France and Belgium, it is either steeped in pools or rivers. In England and Ireland, generally in pools, though occasionally in rivers. The most celebrated steep-water in the world is the river Lys, which rises in the north of France, and flows through the west of Belgium, joining the Escaut at Ghent. Although the water of this stream has been analysed, chemists have not been able to discover why it should be so peculiarly favourable to the steeping of flax. All along its course flax is steeped. The trade is in the hands of factors, who purchase the dried stems from the growers, and undertake all the after-processes, selling the fibre to merchants when it has been prepared for sale. The apparatus in use consists of wooden crates, 12 feet long, 8 wide, and 3 deep. The sheaves of flax-straw are placed erect in the crates, and the root ends of one are tied to the top ends of another, to secure uniformity of packing. The crate, when filled, is carried into the river, and anchored there, the upper part being sunk by the weight of stones, 6 inches underneath the surface. The period of steeping begins in May, and ends about September. The previous year's crop is thus steeped, having lain over in the state of dried straw during the winter. All the flax thus treated produces fibre of a yellowish white colour, very soft and lustrous, with very finely divided filaments, and strong. From it almost exclusively are made cambric, the finest shirtings, and damask table-linen. It is a strange fact that flax-straw is brought to the Lys, from a great distance, and even from Holland, as no other water has yet been found to give such good fibre.

In 1847 a new system of steeping was introduced in Ireland, by Mr. Schenck, of New York. It had been successfully tried in America on hemp, and the inventor crossed the Atlantic to try its efficacy on flax. His plan consisted in hastening the putrefactive fermentation of the vegetable extractive by artificially raising the temperature of the water to 90° F. By this means instead of an uncertain period of seven to twenty-one days being required for the steep, according to the state of the weather and the temperature of the atmosphere, the flax was retted uniformly in sixty hours. The flax-straw, after the separation of the seed, is placed in wooden or brick vats, and the heat is communicated by forcing steam into a coil of iron or leaden pipes, placed under a false bottom perforated with holes.

The annexed plan (*fig.* 918) of a retting on Schenck's system, capable of consuming annually the produce of 400 acres of flax, and employing, in all the operations of seeding, steeping, drying, and scutching, 30 men and 55 girls and boys, or an aggregate of 85 persons, will give an idea of the arrangements. The seeding-house requires to be of large size, as flax-straw is a bulky article. It is on the ground floor, for the convenience of carting-in the flax. The loft above it is used for cleaning and storing the seed. The vat- and spreading-rooms are in a building of one story only, built with a vaulted roof resting on pillars. That part of the roof which is over the vats has lower windows to aid the escape of the vapours from the vats. The drying sheds at the top of the plan are on an open space, well exposed to the wind, and 50 or 60 feet apart. The hot-air rooms, or desiccating house, are fire-proof, each room being capable of containing the flax turned out in one day's work. The scutch mill, with engine and boiler-house, complete the plan.

918



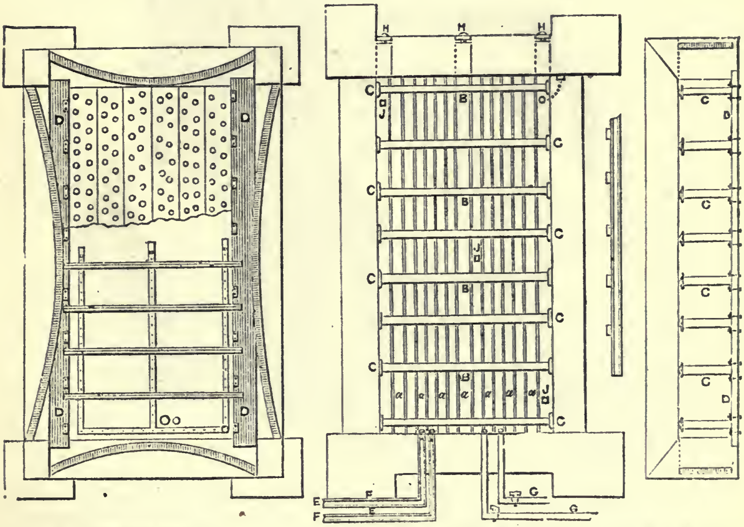
The advantages of this system were so manifest that it was speedily adopted in many parts of the United Kingdom and of the Continent. It was found, however, to have some defects. The small quantity of water soon became thoroughly saturated with the products of decomposition, and the fibre of the flax, when dried, was, consequently, found loaded with a yellow powder, offensive to the smell, causing inconvenience in the preparing and spinning, and, worse still, acting prejudicially on the quality of the fibre itself, rendering it harsh and dry.

To obviate these defects, Mr. Pownall, of London, conceived the idea of pressing the flax-straw, immediately when taken out of the steep, between a pair of smooth cast-iron cylinders, while, at the same time, a stream of water played upon the rollers. By these means the foul water of the vat is pressed out of the flax stems, which are flattened and bruised, thus tending to aid the separation of the bundles of fibres into minute filaments, while the stream of water effectually washed away all remaining impurities.

It has recently been found that better fibre can be obtained by reducing the temperature and extending the time of steeping. The most perfect adaptation of Schenck's system is at the rettery of M. Auguste Scrive, near Lille, and *fig.* 919 is a representation of it. Tanks of wood or stone are used, each to contain two and a half tons of flax-straw. The straw is classified according to quality and length before being packed in the tank. It is put in erect, the root ends resting on the perforated false bottom, and slightly pressed together, but not so much as to prevent a free circulation of water, and a free exit for the gases germinated by the fermentation. The tank being filled with water, the whole is secured at the tops of the sheaves by narrow strips of wood four inches thick *a*, catching the tops on the whole length of each row of bundles.

These strips of wood are kept firm by cross iron holders B, secured by iron bars C, fastened to pieces of wood D, worked into the side walls of the tank, leaving a surface four inches deep of water over the top of the flax. When the tank has been filled with cold water through the wooden shoot E, the whole is rapidly heated to 78° Fahrenheit, by means of steam-pipes coiled under the false bottom. A second open shoot F carries heated water at 90° to discharge on the surface, besides two closed pipes G G, one of which brings hot water of the same temperature, and the other cold water. When fermentation sets in, which is ordinarily in eight hours, the pipe, as well as the shoot of water at 90°, is set at play; the first to create a continual current of fresh water through the mass of flax, clearing off the products of decomposition, and bringing them to the surface; the second to drive this foul water to the openings H H, where it is discharged by the overflow. The two pipes with heated and cold water going to the bottom of the tank, as well as the two shoots containing cold and hot water, to go to the surface, are also made use of to equalise the temperature during the whole operation, which is ascertained by the use of a thermometer in the square wooden box J J. The steeping of coarse straw requires 36 to 48 hours, medium qualities 50 to 60 hours, and the finer descriptions 60 to 72 hours. The 'wet rolling' between cylinders after the steep is accompanied by a shower of water at 78°, not on the flax but on the top of the cylinders. This removes the remaining impurities, and prepares the straw for being easily dried. The heated water may be obtained from the waste water of a spinning-mill, or from a condensing steam-engine.

919



Ground Plan. Top of Tank. Side of Tank.

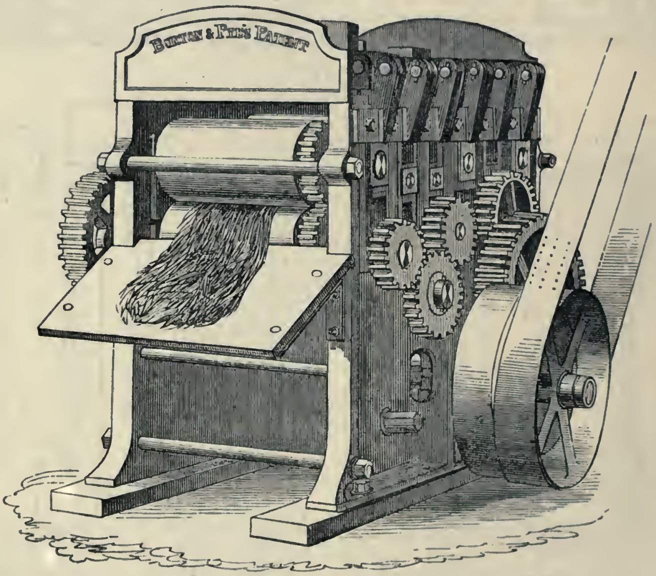
Flax steeped by Schenck's system is dried in various ways. Some retters have drying houses with heated air; others set up the flax loosely on the root end, in the field, or spread it thinly on the grass; while others, again, clasp it between two slender pieces of wood about a yard in length, and hang these up in a building open at the sides, so that a current of atmospheric air is constantly passing through.

In 1852 another mode of retting flax was introduced by Mr. Watt, of Glasgow. Instead of immersing the stems in water, he subjected them to the action of steam. Square iron chambers were employed, in which the flax-straw was packed. The door by which it was introduced was then fastened by bolts or nuts, and steam was then driven in. The steam penetrated the stems of the flax, and being partially condensed on the top and sides of the iron chamber, a constant drip of water, lukewarm, fell upon the flax. In twelve to fourteen hours the stems were removed, and, after being dried, the fibre readily separated from the woody core, the water remaining in the iron chamber being of a dark brown colour, without offensive odour. The fibre obtained by this method was of a greyish colour, and was at first well thought of by manufacturers; but, in the end, on more extended trials it was found to possess several defects, and Watt's system is not now carried out.

Another system of treating flax was introduced by M. Claussen, a Belgian, and for some time it attracted much attention. He separated the fibre from the stem without steeping, and then, by the employment of acids and alkalis, he got rid of the vegetable extractive and other impurities, and produced a fibrous mass strongly resembling cotton. He professed to make an article capable of being spun with cotton or wool. The higher value of flax fibre, however, was a great obstacle, and at present the only use made of his process is to convert scutching tow—the refuse flax fibre—into an article to be spun with wool, and even this is practised to but a very small extent.

Messrs. Burton and Pye's patent (*fig.* 920) is a modification of the hot-water steep. By this process the flax-straw, after the seed is removed, is passed through a machine composed of plain and crimping rollers, by the combined action of which the woody part is rendered easily separable from the fibre. The latter is then placed in a vat, holding about a ton, which is subsequently filled with cold water (*fig.* 921). This vat has a perforated false bottom, under which steam, with a pressure of 50 lbs. to an inch, is introduced and disseminated by perforated tubes. Another tube conveys into the vat a cold mixture of fuller's earth in water. The introduction of the mixture and the steam is continued until the liquid in the vat reaches 80° Fahrenheit. The flax remains in it at this temperature for thirty hours, when the surface of the liquid is covered with a saponaceous froth. Then an apparatus of cross bars of wood, closely fitting into the interior of the vat, and pressed by two powerful screws, expresses the impurities from the fibre. The supply of the fuller's earth is stopped, and cold water is alone supplied with the steam, so regulated that the temperature is by degrees raised to 150°, the pressure being continued until the water appears free from impurities. The water is then withdrawn from the vat through a valve in the bottom, and a pressure equal to 200 tons is applied to the mass of the flax. It remains under this pressure for four hours, when it is half dry. It is then taken out and dried in sheds open at the sides to the air. The fibre produced by Mr. Pye's method appears of good quality and strong, but the system has not as yet been carried out on a sufficiently large scale to admit of a decided opinion on its merits.

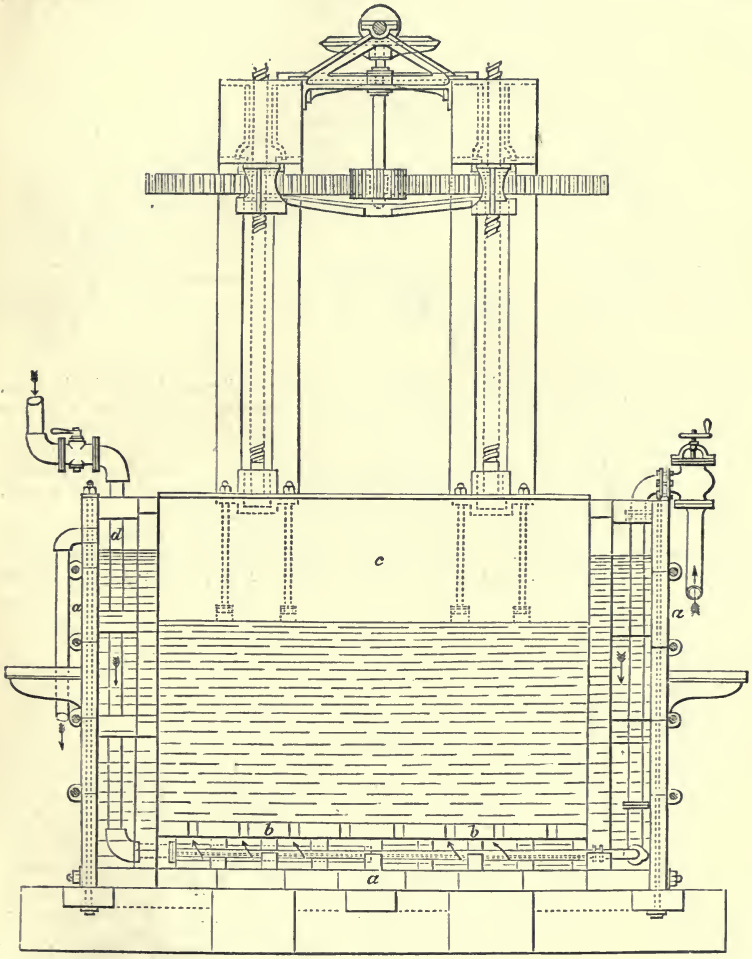
920



The same may be said of the plan of M. Terwangue, of Lille, who employs hot water at a temperature of 15° to 17° Centigrade (60° Fahr.), in which chalk and charcoal have been placed. His process requires seventy-two hours on the average, and he employs brick tanks. The water is, as in all the preceding cases, heated by steam.

Before leaving the subject of steeping, reference may be made to a process patented by Mr. F. M. Jennings, of Cork, by means of which coarse flax fibre is rendered capable of being subdivided into minute filaments, or, in other words, made fine. While the fibre of cotton is incapable of subdivision, that of flax, as viewed through the microscope, is seen to consist of a bundle of extremely delicate filaments adhering together, so that fine and coarse flax are really relative terms. Mr. Jennings throws down upon the flax fibre, as it appears in commerce, a small quantity of oil, say half an ounce to the pound of fibre. He effects this by boiling the fibre in an alkaline soap-lye, washing with water, and then boiling in water slightly acidulated with pyroligneous acid, which decomposes the soap, and leaves its fatty constituent on the fibre. It is afterwards washed once more, and is then found to be soft and silky, and the coarse fibres capable of being readily separated on the hackle, while the strength is not apparently reduced. There is also a greater facility in the bleaching of the linen made from flax fibre so treated, and less loss in weight in the bleaching process.

921

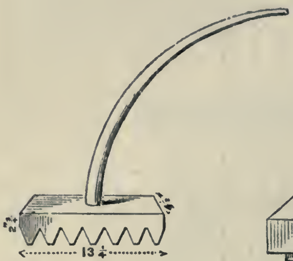


While some of the inventions referred to for hastening and equalising the time of steeping are being carried out to a considerable extent, and promise well, when brought to a greater degree of perfection by experience in practical working, to be yet more largely employed, the great mass of the flax grown throughout the globe is steeped in pools, rivers, or lakes. It will, therefore, be most advisable to follow the processes, as practised by the growers or factors.

When the flax has been sufficiently retted, *i. e.* when on taking a few stalks out of the water the fibre can be readily separated by the fingers along its entire length from the woody interior, it is removed from the water, and placed to drain on the banks of the pool or river. It is then taken to a closely-shorn grass-field or old pasture land, and spread thinly and evenly on the ground. In Flanders, however, the system of drying is somewhat different. Instead of being spread flat on the ground, the sheaves are divided into four portions, and these are set upright in *capelles*, *i. e.*, the butt ends are spread widely out in a circle on the ground, and the tops are kept close together. By this means the sun and air soon dry the flax. When thoroughly dried it is tied up in sheaves, and after remaining a few days in the usual form of a grain stack, it is ricked. In this state it may remain for years without the fibre being deteriorated.

The next process is termed scutching (French, *teillage*), and is intended to separate the fibre from the woody matter of the stem, and thus to make it fit for the spinner.

922



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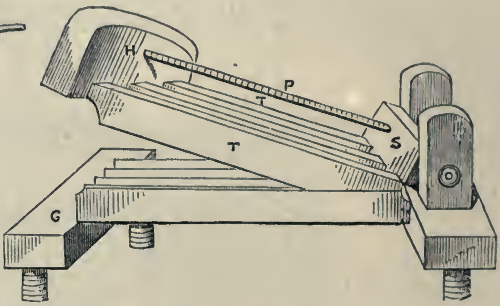
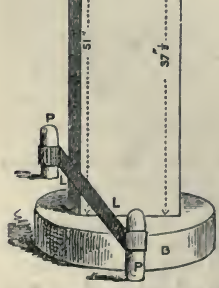


The first part of this process is to bruise the stems thoroughly, so that while the fibre, from its tenacity, is intact, the brittle woody part is flattened and broken in such a manner as to admit of its easily being beaten off by the action of the scutch-blade or scutch-mill. In most countries the bruising is done by hand. In Flanders and France the flax-straw is first laid flat on the ground, the sheaf being untied and spread thinly, and the workman, placing his foot upon it, beats it with an instrument called a *mail*, having a curved handle and a heavy square indented mallet, *fig.* 922.

The next part of the process is to give the flax repeated blows in a machine termed a *bracé* or *braque*, *fig.* 923. This is generally made of wood, but sometimes of iron, and consists of two rows of grooves T T, the upper one moving on a pivot at the socket S. A stout pole P runs from end to end of the upper row of teeth. The latter are wedge-shaped, 4¾ inches deep, 1½ inch thick at top, and 33½ inches long from the head H to the socket S. The head weighs about 8 lbs. and is 10 inches long, and 3¼

924



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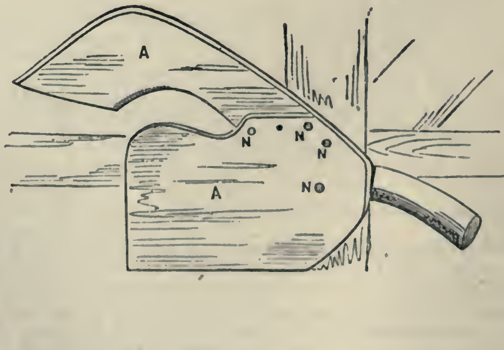


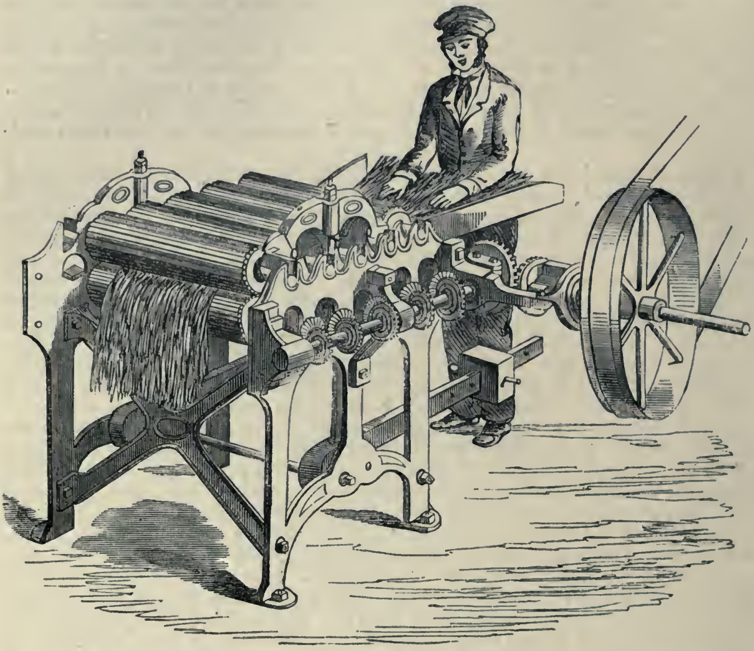
inches thick. The lower row of teeth consists of four, while the upper is three, fitting into the interstices. The best wood for the machine is that of the apple-tree.

Next comes the scutching proper, still following the Belgian, French, and Dutch method of hand-work. After the flax has been bruised by the *mail*, and crushed by the *braque*, it is ready for the scutching process. In Belgium and France the method pursued is by the employment of a wooden stand (*fig.* 924). A broad plank of pine or beech, about 4 feet high, and rather more than a foot broad, about $\frac{3}{4}$ inch thick, is fixed in a wooden sole B. 3 feet from this sole is a cut in the wood of the upright plank, about $1\frac{1}{2}$ to 2 inches wide. This cut serves for the introduction of a handful of the flax-straw, bruised as before described, and the workman, holding it three-fourths exposed through the slit, beats it with a tool called the scutch-blade, *fig.* 925. It is made of walnut wood, and is very tough and flexible. In Ireland the system of scutching by hand is very rude, and prevails chiefly in the western counties. A brake similar to that of Belgium is employed; but instead of the Belgian scutch tool, a rude instrument is employed, generally of ash-wood, in the form of a sword-blade.

It must be stated that the system of hand-scutching is only to be recommended where the quality of the flax fibre is so superior as to render economy in waste of primary importance, or else where the wages of labour are so low as to render the power of machinery of little consequence as regards economy. But, where wages are high, and flax of medium or low quality, there is no question that machine-scutching is the most advisable, and the most economical. This has been especially recognised in Ireland, where in 1870 there were 1540 scutch-mills in operation, when the growers sent their crops to be prepared for market, at a reasonable rate, much less than hand-scutching would have cost. Scutch-mills have been introduced with advantage into Russia, Prussia, Austria, Denmark, Holland, Belgium, France, Italy, and Egypt. In Ireland, although in several districts flax is scutched by hand, machine or mill scutching has been for more than half a century in operation. As in the hand-scutching, the operation consists of two processes: first, the bruising of the stems; and secondly, the beating away of the woody parts from the fibre. The original system of bruising is still very general. It consists of a set of three smooth wooden rollers, one underneath and the two others above it, parallel to each other, and one of them horizontal to the lower roller. The labourer sits opposite the lower roller, and inserts a handful of flax-straw between the latter and the upper one, which is horizontal to it. The flax being drawn in and bruised between these, passes up between the two upper rollers, and reappears at the outside. It is again put through, once or twice, according to its thickness, or to its being more or less steeped, and the fibre, consequently, more or less easily freed from the ligneous part. The scutching apparatus consists of a wooden shaft, to which are attached, at intervals, like radii of a circle, short arms, to which are nailed the *stocks*, which are parallelogram-shaped blades of hard wood, with the edges partially sharpened. The labourer stands beside an upright wooden plank, very similar to that figured in the description of the Belgian hand-scutching apparatus (*fig.* 924), and through just such a slit exposes one half of the handful of bruised flax-straw to the action of the stocks, which revolve with rapidity along with the shaft, and strike the flax-straw, beating off the ligneous matter, and leaving the fibre clear. When the end exposed to the stocks is cleaned, the workman turns the handful, and exposes the other end. It is usual to have a set of either two or three men, at as many different stands, and instead of each thoroughly clearing out the handful of flax, he only partially does so; the second then takes it up and finishes it; or, if there be three in the set, he does not quite clean it, but hands it over to the third to do so. In the latter case, the first workman is called the *buffer*, the second the *middler*, and the third the *finisher*. The motive-power in these scutch-mills is generally water; in some cases they are wind-mills, and in a few instances they are driven by horses. Latterly, the use of steam-engines has considerably increased, as being more to be depended upon than water, which frequently fails in a dry season. It has been found that the woody waste produced in the scutching is quite sufficient fuel for the boiler, without its being necessary to purchase coal or peat, and this waste had hitherto been applied to no useful purpose, being with the greatest difficulty decomposable for manure.

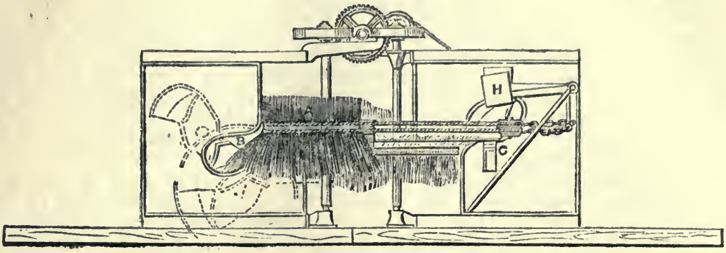
The first improvement on this old scutch-mill apparatus was the introduction, by Messrs. MacAdam Brothers, of Belfast, of a machine for bruising the flax-straw, prior to steeping, and it has since been extensively employed, with very satisfactory results. It consists of a series of fluted rollers, running vertically on each other, the flutings varying in width, the widest set being the first through which the flax-straw passes, and the others diminishing in width, until the finest is the last. While acting strongly on the ligneous matter, at the same time bruising and crimping it, and reducing it almost to powder, it does not injure or disarrange the fibres. One breaking machine of this construction is capable of supplying twelve scutching-stands of the ordinary mill. It is attended by two boys, one to feed the flax-straw into the machine, by means of a feeding table, and the other to remove it at the opposite extremity. Once passing through the machine is quite sufficient to prepare the flax-straw thoroughly for being scutched. The force required to drive it is one horse-power. *Fig.* 926 will best show its construction and mode of action.

926



It having been found that many disadvantages were inherent in the old scutch-mill, several persons have set themselves to work to supply a machine which would reduce the cost of labour, obviate the necessity of obtaining skilled workmen, and diminish the great waste of fibre, which was but too frequent in the ordinary mill. Among the most successful of these scutching machines, is an invention of Mr. MacBride, of Armagh, Ireland, *figs.* 927, 928. It consists of a cast-iron frame, at each end of which is a compartment, enclosing a double set of beaters, of peculiar construction, which revolve rapidly in a contrary direction, striking alternately on each side of the flax, as it is submitted to their action, and thoroughly removing the woody part, which falls down in dust into a pit or hollow under the machine. In order to carry the flax gradually through the machine, and present it in a proper manner to the beaters, in succession, an endless double rope is introduced, carried in the hollow of a large grooved wheel, in which it is kept tight, by means of tension-weights. The flax-straw, made into handfuls, is introduced at A, under the double rope, at one end of the machine, and is at once grasped by it firmly rather above its middle, and carried along slowly, by the movement of the grooved wheel, until it enters, hanging downwards, the compartment B, containing the first set of beaters. By the time the flax-straw has been carried through them, all its lower half, which has been exposed to the action of the beaters, is cleaned out, and the rope, passing on a short way farther, arrives at a point where a second grooved wheel is revolving, furnished with ropes in like manner, but arranged at a rather lower level. By a simple arrangement, the flax is here transferred from one set of ropes to the other, the second set grasping it near its lowest end, thus leaving all the uncleaned part, or upper half, ready to be scutched. The second wheel moves on, and carries the flax towards the compartment containing the second set of beaters, cleaning all the upper portion of the flax. It then issues out at D, cleaned throughout, and is received by a person placed there for that purpose, who makes it up into the usual package for sale, of 16½ lbs. A constant succession of similar handfuls of flax-straw is thus kept pass ing through the machine without interruption. E E are the beaters; F F are two cones, carrying a leather band, which gives the motion to the ropes, or carrying-apparatus.

927



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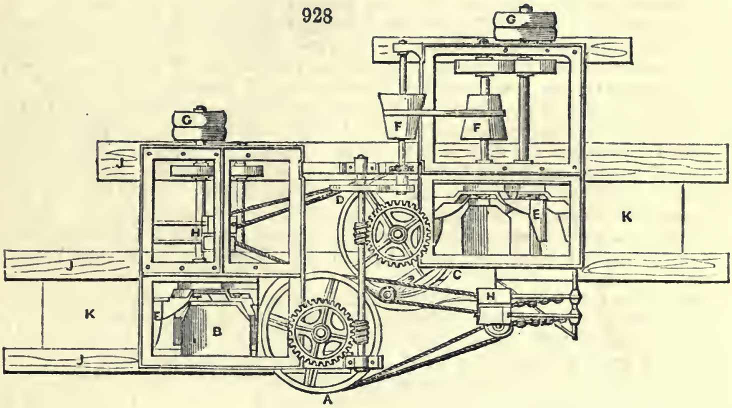


By shifting the position of this band towards one end or the other of the cones, the speed of the carrying-ropes may be varied at pleasure, so as to keep the flax a longer or shorter time under the beaters. Some kinds of flax require more scutching than others. G G are the driving pulleys, for giving motion to the machine by means of a band from motive power, which may be steam, water, wind, or horses. Each pair of pulleys drives one set of beaters separately from the other set, and hence, if requisite to drive one set faster than the other, which is sometimes the case when the top end of the flax is hard to clean, this is easily done by using a similar pulley on the machine, or a larger drum on the driving shaft. H H are the tension-weights and levers for keeping tight the carrying-ropes. J J are bearers of wood for carrying the frame of the machine. K K are pits underneath the compartments containing the beaters, and are for receiving the woody dust as it falls from the flax-straw. The machine occupies a space of 11½ feet, by 10 feet, but some space is required round it for handling the flax. The height of the machine is 6½ feet. The power required is three-horse.

M. Mertens, of Gheel, Belgium, has invented a scutching-machine, which merits notice. It is portable and cheap, and requires the attendance of only boys or girls, to put the flax-straw in and take the scutched fibre out. The action is something similar to that of the Irish scutch-mill, but the bruised flax-straw is placed in iron clasps, one end being first cleaned out, and then the clasps opened, the flax-straw reversed, and a second insertion in the machine clears out the other end.

Messrs. Rowan, of Belfast, have recently introduced a scutching machine, whose action differs from all hitherto in use. The flax-straw is not previously bruised, but is at once fastened in iron clasps, which are placed in a slide, the action of the machine carrying them on along one side, while two parallel bars of iron, toothed, comb the straw and separate the woody part from the fibre. The first portion of these bars have coarse teeth, and the teeth become closer by degrees upto the end of the slide. There a workman or boy takes out the clasps, unscrews the nuts fastening them, and reverses the position of the straw, so that the portion not previously subjected to the action of the machine is now presented to it, while that already cleaned out is untouched. The machine is double, *i.e.* has two sides of combs, each capable of containing twelve of the clasps, and each cleaning out one end of the flax-straw. Hence, after the workman or boy has unclasped the half-cleaned straw, turned it upside down, and presented the uncleaned end to the other side of the machine, the same action of combing, already described, clears out that end thoroughly, and by the time the progressive movement of the mechanism brings the slide to the extreme end, the flax fibre appears free from woody refuse, and in a fit state for market. It is then unclasped and made up into bundles.

There have been a great number of other scutching machines invented, but it is not necessary to particularise them.

In the operation of scutching, however carefully it may be done by hand or by machine, there occurs more or less waste, *i.e.* the beating of the flax-straw, in order to separate the marketable fibre from the useless wood, causes a portion of the former to be torn off in short filaments mingled with the wood, and this torn fibre is very much less valuable than the long filaments when finally cleaned out. In general, it will not average more than an eighth or a tenth of the value of the long fibre. It is termed *scutching-tow* or *codüla*, and when properly cleaned is dry-spun for yarns employed in making coarse sacking, tarpaulins, &c. Being very much mixed with the woody matter of the flax stems, it is necessary to get rid of the latter before the scutching-tow can be spun into yarn. To accomplish this, shaking by hand is the first process, and subsequently the stuff is put into a wooden machine termed a 'devil,' in which, by a mechanism something resembling the shakers in a threshing machine, the woody particles and dust are got rid of. The tow is sorted into different qualities, and, in some cases, it is *hackled* before being sold. In France and Belgium it is chiefly retained at home, spun by hand, and woven into such fabrics as coarse trowsers and shirts, for the labouring classes, aprons, table-covers, &c. What is produced in Russia, is partly used for similar purposes among the lower classes, but the great mass is exported, Great Britain and Ireland being the chief mart, and Dundee especially.

The great aim in all the different methods of scutching, has been to obtain the largest possible yield of long fibre from the flax-straw, and to waste as little as possible in scutching-tow. The French and Flemish system of hand-scutching is most successful in this respect, but as the quality of fibre there produced is very much finer, and consequently more valuable than all others, the additional expense of hand-labour is compensated by the larger yield of long fibre; whereas, in Ireland, the fibre being generally coarser and less valuable, occupying an intermediate place between the Flemish and Russian, the cheapness of mill-scutching turns the scale, and, except in remote districts, it is now universal. In Egypt, until some fifteen years ago, the method of scutching was of the most primitive form. The fellahs, after steeping their flax in the Nile, and drying it on the banks, proceeded to clean out the fibre, by first beating the straw between two flat stones, and then striking it against a wooden post. Mehemet Ali and his successors, however, introduced Irish scutch-mills, driven by steam-power, and since then a marked improvement has taken place in the state in which Egyptian flax has been brought to market. It may be interesting to note here, that in the early period of Egyptian civilisation, the dwellers by the Nile were able to manufacture cambrics of a finer texture than the most finished modern mechanism can produce—as is evidenced by the cerecloths wrapping the mummies—and that from a fibre so coarse in comparison to European flax, that while the latter may be spun by machinery to 300 or 400 leas, and by hand to 1,200 leas, the former cannot be put higher than 40 to 50 leas, and rarely even to that.

In the scutching operation, three several matters are obtained from the flax stems. The first is the fibre, which is the primary object, and which is the really valuable portion, that known as 'flax' in commerce. The second is the woody refuse of the stems, hitherto applied to no other use than as fuel, or occasionally in Ireland as a covering for cuttings of potatoes, when planted, to protect them from frost. Mr. Pye, of Ipswich, however, proposes to make it available as an auxiliary food for cattle, having the authority of Professor Way that a sample analysed by him yielded 7·02 per cent. of oil and fatty matter; 7·93 of albuminous matter (containing 1·25 nitrogen), and 26·29 of starch, gum, sugar, &c. He (Mr. Pye) recommended its use for feeding live stock, in conjunction with ground oats or other farinaceous food. Professor Hodges, nevertheless, in analysing another sample of this ground ligneous matter, gave quite a different result, his estimate of the nutritive constituents being as follows:—nitrogenised flesh-forming matters, 3·23 per cent.; oil and fatty matters, 2·91; gum and soluble matters, 14·66; and he compared this with the average results of seven analyses of oil-cake, giving nitrogenised matters, 28·47; fatty matters, 12·90; gum and other soluble matters, 39·01.

The third portion separated by the scutching process is termed '*scutching-tow*,' in Ireland; in Russia and Prussia, '*codilla*;' in France and Belgium, '*étouppe de teillage*,' described above. These branches of the trade consume annually many thousand tons, imported chiefly into Scotland, from Russia and Prussia. In France, Belgium, and Holland, the codilla or scutching-tow is chiefly retained by the growers or factors at home, for a domestic manufacture of similar goods, and of coarse blouses and trowsers. It has also been employed for conversion, by Claussen's process, into a finely-divided mass of fibres, capable of being mixed with wool and spun along with it into yarn, the fabric made from this yarn being chiefly hose.

Before proceeding to treat of the processes to which flax fibre is subjected subsequent to scutching, it may be well to glance at the uses to which the seed is applied. This valuable product of the plant furnishes two articles of much utility, and of very extensive use,—the oil and the cake. When the seed has been separated, dried, and threshed out, it is either sold again for sowing or for conversion into cake and oil. Of course the former purpose only consumes a small proportion of the seed produced throughout the world, and in many countries it is not of a quality suitable to the chief flax-growing localities. Thus, while northern Russia, Germany, the Low Countries, and France either export seed for sowing, or consume their own produce to a considerable extent for this purpose, the southern provinces of Russia, the States along the Mediterranean, Egypt, Turkey, Greece, and the East Indies, while large exporters of seed for crushing, cannot sell any for sowing. The supply of the seed-crushers of the United Kingdom is more largely obtained from Russia and Hindoostan than from any other countries. The entire annual import of seed into the British Islands averages 600,000 to 800,000 quarters, value between a million and a half and two millions sterling. The conversion of flax seed into oil and cake is carried out by different methods. In France, Belgium, Holland, and the north of Europe generally, where a large quantity is crushed, the apparatus employed is very simple and yet very effective. Lille, in France, Courtrai and Ghent, in Belgium, Neuss, in Prussia, and the province of Holstein, are the great seats of this manufacture. See LINSEED.

The seed is pounded in a kind of wooden mortar, cut out of solid timber, and at the bottom lined with thick copper. By means of a revolving shaft, furnished with projecting notches of wood, beams of oak 20 feet high, having the ends shod with channelled iron, are alternately raised up and let fall into the mortars, where, in a short time, they convert the seed into a pulpy mass. When sufficiently pounded, this is removed and put into woollen bags, which are then wrapped up in a leathern case, lined with a hard twisted web of horse-hair, covering both sides and ends, but open at the edges. These are then ready to be pressed, and for this purpose are packed perpendicularly in an iron receptacle, narrow at the bottom, and widening towards the top. Packings of metal are then put in, and in the centre of the bags is inserted a beech wedge. A beam similar to that employed in pounding the seed is then set in motion, and at each descending stroke it drives the wedge in tighter, thus squeezing the bags of seed against the iron sides of the press. When the wedge has been driven home, another is introduced and battered by the beam, until it will drive no farther. At the bottom of the press are holes through which the oil thus pressed out of the seed runs into a receptacle beneath. In order to loosen the wedges and admit of the bags being removed from the press, a wedge of a different form, wide at bottom and narrow at top, and already a fixture in the press, but raised up and fastened by a rope during the driving of the other wedges, is released from the rope, and another beam drives it home, thus partially starting the differently-constructed wedges and loosening the mass. The bags with the pressed seed are then taken out, and the latter, having lost the greater part of its oil while subjected to so considerable a pressure, is found in a thin hardish cake, taking the form of the leathern case, and off it the woollen bag is readily stripped by the workman's hands. The oil obtained by this process is the purest and most limpid; but another process has to be performed before the seed yields all that the pressure is capable of extracting from it. The cakes, therefore, when taken out of the bags, are broken up and put into the mortar, where the same pounding operation takes place. When again brought into a comminuted state, the powder is put into a circular iron pan or kettle, under which is a fire, and slowly roasted in it, being kept from burning by means of an iron arm which is moved round inside by the machinery, constantly turning the ground seed. When sufficiently warmed by this operation, during which it is made to part more freely with the oil, the mass is again filled in bags and pressed as before, after which they are finally, the bags being stripped off, pared at the edges, put in a rack to dry, and stored for sale. The oil thus obtained is darker in colour than that by the cold process, and contains more mucilaginous matter. Many foreign oil-millers, however, only employ the hot plan, believing that they have thus a larger yield than when the cold pressure is first used. See LINSEED OIL.

In England, the cold pressure is little, if at all, practised, the seed being almost invariably warmed before pressure. The system of crushing, formerly universal here, had some resemblance to the Flemish method above detailed, the chief difference being in the mode of preparing the seed, prior to its being put in the press. The first process is to pass slowly from a hopper the whole seeds into a pair of smooth or fluted metal rollers, which, in turning on each other, crack the seeds. Heavy edged stones then grind them into a meal, a little water being added during the operation, which facilitates the comminution of the seed. The meal is then put in the *kettle* before described, and while heated and stirred in it, the water mixed with it is evaporated. It is then bagged and put in the press, where the *stampers*, falling on the wedges, effect the desired results. The most recent improvement in the mode of pressure, and one now largely adopted, is the hydraulic press, and it is generally considered that a larger yield of oil can be obtained by its use than by the wedge and stamper-beam method. Blundell's (of Hull) patent is that most generally employed, and Messrs. Samuelson of that place are distinguished as makers of it, having themselves introduced some modifications and improvements. The oil obtained from flax-seeds or linseed, as it is generally termed, is of very extensive use in the arts, and is the chief vehicle for paints. To suit it for this purpose, and to make it dry quickly, it is mostly boiled in an iron pan, and during the operation a quantity of litharge is dissolved in it. The cake is a very favourite article with stock-feeders, being combined, as containing much nutriment in small bulk, with roots or other vegetable food, having large bulk with small nutriment. So extensively is it consumed in Great Britain, that besides the very large quantity made from imported seed, fully 80,000 tons of foreign cake are annually imported. On the Continent inferior qualities of cake are ground to a coarse powder, and either applied to the soil as a top-dressing, or steeped in a liquid manure, and the mass spread out on the land in that state.

Scutched flax fibre appears in the market made up in different ways. Russian is in large bales or bundles; Dutch and Flemish in bales weighing 2 cwts., the fibre being tied in 'heads,' each of which is about as much as the hand will grasp. Irish is made up in bundles termed 'stones,' the weight of which is either 16¼ lbs. or 24½ lbs. In this state it is piled in the stores of the spinner, care being taken that it be placed on a ground-floor, flagged or tiled, and not in a boarded loft, as the humid atmosphere of the former is conducive to the preservation of the suppleness and 'spinning quality' of the fibre, whereas it deteriorates considerably when exposed to a drier air.

The first operation which it undergoes in the spinning factory is *hackling*.

This process is required to comb and straighten the fibres, to get rid of any knots, and to lessen and equalise the size of the filaments. The action of the hackles necessarily divides the scutched flax into two portions, the long, straight ones, which remain after the flax has passed through the operation, being termed 'line,' and the woolly- or cottony-looking mass which remains, being designated 'tow.' Both of these are spun, but the line produces the finer and better qualities of yarn, and is consequently much more valuable than the tow. The great object, therefore, is to obtain the largest possible quantity of the former from a given weight of scutched flax, and the yield of line varies considerably according to the nature of the season. Spinners, therefore, are anxious, as each new crop of flax is brought to a marketable state, to test the yield of line, so as to guide them in their purchases. They are thus enabled to ascertain more clearly the suitability of the samples for 'warp' or 'weft' yarns, and for thread-twisting. Warp-yarns, being those which constitute the long threads of a linen fabric, require to be harder and stronger than weft-yarns, which form the cross or short threads.

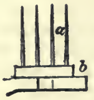
The yield of line, as well as the general economy of the operation, is, of course, greatly dependent on the nature of the hackling-machine employed, and great scope for care and ingenuity is thus given to the machine-makers. A great number of hackling-machines have, from time to time, been brought out, employed in the factories, and subsequently abandoned, when others, having greater merit, have been invented.

In the early period of the linen manufacture, when spinning was done exclusively by hand, no hackling-machines were employed. The process was exclusively effected by hand-hackles. Even after the introduction of machine-spinning, they were, for a long period, the sole means of hackling. Of late years, the machine has been more and more brought into use, and, although hand-hackling still exists to a considerable extent, the other method is by far the more extensively employed.

For hand-hackling, the tools used consist of a surface studded more or less thickly with metal points, called hackle-teeth, through which teeth the flax is drawn by the operator.

The hackles ordinarily used for hand-hackling in this country are in the form of rectangular parallelograms, presenting a line of 7 inches towards the worker, and 4 to 5 inches deep. The first tool employed is called the 'ruffer,' the pins of which are about ¼ inch square at their base, and 7 inches long, and brought to a fine point; the second is the 'common 8,' which is always used after the 'ruffer;' then the 'fine 8,' the '10,' the '12,' the '18.' The pins of all these tools are similarly placed to those of the ruffer, but are somewhat shorter in length, and are more slender as the tools increase in fineness. In all these tools the pins are held in wooden stocks of about ¾ inch in thickness and covered with sheet tin. This sheet tin, through which the pins are driven, helps to support them and prevent the wood from splitting. These tin-covered stocks are only of a size necessary for the extent of pins employed, and are themselves screwed to other larger pieces of board, a little broader and some inches longer than themselves, and by which they are ultimately fixed to the hackler's bench, inclining somewhat backward with their points from the worker, and a sloping board behind to prevent the flax entering too much in the pins thus:

929



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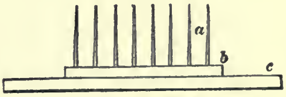

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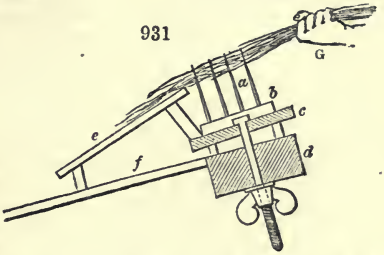


Fig. 929, end view of a hackle; *fig.* 930 front view of hackle; *fig.* 931 hackle, &c., fixed up for working. *a* pins; *b* tin-covered stock; *c* foundation board; *d* beam of table or bench; *e* backboard; *f* table to receive the tow, &c.; G hand of workman. Such is the form of hackle used in England, and also the manner in which they are, of whatever description, fixed for work.

The operation of manual hackling is simple in principle, although it requires much experience to acquire dexterity.

The workman having first divided the flax into handfuls or stricks, of which there are 300 to 400 to the cwt., proceeds to grasp one as flatly spread as possible between his forefinger and thumb, by about its middle, and wind the top end round his hand in order the better to prevent the slipping of the fibres; he then begins by a circular swing of his arm to lash the root end into the hackle; taking care to commence as near the extremity as possible, now and then collecting the fibres by holding his left hand in front of the tool, turning the strick from time to time. He thus gradually works up as near as possible to his right hand, when he seizes the ruffed part of the strick and holds it in the same manner as at first, and proceeds by a similar treatment to 'ruff' the top end; when this is finished the 'ruffed' work is taken to the tool called a 'common 8,' the pins of which are much closer placed than those of the ruffer, and are only 4 or 5 inches long. This '8' is always used after the ruffer, but from it the work can be taken to any of the finer tools, viz. 8, 10, 12, and sometimes 18. It is usual and better to dress both ends over each tool before taking the work to the next. The pins of all these tools are 4 inches long, in order, as was supposed, to have sufficient spring. The flax is not lashed into them as into the ruffers, neither are the ends required to be wound round the hand. But the root end of the flax is always the one to be first worked, and the hackling begun at nearly the extremity of the strick, which on being drawn through the hackle is received by the left hand of the workman, and by it carried back and laid upon the backboard and over the point of the pins, for the angle of inclination of the hackles and a slight lowering of the right hand causes it to enter sufficiently on being drawn forward. As it is impossible to ruff or dress entirely up to the hand, when the hold is changed in either operation, there must of necessity be left a certain space to be repassed through the tools; this is called the 'shift,' but the less length that is required for this purpose the better for the yield of line. The numerous long fibres that slip from the strick in ruffing must be collected and drawn from the mass of tow attached to them, when they can be relaid in the strick, or kept to be dressed separately under the name of 'shorts,' and from time to time the short fibres or tow sticking to the teeth of the finer tools are removed. Whenever one-half of the length of the strick of flax is hackled, it is turned round to hackle the other half. This process is repeated upon each hackle. From 100 pounds of well-cleaned flax, about 45 or 50 pounds of hackled line may be obtained by the hand labour of 12 hours; the rest being tow, with a small waste in woody particles of dust. The process is continued till, by careful handling, little more tow is formed.

To aid the hackle in splitting the filaments, three methods have been had recourse to: beating, brushing, and boiling with soap-water or an alkaline lye.

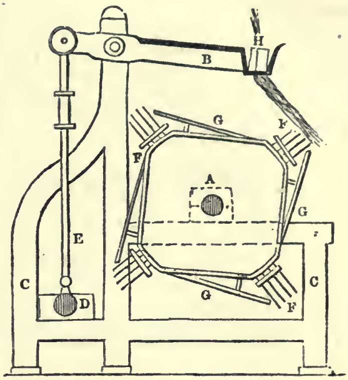
Beating flax either after it is completely hackled, or between the first and second hacklings, is practised in Bohemia and Silesia. Each hackled tress of flax is folded in the middle, twisted once round, its ends being wound about with flaxen threads; and this head, as it is called, is then beaten by a wooden mallet upon a block and repeatedly turned round till it has become hot. It is next loosened out, and rubbed well between the hands. The brushing is no less a very proper operation for parting the flax into fine filaments, softening and strengthening it without risk of tearing the fibres. This process requires, in tools, merely a stiff brush made of swine's bristles, and a smooth board, 3 feet long and 1 foot broad, in which a wooden pin is made fast. The end of the flax is twisted two or three times round this pin to hold it, and then brushed through its whole length. Well-hackled flax suffers no loss in this operation; unhackled, only a little tow; which is of no consequence, as the waste is thereby diminished in the following process. A cylindrical brush turned by machinery might be employed here to advantage. These have been tried in establishments for machine spinning, but not found advantageous.

The object of all hackling being to produce a good yield of line with tow of good quality—that is to say, free from broken, unsplit fibres, lumps and knots—the care and attention necessary to do this, with the expense and uncertain result of the individual skill of workmen, urged manufacturers to attempt the establishment of machines for effecting the process. Therefore many contrivances were invented with this view, but it was long doubted whether any of them made such good work, with so little loss, as hand labour. In hackling by the hand it was supposed that the operator would feel at once the degree of resistance, and be able to accommodate the traction to it, or throw the flax more or less deeply among the teeth, according to circumstances, and draw it with suitable force and velocity. For a considerable period these ideas, or rather prejudices, as they may now be called, seemed to be confirmed: for the earlier attempts to supersede hand-hackling, like those in many other undertakings, though partially favourable, were, on the whole, rather discouraging. In attaining one point desired another was lost, for too much still depended on the care and attention, if not on the actual skill, of the persons attending the machines.

It will be desirable, therefore, to give particulars respecting some of those which have been from time to time invented, although they are not now in use, as a lesson for preventing the repetition of things already known, as well as to illustrate the steps successively taken. The first machine invented, or, at least, published, was called the 'Peter,' and was intended to illustrate, as clearly as possible, the movements of the hand hackler. The flax was first divided into small convenient portions or handfuls, about 4 oz. each, called 'stricks,' which, before being taken to the machine, were slightly straightened and dressed over the ordinary hand 'rougher.' Each of these was then placed between a pair of short iron bars, called a 'holder,' one of which had an indentation in the middle, and the other a corresponding projection. Thus when tightened together by screws 4½ inches apart (such length being equal to a man's grasp), the strick of flax was firmly held while exposed to the action of the hackles. The holder was then suspended from moveable levers over a truncated rectangular cylinder, upon the angles of which were fixed, at a certain angle, hackles similar to those used in the manual operation. The levers supporting the holders received from a crank a short up-and-down motion, so timed in their oscillations as to strike the holder nearly against the points of the pins at the time they were passing under, coming thus as nearly as possible to the effect of a man striking in and drawing through the hackles, except that the flax remained nearly stationary, and the hackle was drawn through it by the rotation of the cylinder, whereas in the hand-process the hackle was stationary, and the flax drawn through it by the operator. Each machine carried two holders. The tow made and collected from the holders was seized and taken off by boys stationed for that purpose, while another, at the ringing of a bell, took out and changed the sides of the stricks to be presented to the action of the hackles, and subsequently withdrew them from the first machine to another similar but with finer hackles, and thus continued until the root end—always the first operated on—was dressed to the desired degree of fineness, when they would be taken to a table where another set of boys, previously to removing the first holder, put on a second to the already-hackled part, leaving about 2½ to 3 inches to be re-hackled. This operation is termed 'shifting,' and the space left, 'the shift;' it is thus performed and remains so called at the present day, the only change being that in the holder now in use one screw is used for two stricks instead of two screws for one strick.

Fig. 932 will more clearly show the construction of this machine. A, square truncated cylinder carrying the hackles; B, oscillating arm or lever for supporting the holder; C C, framing; D, crank and shaft; E, connecting rod from crank to oscillating arm; F F F, hackles; G G G, back board; H, holder. The first motion was given by pulleys on the shaft D, which revolved 4 times to 1 of the hackle cylinder, by the intervention of suitable wheels. The worm and wheels for the bell motion were attached in the usual manner to the shaft of the cylinder.

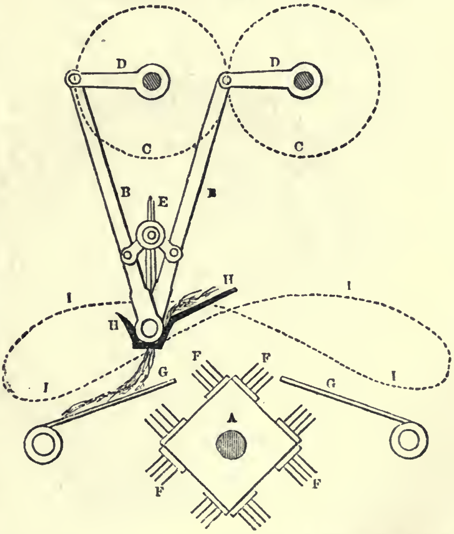
932



Machines of this construction continued in rather limited use without any change or competition till about the year 1825, when a patent was taken for a machine known as the pendulum machine. The flax in the holder being suspended and swung backwards and forwards while the hackle remained fixed, the flax was thus hackled, stroke for stroke, on each of its sides; the boys, as in the last described, snatching off the tow as it was formed, and at certain times, that is at each rise of the pendulum (for it had a rising and falling motion to imitate the hand workers in commencing at the extreme end of the flax), passing the holder from one recess to another of the pendulous table, so as to arrive at the progressively finer tools when ranged along the machine; but sometimes the different tools were fixed upon the angles of a square cylinder that presented a finer range, the whole length of the machine, by turning up a new angle at each rise of the pendulum, when the labour of the boys was simply to put in the tow and take out from it the flax. The adjoining diagram (*fig.* 933), without entering on any details of a machine that was so little used, will make the theory of its action quite clear.

A, hackle bench sometimes revolving so as to present different degrees of hackles at its various angles, sometimes stationary with the gradation of hackles upon its length; B B, pendulum arms; C C, equal wheels working into each other; D D, crank arms; E, radial slide-bars to preserve the holder table; H, holder table; F F F F, hackles; G G, back boards; I I, direction in which the holders swing; there were the same wheels, &c., at each end of the machine, and the holder table H reached from one to the other. The wheels, C C, with all attached to them, were made to rise and lower upon the hackles, and the back-boards C to rise when the hackle bench turned.

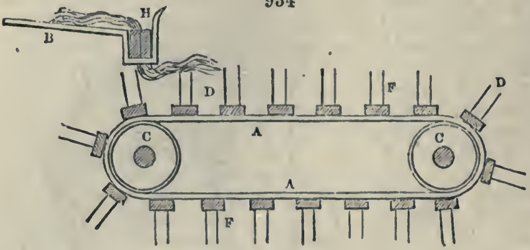
933



About the same time another patent was taken out for a machine where the holders were suspended above one end of a travelling sheet of hackles. This machine also required hand labour to turn and transfer the stricks, though the tow was caused to fall clear from the hackles by mechanical means. The following sketch (*fig.* 934) shows the principle upon which this machine works, and, though never much employed at the time of its appearance, it has subsequently served as foundation for those that are now in the zenith of their prosperity.

A A (*fig.* 934), sheet of hackles; B, support for holders; C C, carrier pulleys for the sheet of hackles. *Fig.* 935, a larger view of the hackle bar G G, in order better to show the faller D D D, in the staples or grooves E E, at the end of the hackle-bar G G; F F, pins of the hackles, between the rows of which the faller D D D acts to push the tow off the pins. There is a clearing faller D to each hackle, which is kept to the bottom of the hackles at that part of their course where they are in contact with the flax, but at the turn F D fly beyond the points, as shown by the effect of the centrifugal force.

934



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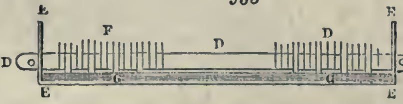

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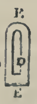
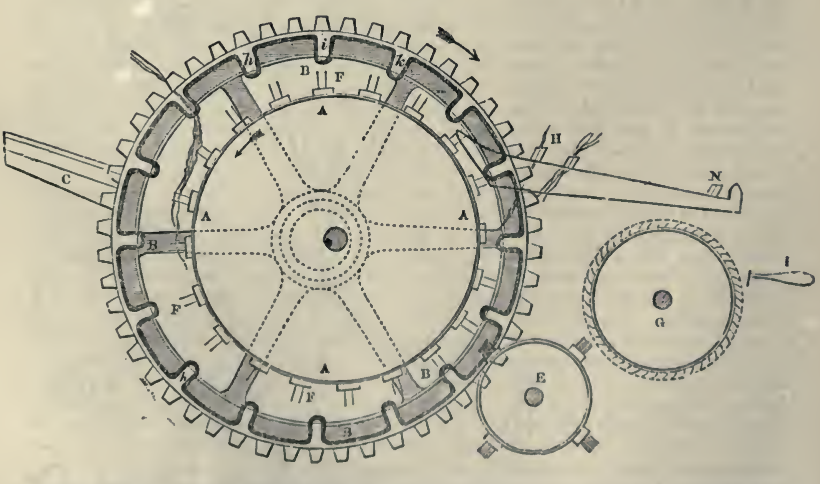


All these machines, possessing great similarity of features in regard to the personal attention required, never came into such general operation as to supersede entirely hand-dressing, either from their own defects, or prejudices against their employment. About the year 1830, in consequence of the new mode of spinning being carried on with considerable energy, it was found advantageous to cut the flax into two, three, or more lengths previously to hackling, which rendered it necessary to have machines peculiarly adapted for this new short description of material. This machine, known as the excentric or circular machine, deserves considerable attention for its own inherent merits, and the extensive utility it has proved to be of in suggesting the principal parts of those by which it has been supplanted. In its original form it was made of a breadth suitable for only one strick, and consisted of a cylinder 3 ft. diameter, upon the whole circumference of which at intervals of 3 or 4 inches were fixed the hackles. As each machine could only carry one description of hackle, it was necessary to employ a series of these machines, called a 'class,' when the flax required to be dressed over a succession of finer tools, each succeeding machine carrying a finer tool than its predecessor. The hackles were cleared of tow by coming in contact at one part of their revolution with a brush roller, which also revolved in contact with a cylinder covered with card clothing, the points of the pin being in such a direction as to clear the brush from tow, and allow itself to be in its turn cleared by

937



the oscillations of a comb, whence by rollers the tow was brought into a sliver. In order to preserve the continuity in the supply of tow, and maintain the regularity of the sliver produced by it, the holders with the flax were presented to the hackle cylinder in a manner peculiar to this machine, and in endless succession by means of certain circular carriers placed at each end of the hackle cylinder, but excentric thereto, and at such a distance apart as each should bear one end of the holder as it extended across the cylinder parallel to its axis. Thus, the holders introduced at that part of the circumference of these carriers furthest from the hackles were carried forward, while the flax was in operation, till they were brought almost into contact with the points of the pins, when, by the intervention of a slide, they were withdrawn from the machine, but with one side only of the flax dressed, and that but on one tool; therefore the holder required replacing in the same machine, in order that the second side of the strick should be dressed as was the first. The holders then required to be carried by hand to each succeeding machine of the class.

The preceding figure (937) shows the leading features of these machines: A A, hackle cylinder; B B, excentric wheel to carry holders in its recesses, *h h*; C, slide upon which the holders were laid so as to fall into the recesses *h h* of wheel B; D, slide for taking out holders; E, brush cylinders with brushes; G, cylinder covered with card clothing; H, holder come out; I, doffing comb. The space of the holder-carrying wheel was filled with holders, and so maintained in endless succession, and thus each served in some measure to keep the end of its preceding one down into the hackles.

About 1833, a machine was patented consisting of two parallel cylinders, over which the flax was carried, revolving in its progress so as to present the alternate sides of the strick to the hackles, the progressively finer tools being ranged along these cylinders, so that having passed the length of one cylinder one end was completely finished. When the holder was taken out, 'shifted,' and replaced, it was carried back along the second cylinder, and thus returned to where it commenced, finished. This machine, however, never was carried further than the experimental one for the patent.

Another machine (Wordsworth's) the same year made its appearance, and for some time enjoyed much celebrity. It consisted of two parallel vertical sheets of hackles running together, and so geared that the hackles of one intersected the interstices of the other. The flax suspended in its holder from a species of trough passed between these two sheets, and was thus hackled simultaneously on each side in its course through the progressively finer hackles from one end of the machine to the other.

A A (*fig.* 938), hackle sheets; B B, holder trough or slide; C C C C, pulleys for carrying the hackle sheets; D D, brush rollers; E E, rollers covered with card clothing to clear the brushes; F F, doffer combs; G G, hackles; H, holder; I I, brushes.

It is unnecessary to notice more at length the different machines brought out, employed for a time, and then rejected. Although the hackling and spinning of flax, in the full length as it grows, was what was first practised by hand, the first really successful machine for hackling was what was known as the 'circular machine' for hackling 'cut line,' as it is called, or the long flax fibre broken into several lengths. It had always been known that the top and root ends of the fibre were of very inferior quality to the middle, and of course when all was spun in one length the yarn produced was inferior to what the middles could be spun to, while superior to what the tops and roots would produce. It therefore occurred that in the general qualities of flax the division of the fibre, so as to separate the different portions named, would be advantageous to the spinner. The operation of cutting was performed by a simple machine consisting of a pair of jaws, so constructed that when the flax is introduced between them the different parts, instead of being clearly cut off, are, so to speak, bitten off, leaving ragged ends. This is desirable in order that the ragged ends might interlace in the spreading prior to going through the preparing machines, which precede the spinning operation. The machine for hackling cut line was brought out about forty years since, and underwent, before it was finally set aside, a considerable number of modifications for the purpose of economising the labour in working it. About the same time the 'flat machine' was introduced, which was more particularly intended for hackling long flax. The nature of the operation of these machines was the same, the flax being acted on by different series of hackles fixed in the circumference of a cylinder in the one machine, and on an endless sheet in the other. The curvature of the cylinder was no objection in hackling cut flax; but for acting on long fibres it was necessary to put the hackles on a sheet, for the purpose of getting sufficient length of flat surface. The most successful machines, and which displaced all previous ones, have been modifications of these of different kinds, some of them being simply contrivances for saving manual labour, and giving certainty to the action, and others combining other improvements with this object. Carmichael's patent machine (*figs.* 939, 940) was, as brought out at first, simply the old flat machine with

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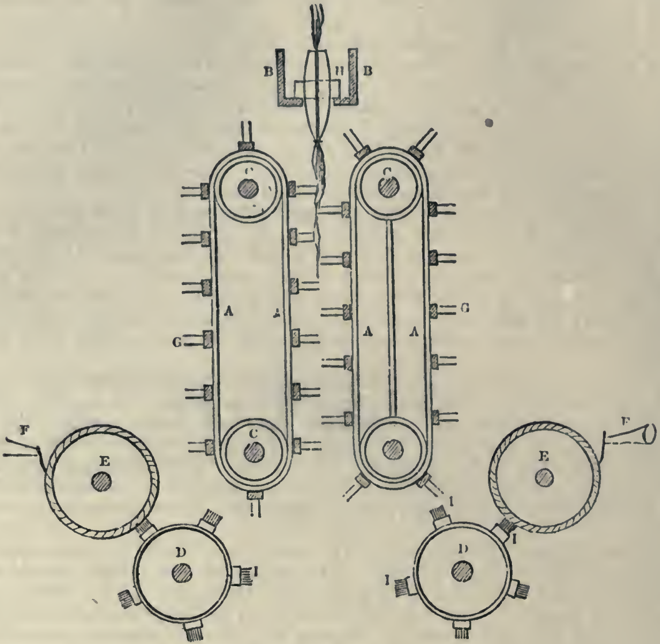


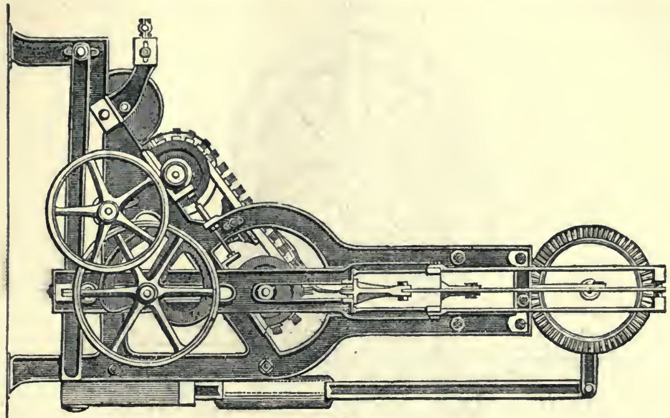
self-acting motions for actuating the holders applied to it. It was afterwards much improved by the adoption of an inclined sheet in imitation of a very successful self-acting modification of the old flat machine which was brought out by Combe, of Belfast, whose machine, at this time, is considered by many to be the best one in use for long line.

The distinguishing feature in these rival machines is, that in Carmichael's the motions are all performed by the descent of ponderous weights, while in the other they are performed by the direct action of the machine.

There are other differences affecting the working of the machines, which are by practical hacklers considered of great importance, and as giving more value to Combe's machine. The most important of these is the facility of adjusting the place where the holders approach the flax, which greatly affects the yield of line.

The same principles of actuating the holders were applied to cylinder machines for hackling cut flax, but, as these have been displaced by more recent inventions, it is not necessary further to refer to them. Wordsworth's machine, already figured (*fig.* 938), was of importance, as being the basis of several other valuable machines. Its essential feature was arranging the hackles on two sets of endless sheets placed opposite each other, and driven and connected by wheel-work so as to revolve together, the surfaces being placed so close together that the hackle pins penetrated the flax from both sides, and hackled at the same time. The large circle described by the points of the hackles in this machine, which prevented them cutting the flax close to the holders, and other imperfections, led to its abandonment. Some years since, Combe of Belfast designed for the eminent flax-spinning firm of Marshall and Co., of Leeds, a modification of this machine, which since has been known as Ardill and Pickard's machine, and has come into extensive use. The principal new feature in this machine was the introduction of cranked wheels for supporting and carrying the hackles, for the purpose of making the points of the hackles describe a small circle, and thus enable them to cut close to the holders. Although successful, this invention did not fully accomplish the object aimed at. About the same time, Marsden's intersecting machine was brought forward, and possessed a great reputation for a length of time. Its success was a good deal owing to the flax hackled by it having an apparent fineness; but this was not found to be of practical value, as the spinning quality was not improved thereby. For this reason it has gone greatly out of use.

The next machine which came into extensive use was Combe's reversing cylinders,



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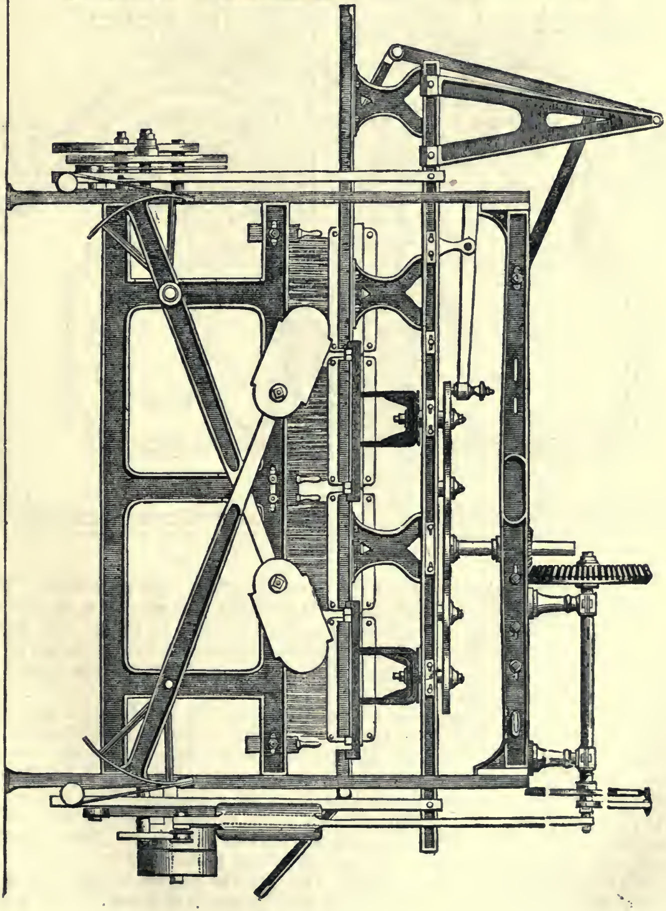

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fig. 941. These machines are constructed in a great variety of forms for different kinds of work, and seem to give very good results. They are simple in their construction, and give little trouble, acting lightly on the flax and making very wiry fibres. They are made of all sizes, from 12 to 30 inches in diameter, and with 4, 6, or 8 graduations of hackles, according to the kind of work to be done on them. The flax is hackled on each side, or each graduation of hackles, by reversing the direction of the rotation of cylinders. The tow, or short fibre, is thrown off the hackles by stripper rods, placed between the rows of pins.

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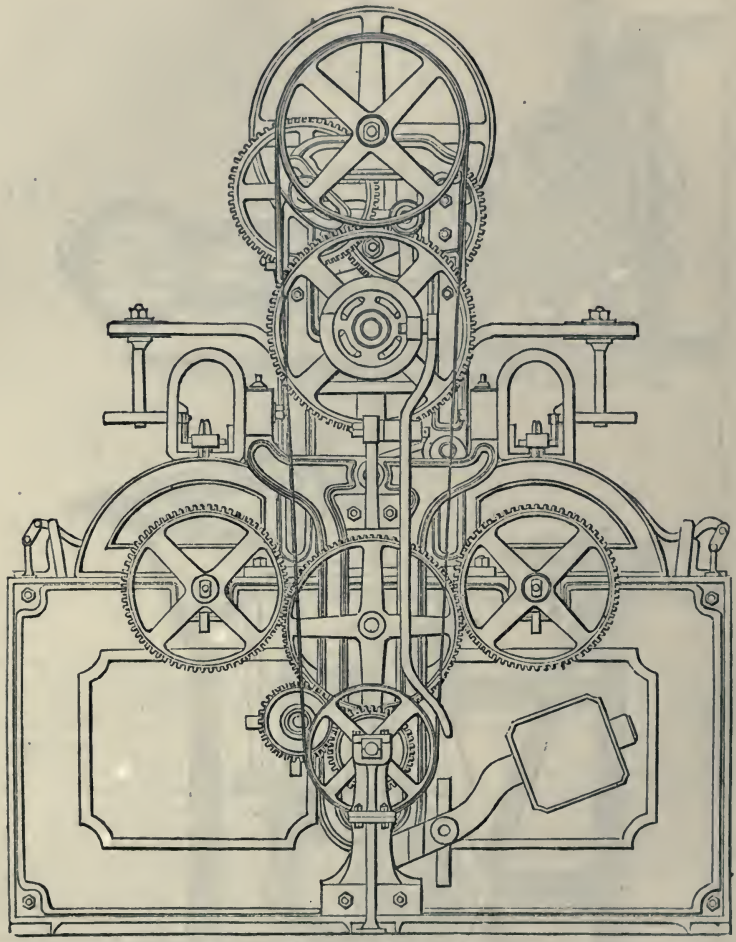
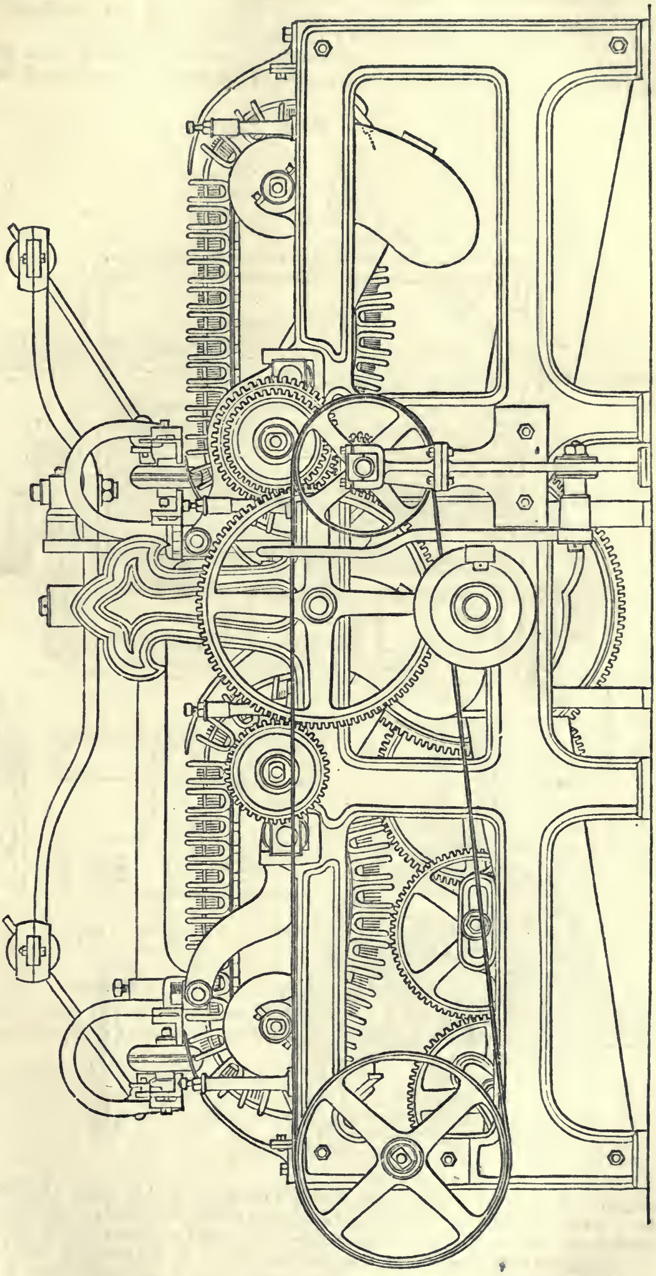


The next machine to be named is by the same inventor, and is styled the patent reversing sheet-hackling machine. It is for long line, on the same principle as that just described, except that it has the hackles fixed on flat sheets, as in the 'old flat' machine. It is simple and complete, easily driven and attended; and a considerable number are now in use. From the hackles being on a flat sheet, it is necessary to make the holders descend, first on one side while the sheets are moving in one direction, and then on the other while they are moving the other way. This is done by supporting the channels which carry the holders on four levers fixed on two oscillating shafts, to which motion is communicated by a shaft. The holders are slid through by a lever on the top, which acts on a sliding bar, by means of a ball, which forms a universal joint and actuates the holders, whatever position the channels are in. The drawing here given, *fig.* 942, will show the mechanism.



942

Both the machines last described are made double, or in fact, the construction of each is that of two machines in one. The table for filling and changing the flax in the holders is attached to the machine. One side hackles one end of the flax, and the other side the other end.

We now have to describe a machine for hackling cut line, patented by Mr. Lowry, of Manchester, and now extensively in use at home and on the Continent. It is virtually a modification of Wordsworth's machine, already described.

Fig. 943 is a side elevation of a sheet-hackling machine to which these improvements are applied; *fig.* 944 is an end elevation of the same; *fig.* 945 is a front view;

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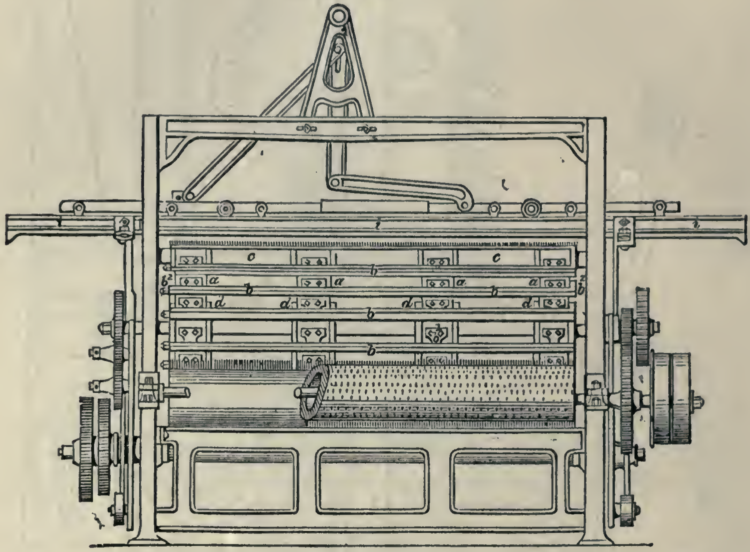

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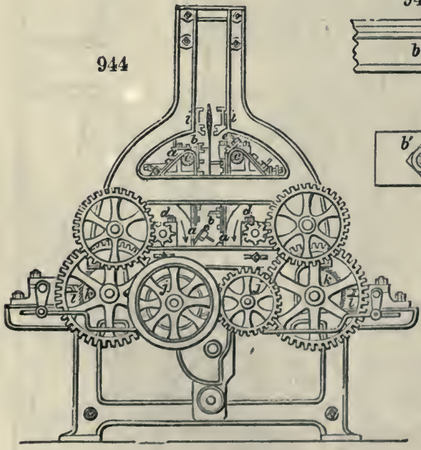

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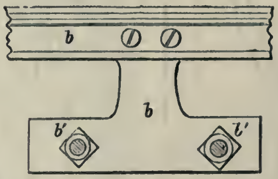

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and *fig.* 946 an end view of one of Lowry's improved hackle bars. In *figs.* 943 and 944, *a a* represent the belts, sheets, or chains to which the hackle bars *b* are attached. These belts, sheets, or chains pass around the small drums *c c*, and larger drums *d d*, which are turned round by the gearing, shown in the drawing, or by any other suitable arrangement of gearing. The hackle bars *b* are made with a recess to receive the stock of the hackles *e*.

The hackle bars *b* are connected to the belts, sheets, or chains *a*, *a*, by means of rivets or screws, passing through the flanges *b*, and through the belts, sheets, or chains *a*; and at each end of each hackle bar is a stud or guide pin *b′*, which, when the hackles arrive near the small drums *c*, *c*, take into the groove in the guide plates. The object of these guide plates is to support the hackle bars in passing over the small rollers *c*, and during the operation of striking into the strick of flax or other fibrous material to be operated upon. The holders, with the stricks depending from them, are placed within the rails *i*, *i*, and these rails are made to rise and fall and the holders are made to pass from one end of the machine to the other, in the usual manner. When the machine is at work, the drums *c* and *d* revolve in the direction of the arrows in *fig.* 944, and the hackle bars being attached to the belts, sheets, or chains *a*, and supported by the guide plates, cause the hackles to enter the stricks of fibrous material at or nearly at right angles to the fibres thereof, and to retain that position at the commencement of their downward motion; whereby as the belts, sheets, or chains continue to descend, the hackles are drawn through the fibrous material for the purpose of removing the short fibres and extraneous matter. Another great advantage resulting from this improved mode of attaching the hackle bars *b* to the belts, sheets, or chains *a*, is, that the hackles can be made to enter the fibrous material at a point closer to the holder than in any of the sheet machines now in use. When the hackles are passing round the drums *d*, *d*, they are cleansed by the revolving brushes *j*, *j*, which deposit the material removed from the hackles on to the card drums *k*, *k*. These drums are cleansed or doffed by the combs *l*, *l*, or in any other convenient manner.

This machine is also used to a very large extent, and well liked for dressing half-line and full-length flax. For this purpose the sheets require to be made 6 inches longer from centre to centre, and the head or trough to lift 3 inches higher, and the top rollers to approach and recede from each other simultaneously with the rising and falling of the head.

Combe, of Belfast, has produced another edition of Wordsworth's machine. Its novel feature consists in dispensing with bars altogether, in carrying the hackles and in fixing them directly on the leather sheets. By this means a very true action is obtained, and the working parts are so light that the machine bears any speed with scarcely any wear and tear. In this invention there are also combined convenient modes of regulating the lift and severity of the cutters to suit different kinds of flax, and the holders are carried through the machine by a separate apparatus for that purpose, while they are at their highest elevation, instead of during the whole process of lifting, as had always been the case in other machines.

The cutting of flax already referred to, is effected by a machine consisting of a species of circular saw about 20 in. in diameter; but, instead of a single blade, it is constructed of 3 or 4 plates of steel, each about $\frac{1}{4}$ in. thick, and having angular projections from their circumference. This revolves at a considerable velocity, while the flax, firmly grasped in each hand by its ends, is still further held and slowly carried against the saw by two pair of grooved pulleys pressed together by a considerable weight. It is thus partly sawn and partly broken through. Flax may be cut into 2, 3, and sometimes 4 divisions: and sometimes the dead harsh fibres that are frequently found at each of its ends only are cut off and used as tow; but more generally the different portions are hackled and used for the purposes they are sorted for.

Description of flax-cutting machine (*figs.* 948, 949). A A, framing; B, the grooved pulleys for holding and carrying the flax; C C, the driving pulley; D, saw or cutter; E, F, wheels for gearing together the pair of holding pulleys; G, H, I, K, pinions and wheels for producing the proper relative speeds between the cutter and pulleys; L, weight, which by levers M and N, causes the pressure of the holding pulleys.

Preparing.—By this term are understood those preliminary operations through which both line and tow must pass after the hackling and before the spinning process.

The mechanism and modes of proceeding for this purpose, which consist of repeated drawings, are similar for 'long' line or 'cut;' though the dimensions and fineness of the machinery must be made suitable for their various lengths and qualities. But in the preparation of tow a peculiar additional operation is demanded, as a consequence of the different state of the fibres of which the material is composed; this operation, termed 'carding,' has for its object to bring the highly irregular and entangled mass into a somewhat more homogeneous and uniform state, previously to its being afterwards drawn and equalised in a manner similar to line.

In the preparation of line the first operation is called 'spreading,' or first drawing; and the machine employed a 'spreader:' those subsequently are the second and third 'drawings' (sometimes a fourth is used), and lastly the 'roving.' It is upon the spreader that the separate stricks of line are first combined and drawn into long uniform bands or ribbons, called 'slivers,' of determinate lengths. This is effected by subdividing the stricks into two or three portions, and then placing them consecutively, slightly elongated, and overlaying each other about ¾ths of their length

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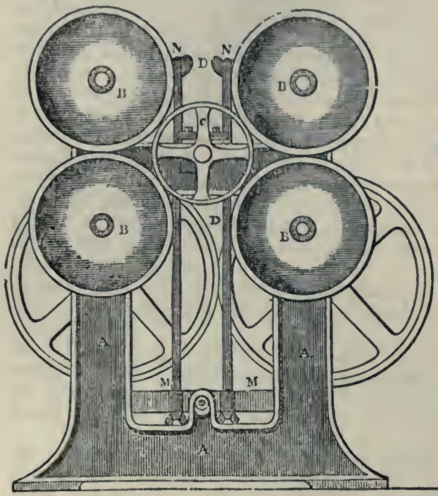

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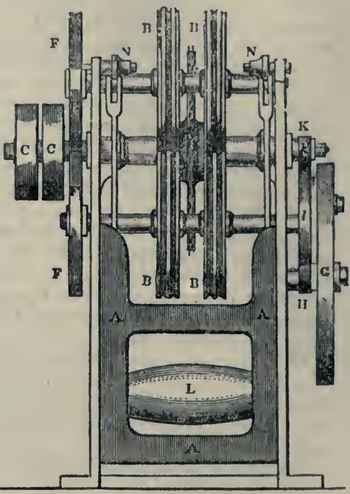

upon and in the direction of an endless creeping sheet or apron. The machines are generally made with two of these creeping sheets or aprons, and upon each sheet are thus laid two distinct lines of stricks; each of which forms a thick uniform body of line, and capable of being maintained to an indefinite length. These endless creeping sheets supply continuously another part of the machine, where the body of 'line' is drawn out to between 20 and 60 times its original length, according to whether it is composed of cut or long flax. This part of the machine comprises a pair of holding

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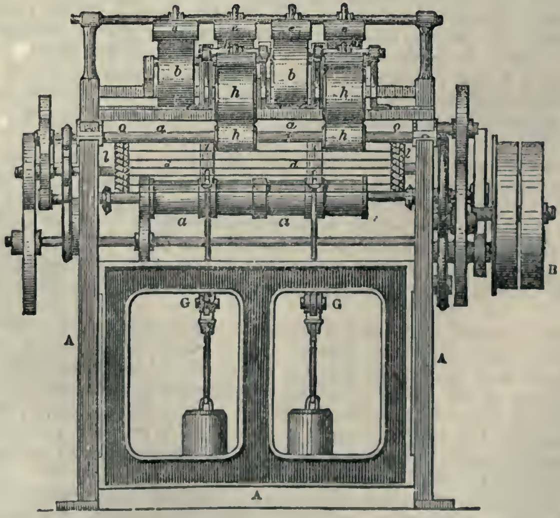

or back rollers; an endless succession of bars called fallers, bearing combs of closely-ranged steel pins, through which the slivers are drawn; a pair of drawing rollers; an arrangement of diagonal or doubling bars; and a pair of delivering rollers. It is generally termed the 'gill frame,' or 'gill head,' probably from the French word *aiguilles* (needles), as descriptive of the combs, and to distinguish this machine from those formerly used for the same purpose, which simply consisted of a series of rollers, under and over which the line was passed.

Figs. 950, 951, 952, show the outline of the present most approved gill spreader or first drawing.

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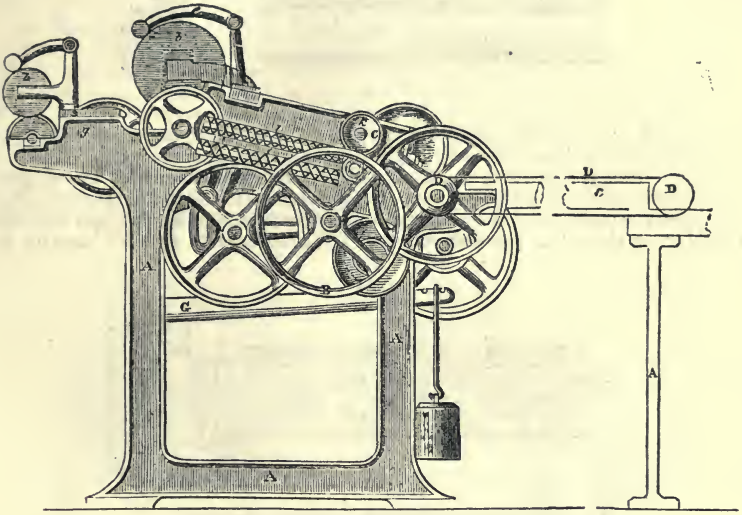

A A, general frame of the machine; B, driving pulleys; C, auxiliary frame for endless sheets; D D D D, rollers for carrying the endless sheets or aprons; E E, conductors to guide and slightly condense the four bodies or slivers of line; F, can for receiving the sliver; G, lever for weight on front or drawing roller; H, lever for weight on back roller; K, delivering-roller shaft, spring, and bell, which, by the

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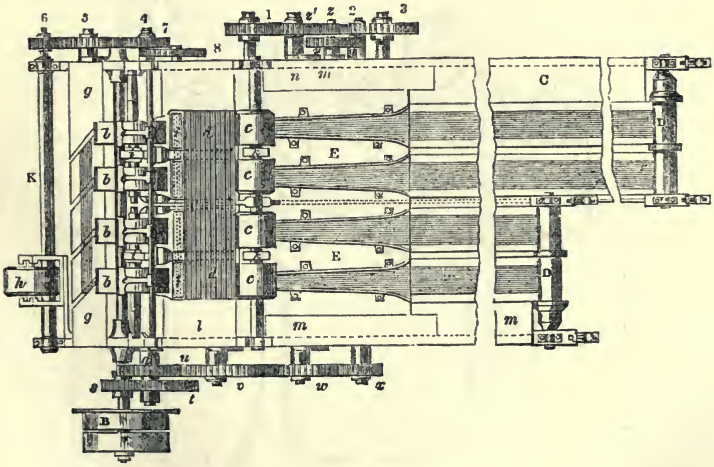

intervention of gearing between it and the front roller, is caused to ring when any desired length of sliver is delivered.

a a, the iron drawing roller or boss; *b b b*, the wooden or pressing roller, by the pressure of which upon *a a* the sliver is held during the greater velocity of these rollers over that of *c*; the holding or back rollers elongate in exact proportion to its augmentation; the holding roller *c* is in like manner pressed against another in order to assist the 'gills' in retaining the fibres; *k k*, hooked rods to connect the weighted lever *h* with the holding roller *c*, and by the pressure thus caused insure its effect; *d* the sheet or surface of 'gills' composed of separate bars, as seen at *figs.* 954, 955; *e*, rubber or cleaner of pressing roller *b*; *f f*, conductors to contract laterally the sliver at the moment of drawing; *g*, plate of metal having diagonal openings at an angle of 45° (this plate is sometimes called the 'doubling bars,' having been first made of separate bars) to the original course of the sliver, in order to enable it to be turned in a rectangular direction and guided to the delivering rollers *h h*; this direction of the sliver is more distinctly seen at *fig.* 952; *i*, hanger or connector of pressing

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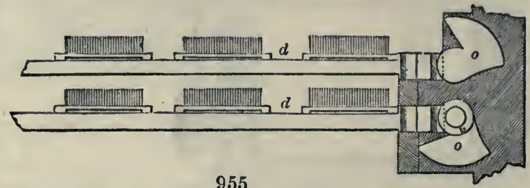

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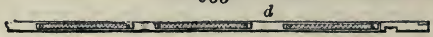

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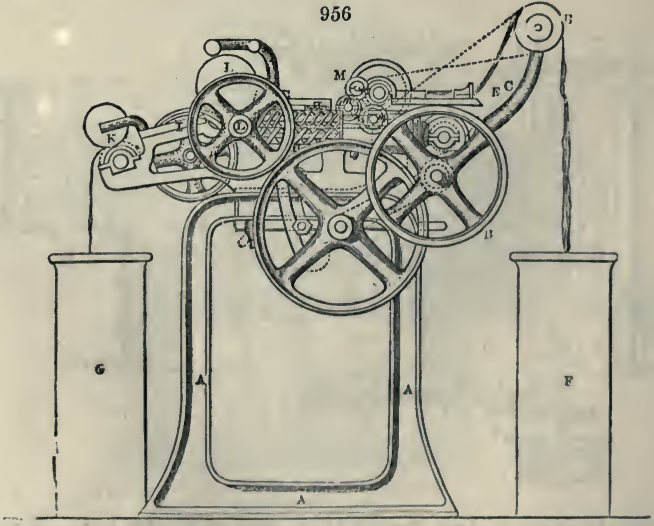

roller *b* to its weight lever *c*; *l l*, the screws or worm shaft for carrying the gill bar *d d*; *m m*, the shaft with bevel wheels by which the screws at opposite sides of the frame are caused to move simultaneously; *n n*, pinions for connecting the upper and lower spirals of each pair; *o o*, the cams or excentrics for lowering and raising the gill bars; *p p*, weighted guide lever or bell cranks for guiding the faller in its descent, and moderating the shock caused by its weight when coming in contact with the lower slide or support; *q* and *r*, worm and wheel for bell motion; *s*, *t*, *u*, *v*, *w*, *x*, line of wheels from pulley to front roller and from front roller to back; 1, 2, 3, line of gearing from back roller to sheet; 4, 5, 6, 7, line of gearing from roller to delivering roller; 8, from roller to brush; *y y*, from back shaft to back roller.

The machines for the second, third, and fourth drawings, though in principle essentially the same, yet differ in some of their minor details from the foregoing, as they do not require the feeding sheet to supply them, the sliver, from the spreader, having sufficient coherence to allow itself to be drawn from the cans direct by the back rollers of these machines; neither is a bell motion requisite to determine the length of slivers produced by them. The subjoined sketches show the general parts requisite.

A A (*figs.* 956, 957), framing; B, driving pulley; C, support of sliver carrier; D, roller for carrying sliver; E, conductors; F, can containing the slivers from the first drawing; G, receiving can; H H, the hackle carrying spirals; I, the diagonal or doubling bars; K, the delivering rollers; L, the drawing rollers; *m*, *m*, *m*, the retaining rollers.

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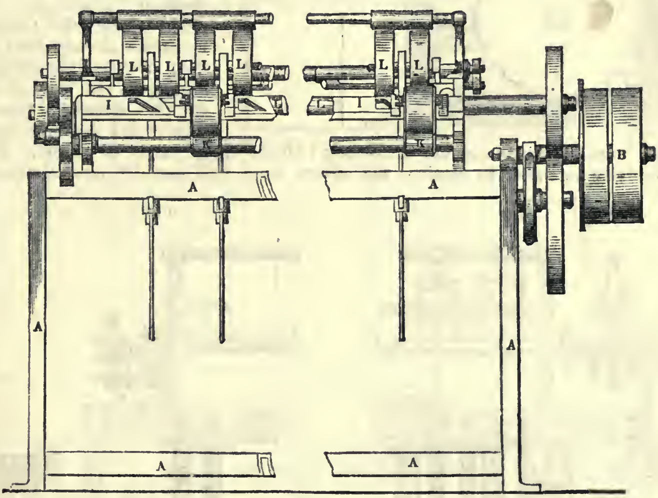

The roving frame is the same in regard to the arrangement of its back and front rollers and gills as the drawing frames; and, as the position and manner of regulating the poles are generally the same as adopted for cotton, the description of these parts, therefore, does not require to be repeated; but an improvement patented a few years since by Sir P. Fairbairn, of Leeds, of that part of these frames which relates to regulating the taking-up movement of the bobbin merits particular attention, as by it the inconveniences of the older method of a weighted belt and cone, and those of the more recent disc frames, are entirely overcome. The principle of this improvement consists of driving a pulley by pressure between two discs running at equal speeds in opposite directions, as seen at *figs.* 958, 959, 960.

To obtain the variable speed, instead of using a cone and belt as in some frames, or the pulley and single disc as in others, we have the following parts: *a b*, the horizontal driving discs; the lower one *a* is keyed to the shaft *d*, while the upper *b* is free to turn upon it; *i*, bevel wheel fitted to or forming one piece with the upper disc *b*; *c*, bevel wheel keyed to shaft *d*; *e*, intermediate bevel wheel gearing in the bevel wheels *c* and *i*, so as to turn them in opposite directions, and consequently the discs to which they are directly or indirectly attached; *g*, the variable pulley covered with leather and resting upon the lower disc *a*, and itself pressed upon by the weight of disc *b*; it is thus driven at speeds varying according to its approach to or from the shaft *d*, thus answering the purpose of the traversing leather belt of the cone movement; *h*, shaft keyed in the pulley *g*, from which the variable motion is transferred to the bobbins.

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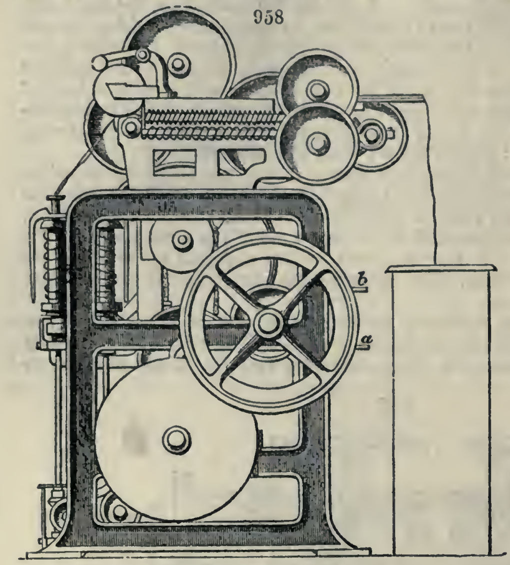

A series of preparing machines, termed a 'system,' consists in general of 1 spreading of 4 slivers at the drawing rollers, united into one by the doubling bars at the delivering roller, 2 frames of second drawing, in all 24 bosses 2 frames, third drawing containing together 36 bosses; if a fourth drawing is required, 2 frames of 24 bosses each, or 48 bosses in all. 180 spindles of roving in 3 frames will well supply 3,000 spindles of medium spinning. The mode of using this 'system is, as has already been said, first to spread the stricks of line upon the feeding-sheet of the spreader, then to receive the sliver or slivers there produced into cans capable of holding 1,000 to 1,200 yards of slivers. Those cans specially intended to receive the slivers from this machine are all made to one regular weight; thus, when filled, the weight of line each contains is correctly ascertained, and by the bell motion the length is also known. Upon this basis is founded the method of producing any desired number of yarn, and by doubling the slivers, a degree of equalisation that the simple spreading would be unable to effect; for at each drawing, and at the roving, several of the slivers from the preceding drawing are put together, to be again reduced to one for this object alone.

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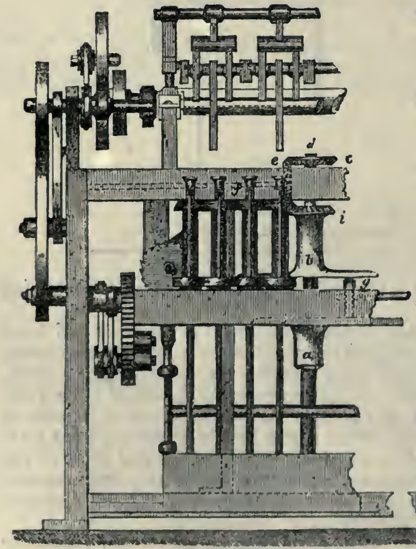

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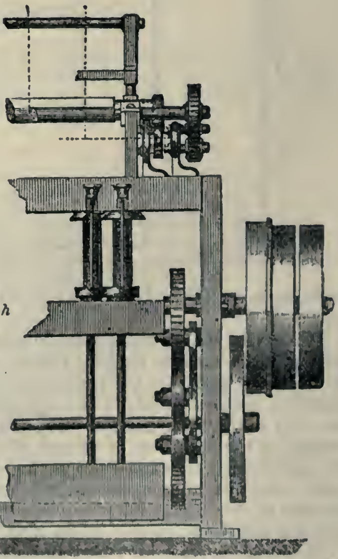
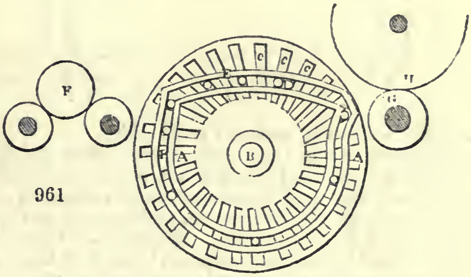


Hence, the weight of a determinate length in yards of the desired yarn being known, a calculation is made, combined of the drafts and number of doublings the material has to undergo, to determine what the weight should be of that length of slivers contained in the cans from the spreader. It is ordinary to put 10 or 15 of these cans together, to form what is called a 'set,' the slivers of which are united at the second drawing with the subsequent drawings and rovings. The combination of two or three slivers at each boss is sufficient.

Though the above is descriptive of the 'gill' frames now in use, yet it should be understood they are by no means the first or only results of the attempts made to correct the defective principle of the original roller machines, which were incapable of holding or retaining the flax with a sufficient degree of regularity, owing to its unequal lengths and unadhesive nature. The consequences were that the yarns produced were 'lumpy' and unlevel, making it evident that some improved means were necessary for more completely restraining and regulating the drawing of the fibres. The most obvious way to do this was to introduce some mode of partial detention by creating a friction among the fibres to imitate the action of the fingers in hand-spinning. This led to causing the slivers to pass through and among several ranks of serrated pins, which was found very nearly to attain the object, and certainly greatly improved the levelness and uniformity of the slivers. Thus the use of 'gills' became general about forty years since.

Those first brought into general use were constructed with circular discs or plates for carrying the faller or gill bar, which at the same time were guided by their ends passing in fixed slides, so as to bring the gill in as vertical a position and as near the drawing roller as possible. The figures (961, 962) are profile and front views of the working parts of one of these gills:—A, slotted plate or disc, of which a pair were keyed upon a shaft B, so as to carry each end of the faller D, passing through the slots *c c*; E, the fixed excentric slide; G, H, the drawing rollers; F, the holding rollers.



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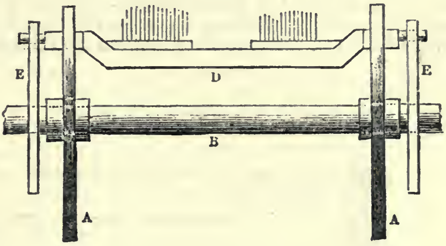

This was succeeded by the 'chain gill,' in which the fallers were carried forward by an endless series of connected links, or jointed together 'slotted plates,' instead of the simple circular. The object of this was to increase the flat surface of gill bars between the holding and drawing rollers, making it more suitable for the longer descriptions of material. The slides and rollers, being similar in these machines to those in the former, are not repeated, but the sketch of five slotted plates is given in *fig.* 963.

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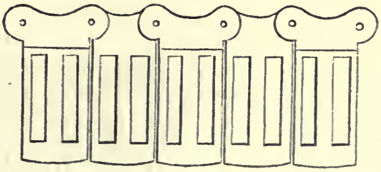
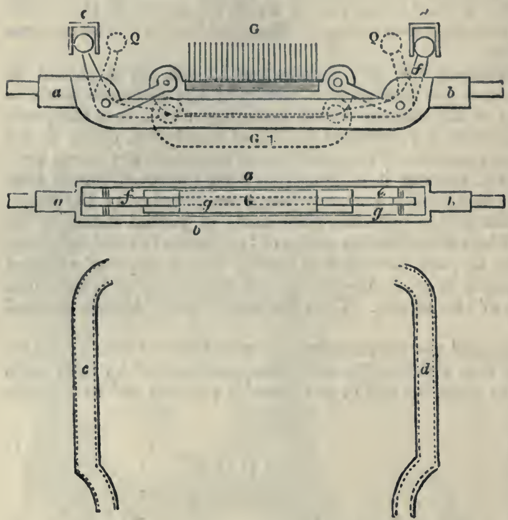


From the evident importance of bringing the retaining effects of the gills as closely as possible to the point where the movement of the drawing fibres is greatest, several attempts have been made to improve the above-described gills in this respect. With this view, Messrs. Taylors and Wordsworth patented a gill of considerable ingenuity (*fig.* 964), which therefore deserves mention, though it never came into use. Its description is as follows:—*a*, *b*, the faller or 'gill bar' in one piece, which was carried forward by an endless chain; *c*, *d*, slides placed horizontally over the gill sheet guiding the ends of certain bell-cranks *e*, *f*, joined at their angle in the recess *f*, *g*, *e*, of the gill bar, and at their other end to the gill or comb G. By this arrangement, as long as the bell-cranks are in the parallel parts of the slides *c*, *d*, the gill teeth will be above the faller *a*, *b*, but when they arrive at the contracted part the guided ends will be brought into the position Q Q, and consequently the gill depressed is G 2; this is so timed as to cause them to clear the drawing roller, when, on again continuing their course, they are again caused to rise and penetrate the sliver by the reversed inclination of the slides *c*, *d*, at the back roller.

964



The objection to this ingenious machine was the largeness of the space suddenly left open by the descent of the gill, as the double faller, bell-crank, and gill necessarily occupied great width.

The screw or spiral movement of the fallers, which was soon afterwards invented, quickly superseded all others in use, as by these means the faller was caused, even in the manner they were first constructed, to approach closer than even in the most perfected construction of the others, to the side of the drawing roller, and still maintain the pins in a vertical position. Recently this object has been more perfectly attained by a patented improved construction adopted by Messrs. P. Fairbairn and Co., whereby the obstacle to the faller wholly touching the roller has been removed, and thus producing the full holding effect of the gill to the latest possible moment. This is effected by employing a method of supporting the spirals by their working in tubular recesses in the side plate of the machine; along these recesses are longitudinal openings through which the faller end passes to enter between the threads of the spiral, and which serve also as slides to support the faller. As by this means the supports or plummer blocks that intervened between the end of the spirals and the roller are suppressed, the faller

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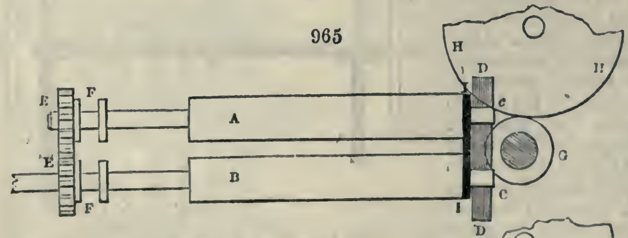

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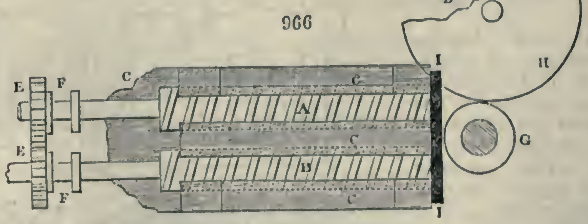
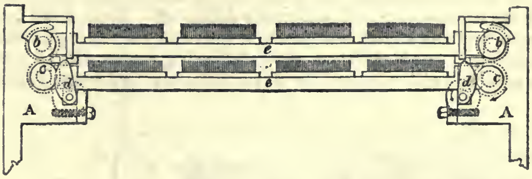


is enabled to advance to the place they formerly occupied. *Figs.* 965 and 966 show this comparison of the older and more recent methods. A, B, spirals; C C, the parts by which they are supported, being in *fig.* 965 small pivots in plummet block D D, and in *fig.* 966 hollow tube-like recesses in frame plate C C; E E, pinions to work the upper and lower spiral together; F, bearings; G, drawing-rollers; H, pressing rollers; I I, passage of the faller's descent.

Here it may be as well to observe that the same parties have still more lately introduced another important amelioration in these machines for remedying the noise and wear and tear which ordinarily attend them by the abrupt and violent descent of the faller. *Fig.* 967 shows a sectional front view of a head having this improvement applied. A A, supports for screws; *b*, *c*, top and bottom screws; *d d*, the new cams fixed on shafts parallel with the screws, and revolving at the same speed. Thus, these cams *d d* receive the faller *e e* at their largest diameter, at the moment they are free to descend, and guide them gradually down to the lower slide.

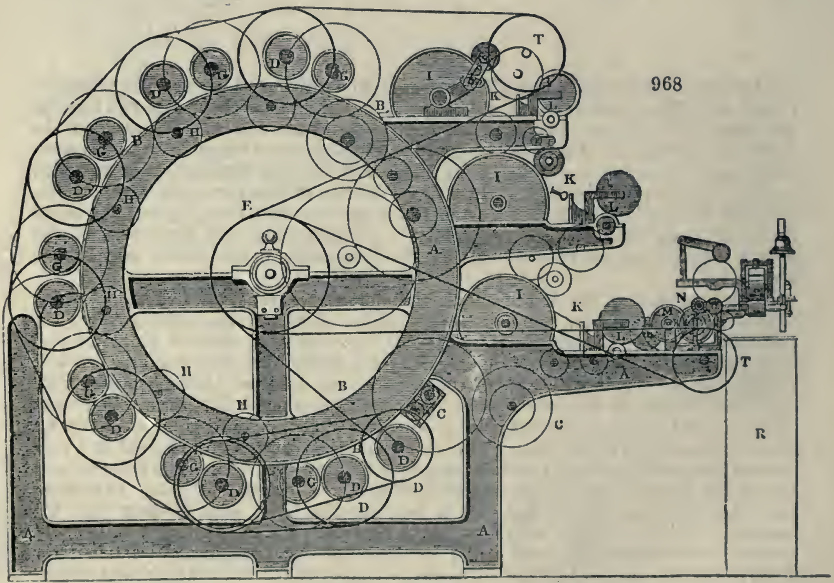
967



Thus constructed, the 'screw gill' continues to be the most esteemed in principle, though not without some serious objections in practice. For the abrupt and angular movement of the faller even here not only liberates too suddenly a portion of the fibres that should be but gradually relaxed at the moment of being drawn, but causes considerable wear and tear to itself, the slides, and the gills attached to it; to which cause of destruction must be added the great friction of the worm movement; these, however, in 'line' preparing, where the fibres are long and straight, and the drafts employed large, and where, consequently, a comparatively slow movement of the gills is required, are not so much felt as in the preparation of tow, where they become serious.

In 'tow preparing' the first operation, as before stated, consists of 'carding,' which is generally repeated over two separate machines, which are respectively called the 'breaker' and the 'finisher' cards. They are essentially the same in principle, and vary but little in construction, the only difference being that the 'breaker' is fed or supplied by the disjointed parcels of tow from a creeping sheet (as the spreader with 'line') and delivers its slivers into a can, whereas the 'finisher' is fed from a bobbin upon which several of the slivers from the breaker are united by a machine expressly for that purpose, called a 'lap frame;' this card thus receives its supply of work in a very regular form, and previously to delivering it in the form of slivers causes them to pass over a gill, to consolidate and strengthen them before delivering them into the receiving can; it is also generally clothed with a finer description of wire filleting than the breaker. Though it is the better method to card thus the tow twice, yet this second carding is sometimes dispensed with; in that case this auxiliary gill is similarly fixed to the first card or breaker. The cards employed for tow are machines of considerable weight and importance, the main cylinder, or, as it is sometimes called, 'swift,' being from 4 to 5 feet diameter and 4 to 8 feet long; those most generally employed are 6 feet long. Previously to entering upon the detailed description of a card, it may be as well first to trace in general terms the progress of its operations, as tending to elucidate the explanation of the machine itself.

The tow is first divided by weighing into small parcels of 10 to 20 drams; these are then shaken out and spread so as to cover certain definite portions of the creeping feeding-sheet, by which they are conducted to the first pair of rollers called the feeders, These rollers are covered with a leathern band, in which are fixed in close array a number of wire points about ½ an inch long, and having a tangential inclination to the circumference of the rollers, which are about 2½ inches diameter. The tow passing at a slow rate of progression between these rollers, is by them gradually presented to the points with which the swift is likewise covered, also set in leathern bands, but which are about 2 inches wide; these points, the same length as those of the feeders, have an inclined direction pointing to that in which the cylinder turns. The much greater velocity of the 'cylinder' combs and somewhat opens and breaks the tow as it slowly arrives in contact, and the inclination of the pins at the same time carries it forward. All such lumps and fibres as are not sufficiently opened and straightened by this first contact, remaining prominent on the surface of points on the cylinder, are carried by it against another roller, whose axis is parallel, and whose wire-covered circumference is brought as near as possible, without absolute contact, in order to catch and retain these prominent lumps and fibres; the points of this roller (called a 'worker') are inclined in a direction opposed to the movement of the swift, and, therefore, hold the tow to be again combed and straightened as at first it was by the feeders: this is repeated eight or nine times, by having that number of workers to the card; each of these workers has its attendant roller also covered with wire points, by whose inclination in a contrary direction, and by the greater velocity of the roller, the tow is stripped from the workers, to be again laid on to the cylinder. The strippers, though running at a greater velocity than the workers, are still slower than the cylinder. The tow thus carried forward gradually improving in openness and regularity as it passes each pair of 'workers and strippers,' finally arrives at the roller called a 'doffer,' of which there are two or three upon a card, the wire points of which are in such a direction as to hook or catch the tow 'as it flies.' The use of these several doffers is, that by placing each succeeding one progressively nearer the swift, the longer and shorter fibres are successively and separately taken off. Each doffer is cleared by an oscillating comb, and the slivers conducted, if intended for the lap machine into a can by delivering rollers; but if finished, these delivering rollers are, as it were, the back rollers of the auxiliary gill, patented for this application by Messrs. Fairbairn and Co.;


968

whereby the slivers are not only saved from all danger of derangement in their loose and porous state as direct from a card, but the hitherto double expense of carding and first drawing is reduced to that of carding alone.

A A A (*fig.* 968), framing; B, swift or main cylinder; C, feed rollers; D D D, strippers to feed rollers and workers driven by one belt from pulley E, and maintained tight by the moveable pulley F; G G G, workers; I I I, the three doffers; H H H, intermediate wheels to connect the movement of the doffers with one another; K K K, oscillating combs for their respective doffers; L, delivering rollers; M, back roller of auxiliary gill; N, gill surface; O, P, drawing rollers; Q, delivering rollers and bell motion for measuring the sliver in the cans R; S S, doubling plate; T, pulley for driving auxiliary gills by bell from the pulley E.

The lap frame, to which allusion has already been made as the necessary adjunct to the cards when double carding is to be performed, is employed to collect together a number of slivers from the breaker by winding or lapping them upon a cylindrical piece of wood, which may be described as a bobbin shank, thus producing an equalisation of the slivers of tow as the making up of sets effected in line preparing; from

50 to 60 lbs. of tow is the usual complement of one of these bobbins; the length and the diameter, when full, about 22 inches; thus, a 6-feet wide finisher card will take off these bobbins at once; from 15 to 20 is the number of slivers usually wound together, and the completion of a bobbin by the ringing of a bell, connected with the measuring cylinder of the machine. The following is a descriptive drawing of the lap machine:—

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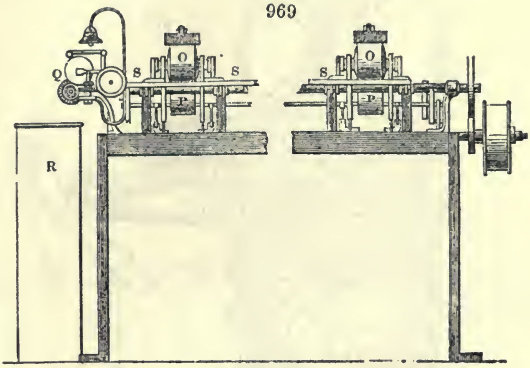

A A A (*figs.* 970, 971), framing; B, measuring and pressing cylinder; C C C, driving pulleys connected with different gearing to change the speed as the bobbins fill; D, bobbin or shank intended to be filled; E, table to receive the bobbin when about to be taken from the machine; F, weight to increase the effect of pressure of the measuring cylinder by the connecting rods G G, which are split for part of their length in order to pass the shaft H, and at another, *g g*, have racks into which work pinions keyed on the shaft of the hand wheel I, for the convenience of raising and lowering the cylinder and weight. The shaft H is divided at the plates K and L, and provided with sockets to receive the end of the bobbin shank D, which is introduced

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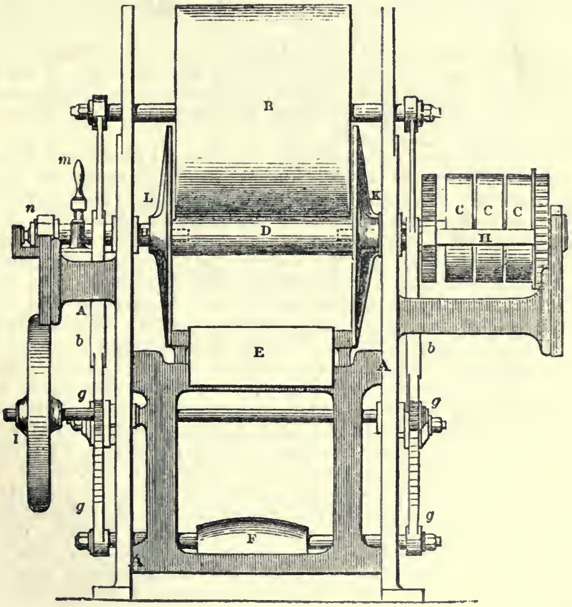
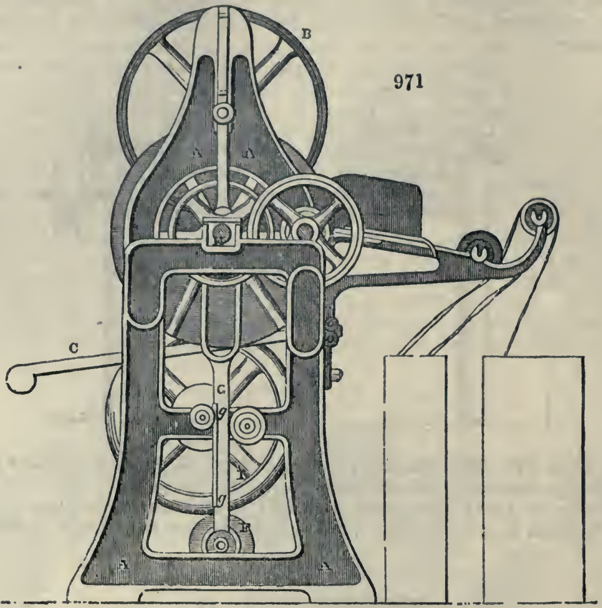


by sliding back the piece H *n*, and returning it by lever *m*, and thus is coupled and turns together with two pieces of shaft H, as also the disc plates K and L, which are


971

to serve as temporary ends to the bobbin during the time of its filling, and thus by turning with it avoid that rubbing and felting effect upon the edges of the tow so injurious in the machines formerly constructed, and by the bobbin acting as the driver to the cylinder the slivers are drawn tighter, and thereby avoid those plaits that the other machines were so liable to produce.

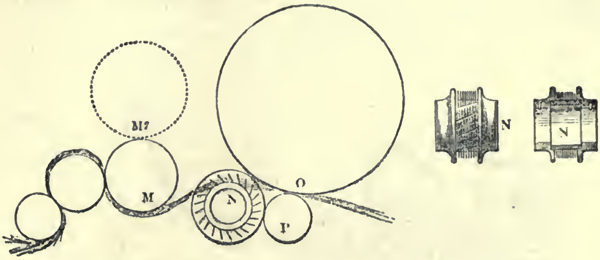
As before mentioned, some objections were found to the working of the screw-gill, of a nature detrimental to the machines themselves, which, though not of great importance in 'line,' were much aggravated in tow preparing, as the lesser drafts there employed cause a greater wear and tear of the fallers and gills. The objection to these machines, however, is not confined to this point only, but extends also to their effect upon the material itself. The fibres of the tow sliver, as coming from the card, are in a light and much confused state, which renders them liable to be easily separated; so that the faller, by its sudden descent, has a tendency to draw some down, and become lapped by them, as well as to make so marked a difference in the thickness of the sliver, by the withdrawal of the retaining comb, as materially to injure the quality of the yarn. Thus this 'gill' was not enabled to hold its place in tow spinning, when other circumstances led to greater attention being paid to this important branch of the flax business, and it became a desideratum to have a machine free from these defects, and capable of working without derangement, at much greater velocity than was safe with the screw-gill. These desiderata the 'rotary' gill, patented by Messrs. Fairbairn and Co., amply supplies. For in this gill the circular form of the gill sheet obviates the necessity of having several fallers, and the simple motion creates neither friction nor abruptness of effect, while, the retention of the fibres being continuous, the slivers produced are perfectly level and uniform; consequently, these gills are extensively applied, as the auxiliary gill explained in carding, as well as for the subsequent drawings and rovings of tow, and sometimes, as will be afterwards seen, to coarse spinning. The theoretical construction of these rotary gills will be seen by the annexed sketch.

M (*fig.* 972), back rollers, but when applied to a card at top and bottom holding-rollers are again employed; N, the rotary gill sheet having the pins inclined backwards, so as to insure the impalement of the sliver when the fibres begin to draw; P and O, the drawing and pressing rollers; the doubling bars or plates are the same to these gills as to the screw gills.

A machine has been invented, and brought out by Sir P. Fairbairn and Co.

of Leeds, called Heilmann's tow-combing machine (*fig.* 973), which, on trial, is much approved of. The tow is first carded in the ordinary way, say on a breaker-card, and then on a finisher-card; the latter delivers the tow in the shape of a sliver into cans, which are next placed at A, or back of the tow-combing machine.

972



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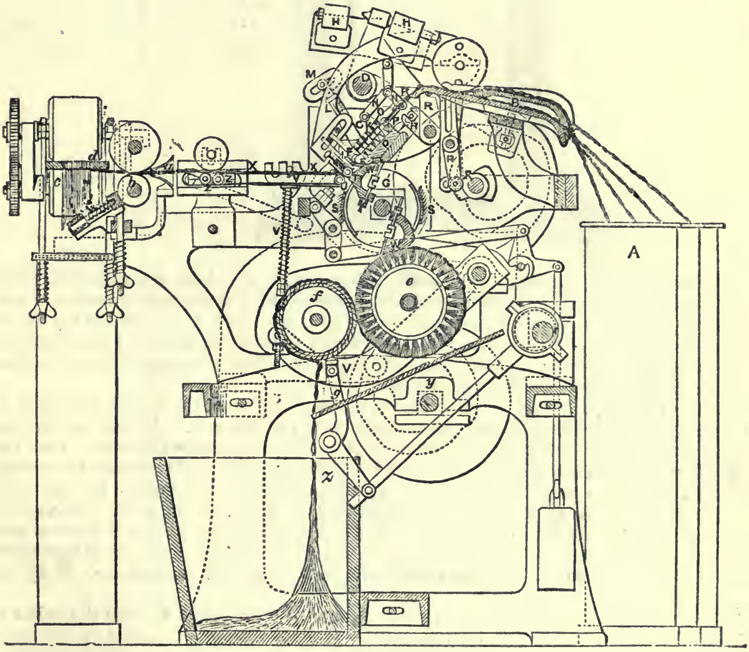


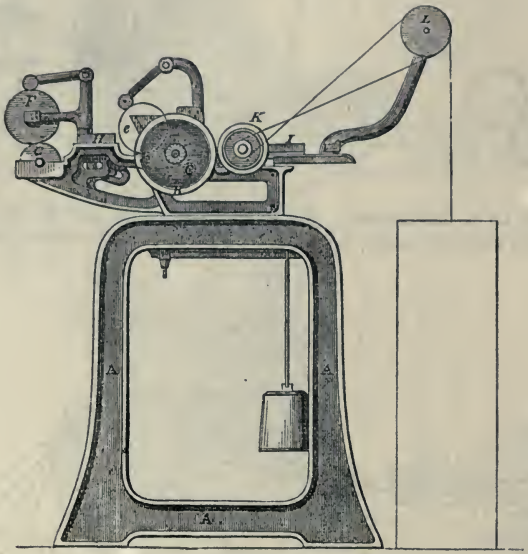
From the cans A the tow goes to the back conductor B, divided into as many compartments as there are slivers; and from the conductor B, to the feeding box C suspended on shaft D, without being keyed to it. The front lip E of the feeding box is fluted and fitted with leather, and a corresponding nipper F hung from the same shaft D, and keyed upon it, completes the jaw which has to hold fast the tow, while the cylinder G combs it.

The feeding box C derives its motion from the nipper F, which is moved by lever and excentric as shown, and follows that nipper by its own weight, until stopped by india-rubber buffers H; when the nipper F in going further back leaves it, and the jaw E F opens for more tow to be fed, and the tow already combed to be drawn through the detaining comb I, as explained hereafter.

The top K of feeding box is moveable up and down, by means of the connecting rod L, hung on a fixed centre M, so that the top part K opens or shuts as the body of the box goes backwards or forwards. The levers N N N are only used to keep the top and bottom of the box parallel to each other.

As shown in the drawing, the top of the feeding box is fitted with hackles passing through two grates O and P, fast on bottom of feeding box, and leaving between them a space through which the sliver has to pass.

974



By the above arrangement, the hackles are caused to withdraw from the tow, while the whole box is drawn backwards on slides of table Q, by the excentric motion R R R. The last backwards motion takes place while the jaw F is yet shut, and the top of the box up; but when the latter has got closed again, then the whole box slides down on the table Q to its former position, bringing with it the sliver of a quantity equal to that move: this completes the feeding motion.

Now as the feeding box recedes, the lip E comes nearer to the combing cylinder G, the hackles S S cleaning the tow projecting outside the nipper F. As soon as they are passed through, the feeding box comes back to the most forward position, when the nipper F leaves it, and the jaw E F opens: at the same time the two rollers T U have reached their top position. The top one T is then thrown forwards (by the lever arrangement shown in V V V) upon the leather W, stretched on parts of surface of cylinder G; this roller T is thus driven, and takes hold of the points of the tow presented to it by lips or bottom jaw E; a fine detaining comb I being just before interposed between them to keep back the 'noils,' that have not been carried off by the combing cylinder.

In that way the points of the tow are driven upon the sheet X, until the roller T, by being thrown back again off the leather W, their motion is stopped at the same moment, the two rollers U and T are allowed to drop down by excentric V, drawing with them (through the detaining comb I, and quite out of the rest of the sliver) the other ends of the fibres of which they have got hold.

While this has been going on, the feeding box has advanced the sliver a step, the nipper closed, and forced the said feeding box forwards so as to bring the lip E within the reach of hackles S on cylinder G, which then met it, cleansed the tow, and so on as before.

At that time the rollers T and U come up again, and during that upwards motion the latter ends of the fibres partly combed and overturned by the cylinder hackles, as shown in drawing, are combed by them in their turn, Then the roller T is once more driven round by the leather W stretched on cylinder, the new points place themselves above the back ends of the fibres combed before, and are carried forwards into a continuous sliver on the leather sheet X, from the leather sheet to the rollers Z Z, then to the trumpet conductor A, the front delivery roller C, and (when more than one head to the machine) from C to the end delivery *c*, over the conducting plate *d*.

In *e*, *f*, *g*, and *h*, are the usual brush, doffer, comb, and tow box for the noils.

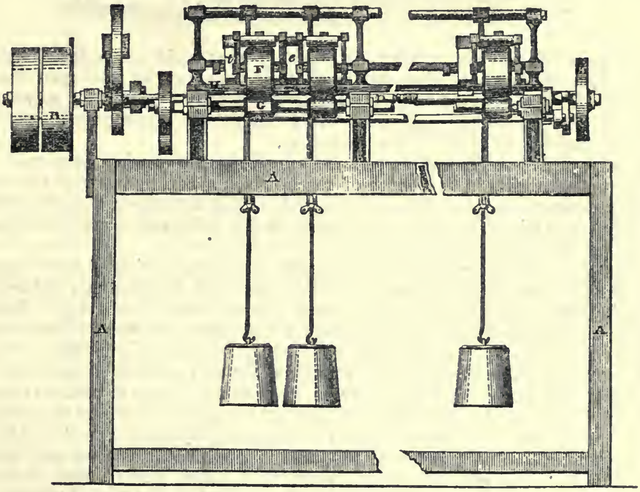
These combing machines are made of different sizes to suit all sorts and lengths of tow; the yarn produced from them is much finer than that produced by the ordinary carding system alone. The combed tow can generally be spun to as high numbers as the line from which it has been combed, and in some instances has produced good yarn, even to higher numbers. The combed tow, after the combing machine, is passed through a system of drawing, roving, and spinning, similar to that used for cut line.

Subsequently to the carding the preparation of tow is completed by making up sets of cans for the second drawing, as explained for line; these slivers are doubled and drawn once or twice more, and then roved. The drafts used in tow-preparing are from 9 to 8, for, as the fibres are shorter, it necessitates the employment of less draft. In both line and tow preparing, lesser drafts are employed as the stages advance, the gills finer, and the conductors narrower: also for both materials much attention is requisite to keep the various parts of the machines in good order, free from bent or broken pins, and chipped or indented rollers, for no subsequent operation can cure the defects that may be produced by negligence in these particulars. The drawing and roving frames for tow are shown in *figs.* 974, 975, 976.

A A (*fig.* 974), drawing frame; B, driving pulleys; C, rotary gill sheet; D, drawing roller; E, pressing; F, G, pairs of delivering rollers; H, doubling plate; I, back conductor; K, back roller wheel with pulley to turn the sliver rail L.

A A (*figs.* 975 and 976), roving frame; B, pulley and fly wheel combined; C, drawing roller; D, rotary gill; *a a*, stand for gill movement. The regulation of the bobbins is effected in the same manner as already described for line roving.

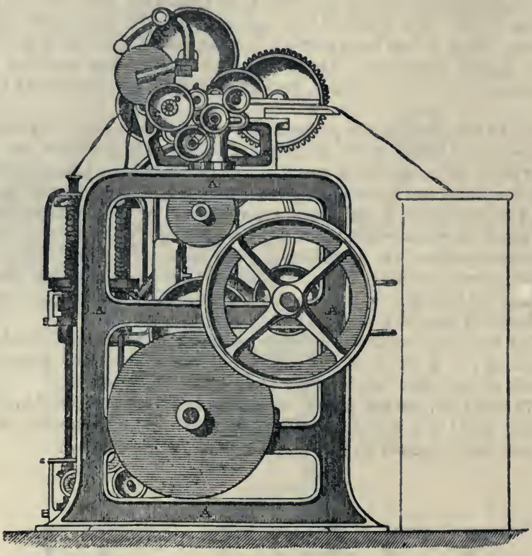
975



Spinning.—This operation consists in drawing the rovings down to the last degree of tenuity desired, and twisting them into hard cylindrical cords, which are called 'yarns.'

There are three modes of performing this operation: the first, and perhaps oldest, is that where the drawing and twisting are performed altogether, with the material preserved dry, and without breaking or shortening the fibre; the second is that which likewise, without changing the length of the fibres, draws them while dry, but wets them just at the moment before twisting. This method is the nearest imitation of hand spinning, and makes the yarn more solid and wiry than the first; as the fibres of flax losing their elasticity while wet, unite and incorporate better with one another. The third mode of spinning has been much more recently introduced than either of the others, and by it the fibres are wetted to saturation previously to being drawn, whereby they are not only much reduced in length, but their degree of fineness is increased by the partial solution of the gummy matter inherent in the flaxen material: owing to these circumstances equally good turns can be produced by this mode of spinning from line and tow of inferior quality, to what could be employed upon either of the others, and not only that, but much finer yarns can be now spun than were possible previous to its introduction. It has therefore not only nearly superseded all other methods of spinning for yarns from 20's to the finest, but has much increased the extent and importance of the flax manufacture.

976



The only difference in spinning frames for line or tow, when employed for the older methods, consists in the length of reach, which generally involves the necessity of having separate machines for each material, though sometimes they are made with a capacity to be adapted to either purpose. In the third method the same machines are used promiscuously for line or tow.

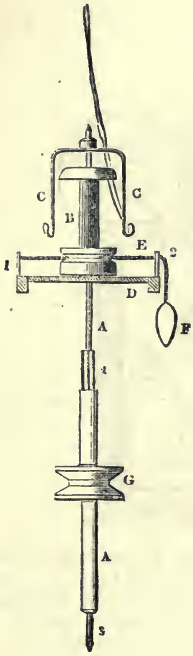
The yarns spun wholly dry are used for the coarse description of woven goods, as packing canvas, corn sacks, and when partially bleached, for sheetings and towellings, as from its greater elasticity and openness it fills up better in weaving. Those spun partially wetted are employed for a somewhat superior description of linen goods, and the solid silky appearance qualifies them for drills, damasks, &c., as well as for sewing and shoe threads; a somewhat inferior material, by this manner of treatment, makes an equally good yarn as a better material spun dry. The yarn produced from this wet principle is rather inclined to have a cottony appearance; and from the comparative ease with which an inferior material can be made to present an apparently fine good yarn, the application of yarns thus produced is exceedingly various and sometimes deceptive, though, when good materials are used, these yarns afford durable and handsome drills, shirtings, lawns, and cambrics, as well as fine sewing threads.

The mechanical arrangements for twisting, and then winding the yarn upon a bobbin, is called the 'throstle' principle, supposed to be so called from the whistling noise they create when working at full speed, which is from 2,500 to 4,000 revolutions a minute. The following diagram will explain the principle, which is applied alike to all the modes of spinning above described.

A A (*fig.* 977), the spindle; B, the bobbin, loose and independent of the spindle in regard to turning, and rising, and lowering, but through which the spindle passes; C C, the flyer screwed to the spindle top; D, table called 'bobbin lifter,' as while at work it rises and lowers to lay the yarn on the whole bobbin equally; E, a small cord to press on the bobbin by the weight F; G, pulley by which the spindle is driven.

Many attempts have been made to improve upon this principle, in order to avoid or lessen the strain upon the thread in its passage from the drawing rollers to the flyer eye; but, till recently, without any degree of success. The only improvement at present known, and which promises to become general, is that where the necessity to have a top to the bobbin is avoided. It will be seen from the diagram (*fig* 977),

977



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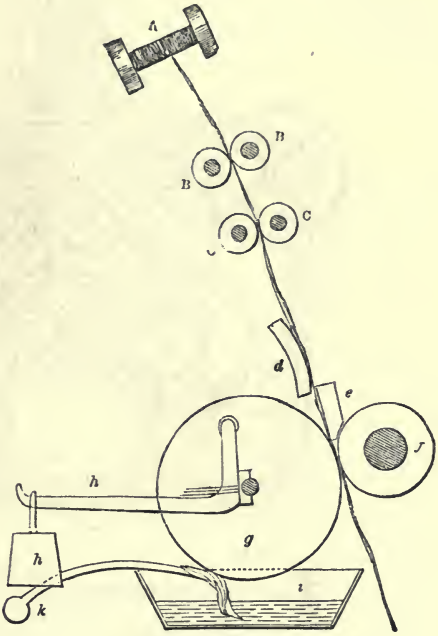


that the yarn is compelled to rub the top of the bobbin, and the friction thereby created quickly causes it to become rough; and therefore it has a tendency to catch and break the thread. The desirableness, therefore, of having a clear course for the yarn was evident, and this improvement that we are about to explain produces the effect by employing what is called a coping motion, which, like that used in mule-spinning, preserves the layers of thread upon the bobbin ever in a pointed or conical state, and therefore self-supporting without the aid of the wooden end of the bobbin. See COTTON SPINNING.

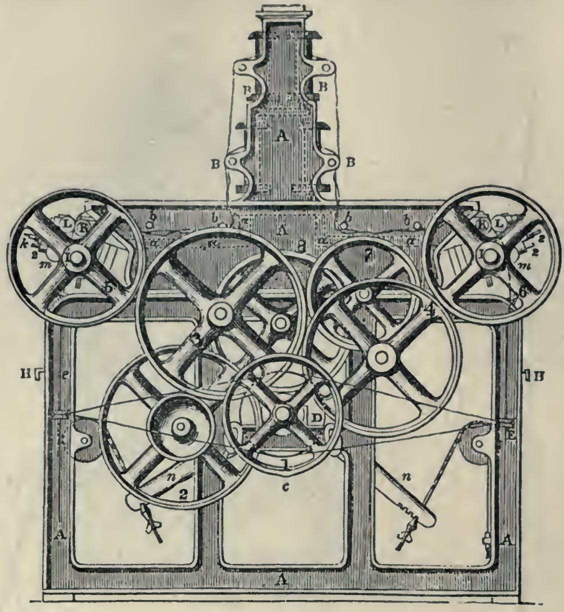
The arrangement of the rollers for holding and drawing the slivers or rovings, as well as the plates and rollers for aiding to retain the twist of the rovings, in order to render their elongation more equable when to be drawn dry and spun upon the older methods, will be seen in *fig.* 978.

A (*fig.* 978), roving bobbin; B, back or holding roller; C, carrying roller; *d*, flat plate with a slightly curved face; the carrying roller and plate are so placed as to cause a degree of friction to the roving when passing over them, so as to retain the twist, and thus act as the pins in the 'gill frames;' *e*, tin conductor for contracting the roving at the moment of being drawn; *f*, metal roller; *g*, wooden roller pressed against the drawing roller in order to pinch the roving; *h*, lever and weight. When it is intended to wet the yarn previously to twisting, the trough *i* is used, in which is water, which is supplied to the roller *g* by the capillary attraction of a piece of cloth immersed therein, and bearing against the roller by lever *k*.

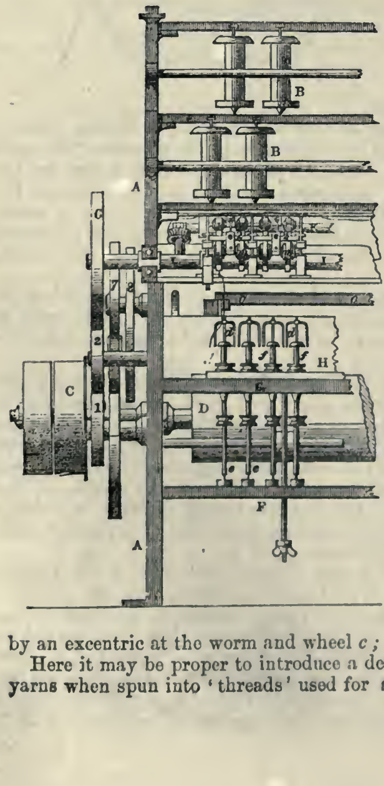
The machines for 'wet' spinning are of a very different construction and appearance; as the close proximity of the holding and drawing rollers prevents the intervention of holding rollers or friction bars, while the force requisite to draw the rovings at the short reaches used, varying from 2½ to 4 inches, requires each pair to be deeply and accurately fluted into one another. The water used is heated, in order by the expulsion of the fixed air more rapidly and completely to saturate the rovings while passing through it. The following drawings and description will be sufficient to give an accurate idea of the principle of these machines, which are generally 20 to

30 feet in length, and contain 200 to nearly 300 spindles; that is, 100 to 150 on each side.

979



980



A A A A (*figs.* 979 and 980), framing; B B, stand for roving bobbins; C, driving pulleys fixed upon the axle of cylinder D, from which pass endless cords to drive the spindles *e e;* F, step-rail of spindles; G, collar rail for ditto; H, bobbin lifter; I I, front roller; K K, back roller; L, back pressing roller; M, top pressing roller (these are generally made of box wood, but sometimes of gutta-percha); N N, levers in connection with the excentric to produce the rise and fall of the bobbin lifter; O O, thread-plate; Q Q, saddles or transverse bars resting on the axles of the back and front pressing rollers, so that one lever and weight acts for both by the connecting rod and lever *r r*, which, in order to cause more pressure on the drawing than on the back roller, is placed on the saddle nearer the former than the latter. 1, 2, 3, 4, 5, 6, 7, 8, train of wheelwork, by which the movements are distributed. *a a a*, the trough of hot water maintained by steam-pipes at the desired temperature; *b b*, guide rods or pipes to cause the roving to pass under the water. In order to avoid the rollers becoming indented by the roving always passing on the same place, they are caused to traverse the breadth of the rollers by a traversing guide rail, moved by an excentric at the worm and wheel *c;* *d*, flyers, and *f*, spindles.

Here it may be proper to introduce a description of the machines for twisting the yarns when spun into 'threads' used for sewing, &c. The yarns spun for this purpose should always be made of a somewhat superior description of line to that employed for the same number of yarns for weaving, and have rather less twist. They are generally taken while wet on the spinning bobbins to the twisting frame, and, when combined together, the union is effected by a torsion in the opposite direction to the original twist of the separate yarns.

Reeling.—This operation consists in winding the yarn off the bobbins of the spinning or twisting frames, and forming it into hanks or skeins. The various denominations of the skeins into which yarn is reeled, and then the forms or combinations they are made up into, are as follow:—

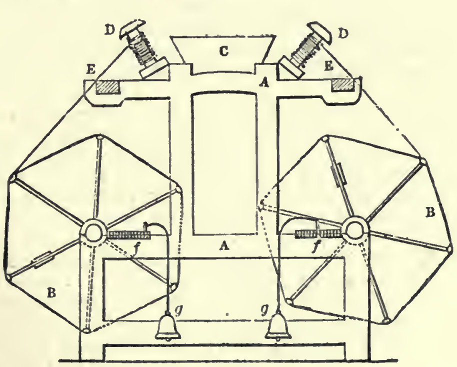
The lea containing 300 yards
10 leas making 1 hank
20 hanks „ 1 bundle
6 bundles „ 1 packet.

It is by the standard lea of 300 yards that the description of yarn is known from the number contained in 1 lb. weight; thus, No. 20 contains 20 leas or 6,000 yards for 1 lb. weight. In Scotland, the subdivisions are rather different from the foregoing, which are employed in England and Ireland; the lea, however, remaining the same:—

38 leas make 1 spindle
6 „ „ 1 rand
12 rands „ 1 dozen.

The reeling is performed upon exceedingly simple machines, generally put in motion by the hand of the person attending them, though sometimes they are driven by the motive power of the factory. The reel is made sufficiently long to receive twenty bobbins, and the barrel upon the yarn is wound in one length; the diameter, however, varies so as to suit the different sizes yarned to be reeled. For the coarsest yarns and down to 16 and 20, the largest circumference is used of 3 yards; from that to about No. 100, 2½ yards; and for the finest yarn 1½ yard is found most convenient. These various circumferences are compensated either by putting a great number of threads into each 'tye,' or increasing the number of tyes, so that opposite to each one of the 20 bobbins an entire hank should be formed before taking the yarn off; thus at each 'stripping,' one bundle is turned off. To facilitate the stripping, one of the rails of the barrel is made to fall in, and thus slacken the hanks; care is taken to leave the lea bands very loose, in order to allow the yarn to be spread out in drying and bleaching. The determinate lengths of yarn, when wound on the reel, are notified by the ringing of a bell connected with the axle of the barrel. *Fig.* 981 below shows the form of an ordinary hand-reel.

981

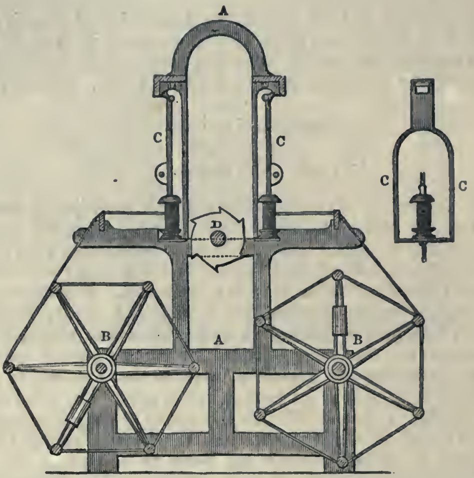


A A (*fig.* 981), framing; B B, reel barrels; C, box or trough to receive empty bobbins, &c.; D D, bobbins in position of being reeled; E E, guide rails, moveable so as to place the leas side by side on the reel; *f f*, bell wheels; *g g*, bells for each reel barrel suspended on springs.

To these hand-reels there are many objections; for it is evident that the correctness of measure depends entirely upon the attention of the reeler, and the stoppages arising from the breaking of a thread or the finishing of a bobbin interrupt the work of all the others. These objections rendered it necessary to attempt some ameliorations of the system by the introduction of a reel that should automatically prevent these causes of error. Such a reel was patented a few years since, and is now in general use in Scotland; it is so contrived as to have the capacity of stopping itself when a thread breaks, when a bobbin finishes, and leas and hanks are completed; and having but four or five bobbins in one compartment, the stoppages affect but few at a time; and as this machine can be worked by less skilful persons without possibility of error, much saving is effected both in wages and material. The annexed figure (982) shows the principle of this improved reel.

A A (*fig.* 982), framing; B reels; C C, pendulums on which are hung the bobbins to be wound off; D, driving shaft with ratchet wheels opposite to each pendulum, so that when a thread breaks, the pendulum to which it is attached falls into the ratchet wheel, and thus stops it.

982



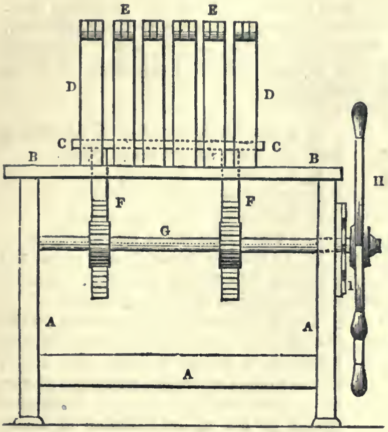
The drying of wet spun yarns should always, when possible, be done in the open air by spreading the hanks upon horizontal poles through them, with another similar pole resting inside upon their lower extremities, in order to keep them straight. If artificial heat is employed, that from steam or hot water is preferable, and it should never exceed 90° Fahr., as otherwise the yarn is apt to become harsh.

Making up.—By this operation is first produced upon the yarns a certain softness and suppleness, and then the hanks are folded and tied up in conveniently-sized packages.

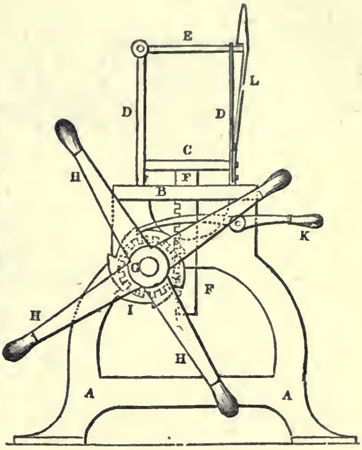
In order to give the yarns that soft and mellow feel so agreeable and characteristic of flax yarns, the hanks when brought from the drying are what is called slaken down and pin-worked. This is done by separating a few at a time, and passing them on to a strong arm of wood fixed to a wall or pillar, when, with a heavy baton put through them, the workman proceeds to stretch the hanks with a sudden check or jerk, which operation he repeats in two or three places so as to thoroughly straighten and shake them loose; he then, using the same baton as a lever, twists them lightly backwards and forwards till the desired degree of suppleness is obtained. A brush is sometimes used to aid the straightening and separating, as well as to increase the gloss on the yarn. The hank or hanks will then be found to have assumed a flat shape, as on the reel, which facilitates their folding with a dexterous twist by their middle, when they are laid in square piles upon a table with their twisted folds one upon another. They are maintained in the perpendicular by a few supports fixed in the table. Sometimes these packages, which, according to the sizes of the yarn, consist of from quarter of a bundle to five or six bundles, are bound together by some of their own hanks, but sometimes by cords in three or four places of their length. It is, however, better to employ a bundling press than an ordinary table, as the yarn can then be made up more solidly, thus both improving its appearance, and causing it to occupy less space for packing and stowage. The bundling presses are made upon the same principle, but on a smaller scale, than those used for making up the small packets in which sewing threads are generally presented for sale, and are upon the following construction (*figs.* 983, 984):—

Fig. 983, front view; *fig.* 984, profile. A A A, frame; B, table or flat top of frame; C, rising table; D D, iron uprights fixed to B; E E, bars hinged at one end to uprights D D, to shut across the press, and be caught and latched down by the spring catch L, fixed to the upright D along one side of the press; F F, racks for lifting the table C by the pinions on shaft G; H, crossed levers for turning the shaft G; I, ratchet wheel engaging the detent K, and thus retaining the shaft G in any required position, and thus of course maintaining the pressure of table C against the top cross-bars E.

983



984



Weaving is the operation by which the yarns are combined into textile fabrics, such as canvas, linens, lawns, drills, damasks, &c., and a great variety of other denominations of articles for use and ornament.

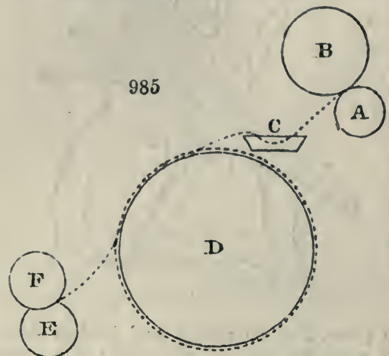
Hitherto the weaving of linens has been carried on by the ancient and well-known hand process, so ancient and so well known as to place the operative practising it among the worst paid of any other art. Now, however, there are several extensive and thriving establishments where machinery has taken the place of much squalid misery, and at much cheaper rates produce to consumers superior articles, and still afford good payment to the operative. The improvements in power-weaving which have led to this result are not founded upon one or even a few successful inventions or contrivances, but are the combination of a great many that have occupied much time to mature. Many difficulties had to be overcome in the weaving of flax, that did not exist in that of other materials; and for a considerable period the expense of linens rendered their consumption so limited, as to make their production by power-weaving but a very secondary object. The greatest obstacle of a practical nature to the introduction of the power-loom weaving of linens was, the stubbornness or want of elasticity in the yarn, which caused frequent breakages and much confusion. In woollen or cotton goods, if a thread or yarn should chance to be a little tighter than the others in the warp, its elasticity will allow it to come up to the general bearing of the others when the weft is struck up by the reed; but in linen, from the want of that elasticity, a thread so situated would break, and by crossing some others, cause those also, if not to be broken direct by that circumstance, at all events to produce an obstruction to the shuttle that would lead to further mischief. Hence it was most material in linens to have such a method of winding the yarns upon the warp beams that should insure the greatest regularity; but strange to say, that point, though now attained, was at first wholly lost sight of. That circumstance, as well as the great mistake of attempting to use the same looms as are found suitable for cotton, produced so much discouragement in the earlier attempts as to give rise to a high degree of prejudice against the possibility of success in this undertaking, which may account for the backwardness in which this branch of the flax manufacture was found till quite recently.

The roving machine, called by the ingenious inventor, Mr. W. K. Westley, of Leeds, the *Sliver Roving Frame*, seems to be a philosophical induction happily drawn from the nature of the material itself, and accommodated to its peculiar constitution. It is remarkable for the simplicity of its construction, and, at the same time, for its comprehensiveness: requiring no nicety of adjustment in its application, and no tedious apprenticeship to be able to work it.

It is known that the mucilaginous matter of the plant may be softened by water, and hardened again by heat; of this fact advantage is taken, in order to produce a roving wholly without twist; that is, in the form of a ribbon or sliver, in which the fibres are held together by the glutinous matter which may be natural to them; or which may, for that purpose, be artificially applied. The sliver roving, as long as it remains dry, possesses all requisite tenacity, and freely unwinds from the bobbin, but on becoming again wetted in the spinning frame, it readily admits, with a slight force, of being drawn into yarn, preserving the fibres quite parallel.

The diagram, *fig.* 985, shows this in explanation:

985



A, is the drawing roller of the roving frame in front of the usual comb.

B, the pressing drawing roller.

C, a shallow trough of water.

D, a cylinder heated by steam.

E, a plain iron roller for winding.

F, a bobbin lying loose upon the winding roller, and revolving upon it by the friction of its own weight.

The roving, or sliver, as shown by the dotted line, after leaving the drawing rollers A, B, passes through the water, in the trough C, which softens the gluten of the fibres: and then it is carried round by the steam cylinder D, which dries it, and delivers it hard and tenacious to the bobbin F, on which it is wound by the action of the roller E.

This is the whole of the mechanism required in producing the sliver roving. All the complex arrangements of the common cone roving are superseded, and the machine at once becomes incomparably more durable, and easier to manage; requiring only half the motive power, and occupying only half the room. A frame of 48 bobbins is only 6 feet long, and affords rovings sufficient to supply 1,200 spinning spindles.

This machine, though here described, is but little used, being capable of but very limited application.

Combe of Belfast has lately introduced an improvement in the roving frame. It consists in the application of a peculiar expanding pulley, instead of the cones or discs and runners which have hitherto been always used for the purpose of regulating the 'take-up' of the bobbins. It is evident that a strop of 2 or 3 inches broad, working over the cones, placed with the small end of one opposite the large end of the other is an imperfect and rude mechanical contrivance, and that there must be a constant straining and stretching of the belts. There is the same imperfection attending the discs and runners. The expanding pulley is free from these objections, as its acting surface is a line; and therefore it works with the greatest accuracy, while it is also a great simplification of the machine generally. In rovings for flax and tow it is generally driven directly from the front roller, by which means a large number of wheels and shafts are avoided (*fig.* 986).

The following sketch shows the arrangement of the machinery in the most important rooms in a modern flax mill of 7,000 to 8,000 spindles, capable of producing, weekly, about 1,900 bundles of line yarn, No. 25's to 120's; and about 700 bundles of tow yarn, No. 10's to 40's.

There are three systems of long-line machinery for No. 25's to 70's; two systems of cut-line machinery for No. 10's to 120's; and three systems of tow machinery for No. 10's to 40's.

The building is 56 feet wide and 162 feet long; which is a very suitable and convenient size, and which admits of the most economical arrangement of the machinery. The following is a description of the machines shown in the preparing room (*fig.* 987):—

A A, two of Baxter's patent sheet hackling machines for long tow.

B, a flax-cutting machine.

C, one of P. Fairbairn and Co.'s patent double line of holder hackling machines for cut line.

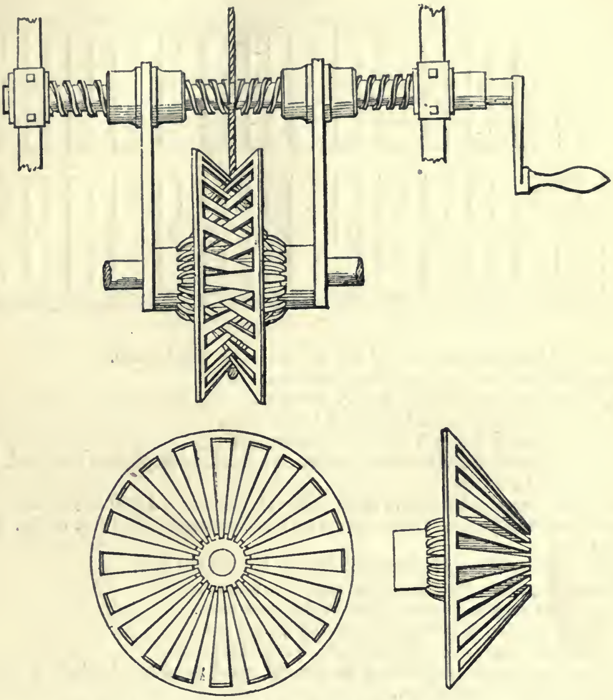
D D, are two breaker cards, 4 feet diameter × 6 feet wide.

E, lap machine.

F F F, are three finisher cards, 4 feet diameter × 6 feet wide, with P. Fairbairn and Co.'s patent rotary gill drawing heads attached.

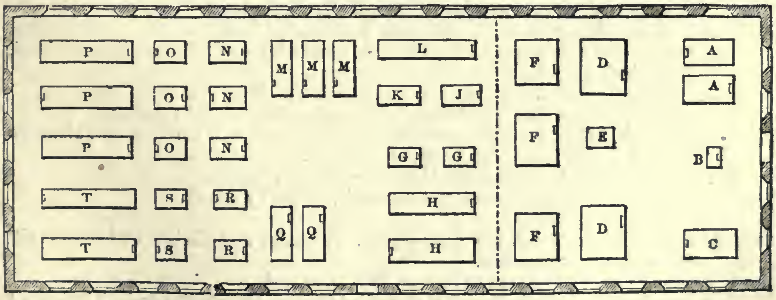
G G, are two patent rotary gill drawing frames for long tow, 12 slivers each.
H H, two ditto regulating roving frames, 48 spindles each, for long tow.

986



J, is a screw gill second drawing frame of 3 heads for cut-line tow.
K, is a screw gill third drawing frame of 3 heads for cut-line tow.
L, a screw gill regulating roving frame of 72 spindles for cut-line tow.
M M M, are three long-line first drawing frames or spreaders of 4 bosses each.

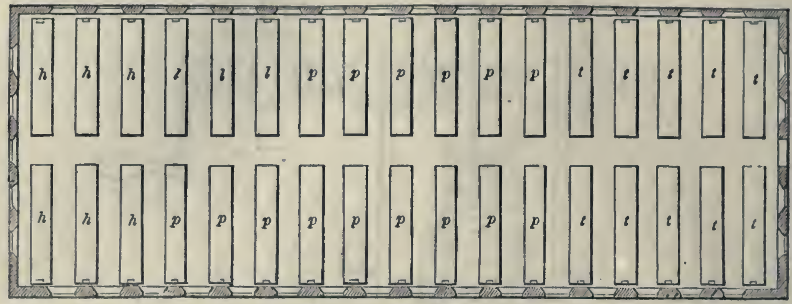
987



N N N, are three long-line second drawing frames of 2 heads each.
O O O, are three long-line third drawing frames of 2 heads each.
P P P, three long-line regulating roving frames, 60 spindles each.
Q Q, are two cut-line spreaders of 4 bosses each.
R R, two cut-line second drawing frames, 2 heads each.
S S, two cut-line third drawing frames, 2 heads each.
T T, two cut-line regulating roving frames, 72 spindles each.

The spinning room (*fig.* 988) contains 34 spinning frames of 184 to 244 spindles each, apportioned to the several systems as described below.

988



I. System of long-line machinery for spinning No. 25's to 40's.
1 Baxter's patent sheet hackling machine, 6 tools.
1 spreader or first drawing frame, 4 bosses.
1 second drawing frame, 2 heads, 4 bosses each.
1 third drawing frame, 2 heads, 6 bosses each.
1 patent disc regulating roving frames, 60 spindles, 10 spindles per head, 8 inches × 4 inches bobbin.
5 spinning frames, $2\frac{3}{4}$ inches pitch, 200 spindles each, 1,000 spindles.
The production of this system is about 66 bundles, or say, 420 lbs. of No. 30's yarn per day.

II. Two systems of long-line machinery for No. 40's to 60's.
1 Baxter's patent sheet hackling machine, 8 tools.
2 spreaders or first drawing frames, 4 bosses each.
2 second drawing frames, 2 heads of 6 bosses each.
2 third drawing frames, 2 heads of 8 bosses each.
2 patent disc regulating roving frames, 60 spindles each, 12 spindles per head, 6 inches × $3\frac{1}{2}$ inches bobbin.
10 spinning frames, 220 spindles each, $2\frac{1}{2}$ inches pitch, 2,200 spindles. Production about 130 bundles, or 472 lbs. of No. 55's yarn per day.

III. Two systems of three cut-line machinery for No. 40's to 120's (one for 40's to 70's, and one for 70's to 120's).
1 flax cutting machine.
1 P. Fairbairn and Co.'s patent double line of holder hackling machine.
2 spreaders or first drawing frames, 4 bosses each.
2 second drawing frames, 2 heads each, 6 slivers per head.
2 third drawing frames, 2 heads each, 8 slivers per head.
2 patent disc regulating roving frames, 72 spindles each, 12 spindles per head, 6 × $3\frac{1}{2}$ inches bobbin.
5 spinning frames, 220 spindles each, $2\frac{1}{2}$ inches pitch = 1,100 spindles.
5 spinning frames, 244 spindles each, $2\frac{1}{4}$ inches pitch = 1,220 spindles.
Production about 65 bundles or 236 lbs. of No. 53's yarn per day, and about 50 bundles or 105 lbs. of No. 95's yarn per day.

IV. Two systems of long-tow machinery for No. 10's to 25's.
1 breaker card, 4 feet diameter, 6 feet wide, doffed by rollers.
1 lap machine.
2 finisher cards, 4 feet × 6 feet, with P. Fairbairn and Co.'s patent rotary gill drawing frames attached.
2 patent rotary gill drawing frames, 12 slivers each.
2 patent rotary gill disc regulating roving frames, 48 spindles each, 8 inches × 4 inches bobbin.
3 spinning frames, 184 spindles each, 4 inches pitch for No. 10's to 18's = 552 spindles.
3 spinning frames, 200 spindles each, $2\frac{3}{4}$ inches pitch for No. 16's to 25's = 600 spindles.
Production about 39 bundles, or 488 lbs. No. 16's per day, and about 39 bundles or 312 lbs., No. 25's per day.

V. One system of cut tow machinery for No. 25's to 40's.
1 breaker card, 4 feet diameter, 6 feet wide, doffed by combs.
1 finisher card, with P. Fairbairn and Co.'s patent rotary gill drawing frame attached.
1 screw gill second drawing frame, 3 heads each, 4 bosses per head.
1 screw gill third drawing frame, 3 heads each, 6 bosses per head.
1 screw gill patent disc regulating roving frame, 72 spindles, 12 spindles per head, 6 × 3½ inches bobbins.
3 spinning frames of 220 spindles each, 2½ inches pitch = 660 spindles.
Production about 36 bundles, or 240 lbs. of No. 30's per day.

The reeling is generally carried on in the attic above the spinning room, and the number of reels required is about the same as the number of spinning frames.

Summary view.

There are 3,200	spindles	long line,	producing	196	bundles, or,	890	lbs. of yarn per day.
1,152	„	long tow,	„	78	„	800	„
2,320	„	3 cut line,	„	115	„	340	„
660	„	cut tow,	„	36	„	240	„
7,332	spindles			425	bundles	2,270	lbs. of yarn per day.

A more effective system of economy, as well in the finish of raw flax as in the make of yarn, has been satisfactorily carried on for years past.

The old mode of hand-scutching, as was usual in farming circles in earlier times, had many drawbacks. It was not only very costly, but exceedingly wasteful. No matter how well skilled may have been the operators, or how careful they were of the flax straw, serious damage was often done to the fibre in course of the scutching process; the actual weight of material produced having rarely exceeded twenty per cent. of the original produce.

Nearly two hundred years ago the native Irish, as well as the various settlers from England and Scotland who had become nationalised in every peculiarity of taste and habit, were still plodding on as their fathers had done in the ancient track. Lands were only partially prepared for flax culture; and, although a few of the more forward growers retained the traditional desire for improvement handed down from the days of Lord Strafford, the general rule was to take little more pains in the management of the flax crop than was then usual in relation to corn or root culture. About that time the cruelty of Louis XIV. was thinning France of some thousands of its Protestant people. Persecution waved the flag of intolerance, Tyranny held its carnival, and whole districts were depopulated. Many of the fugitives fled to Ireland, and the greater number of those French exiles had been connected with manufacturing industry. Dublin, Waterford, Portarlington, and Limerick welcomed numbers of these people, and in the north, Lisburn and Lurgan formed the respective resting-places of others. After the battle of the Boyne large accessions were made to the ranks of the Huguenots, and King William, having taken great interest in the well-being of the settlers, induced Louis Crommelin, a gentleman of immense experience in the linen manufacture, to leave his asylum in Amsterdam and come over to Lisburn, where he set him at the head of the people. A number of Hollanders had also settled there, and those men, being well skilled in the art of flax-growing, were placed in farms which the lord of the soil had given at low rents, and which lands were set apart for the special culture of flax. With the native population of that wide district of Ulster, the Dutchmen and Huguenots formed amicable brotherhood. Difference of creed and of country was never permitted to create social warfare, and the result was that the improvements in the mode of cultivating the flax grounds, as suggested by the foreigners, were readily adopted by the Irish, many of whom, in the course of a few years, showed by their skill and forethought how much they had profited by the lessons of their teachers. M. Crommelin, as director of the linen manufacture, watched with intense interest every phase of progress, and with the means placed in his hands for that purpose rewarded to the utmost of his power the leaders of his industrial army.

The law enacted in 1701 for the encouragement of the Irish linen trade not having been carried into effect, a new Act was passed by Queen Anne in 1711, and a number of nobles and other gentry were appointed to form a Board, the head-quarters of which was in Dublin. This body immediately set to work, and in the first instance commenced operations by directing special attention to the growth of a quality of flax, finer and more silky in texture than any that had ever before been raised in Ireland. Better machinery for scutching purposes had been introduced by M. Crommelin; his

Dutch assistants and the French women having been offered large premiums for spinning, great stimulus was given to the culture of fine flax. In 1718, M. Crommelin, with the assistance of James Turner, a Lurgan carpenter, succeeded in effecting considerable improvements in the mechanism of the wheel then used by spinsters. This machine, we need scarcely state, was that which succeeded the ancient distaff and spindle. The leader of the Huguenot colony had previously purchased some hundreds of spinning wheels in France, and when these came to hand he had them distributed among the women and girls most celebrated for ability in producing fine yarn. But in the French wheels he found it necessary to make certain changes in order to adapt them more especially to the wants as to the peculiar ideas of the spinners. On the improved wheel, however, the native Irish as well as the French settlers spun yarns of a degree of fineness far exceeding anything ever before seen in Ulster.

We have no authentic data on which to found a correct opinion of the area under cultivation in Ireland during M. Crommelin's directorship. Mr. Dobbs, who wrote in 1728, says there were then grown in the different provinces 30,000 Plantation, say about 47,000 English acres. Towards the close of the century the breadth had been largely extended, and the imports of foreign flax, which did not exceed 50,000 cwts. in 1700, had increased to 260,000 cwts. in 1799.

A new era was then setting in on the flax manufacture. The Messrs. Marshall of Leeds had successfully established the enterprise of spinning that fibre by mechanical power, and from that time rapid improvements were made in the finish of material for the spindles. The preparing process known as hackling was then in a comparatively backward state; but, as the new system of producing yarns extended to Scotland and Ireland, the inventive genius of the different sections of the British Isles was called into play, and before the first half of the nineteenth century had gone by every single department of the trade showed its evidence of progress. Among the leading makers of hackling machines we have the Messrs. Lowry of Manchester. To Mr. George Lowry the trade is indebted for the invention of that great improvement, the vertical wheel hackling machine. Then we have Messrs. Combe and Barbour, S. Cotton and Co., and Mr. George Horner of Belfast. Each of these makers has contributed some special improvement in easy working and simple mechanism, and several of them show a high rate of yield of line per cent. compared with other machines.

Flax-spinning by steam-power had been preceded by the same system, but in which the works were driven by water; and these works, generally on a small scale, were attempted in various parts of the isles of Britain before the end of last century. To the Messrs. Marshall of Leeds, the Messrs. Baxter of Dundee, the Messrs. Murland of Castlewellan, and Messrs. Mulholland of Belfast, the trade is indebted for the first effective introduction of the steam-driven flax-spindle. For a long period, however, the enterprise of mill-spinning in the higher numbers of yarn was confined to Leeds, and in the coarse numbers to Dundee. In 1828 the mill at Castlewellan, Co. Down, was started by the brothers Murland, and in 1830 the first bundle of flax yarn produced in Belfast was turned off the spindles of the brothers Mulholland. In 1869 there were in England and Wales 437,623 spindles; in Scotland, 256,228 spindles; and in Ireland, 894,273 spindles. Forty-four years ago—1830—the imports of foreign flax into the United Kingdom amounted to 944,500 cwts.; and in 1873 2,194,473 cwts. were landed. In the meantime, Ireland had become the chief source of home supply, Great Britain having gradually contracted her breadth of flax-lands until the total area for 1873 was narrowed to 14,683 acres, the vast proportion of which was grown for seed rather than for fibre. In course of last year there were 122,432 acres of land under flax in Ireland, producing an aggregate of 406,950 cwts. of marketable material. From various causes, but more especially unfavourable seasons and neglect on the part of some growers of preparing the soil with due care, as well as want of care in selecting the seed, the yield of flax-lands in Ulster fell off considerably. In the famous season of 1853 the average produce was 41 stones to the acre. That rate of yield fell off until in 1869 only 19½ stones were raised, and in the disastrous season of 1871 the average had declined to about 15 stones to the acre. This caused the utmost depression in farming circles, and the very unguarded assertion made by a member of the linen trade that Ireland was 'flaxed out' began to be looked upon as a practical truth. But in the season of 1873 flax crops in most parts of the country were abundant in yield, and superior in quality. Many of the more skilful flax growers in Down raised 80 stones to the Plantation acre, and in other counties equally large produce was reported.

We have thus given full details of the flax and yarn trades down to 1874. Under the head of LINEN we shall note the latest improvements in the make of goods and the mechanism of steam-looms.

Our trade in flax will be seen by the following tables;—

IMPORTS.

Places	1871		1872	
	cwts.	£	cwts.	£
Dressed:				
From Russia	6,316	15,486	2,875	6,235
„ Germany	4,467	8,835	1,629	5,317
„ Holland	18,792	46,341	25,450	86,351
„ Belgium	85,945	206,384	140,738	548,784
„ Australia	14,192	18,838	3,467	5,280
„ other countries	874	2,593	2,630	7,727
Total	130,586	298,477	176,789	659,704
Rough or Undressed:				
From Russia	1,420,633	3,215,611	1,115,804	2,690,610
„ Germany	222,908	472,673	172,436	392,375
„ Holland	117,054	340,233	88,473	264,682
„ Belgium	173,663	562,591	104,082	342,696
„ France	11,156	24,453	11,680	29,299
„ Egypt	22,257	51,297	7,767	18,326
„ Australia	37,152	46,336	7,468	10,534
„ other countries	7,073	18,760	11,145	23,757
Total	2,011,896	4,731,954	1,518,855	3,772,279
Tow or Codilla of Flax:				
From Russia	296,324	523,583	209,349	403,044
„ Germany	16,561	33,160	19,060	36,536
„ Holland	40,043	60,278	19,988	35,940
„ Belgium	78,500	109,680	72,627	96,782
„ France	5,468	8,095		
„ Australia	6,734	8,149		
„ other countries	954	2,041	4,302	6,244
Total	444,584	744,986	325,326	578,546

EXPORTS.

Countries to which exported	1871		1872	
	cwts.	£	cwts.	£
Dressed and Undressed:				
To Belgium	2,528	7,374	5,406	14,088
„ France	6,335	14,232		
„ Portugal, Azores and Madeira	1,019	3,095		
„ Spain and the Canaries	568	1,566		
„ United States: Atlantic	13,043	61,256	23,029	137,541
„ British India, Bengal and Burmah	587	3,362		
„ other countries	1,123	3,990	3,416	9,387
Total	25,203	94,875	31,851	161,016

FLEXIBLE SANDSTONE. A micaceous or talcose sandstone, possessing considerable elasticity, so as to bend to and fro with gentle pressure. It is found in the diamond-bearing districts of Brazil, in the United States, and near Delhi. See Articulite; Itacolumite.

FLEXIBLE SILVER ORE. A name for Stephanite. See Silver.

FLINT. (*Pierre à fusil*, Fr.; *Feuerstein*, Ger.) A massive impure variety of silica allied to chalcedony. It forms a connecting link between quartz and opal, since it consists, according to Fuchs, of an intimate mixture in varying proportions of the two forms of silica—the crystalline or insoluble, and the non-crystalline or soluble; the latter being readily separated by solution of caustic potash. The colours of flint, which are usually various shades of grey, brown, or black, are entirely removed by calcination, the flint thus becoming white and opaque: whence the colour is commonly referred to the presence of organic matter, derived probably from the associated fossils. Although sufficiently hard to strike copious sparks with steel, flint is very easily broken, splitting with a flat conchoidal fracture, usually dull on the surface. It is feebly translucent, and has so fine and homogeneous a texture as to bear polishing, but possesses little lustre.

Flint is found chiefly in the form of nodular masses, of very irregular and frequently fantastic shapes; and of various sizes up to a foot in diameter. These masses occur embedded in calcareous, never in siliceous strata; and are especially abundant in the upper beds of the chalk, which have hence been termed 'Chalk-with-flints.' Although occasionally arranged in layers running across the plane of bedding, as in the 'potstones' of Norfolk, yet as a rule the nodules have a notable tendency to dispose themselves in lines parallel to the direction of the stratification; occasionally they occur so close together as to unite, and thus form continuous horizontal bands or flat tabular masses.

Externally the flint nodules are usually coated with a white opaque crust, apparently siliceous; whilst internally they are often hollow, the cavities sometimes containing pulverulent silica, and sometimes being lined with chalcedony, or with crystals of iron pyrites or other minerals; whilst almost universally they enclose the remains of some marine organism, commonly a sponge. Indeed, the study of the microscopic structure of flint has led Dr. Bowerbank to the conclusion that all flints, both nodular and tabular, contain the remains of spongeous tissue, which appears to have acted as a nucleus or centre of attraction around which the silica was deposited from solution.

Flints when first quarried are exceedingly brittle, and are commonly humid when broken, but by exposure to the air they gradually acquire toughness; hence, when used as road-material, they should never be laid down on immediate removal from the quarry.

Flints calcined and ground to a powder enter into the composition of all kinds of fine pottery, and were formerly employed in the manufacture of the finer varieties of glass, hence termed 'flint glass.'

Flints form excellent building materials; because they give a firm hold to the mortar by their irregularly rough surfaces, and resist, by their nature, every vicissitude of weather. The counties of Kent, Essex, Suffolk, and Norfolk contain many substantial specimens of flint-masonry.

Formerly an important application of this siliceous substance was in the formation of gun-flints, for which purpose it was cut in a peculiar manner. The following characters distinguish good flint nodules from such as are less fit for being manufactured: the best are somewhat convex, approaching to globular; those which are very irregular, knobbed, branched, and tuberose, are generally full of imperfections. Good nodules seldom weigh more than twenty pounds; when less than two they are not worth the working. They should have a greasy lustre, and be particularly smooth and fine grained. The colour may vary from honey-yellow to blackish brown, but it should be uniform throughout the lump, and the translucency should be so great as to render letters legible through a slice about $\frac{1}{50}$th of an inch thick laid down upon the paper. The fracture should be perfectly smooth, uniform, and slightly conchoidal; the last property being essential to the cutting-out of perfect gun-flints. Although flint locks are now but rarely employed, the process of cutting the flints to shape possesses much interest.

Four tools are employed by the gun-flint maker.

First, a hammer or mace of iron with a square head, from 1 to 2 pounds weight, with a handle 7 or 8 inches long. The tool is not made of steel, because so hard a metal would render the strokes too harsh, or 'dry,' as the workmen say, and would shatter the nodules irregularly, instead of cutting them with a clean conchoidal fracture.

Second, a hammer with two points, made of good steel well hardened, and weighing from 10 to 16 ounces, with a handle 7 inches long passing through it in such a way that the points of the hammer are nearer the hand of the workman than the centre of gravity of the mass.

Third, the disc hammer or roller, a small solid wheel or flat segment of a cylinder, parallel to its base, only 2½ inches in diameter, and not more than 12 ounces in weight. It is formed of steel not hardened, and is fixed upon a handle 6 inches long, which passes through a square hole in its centre.

Fourth, a chisel tapering and bevelled at both extremities, 7 or 8 inches long, and 2 inches broad, made of steel not hardened; this is set on a block of wood, which serves also for a bench to the workmen. To these four tools a file must be added, for the purpose of restoring the edge of the chisel from time to time.

After selecting a good mass of flint, the workman executes the four following operations on it:—

1. *He breaks the block.* Being seated upon the ground, he places the nodule of flint on his left thigh, and applies slight strokes with the square hammer to divide it into smaller pieces of about a pound and a half each, with broad surfaces and almost even fractures. The blows should be moderate, lest the lump crack and split in the wrong direction.

2. *He cleaves or chips the flint.* The principal point is to split the flint well, or to chip off scales of the length, thickness, and shape adapted for the subsequent formation of gun-flints. Here the greatest dexterity and steadiness of manipulation are necessary; but the fracture of the flint is not restricted to any particular direction, for it may be chipped in all parts with equal facility.

The workman holds the lump of flint in his left hand, and strikes with the pointed hammer upon the edges of the great planes produced by the first breaking, whereby the white coating of the flint is removed in small scales, and the interior body of the flint is laid bare; after which he continues to detach similar scaly portions from the clean mass.

These scaly portions are nearly 1½ in. broad, 2½ in. long, and ⅛th of an inch thick in the middle. They are slightly convex below, and consequently leave in the part of the lump from which they were separated a space slightly concave, longitudinally bordered by two somewhat projecting straight lines or ridges. The ridges produced by the separation of the first scales must naturally constitute nearly the middle of the subsequent pieces; and such scales alone as have their ridges thus placed in the middle are fit to be made into gun-flints. In this manner the workman continues to split or chip the mass of flint in various directions, until the defects usually found in the interior render it impossible to make the requisite fractures, or until the piece is too much reduced to sustain the smart blows by which the flint is divided.

3. *He fashions the gun-flints.* Five different parts may be distinguished in a gun-flint: 1. The sloping facet or bevel part, which is impelled against the hammer of the lock. Its thickness should be from two to three twelfths of an inch; for if it were thicker it would be too liable to break; and if more obtuse, the scintillations would be less vivid. 2. The sides or lateral edges, which are always somewhat irregular. 3. The back or thick part opposite the tapering edge. 4. The under surface, which is smooth and rather concave. And, 5. The upper face which has a small square plane between the tapering edge and the back for entering into the upper claw of the lock.

In order to fashion the flint, those scales are selected which have at least one of the above-mentioned longitudinal ridges; the workman fixes on one of the two tapering borders to form the striking edge, after which the two sides of the stone that are to form the lateral edges, as well as the part that is to form the back, are successively placed on the edge of the chisel in such a manner that the convex surface of the flint, which rests on the forefinger of the left hand, is turned towards that tool. Then with the disc hammer he applies some slight strokes to the flint just opposite the edge of the chisel underneath, and thereby breaks it exactly along the edge of the chisel.

4. The finishing operation is the *trimming*, or the process of giving the flint a smooth and equal edge; this is done by turning up the stone and placing the edge of its tapering end upon the chisel, in which position it is completed by five or six slight strokes of the disc hammer. The whole operation of making a gun-flint, to describe which so many words are here used, is performed in less than one minute. A good workman is able to manufacture 1,000 good chips or scales in a day (if the flint balls be of good quality); or 500 gun-flints. Hence, in the space of three days, he can easily cleave and finish 1,000 gun-flints without any assistance.

The manufacture of gun-flints is still carried on to a limited extent at Brandon, in Suffolk, where the trade has been established for several centuries. In 1870 there were three masters and thirty workmen engaged in flint-working at Brandon.

An excellent paper on flint-knapping by Mr. J. Wyatt of Bedford, is published in Stevens's 'Flint Chips' (1870). A description of the processes still in use is also given in Evans's 'Ancient Stone Implements, Weapons, and Ornaments of Great Britain' (1872).

The facility with which flint, in spite of its hardness, may, with sufficient practice, be fractured in almost any given direction, yielding fragments with sharp-cutting edges, has led to its employment as one of the commonest materials of those rude stone implements which have in all ages been fashioned by savage tribes ignorant of the use of metal. The antiquary has long been familiar with the occurrence of such implements in tumuli or ancient burial-mounds; and of late years they have also been found in the Pfahlbauten or pile-dwellings in the Swiss lakes; in the Kjökkenmöddings or Danish shell-mounds; in bone-caverns, &c. The worked flints found in these situations are referred, in most cases, to an early pre-historic period known to archæologists as the 'stone-age;' a period apparently anterior to the knowledge of any metal, excepting gold. The so-called stone-age, which indicates a phase of civilisation rather than an epoch of definite date, has been divided by Sir John Lubbock into a *newer* and an *older* period, termed respectively the *neolithic* and the *palæolithic* age. The neolithic implements, although commonly of flint, are by no means exclusively so; blood-stone, jade, porphyry, and indeed any stone sufficiently hard, having been also employed. In form they present considerable variety, comprising axes or celts, knives, scrapers, sling-stones, spear-heads, arrow-heads, and the like; many of them, especially the celts, being wrought into highly-finished forms, and even ground and polished to a cutting-edge.

Of a far higher antiquity and of a much ruder type than any of these polished relics of the newer stone-period are those primitive flint implements of palæolithic age which within the last few years have been found in deposits of drift-gravels, frequently at considerable depths and, in many cases, associated with the remains of extinct mammalia—discoveries which have excited an intense interest from their bearing upon the much-vexed question of the antiquity of the human race. To these early flint implements attention was first directed by the late M. Boucher de Perthes, a French antiquary, who had from time to time discovered them in the gravel-pits in the valley of the Somme, chiefly in the neighbourhood of Amiens and of Abbeville. Although the first discovery was made as early as 1841, the subject attracted but little notice until the year 1859, when the locality was visited, and the instruments and their mode of occurrence described, by Messrs. Prestwich and Evans. The deposits in which these worked flints are found consist of stratified sands and gravels, often of considerable thickness, resting upon an eroded surface of chalk, and referred by geologists to the pleistocene or post-pliocene period; a time when the climate of Northern Europe was considerably colder than at present, and when these latitudes were inhabited by the mammoth, the woolly rhinoceros, the cave-bear, and other mammalia now extinct. The flint implements have been found chiefly in the lower beds of these drift deposits, immediately overlying the chalk, and frequently beneath a thickness of more than 20 feet of undisturbed sand, brick-earth, &c., containing shells in some places marine, in others land and freshwater, together with the bones and teeth of certain extinct mammalia, but never with the remains of man. It should be remarked that these drift-implements, unlike those of the more recent stone-age, are formed exclusively of flint, and that they never exhibit the slightest trace of having been either ground or polished. The form of these implements is, moreover, quite characteristic. But, although of an extremely rude type, they bear quite sufficient evidence of design to verify them as the results of human workmanship; whilst, on the other hand, their extreme antiquity is attested not only by the position in which they occur, but also by the glossy varnish-like character of their surface, totally unlike that of recently-fractured flint. The possibility of their having been modern forgeries is further precluded by the fact that many of them are coated with a calcareous incrustation, and that they occasionally exhibit on the surface dendritic markings produced by the slow action of the oxides of manganese and iron.

Since these discoveries have been made in the valley of the Somme, flint-hatchets of the drift-type have been recognised in several localities in this country and elsewhere. Among the more productive English localities may be mentioned the valley of the Little Ouse, Thetford, Fareham, Bournemouth, the Reculvers, and the valley of the Thames.

FLINT GLASS. See Glass.

FLINTY SLATE. A very siliceous black schist, often containing 75 per cent. of silica. It is used as a 'touchstone' for testing gold, by a comparison of the colour of the streak made by the metal. See Assay.

FLITTERN BARK. The bark of young oak trees, which is distinguished from *coppice bark* by its superior quality, and also from the bark of old oak trees, known as *timber bark*. Flittern bark is much used by the tanner.

FLOAT-STONE. (*Quartz nectique*, Fr.; *Schwimmstein*, Ger.) A light concretionary or cellular form of silica, sufficiently open in texture to float on water.

FLOCK and **FLOCKS.** The first is finely-powdered wool, used when dyed of various colours to prepare paper hangings.

The second is a name given to the refuse or waste of cotton and wool, and is used for stuffing mattresses.

FLOCK PAPER. Paper prepared for walls by being sized in the first instance, either over the whole surface or over special parts, constituting the pattern only, and then powdering over it flock or powdered wool which had been previously dyed.

FLOOKAN or **FLUKAN.** The name given by the Cornish miners to veins filled wholly with clay. This is usually applied to such veins or lodes as are at right angles, or nearly so, to the true metalliferous lodes.

FLOOR-CLOTH MANUFACTURE has become of late years a very large branch of trade. The cloth is a strong somewhat open canvas, woven of flax with a little hemp, and from 6 to 8 yards wide, being manufactured in appropriate looms, chiefly at Dundee. A piece of this canvas, from 60 to 100 feet in length, is secured tight in an upright open frame of oaken bars, in which position it is brushed over with glue size, and rubbed smooth with pumice-stones; it next receives the foundation-coats of paint, two or three in number, first on the back side, and then on the front. The foundation-paint, made with linseed oil and ochre, or any cheap colouring matter, is too thick to be applied by the brush, and is therefore spread evenly by a long narrow trowel, held in the right hand, from a patch of it laid on just before with a brush in the left hand of the workman. Each foundation-coat of the front surface is smoothed by pumice-stone whenever it is hard enough to bear the operation. When both sides are dry, the painted cloth is detached from the frame, coiled round a roller, and in this state transferred to the printing room, where it is spread flat on a table, and variously figured and coloured devices are given to it by wooden blocks, exactly as in the block printing of calicoes or papers. The blocks of the floor-cloth manufacture are formed of two layers of white deal and one of pear-tree timber, placed with their grain crossing one another alternately. There is a block for each colour in the pattern, and in each block those parts are cut away that correspond to the impressions given by the others; a practice now well understood in the printing of two or more colours by the press. The faces of the blocks are so indented with fine lines, that they do not take up the paint in a heavy daub from the flat cushion on which it is spread with a brush, but in minute dots, so as to lay on the paint (somewhat thicker than that of the house painter) in a congeries of little dots or teeth, with minute interstices between. Applied in this way, the various pigments lie more evenly, are more sightly, and dry much sooner than if the prominent part of the block which takes up the colour were a smooth surface. The best kinds of floor-cloth require from two to three months for their production.

From the use of the sulphate of baryta with the white lead, sometimes to the extent of 75 per cent. of the former, not merely in the foundation-paint, but in the subsequent colours with which the canvas is painted, there is a very general complaint that the floor-cloths for halls, &c., where they are necessarily exposed to washing, very soon lose their colours and become bare, the barytes washing out, and, of course, removing at the same time the lead and other colours.

The same principle in colouring floor-cloth is now applied to *paper*, and is carried on to a very large extent at Egham under the patent of Mr. Walton. The oil is there first dried or oxidised, then dissolved in naphtha with the colouring; as the naphtha dries, the paper is ready for use. See OXIDISED OIL; WHITE LEAD.

FLORAN. A mining term; tin ore scarcely perceptible in the stone; tin ore stamped very small.—*Pryce.*

FLOS FERRI. Coral-like forms of aragonite, or carbonate of lime, occurring especially in the iron mines of the Eisenerz in Styria.

FLOSS, of the puddling furnace, is the fluid glass floating upon the iron produced by the vitrification of the oxides and earths which are present. See IRON.

FLOSS-SILK (*Filoselle, Bourre de soie, Fleuret,* Fr.) is the name given to the portions of ravelled silk broken off in the filature of the cocoons, which is carded like cotton or wool, and spun into a soft coarse yarn or thread, for making bands, shawls, socks, and other common silk fabrics. The floss or fleuret, as first obtained, must be steeped in water, and then subjected to pressure, in order to extract the gummy matter which renders it too harsh and short for the spinning wheel. After being dried it is made still more pliant by working a little oil into it with the hands. It is now ready to be submitted to the carding engine, and it is spun upon the flax wheel.

The female peasants of Lombardy generally wear clothes of homespun floss silk. Of late years, by improved processes, fine fabrics of this material have been produced, both in England and France. M. Ajac, of Lyons, manufactures a variety of scarfs and square shawls of *bourre de soie,* closely resembling those of *cachemire.*

FLOTSAM. See JETSAM.

FLOUR. The finely-ground meal of wheat, and of any other corns or *cerealia.* See BREAD.

Since the analysis of grain represents the total chemical constituents of the flour, and the cell in which it is contained, a few analyses from the researches of Way and Ogston are given:—

	WHEAT			BARLEY		
	Hopeton	Red Straw	Old Red Lammas	Chevalier	Unknown	Moldavia
Potassa	30·32	29·75	32·46	27·43	21·14	31·55
Soda	0·07	0·64	4·53	0·05	...	1·06
Lime	2·51	3·27	3·21	2·79	1·65	1·21
Magnesia	12·38	13·75	9·56	8·67	7·26	10·17
Sesquioxide of iron	0·08	0·23	2·06	0·09	2·13	1·02
Sulphuric acid	0·18	0·60	0·32	2·72	1·91	0·27
Silica	3·60	2·14	5·49	23·60	30·68	24·26
Phosphoric acid	49·22	49·58	40·57	26·01	28·53	28·64

The produce of one quarter of wheat weighing 504 lbs. is, according to Mr. Hard of Dartford—

Flour	392 lbs.
Biscuit or fine middlings	10
Toppings or specks	8
Best pollard	15
Fine pollard	18
Bran and coarse pollard	50
Loss	11
	504 lbs.

Vauquelin has given the following as the results of his examination of wheat flour:—

	French	Odessa hard	Odessa soft	Paris Flour	Inferior Flour
Starch	71·49	56·5	62·00	72·8	67·78
Gluten	10·96	14·55	12·00	10·2	9·02
Sugar	4·72	8·48	7·56	4·2	4·80
Gum	3·82	4·90	5·80	2·8	4·60
Bran	...	2·30	1·20	...	...
Water	10·00	12·00	10·00	10·0	12·00

Adulterations of, to detect.—The first method is by specific gravity. If potato flour be added, which is frequently done in France, since a vessel which contains one pound of wheat flour will contain one pound and a half of the fecula, the proportion of this adulteration may be easily estimated. If gypsum or ground bones be mixed with the flour, they will not only increase its density still more, but they will remain after burning away the meal as ashes.

The second method is by ascertaining the quantity of gluten which the suspected sample will afford, as described in the article BREAD. The two following chemical criteria may also be employed:—

1st. Nitric acid has the property of colouring wheat flour of a fine orange yellow, whereas it affects the colour neither of fecula nor starch.

2nd. Muriatic acid colours good wheat flour of a deep violet, but dissolves fecula or starch, and forms with it a light and colourless viscous fluid, decomposable by alkalis.

Sulphate of iron renders an infusion of pure flour somewhat yellow, and imparts a bottle-green to that which is adulterated with bean meal.— (*Lassaigne.*) Nitric acid and ammonia poured successively on good flour shows nothing remarkable; but bean meal strikes a deep red colour.— (*Donny.*)

The amount of ash left by the flour has been proposed by Louyet as a test of its purity. He says, 'Wheat flour yields on the average 0·8 per cent.; rye flour, 1·0; bean and pea meal, 3; linseed meal, 10 per cent. of ash.'

FLOWERS. The name formerly given to those substances which were obtained by sublimation; as the flowers of sulphur, the flowers of Benjamin, &c.

FLOWERS, ARTIFICIAL, *Manufacture of.* The art of representing by flowers, leaves, plants, &c., vegetable nature in her ornamental productions, constitutes the business of the artificial florist. The Italians appear to have been the first people in Europe who excelled in the art of making artificial flowers; but of late years the French have been most ingenious in this branch of industry.

Ribbons folded in different forms and of different colours were originally employed for imitating flowers, by being attached to wire stems. This imitation soon gave way to that by feathers, which are more delicate in texture, and more capable of assuming a variety of flower-like figures. But a great difficulty was encountered in dyeing them with due vivacity. The savages of South America manufacture perfect feather flowers, derived from the brilliant plumage of their birds, which closely resemble the products of vegetation. The blossoms and leaves are admirable, while the colours never fade.

The Italians employ frequently the cocoons of the silkworm for this purpose; these take a brilliant dye, preserve their colour, and possess a transparent velvety appearance, suitable for petals. Of late years, the French have adopted the finest cambric for making petals, and the taffeta of Florence for the leaves. M. de Bernardière employs whalebone in very thin leaves for artificial flowers; and, by bleaching and dyeing them of various hues, he has succeeded in making his imitations of nature very remarkable.

Gutta-percha dissolved in benzole, and freed from all impurities, will, when spread out on a sheet of glass, dry into a beautifully white and delicate film, of great strength, and capable of receiving any colour. This has been employed in Paris in the manufacture of flowers. Vegetable parchment (paper prepared by the action of sulphuric acid) has been employed for the same purpose in this country. See VEGETABLE PARCHMENT.

The colouring matters used in flower-dyeing are the following:—

For red; carmine dissolved in a solution of carbonate of potash.

For blue; indigo dissolved in sulphuric acid, diluted and neutralised in part by Spanish whitening.

For bright yellow; a solution of turmeric in spirit of wine. Cream of tartar brightens all these colours.

For violet; archil, and a blue bath. For lilac; archil.

The aniline colours are now largely used.

Some petals are made of velvet, and are coloured merely by the application of the finger dipped in the dye.

Artificial flowers imported were of the values given in each year:—

	Value		Value		Value
1868	341,176*l.*	1869	365,407*l.*	1870	266,502*l.*

In 1872 we imported from—

	Value
Germany	4,657*l.*
Belgium	18,966
France	387,768
Other countries	149
Total	411,510*l.*

FLUATES. A term formerly applied to the compounds now called *fluorides*, on the supposition that they contained fluoric acid. When, however, the true constitution of this acid, as a hydrogen-compound, was determined, it became evident that the substances called fluates must belong to the class of so-called haloïd salts, and consist therefore of the element fluorine united directly with a metal or radical; whence they are properly termed fluorides. Thus, fluor-spar, formerly known as fluate of lime, is, according to the new nomenclature, a fluoride of calcium; containing—fluorine, 48·7; calcium, 51·3.

It may be remarked that fluorine has a strong tendency to form double salts, many of which occur native. Thus, the minerals called cryolite and chiolite are double fluorides of sodium and aluminium.

FLUE CINDER. The cinder from the reheating furnace. See IRON MANUFACTURE.

FLUELLITE. A rare mineral, containing fluorine and aluminium, found at Stennagwyne in Cornwall.

FLUKES. See ANCHOR.

FLUOR. See FLUOR-SPAR.

FLUORESCENCE, the name given to a peculiar phenomenon rendered evident by many crystals of fluor-spar. If we look through a crystal of fluor-spar it will appear yellow or green as the case may be; now, if we look at it, the light falling upon the surface upon which we look, it will appear beautifully blue or purple. Prof. Stokes, to whom we are indebted for a very exact examination of the whole of the phenomena of this class, refers this effect to an alteration of the refraction of the ray by the first surface upon which it falls. Sir John Herschel first drew attention to this peculiar condition as exhibited in a solution of sulphate of quinine in water slightly acidulated with sulphuric acid. Here we have a perfectly colourless solution when we look through it, which sends back to the eye fine blue rays when we look at the surface on which the solar rays fall. Sir John Herschel referred this to epipolic dispersion, or dispersion from the first surface of the fluid on which the light fell. There are many substances which appear to possess this property of altering the refraction of rays, or are fluorescent. Beyond this brief explanation, we cannot afford space in this dictionary to deal with the subject. We must refer those interested to the *Philosophical Transactions*, in which Prof. Stokes's communications appeared.

FLUORINE. (*Symbol*, F.; *Atomic weight*, 19.) The elementary base of hydrofluoric acid, which has never yet been isolated.

The power of liberating a principle from fluor-spar which would etch glass was known as far back as 1670; Scheele, in 1771, examined hydrofluoric acid, and regarded it as an oxygen compound with an unknown element. Ampère, in 1810, determined that hydrofluoric acid was a compound of hydrogen and fluorine.

Fluorine combines with most of the metals, and with hydrogen, boron, silicon, sulphur, and phosphorus; with chlorine, bromine, iodine, and oxygen, it exhibits no tendency to unite. It has been suggested to employ hydrofluoric acid in the purification of beet-root sugar; the alkalis present in the juice being effectually removed by the acid, while the organic matter remains unaffected.

FLUOR-SPAR. (*Chaux fluatée*, Fr.; *Fluss-Spath*, Ger.) This mineral often exhibits a variety of vivid colours. It crystallises in the cubic (monometric) system, with regular octahedral cleavages; spec. grav. 3·14 to 3·19; hardness = 4·0; scratches calc spar, but is scratched by a steel point; usually phosphorescent with heat; at the blowpipe decrepitates and fuses into an opaque bead; acted on by the acids with disengagement of a vapour which corrodes glass; its solution affords precipitates with the oxalates, but not with ammonia. Its constituents are, fluorine, 48·7; calcium, 51·13 in 100.

Fluor-spar occurs subordinate to metallic veins; as to those of lead, in Derbyshire and Cumberland; of lead and copper, in Cornwall, and in Saxony and Bohemia; but it is found also in masses or veins, either in crystalline rocks, associated with quartz, barytes, &c., as in Auvergne, Forez, Vosges, Norberg in Sweden; Norway; Petersburg; Gourock, in Scotland, &c.; or among limestones, slates, and sandstones, in Derbyshire, Cumberland, Cornwall, and New Jersey. It exists also in the amygdaloids of Scotland, and in the volcanic products of Monte Somma at Vesuvius. The variously-coloured specimens, called Derbyshire spar, are worked upon the turning lathe into vases and other ornamental objects.

A very beautiful variety, which has been much used for ornamental purposes, known from its colour as 'Blue John,' has been obtained from Tray Cliff, near Castleton, Derbyshire. The beautiful colour of the natural fluor has been successfully imitated by exposing some of the common varieties to heat.

Fluor-spar is employed to a considerable extent in the production of hydrofluoric acid and for etching on glass. It is also used by lead smelters as a flux. The beautiful phenomenon of *fluorescence* is so named from the fact that many of the fluor-spars have the power in a high degree of thus affecting the rays of light. See FLUORESCENCE.

FLUVIATILE (*fluvius*, a river), belonging to a river.

FLUX (Eng. and Fr.; *Fluss*, Ger.) signifies any substance capable of promoting the fusion of earths or metallic ores by heat. White flux is the residuum of the deflagration, in a red-hot crucible, of a mixture of two parts of nitre and one of cream of tartar. It is in fact merely a carbonate of potash. Black flux is obtained when equal parts of nitre and tartar are deflagrated. It owes its colour to the carbonaceous matter of the tartaric acid, which remains unconsumed; the quantity of nitre being too small for that purpose. The presence of the charcoal renders this preparation a convenient flux for reducing calcined or oxidised ores to the metallic state. Limestone, fluor-spar, borax, and several earthy or metallic oxides, are employed as fluxes in metallurgy. See METALLURGY.

FLY POWDER. Under this name there is sold on the Continent the black coloured powder obtained by the spontaneous oxidation of metallic arsenic in the air. Various preparations of white arsenic are used for the same purpose in this country. King's yellow is much used; it should be made by boiling together sulphur, lime, and white arsenic, but much that is sold is merely arsenic and sulphur mixed.

Objecting on principle to the familiar use of arsenic and dangerous substances, a preference may be given to a substitute for the above, made by boiling quassia chips into a strong decoction and sweetening with loaf sugar. This seems to have deadly power over the flies, who can scarcely quit the liquid without imbibing a deadly potion, and they are seen to fall from the ceilings and walls of the rooms soon afterwards. Many of these compounds for killing flies are supposed by their odour to attract flies into the rooms.

The inconvenience to manufacturers and others from flies, may be obviated in many cases where apartments are required to be kept as free as possible from them, by reference to facts recorded by Herodotus, of fishermen surrounding themselves with their nets to keep off the gnats. We are indebted to William Spence, Esq. F.R.S., for some very curious particulars respecting the common house fly communicated in a paper to the Entomological Society. The common house fly will not in general pass through the meshes of a net. The inhabitants of Florence and other parts of Italy are aware of this fact, and protect their apartments by hanging network up at the windows; thus at all times the doors and windows may be kept wide open by hanging a light network over the aperture. The meshes may be of considerable width, say enough for several flies on the wing to pass through, and no fly will attempt to pass, unless there be a strong light (another window opposite, or reflection from a looking-glass). A knowledge of this simple means of protection from flies on the wing may prevent inconvenience from these intruders, and obviate the necessity for poisons to destroy them.

FODDER, is the name of a weight by which lead and some other metals were sold in this country; but it is now rarely used. It varied in its amount in different parts of the kingdom, being 19½ cwts. at Hull; 21 cwts. at Newcastle; 22 cwts. at Stockton; 24 cwts. in Derbyshire.

FOILS. Thin sheet copper silvered and burnished, and afterwards coated with transparent colours mixed with isinglass, employed by jewellers to improve the brilliancy of pastes and inferior stones. The foil is inclosed in the setting, and entirely covers the back of the stone, to which it imparts much of its own brilliancy.

FOLIATED TELLURIUM. See NAGYAGITE.

FONDUS. The name given by the French to a particular style of calico-printing resembling the rainbow, in which the colours are graduated or melted (*fondus*) into one another, as in the prismatic spectrum. See CALICO PRINTING for a description of the process.

FONTAINEBLEAU SANDSTONE. This stone consists of grains of siliceous sand, agglutinated by carbonate of lime: the carbonate, in spite of its association with the sand, crystallises in bold rhombohedral forms. In specimens from the forest of Fontainebleau, in France, the proportion of silica may reach 50 or 60 per cent.

FOOD. See NUTRITION.

FOOL'S-PARSLEY. The *Æthusa cynapium*, a very poisonous umbelliferous plant, common in Britain, and occasionally mistaken for parsley.

FOOT-WALL, *a mining term.* The 'wall' or side of the rock under the mineral vein: it is as commonly called the *under-laying wall.*

FOOT-WAY, *a mining term.* The ladders by which the miners descend and ascend.

FORBESITE. A hydrous arsenate of nickel and cobalt, from the Desert of Atacama, in South America. It has been named after Mr. David Forbes, by whom it was described.

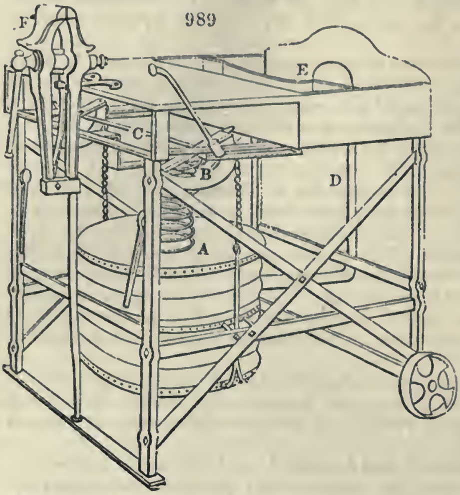
FORBIDDEN FRUIT. The large orange-like fruit of the *Citrus Paradisi* is often sold under this name.

FOREST-BED. The name given by some English geologists to the stratum underlying the glacial drift at Cromer, in Norfolk.

FOREST-MARBLE. An argillaceous laminated shelly limestone, alternating with clays and calcareous sandstones, forming one of the upper portions of the Lower Oolite. In Whichwood Forest, in Oxfordshire, the finer bands are quarried as marble, hence its name.

FORGE (Eng. and Fr.; *Feuer*, Ger.) is the name either of the furnace, where wrought iron is hammered and fashioned with the aid of heat, or the great workshop where iron is made malleable. The former is called a smith's forge, the latter a shingling mill. See IRON.

Fig. 989 represents a portable truck-forge of a very commodious construction. A is the cylindric leather bellows, pressed down by a helical spring, and worked by means of the handle at B, which moves the horizontal shaft C, with its two attached semicircular levers and chains. D is the pipe which conducts the blast to the nozzle at E. The hearth may be covered with a thin fire-tile or with cinders. F is a vice, fixed to the strong rectangular frame. This apparatus answers all the ordinary purposes of a smith's forge; and is peculiarly adapted to ships, and to the execution of engineering jobs upon railways, or in the country. The height is 2 feet 6 inches; the length is 2 feet 9 inches; the width 2 feet; weight about 2 cwts.



989

Holtzapffel describes another portable forge of his own construction, possessing many advantages.

With the manipulations of the forge, it is not the province of this work to deal.

FORK, *a mining term.* A mine is said to be 'in fork,' or an engine to have the 'water in fork,' when all the water is drawn out.

FORMATES. Compounds with formic acid. See Watts's 'Dictionary of Chemistry.'

FORMATION. When employed in a geological sense it signifies a group of rocks, referred to a common origin, or belonging to the same period.

FORMIC ACID. (*Acide formique*, Fr.; *Ameisensäure*, Ger.) The acid which exists in the bodies of ants, associated with malic acid.

Formic acid was obtained artificially, originally by Fisher of Leeds in 1670, and subsequently by Dr. Hulse, by distilling red ants.

It may be prepared by boiling 1 part of starch with 4 of sulphuric acid, and 4 of water, allowing the liquor to cool, and adding gradually 4 parts of the black oxide of manganese, and distilling. For the reactions which take place, see Watts's 'Dictionary of Chemistry.' Its formula is C^2HO^3,HO ($\mathbf{CH^2O^2}$). It is a clear colourless fluid, which crystallises below 32° Fahr., into brilliant plates.

FORMULÆ, CHEMICAL. The term *formula*, in ordinary chemical language, is always understood to mean the collection of symbols indicating a compound substance. Thus, if we allude to the letter or letters indicating an element, we say its *symbol*; but if we are speaking of a compound, we say its *formula*. It appears that some short notice of the principles upon which the construction of chemical formulæ depends is necessary to enable those who are not familiar with chemical language to understand the few formulæ employed in these volumes. For a complete account of the philosophy involved in the construction, consult 'Watts's Dictionary of Chemistry.' The symbols of all the elements will be found under the head 'ATOMIC WEIGHTS.' In constructing formulæ there are several rules to be observed, the neglect of which will lead to misapprehension of the meaning intended to be conveyed. Substances in the most intimate union are expressed by placing the symbols in juxtaposition. Thus oxide of lead is represented by PbO, dry sulphuric acid (sulphuric anhydride) by SO^3, acetic acid by $C^4H^4O^4$. But where a compound is to be expressed which is itself formed by the union of two compounds of the class first mentioned, such as an acid and a base, a comma is placed between them; thus, sulphate of lead is PbO,SO^3, nitrate of copper CuO,NO^5. The number of atoms, when more than one enters into a compound, is expressed by writing the number on the upper part of the right hand of the element. But if only one atom is to be expressed, the mere symbol is written. Thus oxide of copper is CuO, but the suboxide is Cu^2O. If preferred, the number multiplying the atom may be written at the lower right-hand corner of the symbol; Cu_2O, and Cu^2O are identical in meaning. If it be intended to multiply a formula not containing a comma or any other sign, such as SO^3; $C^4H^4O^4$, &c., the number is to be written on the left hand of the formula, and is to be made larger than would be the case if it merely multiplied the atoms of an element. Thus two atoms of oxide of lead are written $2PbO$; three atoms of acetic acid, $3C^4H^4O^4$. But it is to be remembered that a number placed on the left hand of a symbol or formula only multiplies as far as the first comma or sign, so that if we wish to multiply a formula containing a comma or other sign, the formula must be placed between parentheses. Thus two atoms of sulphate of lead are written $2(PbO,SO^3)$. If it be intended to express the fact that one substance is to be added to another, with a view to the production of a given compound or reaction, the substances to be added together are connected by a plus sign. For example, suppose it be necessary to express the fact that one equivalent of oxide of lead added to one equivalent of sulphuric acid produces sulphate of lead, we write, $PbO + SO^3$ forms sulphate of lead. But it is more usual and brief to put down the terms connected by the plus sign followed by the sign of equality, and then the formula of the resulting compound, thus:—$PbO + SO^3 = PbO,SO^3$. A collection of symbols expressing the nature of a reaction or decomposition, the two terms being united by the symbol of equality, is called an equation. Equations are of the highest value to the chemist, as enabling him to express in the simplest possible manner the most complicated reactions. Moreover, these equations enable us to see at a glance the true nature of a decomposition. To take a simple case, namely, that of the decomposition of terchloride of antimony by carbonate of ammonia, we have

$$SbCl^3 + 3(NH^4O,CO^2) = SbO^3 + 3NH^4Cl + 3CO^2.$$

Or, in words, terchloride of antimony plus three equivalents of carbonate of ammonia, yields one equivalent of teroxide of antimony, three of chloride of ammonium, and three of carbonic acid (carbonic anhydride).

The above illustrations will suffice to show the principles upon which formulæ and equations expressive of chemical decompositions are constructed. In writing equations showing the metamorphoses of substances with which it may be supposed the reader of them may not be very fully acquainted, it is proper to place beneath them the names of the substances in full; thus: in writing the change supposed to be experienced by amygdaline under the influence of a ferment which does not itself contribute any substance to the reaction, we might say:—

$$\underbrace{C^{40}H^{27}NO^{22}}_{\substack{\text{Amygdaline}\\\text{oil.}}} + 4HO = \underbrace{C^{14}H^6O^2}_{\substack{\text{Bitter almond}\\\text{oil.}}} + \underbrace{C^2NH}_{\substack{\text{Prussic}\\\text{acid.}}} + \underbrace{2C^{12}H^{12}O^{12}}_{\text{Grape sugar.}}$$

In writing the formulæ of substitution-compounds, it is convenient to place the replaced and replacing substances in a vertical line, so as to indicate at a glance the substitution which has taken place. As an illustration, we shall place side by side the chemical type ammonia and some bodies derived from it by substitution.

$$\underbrace{N\left\{\begin{matrix}H\\H\\H\end{matrix}\right.}_{\text{Ammonia.}} \quad \underbrace{N\left\{\begin{matrix}C^2H^3\\H\\H\end{matrix}\right.}_{\text{Methylamine.}} \quad \underbrace{N\left\{\begin{matrix}C^2H^3\\C^2H^3\\H\end{matrix}\right.}_{\substack{\text{Bimethy-}\\\text{lamine.}}} \quad \underbrace{N\left\{\begin{matrix}C^2H^3\\C^2H^3\\C^2H^3\end{matrix}\right.}_{\substack{\text{Trimethy-}\\\text{lamine.}}} \quad \underbrace{N\left\{\begin{matrix}C^{12}H^5\\H\\H\end{matrix}\right.}_{\text{Aniline.}} \quad \underbrace{N\left\{\begin{matrix}pt\\pt\\H\end{matrix}\right.}_{\substack{\text{Platina-}\\\text{mine.}}} \quad \underbrace{P\left\{\begin{matrix}C^2H^3\\C^2H^3\\C^2H^3\end{matrix}\right.}_{\substack{\text{Triphosphme-}\\\text{thylamine.}}}$$

In the first of the above formulæ we have the type or starting point, ammonia itself. In the next we find one atom of hydrogen (two volumes) replaced by one atom (two volumes) of the radical methyle. In the third we find two atoms of hydrogen replaced; and in the fourth illustration all three have been replaced by methyle. The fifth formula is that of ammonia, in which one atom of hydrogen is replaced by phenyle, forming phenylamine, or, as it is more usually termed, aniline. The sixth illustrates a very peculiar substitution. In it we find two atoms of hydrogen replaced by the *platinicum* of the late illustrious chemist, M. Gerhardt, who regarded platinum as entering into substitutions with two atomic weights, as if it were two metals. The one being the platinum of chemists generally, its atomic weight being 99 (and its symbol Pt); this he calls *platinosum*. The other being *platinicum* (pt), with an atomic weight half that of *platinosum*, namely, 49·5. The last formula is that of the singular base, triphosphmethylamine. In it we see the nitrogen of the original type replaced by phosphorus, and each atom of hydrogen by methyle.

It will greatly assist the student in his endeavours to recollect chemical formulæ, if he commits to memory the principal types and the substances which are regarded as formed on their model. The following are those which are best established:—

Type, two atoms of water.—This type is written in such a manner that the replacement of the hydrogen can be distinctly seen. By its side are placed a few of the substances formed on the same model.

$$\overbrace{O^2\left\{\begin{matrix}H\\H\end{matrix}\right.}^{\substack{\text{Two atoms}\\\text{of water.}}} \quad \overbrace{O^2\left\{\begin{matrix}C^4H^3O^2\\H\end{matrix}\right.}^{\text{Acetic acid.}} \quad \overbrace{O^2\left\{\begin{matrix}C^4H^5\\H\end{matrix}\right.}^{\text{Alcohol.}} \quad \overbrace{C^2\left\{\begin{matrix}C^4H^5\\C^4H^5\end{matrix}\right.}^{\text{Ether.}} \quad \overbrace{O^2\left\{\begin{matrix}K\\H\end{matrix}\right.}^{\substack{\text{Hydrate of}\\\text{potash.}}} \quad \overbrace{O^2\left\{\begin{matrix}K\\K\end{matrix}\right.}^{\substack{\text{Anhydrous}\\\text{potash.}}}$$

In the above simple illustrations of the type water we have, in the case of acetic acid, one atom of hydrogen replaced by the oxidised radical acetyle, $C^4H^3O^2$, and the other by one atom of basic hydrogen. By 'basic' hydrogen is meant, that it acts the part of, and can be replaced by, a metal. The opinions of chemists with regard to the nature of the radical existing in acetic acid are divided. Some consider the acid as the hydrated teroxide of the non-oxidised radical acetyle (C^4H^3), and therefore write its formula $C^4H^3O^3 + HO$. But as the chloride of the oxidised radical can be isolated, we cannot doubt its existence. Moreover, there is no doubt of the existence of the other radical, C^4H^3, because we find it replacing hydrogen in the base acetylamine. See ACETYLAMINE. But the conclusion must be drawn from these facts that there are two radicals, one existing in acetic acid $C^4H^3O^2$, which Williamson calls *othyle*, and another, sometimes called *vinyle* C^4H^3, which exists in aldehyde, in olefiant gas, and several other bodies. The radical in acetic acid is, consequently, not C^4H^3, but $C^4H^3O^2$.

The next illustration is that of alcohol, which consists of two atoms of water, in which one atom of hydrogen is replaced by ethyle, and the other by hydrogen. Ether, on the other hand, is derived from the same type, both atoms of basic hydrogen being replaced by ethyle. Hydrate of potash and anhydrous potash will, after what has been said, explain themselves. It will be seen that in all these illustrations, the same vapour-volume is preserved, and by this means the apparent anomaly of ether and alcohol being of different vapour-volumes is removed. While the type two atoms of water (=4 volumes) has an actual existence, it remains for chemists to discover whether we are justified in receiving as types bodies which have no real existence, such as three atoms of water.

Type, two atoms of hydrogen.—The type ammonia has already been sufficiently illustrated; it remains, then, only to show what substances are to be regarded as formed on the type hydrogen. M. Gerhardt, in addition to these, adopts hydrochloric acid as a type; but when we consider that that acid is itself formed on the hydrogen model, it appears unnecessary to raise it to the dignity of a separate type.

Two atoms of hydrogen.	Olefiant gas.	Marsh gas.	Hydrochloric acid.	Benzole.	Prussic acid.	Chloride of ethyle.
$\overbrace{H}$	$\overbrace{C^4H^3}$	$\overbrace{C^2H^3}$	$\overbrace{Cl}$	$\overbrace{C^{12}H^5}$	$\overbrace{C^2N}$	$\overbrace{C^4H^5}$
H	H	H	H	H	H	Cl

The above will be sufficiently plain after what has been said, it being remembered that C^2H^3 is methyle, C^4H^5 ethyle, $C^{12}H^5$ phenyle, and C^2N cyanogen.

It is a fruitful source of annoyance to students and others to find, on looking through chemical works, the same substance represented by different authors with totally different formulæ. We shall endeavour to give a few instances and such explanations as will assist in enabling the student to overcome the difficulty. It is often the case that the differences in the formulæ arise from the works consulted having been written at different dates; the older one is then, in most cases, to be rejected, because it is probable that the formulæ in it have been corrected by subsequent and more accurate researches. It not unfrequently happens that an author writes nitrous acid NO^4, and the true nitrous acid (NO^3) is called hyponitrous acid. It may serve to assist the student in correcting any errors on this point, to consult a list of the oxides of nitrogen according to the nomenclature at present employed: such a list will be found in the article NITROGEN.

A still more common cause of difficulty is to be found in the different theoretical views of certain chemists regarding the constitution of certain chemical substances. It is explained under the article ATOMIC WEIGHTS that many of the elements have within the last few years had their atomic weights doubled; and this alteration has of course greatly affected chemical formulæ. But even with the same atomic weights, the formula of a given substance may admit of considerable variety of expression, which becomes a source of perplexity to those who are not accustomed to such changes. It may be instructive to show in how many ways the formula of a simple compound like sulphuric acid may be written, according to the different views which may be taken of its constitution. Thus, it may be supposed that this acid is a compound of water (H^2O)[1] and sulphuric anhydride (SO^3); hence the formula of sulphuric acid may be written $H^2O.SO^3$. Another chemist may regard this acid as a compound of a radical (SO^4) with hydrogen; for example, when sulphuric acid is acted upon by zinc, the zinc replaces the hydrogen, which is set free, and zinc sulphate is formed; hence we may formulate sulphuric acid as H^2SO^4. But by the reaction of peroxide of barium and sulphuric acid, peroxide of hydrogen (H^2O^2) is set free; hence there is a reason for writing its formula, $H^2O^2.SO^2$. Yet another mode of expressing

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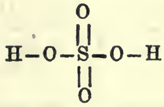
[1] It will be convenient for the purposes of this illustration to employ the modern atomic weights, O=16, S=32.

the constitution of this acid is suggested by the system introduced by Dr. Frankland. According to his method, sulphuric acid should be thus formulated: $\mathbf{S}^{vi}O_2Ho_2$. In this expression, sulphur being the element of highest atomicity is placed at the head of the formula, and written in thick black type, whilst its hexatomic character is indicated by the Roman numerals at the upper right-hand side. These six bonds, or units of equivalence, are satisfied partly by the two atoms of diatomic oxygen, and partly by the two atoms of the monatomic radical hydroxyl (HO), which is written by Dr. Frankland Ho. This hydroxyl may be replaced by other radicals; for example, in zinc sulphate the two atoms of monatomic hydroxyl are replaced by one atom of diatomic zincoxyl, and this salt will be represented by the formula: $\mathbf{S}^{vi}O_2Zno^{ii}$.

The modern doctrine of atomicity has also introduced other forms of constitutional formulæ. Thus, many chemists would now express the composition of sulphuric acid in this form:—



$$H-O-\overset{\overset{O}{\|}}{\underset{\underset{O}{\|}}{S}}-O-H$$

Such a formula is not intended to indicate the relative positions of the several atoms in the compound, but the lines connecting these atoms are supposed to represent the number of units of equivalency enjoyed by each atom, and the manner in which these bonds of affinity are engaged with those of other atoms. Looking, for example, at the centre of this formula we see that the atom of sulphur has six combining bonds, and how these are engaged with the four atoms of oxygen, each of which has only two such bonds.

Instead of indicating the atomicity in this way, other chemists prefer to enclose each symbol in a circle from which lines diverge to represent the units of equivalence. Professor Kekulé, Dr. Crum Brown, and Dr. Frankland have been foremost among modern chemists in devising these *graphic* formulæ.

For the purposes of lecture-illustration material expressions may be constructed by means of solid balls representing atoms, and rods representing bonds of union. These concrete systems, called *glyptic* formulæ, were introduced by Dr. Hofmann.

For reasons given under the article ATOMIC WEIGHTS, it has been considered desirable to employ generally throughout this Dictionary the old atomic weights, and a system of dualistic formulæ; but for the convenience of those who are familiar with modern formulæ, most of the expressions are also constructed with the modern atomic weights, and these formulæ are printed, for the sake of distinction, in thick black type.

On the modes of determining the empirical and rational formulæ of substances from the results of their analysis.—It now remains to show how the formulæ of bodies are determined. There are two kinds of formulæ—the *empirical* and *rational*. An empirical formula merely indicates the simplest ratio existing between the elements present; a rational formula shows the absolute constitution of an atom or equivalent of any substance. Sometimes the expression rational formula is used in a more extended sense, and then signifies the actual manner in which the elements are arranged in a compound molecule, but this happens so seldom, that we shall in this work understand the term in the sense first given.

An empirical formula can always be deduced from the mere result of an accurate analysis. A rational formula, on the other hand, demands a knowledge of the atomic weight of the substance. The latter datum can be best determined—1st, by the analysis of a compound with a substance the atomic weight of which is well established; 2nd, by determining the density of its vapour.

Empirical formulæ.—The percentage composition of a compound having been accurately found, the empirical formula may be deduced from the following rule:—Divide the percentage of each constituent by its atomic weight, and reduce the number so obtained to its lowest terms. Suppose, for example, the empirical formula of nitric acid to be required, the percentage being:—Nitrogen, 25·9; oxygen, 74·1.

These numbers, divided by their respective atomic weights, give—

$$\frac{25{\cdot}9}{14}=1{\cdot}85.$$

$$\frac{74{\cdot}1}{8}=9{\cdot}26.$$

To reduce these numbers to their lowest terms, it is merely necessary to divide 9·26 by 1·85. The simplest terms being:—Nitrogen, 1·00; oxygen, 5·00. Nitric acid consequently consists of one atom of nitrogen, and five of oxygen.

Rational formulæ.—In the above illustration we found the simplest ratio existing between the elements of nitric acid. But it will be seen that, for aught that appears there, it may consist of *n* times NO^5. It becomes necessary, therefore, to find the atomic weight of the acid, and then to find the number of atoms of the elements (combined in the above ratio), which will make that atomic weight. In order to do this, it will be proper to determine the atomic weight of the acid from the data procured by the first method, given above. In order to accomplish this, a salt was analysed for the percentages of soda and nitric acid, with the annexed result:—Soda, 36·47; nitric acid, 63·53.

The required datum, namely, the atomic weight of the acid can easily be obtained by saying,—*As the percentage of base is to the percentage of acid, so is the atomic weight of the base to the atomic weight of the acid.* In the instance given we have, therefore:—

$$\underbrace{36{\cdot}47}_{\substack{\text{Percentage of}\\ \text{base.}}} \;:\; \underbrace{63{\cdot}53}_{\substack{\text{Percentage of}\\ \text{acid.}}} \;::\; \underbrace{31}_{\substack{\text{Atomic weight of}\\ \text{base.}}} \;:\; \underbrace{53{\cdot}999}_{\substack{\text{Atomic weight of}\\ \text{acid.}}}$$

It is evident that 53·999 may be written 54·0 without any inaccuracy. If, therefore we add together the equivalents of nitrogen and oxygen in the ratio found in the empirical formula, we shall have—

$$\begin{array}{lr} \text{1 equivalent of nitrogen} = & 14 \\ \text{5 equivalents of oxygen} \;\; = & 40 \\ \hline & 54 = \text{the atomic weight of the acid.} \end{array}$$

We will now consider the mode of determining the rational formula of a substance from the results of the analysis and the density of the vapour. Suppose a hydrocarbon to have yielded on analysis:—Carbon, 85·714; Hydrogen, 14·286 (=100):

$$\text{And—} \qquad \frac{85{\cdot}714}{6} = 14{\cdot}286 \qquad \frac{14{\cdot}286}{1} = 14{\cdot}286$$

The quotient being the same, the empirical formula becomes C^nH^n. It remains, therefore, to determine the value of ^{n}. The density of the vapour was found to be 2·9064. Now the hydrocarbons always possess a condensation to four volumes. In the article EQUIVALENTS, CHEMICAL, rules are given for ascertaining the equivalents of substances from the densities of their vapours. For four-volume formulæ the rule is:—Divide the density of the gas by half the density of hydrogen. Applying this rule, we have—

$$\frac{2{\cdot}9064}{{\cdot}0346} = 84{\cdot}00$$

It is therefore necessary to find what multiple of the atomic weight of CH will make 84·00. Now $C + H = 6 + 1 = 7$, and $7 \times 12 = 84$. Consequently, the formula is 12(CH), or as it is always written, $C^{12}H^{12}$.

The above rules will suffice to enable any person to determine the empirical and rational formulæ of substances from the results of analysis.

For further information on the subject of Chemical Formulæ, the reader may consult Watts's 'Dictionary of Chemistry.'

FORMYLE. The hypothetical base of formic acid.

FOSSIL. (*Fossilis*, anything dug from the earth.) Formerly all minerals were called fossils, but the word is now restricted to express the remains of animals and plants found buried in the earth.

FOSSIL IVORY. The bones and tusks of elephants and mammoths are found in eastern Siberia, and along the shores of the Arctic sea in great abundance. The tusks are collected for sale, but are much less valuable than the recent ivory.

FOSSIL PAPER, or *Wood*, or *Flax*, or *Cork*. Terms used to distinguish familiar varieties of Amianthus, according as they resemble one or other of the substances named.

FOUNDING; FOUNDRY. In foundries attached to blast-furnaces where from 20 to 30 tons of iron are made *per diem* the moulds are generally mere troughs cut in the sand, into which the melted metal flows and cools in contact with the air. The surfaces of the castings made in this manner present appearances which vary according to the quality of the iron.

The kinds of iron adapted for founding purposes are those which are most fluid when melted, and which contain most carbon, and are called Nos. 1 and 2. They are distinguished by the surface of the pig of iron, which was exposed to the air during cooling, being smooth, and presenting a slightly convex figure. The surfaces of Nos. 3 and 4 pig-iron, and of the white crystalline pig-iron (most suitable for making into wrought iron) present a concave figure, and the surfaces are very irregular and pitted with holes. The colour of the fracture, and the closeness of the grain, also indicate the proportion of carbon in pig-iron.

The mixtures of metal, melting temperatures of metal, &c., require the closest observation on the part of the workmen and foremen who practise iron-founding, and these mechanics are in the practice of observing differences so minute that they cannot be appreciated by the chemist, or expressed in words.

Machinery has enabled the modern founder, by means of railways, turn-tables, travelling-cranes, and steam-power to move at will the heaviest masses without confusion and with great expedition; but nothing but the traditions of the factory, and the constant habit of observation will enable him to conduct properly the melting and casting of metal so as to arrive at certain results.

This is proved by the constant failures of those who undertake to make descriptions of castings, of which they have had no previous knowledge.

Each branch of foundry work must be studied in detail, and we can only pretend to indicate those directions in which progress has been and is being made.

Foundry.—The process of iron smelting and the construction of furnaces having been described under other heads, the remaining part of the business of a foundry, viz., that which relates to the preparation of the moulds and moulding, will now be described.

Moulding.—The art of moulding is one of the most important processes carried on in a foundry, and the success of the founder is directly proportioned to the skill and ingenuity brought to bear upon the production of the patterns and the system of moulding.

Before metals can be cast into the variety of shapes in which they are wanted, patterns must be prepared of wood or metal, and then moulds constructed of some sufficiently infusible material capable of receiving the fluid metal, and retaining it without uniting with it until it has solidified.

A mixture of sand and loam (packed tightly into metal boxes, called flasks) is generally chosen as the material for making moulds, and is employed advantageously for several important reasons.

Flasks.—In modern foundries a system has been invented, by which flasks of any dimensions may be constructed by means of bolting together a number of rectangular frames of cast iron, so arranged as to admit of being easily connected together.

When the particular castings for which the flask has been constructed, or rather compounded, are completed, the separate pieces are unbolted, and are ready to be combined in some new form appropriate to the dimensions of the pattern next to be moulded in them.

The loss of capital, &c., invested in flasks, only occasionally used, is thus saved, as well as loss of time in searching for the size required. The space devoted, on the old system, to the reception of flasks belonging to a foundry was very large, and this may now be appropriated to other purposes.

Sand and loam.—Founders formerly used, on account of price, the description of sand most accessible to them, but at the present time, the convenience and cheapness of railway carriage has enabled special qualities of sand to be delivered to all parts of England.

For founding purposes sand is much improved by the admixture of coke, crushed and reduced to a fine powder, and a mill for this purpose is as necessary in every large foundry as those for grinding and mixing loam.

Moulding-sand must be a mixture of a large quantity of silex and a small quantity of alumina—the property of the latter material being to cement the grains of silex together. Loam consists of the same materials mingled in opposite proportions.

The preparation of loam for those purposes for which sand is not adapted, is an important duty in a foundry, for a great quantity of loam cores have to be made and dried in proper ovens, which is a tedious operation.

Many castings, such as the screws for steamers, are more conveniently cast in moulds constructed of wet loam. These are shaped to the required form when the clay is moist, and then carefully dried afterwards.

Other castings are of such peculiar shapes that they can only be produced in moulds that take in a vast number of pieces. These moulds are then formed of a number of pieces of hardened sand, held together by strips of iron or of plaster, if the sand used is not coherent enough in itself.

Compounds of silex and alumina are very infusible, and when moistened with water and faced with carbonaceous matter, they are capable of receiving the most delicate impressions from the patterns which the founder employs.

Grains of sand are so irregular in shape themselves that they leave innumerable irregular spaces between them, and these intervals form a network of channels which permit the rapid escape of the gases, which are so violently generated by the contact of hot metal falling upon wet sand.

Machine Castings.—Every year, engineers order castings to be prepared of more difficult and complicated forms, and with greater perfection of surface than they have required before.

The reason of this is, that with the progress of the mechanical arts larger and stronger machines are continually being introduced. In these machines greater steadiness of cast-iron framework is necessary than can conveniently be obtained when the frame is made out of a number of pieces of iron cast separately and then bolted together. It would be impossible to mould large frames with pieces projecting on all sides (prepared to receive the moving parts of the machines), and jutting out in contrary directions, in any flasks filled with wet sand, for the pattern never could be removed without destroying the impression. To meet these difficulties, the modern ironfounder has had to follow those plans which were first proved practicable to those who have devoted themselves to casting bronze statues. In founding, as in so many other branches of manufacture, the discoveries made in prosecuting the fine arts have been advantageously adopted by those engaged in works of utility.

False Cores.—The introduction of the drawbacks, or false cores, made of sand pressed hard (and admitting of taking to pieces by joints, at each of which a layer of parting sand is prepared), using for figure casting, enables the moulder to work at his leisure, without fearing that his mould may tumble to pieces, and also enables him to fashion these drawbacks or cores into the most complicated forms, with the power to remove them while the pattern is removed, and build them up again round the empty space (formerly occupied by the pattern) with the greatest facility and accuracy.

The workmen, whose occupation is to knead the sand into the forms required by the founder, are termed moulders, and they form a very numerous body of mechanics, demanding and receiving high wages.

The moulder has often only his sand, his flasks, cranes, and a few simple tools (for smoothing rough places, and for repairing the places in the sand where the mould has broken away during the lifting of the pattern); he has to make proper arrangements for the exit of the atmospheric air which leaves the mould as the fluid metal takes its place; and he is expected to produce an exact copy in metal from any pattern, simple or complicated which may be brought before him.

It will be evident that to produce a good result with such imperfect appliances as the ordinary moulder uses, a skilful workman must be employed, and time expended in proportion the difficulty of the operations to be performed.

Where only a few impressions from a model are required, it is not worth while to spend money in making expensive patterns, or providing those appliances which may enable patterns to be moulded with facility and little skill; but where thousands of castings are wanted of one shape, it is expedient to spend money and skill on patterns and tools, and reduce the work of the moulder to its minimum.

Management.—The best managed foundry is not that in which good castings are obtained by the employment of skilled workmen at a great expense, and without trouble or thought on the part of the principal, but rather that in which the patterns have been constructed with a special reference to their being cast with the minimum of skill and the maximum of accuracy. It is only by the forethought and calculation of the manager that subsequent operations can be reduced to their smallest cost: and in the foundry, as in all other manufactories, the true principles of economy are only practised where the head-work of one person saves the manual labour of a large number.

Improvements.—The attention of founders has been turned—1st, to the methods by which the labour of making moulds in sand might be reduced; 2nd, to the introduction of improvements in the mode of constructing patterns and moulds; and 3rd, to the manufacture of metallic moulds for those purposes for which they could be applied. A great progress has been made during the last twenty years in these different directions.

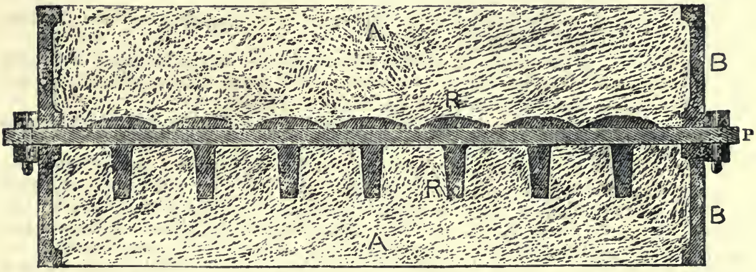
Machine Moulding.—In the large industry carried on for the production of cast-iron pipes for the conveyance of water and gas, machinery has been applied so that the operation of pipe-moulding is performed almost without manual labour, with great rapidity and precision. The cost of pipes at the present time is only about 2*l.* per ton above the value of pig-iron, out of which they are made; a sum very small when it is considered that the iron has to be re-melted, an operation involving both a cost of fuel and a loss of 5 to 20 per cent. of the iron in the cupola. An ingenious machine for moulding in sand, spur and bevel wheels of any pitch or diameter has been employed in Lancashire; the advantage being that the machine moulding tool acts directly upon the sand without the intervention of any pattern or mould. In any large foundry there is an enormous accumulation of costly wheel-patterns, taking up a great deal of space, and these can now be dispensed with by substituting the wheel moulding-machine. Railway chairs are moulded in a machine; and ploughshares, which although only weighing a few pounds each, are sold at the low rate of 8*l.* a ton, are moulded in a machine.

Plate Casting.—Under the next class of improvements the introduction of plate-casting has been the most fruitful of good results.

One great source of expense and trouble in a foundry is the injury done to patterns and to their impressions in the sand by the necessity, under the ordinary system of moulding, of striking the pattern, or pushing it first in one direction and then in another in order to loosen it. Now, the object of the machinist is to construct all his spindles, bearings, bolts, and wheels, of specified sizes, and then to cast the framing of his machine so accurately that the working parts may fit into the frame without any manual labour. In order to effect this, every projection and every aperture in the casting must be at an exact distance, and this can only be attained by employing such a system as that of plate-casting, where the pattern is attached firmly to a plate, and it is impossible for the moulder to distort or injure the impression. Plate-casting has been long known, but was practically confined for many years to the production of small articles, such as cast nails and rivets.

In a plate-mould for rivet-casting, the shafts of the rivets are attached to one side of the plate, which is ¾-in. thick, and planed on both sides. The heads of the rivets are on the opposite side of the plate. The guides on the upper and lower flask admit the plate to fit between them, and when the plate is withdrawn the upper and lower flasks close perfectly, and are in all respects like ordinary moulders' flasks. The principle of moulding is very simple, and can be performed without skilled labour ten times as fast as ordinary moulding, and with far greater accuracy. The plate is inserted between the upper and lower flasks, and sand is filled in; the plate is then withdrawn by simply lifting it; the guides prevent any shaking in this operation; when the flasks are closed, the impression of the head of each rivet is exactly perpendicular to its shaft. The first expense of patterns and plates of this description is large, but the accuracy and rapidity of the process of moulding is so advantageous as to cause us to look to the applications of plate-castings becoming very extensive, since the requirements of the machine-maker demand every year better castings at lower prices.

990



A, sand. B B, flask. R R, rivet pattern. P, plate.

When both sides of a pattern are symmetrical one-half only need be attached to the smooth plate, the other face of the plate being left blank. An impression of the pattern must be taken off both in the upper and lower flask, and when these are united the result will be the same as if both sides of the plate had been moulded from. For unsymmetrical patterns both sides of the plate must be employed. The system of using plates with apertures in them, through which patterns could be pushed and withdrawn by means of a lever, was first employed in casting brass nails. A modification of this system has been extensively employed at Woolwich for moulding shot and shells, in the following manner:—

Shell Casting.—A circular aperture is made in a horizontal planed plate of iron, two inches thick. Through this a sphere of iron, of the same diameter as the aperture, is pushed until exactly a hemisphere appears above the plate. The lower flask is put on to the plate, and sand filled in; the lever being relieved, the sphere falls by its own weight; the lower flask is removed, and the upper flask put on the plate; the sphere is pushed through the plate as before, and sand filled in, with great rapidity and accuracy.

The sand cores for filling up that part of the shell which is to be hollow are also carefully and quickly made at Woolwich. The halves of the core-mould, open and shut with a lever, so that the bad plan of striking the core-mould is avoided as completely as the bad plan of striking the pattern is in the process of moulding shot and shell.

Theory of Casting.—Before leaving the subject of the use of sand-moulds, we may remark that iron and brass castings with a perfect surface can only be produced when the mould is well dried and heated, so as to drive out any moisture from the apertures between the grains of sand. By this means channels are opened for the rapid escape of the heated air and gas expelled by the entrance of the fluid metal into the mould, and the surface of the metal is not cooled by its contact with damp or cold sand. It is also well to mix charcoal-dust, or coke-dust, with the sand; and for fine castings to cover the surface of the sand with a coating of charcoal-dust. The object of this proceeding is to reduce the oxide which may be present in the metal. This operation of reducing the oxide of a metal instantaneously is performed with the greatest certainty by this simple means, invented, probably, by the earliest metallurgists. By incorporating a quantity of charcoal- or coke-dust with the sand, or facing the sand with carbonaceous matter, any oxide of the metal which may be floating amongst the pure metal is at once reduced. Sand (being a non-conductor) does not abstract the heat from the fluid metal rapidly, and, therefore, solidification of the metal takes place comparatively regularly and equally throughout the mass; when one part of the casting solidifies before the adjoining part, flaws often occur, and to avoid these the skill of the practical founder is necessary in arranging for the entrance of the metal at the proper point, and for the exit of the air.

We next proceed to the third class of improvements in moulding, that of the extension of the application of metallic moulds.

Metal Moulds.—The practice of casting bronze weapons in moulds made of bronze (blackened over on their surface to prevent the fluid metal uniting with the mould) appears to have been a very general one among the ancients.

Some moulds of this description have been discovered amongst the prehistoric remains disinterred in different parts of Europe.

The facility for the escape of the heated air and gases from the sand-moulds into which liquid metal is poured, is so much greater than that from moulds of metal, that at the present time neither brass nor iron is poured into metallic moulds, except when a particular purpose is to be attained, viz., that of chilling the surface of the iron and making it as hard as steel. Iron cannot be chilled or hardened in a sand-mould.

Chilled Iron.—This process of casting in metal moulds was once supposed to be a modern invention; but it now appears, from the metal moulds discovered among the remains of the Celtic race throughout Europe, that the bronze weapons of the people who preceded the Romans were generally cast in metallic moulds, and not in sand. Chilled castings have been brought to great perfection by Messrs. Ransome, of Ipswich. Their chilled ploughshares and chilled railway chairs are cast in moulds of such a construction that the melted iron comes in contact with iron in those parts of the moulds where it is wanted to be chilled. A section of the casting shows the effect of chilling.

Zinc.—In casting zinc (a cheap and abundant metal), which fuses at a low temperature, metallic moulds may be most advantageously used. It is, however, necessary to heat the iron or brass mould nearly to the temperature of melting zinc, in order that the rapid abstraction of heat from the fluid metal may be prevented. The preparation of metal moulds, and the casting soft metal in them is now an extensive and important industry on the Continent, for ornamental zinc castings have suddenly come into extensive use in consequence of the discovery of the electrotyping process. When covered with a thin coating of brass or copper by a galvanic battery, zinc may be bronzed so as to present almost the exact external appearances of real bronze at a tenth of the cost.

When metal moulds are used their first cost is very great, as they must be made in numerous separate pieces so as to liberate the castings. The joints and ornaments have to be chased and accurately fitted at a great expense. Their use, however, requires no skill in the workman, and the rapidity with which the zinc is cast, the mould taken to pieces, and the casting removed, renders the operation a very rapid and economical one.

Such is a general view of the practice of founding. The details, however, which are contained in the original article in the earlier editions of this Dictionary appear so valuable that that article is retained in addition to the above.

The essential parts of a well-mounted iron foundry, are,

1. Magazines for pig irons of different qualities, which are to be mixed in certain

proportions, for producing castings of peculiar qualities; as also for coal, coke, sands, clay, powdered charcoal, and cow-hair for giving tenacity to the loam mouldings.

2. One or more coke ovens.

3. A workshop for preparing the patterns and materials of the moulds. It should contain small edge millstones for grinding and mixing the loam, and another mill for grinding coal and charcoal.

4. A vast area, called properly the foundry, in which the moulds are made and filled with the melted metal. These moulds are in general very heavy, consisting of two parts at least, which must be separated, turned upside down several times, and replaced very exactly upon one another. The casting is generally effected by means of large ladles or pots, in which the melted iron is transported from the cupola where it is fused. Hence the foundry ought to be provided with cranes, having jibs moveable in every direction.

5. A stove in which such moulds may be readily introduced, as require to be entirely deprived of humidity, and where a strong heat may be uniformly maintained.

6. Both blast and air furnaces, capable of melting speedily the quantity of cast-iron to be employed each day.

7. A blowing machine to urge the fusion in the furnaces.

Fig. 991, represents the general plan of a well-mounted foundry.

a, is a cupola furnace; it is capable of containing 5 tons of cast iron.

a′, is a similar furnace, but of smaller dimensions, for bringing down $1\frac{3}{4}$ ton.

a″, is a furnace like the first, in reserve for great castings.

b b b b, a vast foundry apartment, whose floor to a yard in depth, is formed of sand and charcoal powder, which have already been used for castings, and are ready for heaping up into a substratum, or to be scooped out when depth is wanted for the moulds. There are besides several cylindrical pits, from 5 to 7 yards in depth, placed near the furnaces. They are lined with brick-work, and are usually left full of moulding sand. They are emptied in order to receive large moulds, care being had that their top is always below the orifice from which the melted metal is tapped.

These moulds, and the ladles full of melted metal are lifted and transported by the arms of one or more men, when their weight is moderate; but if it be considerable, they are moved about by cranes, whose vertical shafts are placed at *c*, *d*, *e*, in correspondence, so that they may upon occasion transfer the load from one to another. Each crane is composed principally of an upright shaft, embraced at top by a collet, and turning below upon a pivot in a step; next of a horizontal beam, stretched out from nearly the top of the former, with an oblique stay running downwards, like that of a gallows. The horizontal beam supports a moveable carriage, to which the tackle is suspended for raising the weights. This carriage is made to glide backwards or forwards along the beam by means of a simple rack-and-pinion mechanism, whose long handle descends within reach of the workman's hand.

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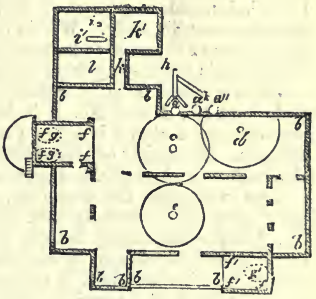


By these arrangements in the play of the three cranes, masses weighing 5 tons may be transported and laid down with the greatest precision upon any point whatever in the interior of the three circles traced upon *fig.* 991, with the points *c*, *d*, *e*, as centres.

c, *d*, *e*, are the steps, upon which the upright shafts of the three cranes rest and turn. Each shaft is 16 feet high.

f f, is the drying stove, having its floor upon a level with that of the foundry.

f′ f′, is a supplementary stove for small articles.

g g g′, are the coking ovens.

h is the blowing machine or fan.

i, is the steam-engine, for driving the fan, the loam-edge stones,

k, and the charcoal mill.

i′, are the boiler and the furnace of the engine.

k′, workshop for preparing the loam and other materials of moulding.

l, is the apartment for the patterns.

The pig-iron, coals, &c., are placed either under sheds or in the open air, round the above buildings; where are also a smith's forge, a carpenter's shop, and an apartment mounted with vices for chipping and rough cleaning the castings by chisels and files.

Such a foundry may be erected upon a square surface of about 80 yards on each side, and will be capable, by casting in the afternoon and evening of each day, partly in large and partly in small pieces, of turning out from 700 to 800 tons per annum, with an establishment of 100 operatives, including some moulding boys.

Of making the Moulds.—1. Each mould ought to present the exact form of its object.

2. It should have such solidity that the melted metal may be poured into it, and fill it entirely without altering its shape in any point.

3. The air which occupies the vacant spaces in it, as well as the carburetted gases generated by the heat, must have a ready vent; for if they are but partially confined, they expand by the heat, and may crack, even blow up the moulds, or at any rate become dispersed through the metal, making it vesicular and unsound.

There are three distinct methods of making the moulds:—

1. In green sand; 2. In baked sand; 3. In loam.

To enumerate the different means employed to make every sort of mould exceeds the limits prescribed to this work. We shall merely indicate for each species of moulding, what is common to all the operations; and then describe the fabrication of a few such moulds as appear most proper to give general views of this peculiar art.

Moulding in green sand.—The name green is given to a mixture of the sand as it comes from its native bed, with about one twelfth its bulk of coal reduced to powder, and damped in such a manner as to form a porous compound, capable of preserving the forms of the objects impressed upon it. This sand ought to be slightly argillaceous, with particles not exceeding a pin's head in size. When this mixture has once served for a mould, and been filled with metal, it cannot be employed again except for the coarsest castings, and is generally used for filling up the bottoms of fresh moulds.

For moulding any piece in green sand, an exact pattern of the object must be prepared in wood or metal; the latter being preferable, as not liable to warping, swelling, or shrinkage.

A couple of iron frames form a case or box, which serves as an envelope to the mould. Such boxes constitute an essential and very expensive part of the furniture of a foundry. It is a rectangular frame, without bottom or lid, whose two largest sides are united by a series of cross bars, parallel to each other, and placed from 6 to 8 inches apart.

The two halves of the box carry ears corresponding exactly with one another; of which one set is pierced with holes, but the other has points which enter truly into these holes, and may be made fast in them by cross pins or wedges, so that the pair becomes one solid body. Within this frame there is abundance of room for containing the pattern of the piece to be moulded with its encasing sand, which being rammed into the frame, is retained by friction against the lateral faces and cross bars of the mould.

When a mould is to be formed, a box of suitable dimensions is taken asunder, and each half, No. 1 and No. 2, is laid upon the floor of the foundry. Green sand is thrown with a shovel into No. 1 so as to fill it; when it is gently pressed in with a rammer. The object of this operation is to form a plane surface upon which to lay in the pattern with a slight degree of pressure, varying with its shape. No. 1 being covered with sand, the frame No. 2 is laid upon it, so as to form the box. No. 2 being now filled carefully with the green sand, the box is inverted, so as to place No. 1 uppermost, which is then detached and lifted off in a truly vertical position; carrying with it the body of sand formed at the commencement of the operation. The pattern remains imbedded in the sand of No. 2, which has been exactly moulded upon a great portion of its surface. The moulder condenses the sand in the parts nearest to the pattern, by sprinkling a little water upon it, and trimming the ill-shaped parts with small iron trowels of different kinds. He then dusts a little well-dried finely-sifted sand over all the visible surface of the pattern, and of the sand surrounding it; this is done to prevent adhesion when he replaces the frame No. 1.

He next destroys the preparatory smooth bed or area formed in this frame, covers the pattern with green sand, replaces the frame 1 upon 2 to reproduce the box, and proceeds to fill and ram No. 1, as he had previously done No. 2. The object of this operation is to obtain very exactly a concavity in the frame No. 1, having the shape of the part of the model impressed coarsely upon the surface formed at the beginning, and which was meant merely to support the pattern and the sand sprinkled over it, till it got imbedded in No. 2.

The two frames in their last position, along with their sand, may be compared to a box of which No. 1 is the lid, and whose interior is adjusted exactly upon the enclosed pattern.

If we open this box, and after taking out the pattern, close its two halves again, then pour in melted metal till it fill every void space, and become solid, we shall obviously attain the wished-for end, and produce a piece of cast iron similar to the pattern. But many precautions must still be taken before we can hit this point. We must first lead through the mass of sand in the frame No. 1, one or more channels for the introduction of the melted metal; and though one may suffice for this purpose, another must be made for letting the air escape. The metal is run in by several orifices at once, when the piece has considerable surface, but little thickness, so that it may reach the remotest points sufficiently hot and liquid.

The parts of the mould near the pattern must likewise be pierced with small holes. by means of wires traversing the whole body of the sand, in order to render the mould more porous, and to facilitate the escape of the air and the gases. Then, before lifting off the frame No. 1, we must tap the pattern slightly, otherwise the sand enclosing it would stick to it in several points, and the operation would not succeed. These gentle jolts are given by means of one or more pieces of iron wire which have been screwed vertically into the pattern before finally ramming the sand into the frame No. 1, or which enter merely into holes in the pattern. These pieces are sufficiently long to pass out through the sand when the box is filled; and it is upon their upper ends that the horizontal blows of the hammer are given; their force being regulated by the weight and magnitude of the pattern. These rods are then removed by drawing them straight out; after which the frame No. 1 may be lifted off smoothly from the pattern.

The pattern itself is taken out, by lifting it in all its parts at once, by means of screw pins adjusted at the moment. This manœuvre is executed, for large pieces, almost always by several men, who while they lift the pattern with one hand, strike it with the other with small repeated blows to detach the sand entirely, in which it is generally more engaged than it was in that of the frame No. 1. But in spite of all these precautions, there are always some degradations in one or other of the two parts of the mould: which are immediately repaired by the workman with damp sand, which he applies and presses gently with his trowel, so as to restore the injured forms.

Hitherto it has been supposed that all the sand rammed into the box is of one kind, but from economy, the green sand is used only to form the portion of the mould next the pattern, in a stratum of about an inch thick; the rest of the surrounding space is filled with the sand of the floor which has been used in former castings. The interior layer round the pattern is called in this case, *new sand.*

It may happen that the pattern is too complex to be taken out without damaging the mould, by two frames alone; then three or more are mutually adjusted to form the box.

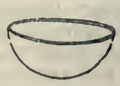
When the mould, taken asunder into two or more parts, has been properly repaired. its interior surface must be dusted over with wood charcoal reduced to a very fine powder, and tied up in a small linen bag, which is shaken by hand. The charcoal is thus sifted at the moment of application, and sticks to the whole surface which has been previously damped a little. It is afterwards polished with a fine trowel. Sometimes, in order to avoid using too much charcoal, the surfaces are finally dusted over with sand, very finely pulverised, from a bag like the charcoal. The two frames are now replaced with great exactness, made fast together by the ears, with wedged bolts laid truly level, or at the requisite slope, and loaded with considerable weights. When the casting is large, the charcoal dusting, as well as that of fine sand, is suppressed. Everything is now ready for the introduction of the fused metal.

Moulding in baked or used sand.—The mechanical part of this process is the same as that of the preceding. But when the castings are large, and especially if they are tall, hydrostatic pressure of the melted metal upon the sides of the mould cannot be counteracted by the force of cohesion which the sand acquires by ramming. We must in that case adapt to each of these frames a solid side, pierced with numerous small holes to give issue to the gases. This does not form one body with the rest of the frame, but is attached extemporaneously to it by bars and wedged bolts. In general no ground coal is mixed with this sand. Whenever the mould is finished, it is transferred to the drying stove, where it may remain from twelve to twenty-four hours, at most, till it be deprived of all its humidity. The sand is then said to be baked, or annealed. The experienced moulder knows how to mix the different sands placed at his disposal, so that the mass of the mould as it comes out of the stove, may preserve its form, and be sufficiently porous. Such moulds allow the gases to pass through them much more readily than those made of *green* sand; and in general the cattings they turn out are less vesicular, and smoother upon the surface. Sometimes in a large piece, the three kinds of moulding, that in green sand, in baked sand, and in loam, are combined to produce the best result.

Moulding in loam.—This kind of work is executed from drawings of the pieces to be moulded, without being at the expense of making patterns. The mould is formed of a pasty mixture of clay, water, sand, and cows'-hair, or other cheap filamentous matter, kneaded together in what is called the loam mill. The proportions of the ingredients are varied to suit the nature of the casting. When the paste requires to be made very light, horse-dung or chopped straw is added to it.

We shall illustrate the mode of fabricating loam moulds, by a simple case, such as that of a sugar-pan. *Fig.* 992 is the pan. There is laid upon the floor of the foundry an annular platform of cast iron, *a*, *b*, *fig.* 993; and upon its centre *c*, rests the lower extremity of a vertical shaft, adjusted so as to turn freely upon itself, while it makes a wooden pattern *e f*, *fig.* 994, describe a surface of revolution identical with the internal surface reversed of the boiler intended to be made. The outline *e g*, of the pattern is fashioned so as to describe the surface of the edge of the vessel. Upon the part *a*, *d*, *b*, *d*, *fig.* 993, of the flat cast-iron ring, there must next be constructed, with bricks laid either flat or on their edge, and clay, a kind of dome, *h i k*, *fig.* 994, from two to four inches thick, according to the size and weight of the piece to be moulded. The external surface of the brick dome ought to be everywhere two inches distant at least, from the surface described by the arc *e f*. Before building up the dome to the point *i*, coals are to be placed in its inside upon the floor, which may be afterwards kindled for drying the mould. The top is then formed, leaving at *i*, round the upright shaft of revolution, only a very small outlet. This aperture, as also some others left under the edges of the iron ring, enable the moulder to light the fire when it becomes necessary, and to graduate it so as to make it last long enough without needing more fuel, till the mould be quite finished and dry. The combustion should be always extremely slow.

992



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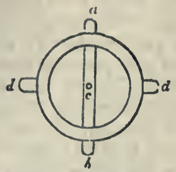

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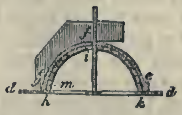

Over the brick dome a pasty layer of loam is applied, and rounded with the mould *g*, *e*, *f*; this surface is then coated with a much smoother loam, by means of the concave edge of the same mould. Upon the latter surface, the inside of the sugar-pan is cast; the line *e g* having traced, in its revolution, a ledge, *m*. The fire is now kindled, and as the surface of the mould becomes dry, it is painted over by a brush with a mixture of water, charcoal-powder, and a little clay in order to prevent adhesion between the surface already dried and the coats of clay about to be applied to it. The board *g e f* is now removed, and replaced by another, *g′ e′ f′*, *fig.* 995, whose edge *e′ f′* describes the outer surface of the pan. Over the surface *e f*, a layer of loam is applied, which is turned and polished so as to produce the surface of revolution *e′ f′*, as was done for the surface *e f*; only in the latter case, the line *e′ g′* of the board does not form a new shoulder, but rubs lightly against *m*.

The layer of loam included between the two surfaces *e f*, *e′ f′* is an exact representation of the sugar-pan. When this layer is well dried by the heat of the interior fire, it must be painted like the former. The upright shaft is now removed, leaving the small vent-hole through which it passed to promote the complete combustion of the coal. There must be now laid horizontally upon the ears of the platform *d d*, *fig.* 993, another annular platform *p q*, like the former, but a little larger, and without any cross-bar. The relative position of these two platforms is shown in *fig.* 997. Upon the surface *e′ f′ fig.* 996, a new layer of loam is laid, two inches thick, of which the surface is smoothed by hand. Then upon the platform *p q*, *fig.* 997, a brick vault is constructed, whose inner surface is applied to the layer of loam. This contracts a strong adherence with the bricks which absorb a part of its moisture, while the coat of paint spread over the surface *e′ f′*, prevents it from sticking to the preceding layers of loam. The brick dome ought to be built solidly.

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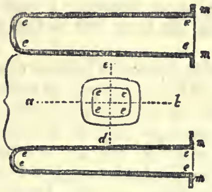
997

The whole mass is now to be thoroughly dried by the continuance of the fire, the draught of which is supported by a small vent left in the upper part of the new dome; and when all is properly dry, the two iron platforms are adjusted to each other by pin points, and *p q* is lifted off, taking care to keep it in a horizontal position. Upon this platform are removed the last brick dome, and the layer of loam which had been applied next to it; the latter of which represents exactly by its inside the mould of the surface *e′ f′*, that is, of the outside of the pan. The crust contained between *e f* and *e′ f′* is broken away, an operation easily done without injury to the surface *e f*, which represents exactly the inner surface of the pan; or only to the shoulder *m*, corresponding to the edge of the vessel. The top aperture through which the upright shaft passed must be now closed; only the one is kept open in the portion of the mould lifted off upon *p q*; because through this opening the melted metal is to be poured in the process of casting. The two platforms being replaced above each other exactly, by means of the adjusting pin-points, the mould is completely formed, and ready for the reception of the metal.

998



999

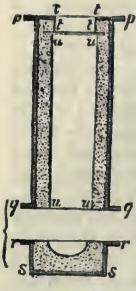
When the object to be moulded presents more complicated forms than the one now chosen for the sake of illustration, it is always by analogous processes that the workman constructs his loam moulds, but his sagacity must hit upon modes of executing many things which at first sight appear to be scarcely possible. Thus, when the forms of the interior and exterior do not permit the mould to be separated in two pieces, it is divided into several, which are nicely fitted with adjusting pins. More than two cast-iron rings or platforms are sometimes necessary. When ovals or angular surfaces must be traced instead of those of revolution, no upright shaft is used, but wooden or cast-iron guides made on purpose, along which the pattern cut-out board is slid according to the drawing of the piece. Iron wires and claws are often interspersed through the brick-work to give it cohesion. The core, kernel, or inner mould of a hollow casting is frequently fitted in when the outer shell is moulded. The case of a gas-light retort, *fig.* 998, will illustrate this matter. The core of the retort ought to have the form *e e e e*, and be very solid, since it cannot be fixed in the outer mould for the casting, except in the part standing out of the retort towards *m m*. It must be modelled in loam, upon a piece of cast iron called a *lantern*, made expressly for this purpose. The lantern is a cylinder or a truncated hollow cone of cast iron, about half an inch thick; and differently shaped for every different core. The surface is perforated with holes of about half an inch in diameter. It is mounted by means of iron cross-bars, upon an iron axis, which traverses it in the direction of its length. *Fig.* 999, represents a horizontal section through the axis of the core; *g h* is the axis of the lantern, figured itself at *i k k i*; *o i i o* is a kind of disc or dish, perpendicular to the axis, open at *i i*, forming one piece with the lantern, whose circumference *o o* presents a curve similar to the section of the core, made at right angles to its axis. We shall see presently the two uses for which this dish is intended. The axis *g h* is laid upon two gudgeons, and handles are placed at each of its extremities, to facilitate the operation in making the core. Upon the whole surface of the lantern, from the point *h* to the collet formed by the dish, a hay cord as thick as the finger is wound. Even two or more coils may be applied, as occasion requires, over which loam is spread to the exact form of the core, by applying with a hand a board, against the dish *o o*, with its edge cut out to the desired shape; as also against another dish, adjusted at the time towards *h;* while by means of the handles a rotatory movement is given to the whole apparatus.

The hay interposed between the lantern and the loam, which represents the crust of the core. aids the adhesion of the clay with the cast iron of the lantern, and gives passage to the holes in its surface, for the air to escape through in the casting.

When the core is finished, and has been put into the drying stove, the axis *g h* is taken out, then the small opening which it leaves at the point *h*, is plugged with clay. This is done by supporting the core by the edges of the dish, in a vertical position. It is now ready to be introduced into the hollow mould of the piece.

This mould, executed in baked sand, consists of three pieces; two of which, absolutely similar, are represented, *fig.* 1000, at *p q*, the third is shown at *r s*. The two similar parts *p q*, present each the longitudinal half of the nearly cylindrical portion of the outer surface of the gas retort; so that when they are brought together, the cylinder is formed; *r s* contains in its cavity the kind of hemisphere which forms the bottom of the retort. Hence, by adding this part of the mould to the end of the two others, the resulting apparatus presents, in its interior, the exact mould of the outside of the retort; an empty cylindrical portion *t t*, whose axis is the same as that of the cylinder *u u*, and whose surface, if prolonged, would be everywhere distant from the surface *u u*, by a quantity equal to the desired thickness of the retort. The diameter of the cylinder *t t* is precisely equal to that of the core, which is slightly conical, in order that it may enter easily into this aperture *t t*, and close it very exactly when it is introduced to the collet or neck.

1000



1001

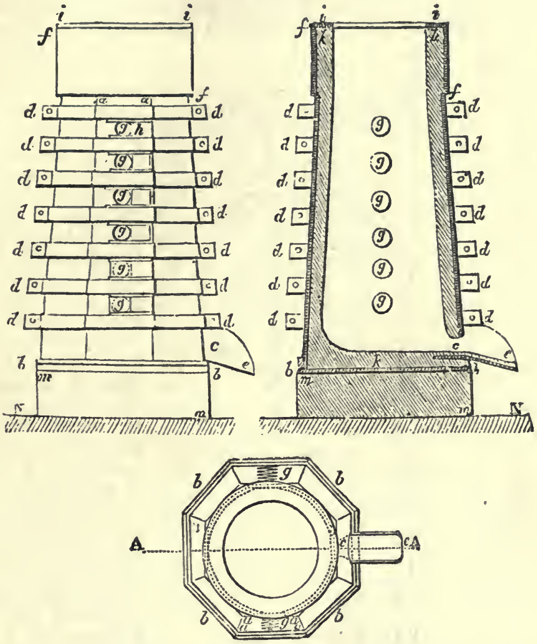
The three parts of the mould and the core being prepared, the two pieces *p q*, must first be united, and supported in an upright position, then the core must be let down into the opening *t t*, *fig.* 1001. When the plate or disc *o o* of the core is supported upon the mould, we must see that the end of the core is everywhere equally distant from the edge of the external surface *u u*, and that it does not go too far beyond the line *q q*. Should there be an inaccuracy, we must correct it by slender iron slips placed under the edge of the disc *o o*; then by means of a cast-iron cross, and screw bolts *v v*, we fix the core immovably. The whole apparatus is now set down upon *r s*, and we fix with screw bolts the plane surface *q q* upon *r r*; then introduce the melted metal by an aperture *z*, which has been left at the upper part of the mould.

When, instead af the example now selected, the core of the piece to be cast must go beyond the mould of the external surface, as is the case with a pipe open at each end, the thing is more simple, because we may easily adjust and fix the core by its two ends.

In casting a retort, the metal is poured into the mould set upright. It is important to maintain this position in the last two examples of casting; for all the foreign matters which may soil the metal during its flow, as the sand, the charcoal, gases, scoriæ, being less dense than it, rise constantly to the surface. The hydrostatic pressure produced by a high gate, or filling-in aperture, contributes much to secure the soundness and solidity of the casting. This gate piece being superfluous, is knocked off almost immediately after, or even before the casting cools. Very long, and somewhat slender pieces, are usually cast in moulds set up obliquely to the horizon. As the metal shrinks in cooling, the mould should always be somewhat larger than the object intended to be cast. The iron founder reckons in general upon a linear shrinkage of a ninety-sixth part; that is one-eighth of an inch per foot.

Melting of the cast iron.—The metal is usually melted in a cupola furnace, of which the dimensions are very various. *Fig.* 1002 represents in plan, section, and elevation, one of these furnaces of the largest size; being capable of founding 5 tons of cast iron at a time. It is kindled by laying a few chips of wood upon its bottom, leaving the orifice *c* open, and it is then filled up to the throat with coke. The fire is lit at *c*, and in a quarter or half an hour, when the body of fuel is sufficiently kindled, the tuyère blast is set in action. The flame issues then by the mouth as well as the orifice *c*, which has been left open on purpose to consolidate it by the heat. Without this precaution the sides, which are made up in argillaceous sand after each day's work, would not present the necessary resistance. A quarter of an hour afterwards, the orifice *c* is closed with a lump of moist clay, and sometimes, when the surface is to contain a great body of melted metal, the clay is supported by means of a small plase of cast iron fixed against the furnace. Before the blowing-machine is set a-going, the openings, *g g g* had been kept shut. Those of them wanted for the tuyères are opened in succession, beginning at the lowest, the tuyères being raised according as the level of the fused iron stands higher in the furnace. The same cupola may receive at a time from one to six tuyères, through which the wind is propelled by the centrifugal action of an excentric fan or ventilator. It does not appear to be ascertained whether there be any advantage in placing more than two tuyères facing each other upon opposite sides of the furnace. Their diameter at the nozzle varies from 3 to 5 inches. They are either cylindrical or slightly conical. A few minutes after the tuyères have begun to blow, when the coke sinks in the furnace, alternate charges of coke and pig-iron must be thrown in. The metal begins to melt in about 20 minutes after its introduction; and successive charges are then made every 10 minutes nearly; each charge containing from 3 cwts. to 5 cwts. of iron, and a quantity proportional to the estimate given below. The amount of the charges varies of course with the size of the furnace, and the speed required for the operation. The pigs must be previously broken into pieces weighing at most 14 or 16 lbs. The vanes of the blowing fan make from 625 to 650 turns per minute. The two cupolas represented in *fig.* 1003, and another alongside in the plan, may easily melt $6\frac{1}{2}$ tons of metal in $2\frac{3}{4}$ hours; that is $2\frac{1}{3}$ tons per hour. This result is three or four times greater than what was formerly obtained in similar cupolas, when the blast was thrown in from small nozzles with cylinder bellows, moved by a steam-engine of 10 horse-power.

1002



In the course of a year, a considerable foundry like that represented in the plan, *fig.* 991, will consume about 300 tons of coke in melting 1,240 tons of cast iron; consisting of 940 tons of pigs, of different qualities, and 300 tons of broken castings, gate-pieces, &c. Thus it appears that 48 lbs. of coke are consumed for melting every 2 cwts. of metal.

Somewhat less coke is consumed when the fusion is pushed more rapidly, to collect a great body of melted metal for casting heavy articles; and more is consumed when, as in making many small castings, the progress of the founding has to be slackened from time to time; otherwise, the metal would remain too long in a state of fusion, and probably become too cold to afford sharp impressions of the moulds.

It sometimes happens that in the same day, with the same furnace, pieces are to be cast containing several proportions of different kinds of iron; in which case, to prevent an intermixture with the preceding or following charges, a considerable bed of coke is interposed. Though there be thus a little waste of fuel, it is compensated by the improved adaptation of the castings to their specific objects. The founding generally begins at about 3 o'clock P.M., and goes on till 6 or 8 o'clock. One founder aided by four labourers for charging, &c., can manage two furnaces.

The following is the work of a well-managed foundry in Derby.

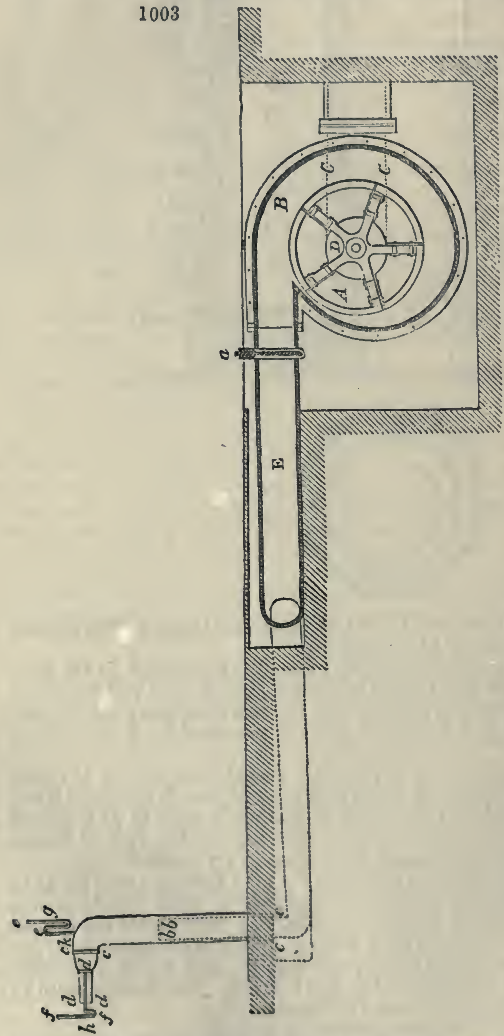
200 lbs. of coke are requisite to melt, or bring down (in the language of the founder), 1 ton of cast iron, after the cupola has been brought to its proper heat, by the combustion in it of 9 baskets of coke, weighing, by my trials, 40 lbs. each = 360 lbs.

The chief talent of the founder consists in discovering the most economical mixtures and so compounding them as to produce the desired properties in the castings. One piece, for example, may be required to have great strength and tenacity to bear heavy weights or strains; another must yield readily to the chisel or the file; a third must resist sudden alternations of temperature; and a fourth must be pretty hard.

The filling-in of the melted metal is managed in two ways. For strong pieces, whose moulds can be buried in the ground at 7 or 8 yards' distance from the furnace, the metal may be run in gutters, formed in the sand of the floor, sustained by plates or stones. The clay plug is pierced with an iron rod, when all is ready.

When from the smaller size, or greater distance of the moulds, the melted metal cannot be run along the floor from the furnace, it is received in cast-iron pots or ladles, lined with a coat of loam. These are either carried by the hands of two or more men, or transported by the crane. Between the successive castings, the discharge hole of the furnace is closed with a lump of clay, applied by means of a stick, having a small disc of iron fixed at its end.

1003



After the metal is somewhat cooled, the moulds are taken asunder, and the excrescences upon the edges of the castings are broken off with a hammer. They are afterwards more carefully trimmed or chipped by a chisel when quite cold. The loss of weight in founding is about 6½ per cent. upon the pig iron employed. Each casting always requires the melting of considerably more than its own weight of iron. This excess forms the gates, false seams, &c.; the whole of which being deducted, shows that 1 cwt. of coke is consumed for every 3 cwts. of iron put into the furnace; for every 138 cwts. of crude metal, there will be 100 cwts. of castings, 32 of refuse pieces, and 6 of waste.

Fig. 1002, *Cupola furnace*, requires a little further description. It is 3 feet wide within, and 13½ feet high. *m m*, solid body of masonry, as a basis to the furnace.

b b, octagonal platform of cast iron, with a ledge in which the plates *a a a a* are engaged.

a a, eight plates of cast iron, 1 inch thick, absolutely similar; only one of them is notched at its lower part in *c*, to allow the melted metal to run out, and two of the others have six apertures, *g g g*, &c. to admit the tuyères.

c, orifice for letting the metal flow out. A kind of cast-iron gutter, *e*, lined with loam, is fitted to the orifice.

d, hoops of hammered iron, 4½ inches broad; ½ inch thick for the bottom ones; and ¼ inch for the upper ones. The intermediate hoops decrease in thickness from below upwards between these limits.

e, cast-iron gutter or spout, lined with loam, for running off the metal.

f f, cylindrical piece of cast iron, for increasing the height and draught of the furnace.

g, side openings for receiving the tuyères, of which there are six upon each side of the furnace. Each of them may be shut at pleasure, by means of a small cast-iron plate, *h*, made to slide horizontally in grooves sunk in the main plate, pierced with the holes *g g*.

k k, interior lining of the surface, made of sand, somewhat argillaceous, in the following way:—After having laid at the bottom of the furnace a bed of sand a few inches thick, slightly sloped towards the orifice of discharge, there is set upright, in the axis of the cupola, a wooden cylinder of its whole height, and of a diameter a little less than that of the vacant space belonging to the top of the furnace. Sand is to be then rammed in so as to fill the whole of the furnace; after which the wooden cylinder is withdrawn, and the lining of the sand is cut or shaved away, till it has received the proper form.

This lining lasts generally five or six weeks, when there are six meltings weekly.

i i, cast-iron circular plate, through which the mouth of the furnace passes for protecting the lining in *k* during the introduction of the charges.

N N, level of the floor of the foundry. The portion of it below the running-out orifice consists of sand, so that it may be readily sunk when it is wished to receive the melted metal in ladles or pots of large dimensions.

The fan distributes the blast from the main pipe to three principal points, by three branch tubes of distribution. A register, consisting of a cast-iron plate sliding with friction in a frame, serves to intercept the blast at any moment, when it is not desirable to stop the moving power. A large main pipe of zinc or sheet iron is fitted to the orifice of the slide valve. It is square at the beginning, or only rounded at the angles; but at a little distance it becomes cylindrical, and conducts the blast to the divaricating points. There, each of the branches turns up vertically, and terminates at *b b*, *fig.* 1003, where it presents a circular orifice of 7½ inches. Upon each of the upright pipes *b*, the one end of an elbow-tube of zinc *c c c*, *fig.* 1003, is adjusted rather loosely, and the other end receives a tuyère of wrought iron *d d*, through the intervention of a shifting hose or collar of leather *c c d*, hooped with iron wire to both the tube and the tuyère. The portion *c c c* may be raised or lowered, by sliding upon the pipe *b*, in order to bring the nozzle of the tuyère *d d*, to the requisite point of the furnace. The portion *c c c* may be made also of wrought iron. A power of 4 horses is adequate to drive this fan, for supplying blast to 3 furnaces.

The founders have observed that the efflux of air was not the same when blown into the atmosphere as it was when blown into the furnaces; the velocity of the fan, with the same impulsive power, being considerably increased in the latter case. They imagine that this circumstance arises from the blast being sucked in, so to speak, by the draught of the furnace, and that the fan then supplied a greater quantity of air.

The following experimental researches show the fallacy of this opinion. Two water siphons, *e e e*, *f f f*, made of glass tubes, one-fifth of an inch in the bore, were inserted into the tuyère, containing water in the portions *g*, *h*. The one of these *manometers* for measuring the pressure of the air was inserted at *k*, the other in the centre of the nozzle. The size of this glass tube was too small to obstruct in any sensible degree the outlet of the air. It was found that when the tuyères of the fan discharged into the open air, the expenditure by a nozzle of a constant diameter was proportional to the number of the revolutions of the vanes. It was further found, that when the speed of the vanes was constant, the expenditure by one or two nozzles was proportional to the total area of these nozzles. The following formulæ give the volume of air furnished by the fan, when the number of turns and the area of the nozzles are known:—

$$\text{Volume} = \frac{25{\cdot}32\ S\,n}{1{\cdot}000{,}000} \qquad (1)$$

$$\text{Volume} = \frac{0{\cdot}86'6'7\ S\,n}{1{,}000{,}000} \qquad (2)$$

The volume is measured at 32° Fahr., under a pressure of 29·6 inches barom.

S = the total area of the orifices of the tuyères in square inches.

n = the number of turns of the vanes in a minute.

After measuring the speed of the vanes blowing into the atmosphere, if we introduce the nozzle of discharge into the orifice of the furnace, we shall find that their speed immediately augments in a notable degree. We might, therefore, naturally suppose that the fan furnishes more air in the second case than in the first; but a little reflection will show that it is not so. In fact, the air which issues in a cold state from the tuyère encounters instantly in the furnace a very high temperature, which expands it, and contributes, along with the solid matters with which the furnace is filled, to diminish the facility of the discharge, and consequently to retard the efflux by the nozzles. The oxygen gas consumed is replaced by a like volume of carbonic acid gas, equally expansible by heat. Reason leads us to conclude that less air flows from the nozzles into the furnace than into the open atmosphere.

The increase in the velocity of the vanes takes place precisely in the same manner, when after having made the nozzles blow into the atmosphere, we substitute for these nozzles others of a smaller diameter, instead of directing the larger ones into the furnace. Hence we may conceive that the proximity of the charged furnace acts upon the blast like the contraction of the nozzles. When the moving power is uniform, and the velocity of the vanes remains the same, the quantity of air discharged must also be the same in the two cases.

Two tuyères, one 5 inches in diameter, the other 4½, and which, consequently, presented a total area of 35½ square inches, discharged air into one of the furnaces, from a fan whose vanes performed 654 turns in the minute. These two nozzles being briskly withdrawn from the furnace, and turned round to the free air, while a truncated pasteboard cone of 3½ inches diameter was substituted for the nozzle of 4½ inches, wherein the area of efflux was reduced to 29·3 square inches, the velocity of the vanes continued exactly the same. The inverse operation having been performed, that is to say, the two original nozzles having been smartly replaced in the furnace, to discover whether or not the moving power had changed in the interval of the experiment, they betrayed no perceptible alteration of speed. From the measures taken to count the speed, the error could not exceed three revolutions per minute, which is altogether unimportant upon the number 654.

It follows, therefore, that when the vanes of the fan have the velocity of 654 turns per minute, the expenditure by two nozzles, whose joint area is 35½ square inches, both blowing into a furnace, is to the expenditure which takes place, when the same nozzles blow into the air, as 35·5 is to 29·3; that is, a little more than ⅘ths.

If this be, as is probable, a general rule for areas and speeds considerably different from the above, to find the quantity of air blown into one or more furnaces by the fan, we should calculate the volume by one of the above formulæ (1) or (2), and take ⅘ths of the result as the true quantity.

The fan A C, represented (*fig.* 1003), is of the best excentric form, as constructed by Messrs. Braithwaite and Ericsson. D is the circular orifice round the axis by which the air is admitted; and C C B is the excentric channel through which the air is wafted towards the main discharge pipe E. See Ventilation.

FOUNTAIN. A stream of water rising through the superficial strata.

FOWLER'S SOLUTION. A solution of arsenite of potash used in pharmacy.

FOXGLOVE. The *Digitalis purpurea*, a common British plant, belonging to the natural order *Scrophulariaceæ*. The leaves and other parts contain a poisonous principle called *digitaline*. In small doses foxglove is used as a diuretic and for lessening the action of the heart, but in larger doses it altogether stops the circulation. The vulgar name *foxglove* is said to be a corruption of *folk's-glove* (fairy's glove), in allusion to the shape of the flower.

FOXING, is a term employed by brewers to characterise the souring of beer, in the process of its fermentation or ripening.

FRACTIONAL DISTILLATION. A process of distillation, in which, by regulating the heat, fluids possessing different degrees of volatility are separated from each other. See Naphtha, Boghead.

FRACTURE OF MINERALS. The fracture of minerals has been grouped under the following heads, there being very few variations from them :—

1. *Conchoidal;* from *concha*, like *a shell*, when a mineral breaks with curved concavities; example, flint.

2. *Even;* when the surface of fracture is not rough, and has no small elevations and depressions.

3. *Splintery;* when the broken surface exhibits protruding points.

4. *Hackly;* when the elevations are sharp or jagged, as iron.

FRAME, *a mining term.* See Dressing of Ores.

FRANCOLITE. A variety of apatite. See Apatite.

FRANGULIN. A yellow crystalline substance obtained from the bark of the *Rhamnus frangula.*

FRANKFORT BLACK is a black used in copper-plate printing. It is said to be a charcoal obtained from grape and vine lees, peach kernels, and bone shavings. It is doubtful whether the finest black is not a soot produced from the combustion of some of these bodies. The preparation is, however, made much of a mystery.

FRANKINCENSE. The spontaneous exudations of the *Abies excelsa*, the *Norway spruce fir.* East Indian frankincense is said to be derived from certain species of *Boswellia.*

FRANKLINITE. A mineral related to magnetic iron-ore, crystallising in regular octahedra of an iron-black colour and metallic lustre. When scratched, it affords a dark reddish-brown streak. Its spec. grav. is 5·05 to 5·16. Franklinite is a combination of the sesquioxides of iron and manganese, with protoxide of zinc. The following figures give the mean of several recent analyses by Mr. F. C. Van Dyck ('Geology of New Jersey, 1868'); the excess in these analyses is probably due to the oxidation of the iron, which appears to exist partly in the state of protoxide; the magnetic properties of this species have also been attributed to the presence of protoxide of iron:—

	I	II
Sesquioxide of iron	68·3	74·8
Oxide of zinc	24·8	21·7
Red oxide of manganese	10·5	7·8
	103·6	104·3

I. From Stirling Hill Mine, N. J. II. From Mine Hill, N. J.

These are the two principal localities of franklinite. It occurs associated with red oxide of zinc (spartalite) and silicate of zinc (willemite) in metamorphic limestones of Silurian age. At Stirling Hill it forms the main constituent of the irregular deposit known as the 'Franklinite Vein.'

Franklinite was at first employed for the production of zinc; but for that purpose it did not answer commercially. It was then employed in combination with iron, and Major Farrington of New Jersey thus speaks of it:—'Many experiments have been made under my superintendence upon the ores of franklinite, and I have also witnessed several others of an interesting character made by other parties in mixing franklinite with pig iron in the puddling furnace, and also a mixture of franklinite-pig with other irons in their conversion to wrought iron. The result in all cases has been a great improvement in the quality of iron as manufactured. The most marked and, as I consider, the most valuable result is obtained by using from 10 to 15 per cent. of the weight of pig iron to be puddled with pulverised franklinite ore in the furnace at each heat. Iron of the most inferior quality when thus treated is converted into an article of No. 1 grade. The volatile nature of zinc at a high temperature, combining with the sulphur, phosphorus, and other volatile constituents of the coal, or that may be in the iron, being carried off mechanically, I consider is one of the causes of the improvement; the manganese also of the ore combines with silica at a high temperature, and pig iron that contains silica is thus freed from it. The great advantage to be obtained by using the pulverised ore in the puddling furnace is, that a high grade of iron may be made; and where re-heating has been hitherto deemed indispensable, one heating is found sufficient for such uses as wire billets, nuts, bolts, horseshoe iron, and nails. A particular selection of fuel is not required, coke and charcoal can be dispensed with, and bituminous or anthracite coal used.'

Franklinite is now employed by the New Jersey Zinc Company for the production of zinc, which is converted into oxide, whilst the cindery residues are smelted for Spiegeleisen. See Iron.

FREESTONE. A term used to denote any stone which is capable of being worked freely in every direction, and, which has no tendency to break in one direction more than another. In the counties of Wicklow and Dublin, and also in Cornwall, the term is applied to granite which works freely.—H.W.B.

FREEZING. (*Congélation*, Fr.; *Gefrierung*, Ger.) The three general forms, solid, liquid, and gaseous, under one or other of which all kinds of matter exist, are referrible to the influence of heat, modifying, balancing, or subduing the attraction of cohesion. Nearly every solid may be liquefied, and every liquid may be vaporised, by a certain infusion of heat, whether this be regarded as a moving power, or an elastic essence. The converse of this proposition is equally true; for many gases, till lately styled permanent, may be liquefied, nay, even solidified, by diminution of their temperature, either alone, or aided by a sufficient mechanical condensation, to bring their particles within the sphere of aggregative attraction. When a solid is transformed into a liquid, and a liquid into a gas or vapour, a quantity more or less considerable of heat is absorbed, or becomes latent, to use the term of Dr. Black. When the opposite transformation takes place, the heat absorbed is again emitted, or what was latent becomes sensible. See Heat for the more recent hypotheses.

The production of cold is a curious and interesting branch of physical inquiry. A few general laws may be distinctly named.

If a solid body suddenly liquefies, without the application of external heat, it abstracts from the surrounding bodies the heat necessary for its liquefaction.

When a salt is dissolved in water cold is produced.

If a liquid vaporises, the vapour is produced at the expense of the heat of some neighbouring body.

When spirits of wine, or ether, is thrown on the body, a sensation of coldness is produced from the vaporising liquids robbing the body of heat.

By placing water in a porous vessel, and exposing it to the sun, it becomes very cold. The solar heat-rays occasion a rapid evaporation of the water which has filtered through the pores of the vessel, and some heat is taken by the process from the fluid in the interior.

If air is allowed suddenly to expand, it takes heat from the surrounding bodies, or produces cold.

Sir John Herschel some years since recommended the following method for obtaining at moderate cost large quantities of ice:—

A steam-engine boiler was to be sunk into the earth and the quantity of water which it was desired to freeze placed in it. By means of a condensing pump, several atmospheres of air were forced into the boiler, and then everything was allowed to remain for a night, or until the whole had acquired the temperature of the surrounding earth. Then, by opening a stop-cock, the air expanding escaped with much violence, and the water being robbed of its heat to supply the expanding air, the temperature of the whole was so reduced, that a mass of ice was the result.

The most familiar method of producing intense cold is by means of freezing mixtures. A great number of these were invented by Mr. Walker; the principal results are contained in the following tables:—

I.—Table, consisting of Frigorific Mixtures, having the power of generating or creating cold without the aid of ice sufficient for all useful and philosophical purposes, in any part of the world at any season.

Frigorific Mixtures without Ice.

MIXTURES		Thermometer sinks	Deg. of cold produced
Nitrate of ammonia . . . Water	1 part 1	From + 50° to + 4°	46°
Chloride of ammonium . Nitrate of potash . . . Water	5 parts 5 16	From + 50° to + 10°	40
Chloride of ammonium . Nitrate of potash . . . Sulphate of soda . . . Water	5 parts 5 8 16	From + 50° to + 4°	46
Sulphate of soda . . . Diluted nitric acid . .	3 parts 2	From + 50° to − 3°	53
Nitrate of ammonia . . Carbonate of soda . . Water	1 part 1 1	From + 50° to − 7°	57
Phosphate of soda . . Dilute nitric acid . . .	9 parts 4	From + 50° to − 12°	62
Sulphate of soda . . . Hydrochloric acid . .	8 parts 5	From + 50° to − 0°	50
Sulphate of soda . . . Dilute sulphuric acid . .	5 parts 4	From + 50° to + 3°	47
Sulphate of soda . . . Chloride of ammonium . Nitrate of potash . . . Dilute nitric acid . . .	6 parts 4 2 4	From + 50° to − 10°	60
Sulphate of soda . . . Nitrate of ammonia . . Dilute nitric acid . .	6 parts 5 4	From + 50° to − 40°	64

II.—Table consisting of Frigorific Mixtures, composed of ice, with chemical salts and acids.

Frigorific Mixtures with Ice.

MIXTURES		Thermometer sinks		Deg. of cold produced
Snow, or pounded ice . . Chloride of sodium . .	2 parts 1	From any temperature	to −5°	*
Snow, or pounded ice . . Chloride of sodium . . Chloride of ammonium .	5 parts 2 1		to −12°	*
Snow, or pounded ice . . Chloride of sodium . . Chloride of ammonium . Nitrate of potash . . .	24 parts 10 5 5		to −18°	*
Snow, or pounded ice . . Chloride of sodium . . Nitrate of ammonium . .	12 parts 5 5		to −25°	*
Snow . . . . . . Dilute sulphuric acid . .	3 parts 2	From +32° to −23°		55
Snow . . . . . . Hydrochloric acid . .	8 parts 5	From +32° to −27°		59
Snow . . . . . . Dilute nitric acid . . .	7 parts 4	From +32° to −30°		62
Snow . . . . . . Chloride of calcium . .	4 parts 5	From +32° to −40°		72
Snow . . . . . . Cryst. chloride of calcium .	2 parts 3	From +32° to −50°		82
Snow . . . . . . Potash	3 parts 4	From +32° to −51°		83

N. B.—The reason for the omissions in the last column of the preceding table is, the thermometer sinking in these mixtures to the degree mentioned in the preceding column, and never lower, whatever may be the temperature of the materials at mixing. To produce these results in a satisfactory manner, it is necessary to cool, previously to the experiments, the vessels in which the mixtures are made.

A very intense cold may be obtained from the evaporation of a mixture of solid carbonic acid and sulphuric ether, by which a temperature of 166° Fahr. below the freezing point of water is produced. By means of this intense cold, assisted by mechanical pressure several of the gaseous bodies have been condensed into liquids, and in some instances solidified.

Natterer has obtained a temperature as low as −220° Fahr. by evaporation *in vacuo* of a mixture of liquid nitrous oxide and bisulphide of carbon.

The following process for producing cold has been patented in this country:—

In a reservoir, or what may with propriety be called a boiler, was placed a quantity of sulphuric ether. This reservoir was placed in a long vessel of saline water, this fluid by the arrangement being made to flow from one end of the trough to the other, that is to and from the reservoir. In this water was placed a number of vessels, the depth and breadth of the trough, but of only two inches in width, and these were filled with the water to be frozen.

A steam-engine was employed to pump the air from the reservoir; this being done, of course the ether boiled, and the vapour of the ether was removed by the engine as fast as it was formed. The heat required to vaporise the ether was derived from the saline water in the trough, and this again took the heat from the water in the cells; thus eventually every cell of water was converted into ice. The ether was, after it had passed through the engine, condensed by a refrigeratory of the ordinary kind. The statement made by the patentee was very satisfactory, as it regarded the cost of production. An apparatus of this kind is of course intended for hot countries only, where ice becomes actually one of the necessaries of life.

A peculiar physical fact connected with the freezing of water has been made available to some important uses. Water in freezing really rejects everything it may contain—even air, and hence solid ice is actually *pure* water. This may be easily proved. Make a good freezing mixture, and place some water in a flask, and while it is undergoing consolidation by being placed in the frigorific compound, gently agitate it with a feather. Now, if the water contains spirit, acid, salt, or colouring matter, either of them are alike rejected, and the solid obtained, when washed from the matter adhering to its surface, is absolutely pure solid water.

This philosophic fact, although it has only been subjected to examination within the last few years, has long been known.

Byron, in his 13th canto of 'Don Juan,' has the following allusion to it:—

> "I'll have another figure in a trice:—
> What say you to a bottle of champagne?
> Frozen into a very vinous ice,
> Which leaves few drops of that immortal rain,
> Yet in the very centre, past all price,
> About a liquid glassful will remain;
> And this is stronger than the strongest grape
> Could e'er express in its expanded shape."

The old nobles of Russia, when they desired a more intoxicating drink than usual, placed their wines or spirit in the ice of their frozen rivers, until all the aqueous portion was frozen; when they drank the ardent fluid accumulated in the centre. This plan has been employed also for concentrating lemon-juice and the like.

The manufacture of ice by machinery is one of the many interesting applications of science, and this has now become a practical trade. In 1851 M. Rezet, of Rouen, volatilized ether in a close vessel by exhausting the air from its surface. After the air, the ether-vapour itself was exhausted by a pump, then condensed by the aid of cold water, and forced back into the same vessel, by which a continual absorption of caloric from the surrounding bodies was effected, and a continual refrigeration obtained as long as the circulation of ether was kept up by working the pump.

Harrison's ice-making machine, and its improved form by Mr. Siebe, is a particular application of the exhausting air-pump. The working of the process is as follows:—A quantity of sulphuric ether, contained in a close vessel surrounded by a current of salt water, is made to pass rapidly into a state of vapour by the action of a large air-pump driven by steam-power; the necessary amount of heat requisite to effect this change in the ether is abstracted from the surrounding salt water casing, which is thus cooled to a temperature below the freezing point of water, and is then made to circulate through a box, containing the water to be frozen, in tin moulds arranged on a travelling frame, which moves in a direction contrary to the refrigerating current. The ether-vapour removed at every stroke of the pump is passed over to a condenser, where it reassumes the liquid form, and is returned to the evaporating vessel.

It will be seen that the principle in the machines of Harrison, Rezet, and Siebe is the same. The machine invented by M. Carré appears to be much more effective.

Messrs. Carré and Co.'s ice-making machines are of two kinds, one being continuous, and the other intermittent in action; but the principle involved is the same in both cases, viz., the production of cold by the volatilisation of a gas which is easily liquefiable, and at the same time in a high degree soluble in water. The smaller, or intermittent apparatus consists essentially of a pair of distilling and condensing vessels, united together by an air-tight joint, and capable of resisting an internal pressure of 150 lbs. to the square inch. The distilling vessel is filled with a watery solution of ammonia, at the maximum point of saturation. By the application of heat, the ammoniacal gas is driven off, and passes over into the receiver or condensing vessel, where it is soon liquefied by the constantly increasing pressure of the gas given off by the watery solution, a pressure of 97 lbs. to the square inch being sufficient to effect the liquefaction of the gas, when the temperature of the vapour does not exceed 50° Fahr. When the condenser is filled with pure fluid ammonia, the distilling vessel is removed from the fire, and is immersed in a vessel of water at the ordinary temperature of the air. By this means the water remaining in the distilling vessel is slightly cooled, and it immediately redissolves the column of ammoniacal gas standing above it, a vacuum is formed, and the liquefied gas immediately begins to distil back and redissolve. The heat necessary to effect this redistillation is abstracted from the water to be frozen, which is contained in a cylindrical mould, placed in the internal tube of the annular condensing vessel. The time required for producing 1 lb. of ice in the smallest size of the portable apparatus is 55 minutes; 25 minutes being required for the preliminary, and 30 minutes for the reverse distillation; it is during the latter period that the ice is produced. About four pounds of ice are produced for every pound of fuel consumed in the preliminary distillation.

The continuous apparatus is more complicated in construction; it consists of a boiler or distilling vessel, with the addition of a rectifier, formed of a series of horizontal tubes in which the gas is freed from the last trace of water by a current of weak ammonia water circulating in the opposite direction. From the rectifier the gas passes to a serpentine tube, forming part of the boiler, and thence into the condenser, a series of tubes cooled by a current of water to 60° Fahr. Here the gas is liquefied, and is driven over by the pressure in the boiler into a regulator, from which it passes into the freezing vessel, also formed of a series of spiral tubes, which are surrounded by a solution of chloride of calcium; the moulds containing the water to be frozen are placed in a vibrating frame, in order to cause the ice to form more rapidly. The return current of ammoniacal gas from the freezing vessel is passed over by an exhausting pump into a receiver, where it is redissolved in the spent water drawn from the boiler. The ice produced in the continuous apparatus varies between eight and fifteen times the weight of the fuel consumed: about a gallon of condensing water is required for every pound of ice produced. For some further matters connected with this peculiar condition, see WATER.

FREIBERGITE. An argentiferous fahlerz. See FAHLERZ.

FREIESLEBENITE. A sulphide of silver, lead, and antimony. See SILVER.

FRENCH BERRIES. The berries of the *Rhamnus catharticus*, and other species of the Buckthorn. The true French berries, which should be four-seeded, belong to the first named; all the two-seeded berries are obtained from other and inferior kinds. See BUCKTHORN.

FRENCH CHALK. A steatite; a soft magnesian mineral.

FRENCH POLISH. There are numerous methods given for the preparation of this polish; one of the best is probably the following: 1½ lb. of shell lac dissolved in a gallon of spirits of wine without heat. Another recipe is 12 ounces of shell lac, 2 ounces of gum elemi, and 3 ounces of copal to 1 gallon of spirits of wine.

FRENCH PURPLE. Amongst the most important of the modern improvements in the preparation of colouring matter from the lichens may be mentioned the preliminary extraction of the colouring acids of the lichens by digestion with an alkali (potash or lime) and the subsequent precipitation of these acids, whereby they are completely separated from the woody matters and other impurities. Dr. Stenhouse, to whom this valuable suggestion is due, recommends manufacturers to macerate the lichens on the spot with milk of lime, and then to precipitate the clear solution by means of an acid such as hydrochloric, or acetic acid, whereby the colour-yielding acids are separated. By subjecting these acids, more or less pure, to the action of air and ammonia, products are obtained not only free from woody fibre, but exhibiting brighter and deeper colours, not to speak of the economy and facility of manipulating a much smaller bulk of material during the most important stage of the manufacture.

Archil prepared by the usual methods, notwithstanding its fine colour, has the defect of being extremely liable to change by the action of acids and alkalis, and of easily deteriorating in colour when applied to silk, wool, or animalized cotton. Recently, however, a new kind of archil has been prepared, under the name of *French Purple*, distinguished in the first place by its very pure mauve or dahlia colour, and, secondly, by being much faster than common archil, and less sensitive to the action of acids.

This beautiful colour has been introduced and is chiefly manufactured by MM. Guinon, Marnas, and Bonnet, of Lyons. It is prepared as follows:—The lecanoric, erythic, evernic acids, &c., of the lichens are extracted by digestion with ammonia; the mass is pressed, the solution precipitated by a mineral acid, and the precipitate collected, washed, and re-dissolved in ammonia by the aid of heat, whereby a solution is obtained which, on exposure to the air at a temperature of 19° or 20° C., gradually assumes a very bright red colour. As soon as the tint has acquired sufficient intensity the liquid is introduced into shallow basins, and very slowly evaporated at a temperature between 40° and 60° C., care being taken not to exceed the latter limit. By this evaporation in contact with the air the liquid after a few days acquires a very deep violet colour, which undergoes no further change even by the action of acids. The violet solution, super-saturated with a strong acid, yields a copious flocculent precipitate of a very fine and rich garnet colour, which when collected on a filter, and washed to remove the saline mother liquid, constitutes French purple.

The dye thus prepared has not, however, attained the highest degree of beauty and purity of which it is susceptible. When used directly for dyeing wool or silk (for which purpose it does not require the aid of mordants, the colouring matter being simply dissolved in ammonia, and the solution diluted with the proper quantity of water), it imparts to them a violet colour having a reddish cast.

To obtain the dye in a state of greater purity it is converted into a lime or alumina lake. For this purpose the ammoniacal solution is precipitated with chloride of calcium or with alum; the red colouring matter then remains almost wholly in solution, and the lakes are collected, carefully washed with cold water, and dried at a gentle heat. They then present a violet or bluish aspect, and acquire a coppery lustre by friction.

French purple is generally sent into the market in the form of lime lake. To render it available for dyeing, the lake is decomposed and the colouring matter set free. For this purpose the lake is reduced to an impalpable powder, which is boiled with oxalic acid to separate the lime, and the colouring matter then dissolved out by ammonia. The lake may also be directly decomposed by boiling it with carbonate of ammonia. For printing, the lake is dissolved in acetic acid, and the solution mixed with alcohol and thickened.

In this manner, very fine and pure mauve and dahlia tints are obtained, especially on silk, without the use of mordants, properly so called. French purple, moreover, mixes easily with other colouring matters, such as ultramarine, indigo, carmine, cochineal, aniline red, &c., producing the most varied and delicate tints.

Recently, however, the manufacture of French purple has diminished in importance by the competition of the coal-tar purple. The upshot of this struggle will depend on the relative beauty and purity of the tints obtained, and on their comparative cost: for, so far as regards fastness and resistance to the influence of light, French purple is superior to aniline purple. See Watts's 'Dictionary of Chemistry.'

FRENCH TUB. A dyer's term for a mixture of protochloride of tin and logwood, called also 'plum tub.'

FRICTION. The resistance to motion which depends on the structure of the surfaces in contact. Friction is usually divided into two kinds: *sliding friction* and *rolling friction.* The questions involved in the consideration of friction are purely engineering, and cannot therefore be treated here. One very important element may, however, be named, as showing the importance of exact science in connection with the improvements in mechanics. By friction *heat* is evolved. It is found by accurate experiment, that the *quantity of heat evolved is exactly sufficient to reproduce the effort caused in overcoming the friction.—Joule and Thomson.*

FRIEZE. (*Frise,* Fr.; *Frisa,* Sp.) The nap on woollen cloth; hence it is applied to a coarse kind of woollen cloth or stuff with a nap on one side. See BAIZE.

FRIT. See ENAMEL and GLASS.

FRITTING. It was formerly the practice in glass-making to heat the glass-mixture to such an extent that an incipient fusion, or caking-together, commenced, during which the silica began to act upon the bases, the carbonic acid was partially expelled, and a *frit* was produced. The *Schmelz* of the Austrian and Bohemian glass-houses is a true *frit,* or an imperfectly-melted mixture, composed of lixiviated ashes and sand. See GLASS.

FRUIT. The fruit of a plant consists essentially of the matured ovary enclosing the seeds, or ripened ovules. But in many cases other parts of the flower enter into the composition of the fruit; in the apple, for example, the calyx adheres to the ovary, and, becoming succulent, forms the greater portion of the fruit. Few vegetable structures are more liable to be misunderstood than the fruit; many parts of a plant being popularly called fruit which have no scientific claim to the name, whilst many structures which are truly fruit in botanical language would not be generally recognised as such. The common idea of a soft succulent structure, like the berry and the drupe, is by no means necessary to the constitution of a fruit, many kinds of fruit, such as the nut and the capsule being dry and more or less hard. Among umbelliferous plants, the structures commonly called 'seeds,' such as aniseed, caraway seeds, coriander seed, &c., are true fruits; the external envelope, or seed-vessel, being firmly adherent to the enclosed seed. So too the grains of cereals are fruits, the albuminous seed being closely invested in a thin membranous coat, or pericarp.

Fruits not only furnish articles of diet—in some cases of great importance, as the date and the bread-fruit—but some of them yield oil—olive-oil and palm-oil, for example—whilst others possess a strong integument from which useful vessels are prepared, such as the gourds and calabashes.

FUCHSINE. See ANILINE RED.

FUCHSITE. A green micaceous mineral, containing chromium, found in the Tyrol.

FUCUS. A genus of sea-weeds. In the *Fucus serratus* and *F. ceramoides* silver has been detected: Malaguto has stated to the extent of $\frac{1}{100000}$, in the ashes of these plants. It has also been stated that these and some other plants contain lead and copper.

FUCUSINE and **FUCUSOL.** Two substances obtained by Dr. Stenhouse, by acting with sulphuric acid on certain species of *Fucus*.

FUD, or *Woollen Waste*, is the refuse of the new wool taken out in the scribbling process, and is mixed with the mungo for use. See MUNGO.

FUEL. (*Combustible*, Fr.; *Brennstoff*, Ger.) Such matters as are used for the economical production of fire. Wood, Turf, Coal, are familiar examples. Fuels differ in their nature, and in their power of giving heat, and consequently in their properties of developing heat when undergoing combustion. It is therefore important to understand the principle upon which depends the value of a particular fuel.

With the philosophy of the question we are scarcely called upon to deal in the present volume. A few remarks may not, however, be entirely out of place, and they may serve to guide the reader in his consideration of the production of heat by combustion—which is the only means of production with which we have to deal.

In his 'Novum Organum' Bacon writes: 'Heat is an expansive motion whereby a body strives to dilate and stretch itself to a larger sphere or dimension than it had previously occupied. This difference is most observable in flame—when the smoke or thick vapour manifestly dilates and expands into flame. . . . *Heat is a motion*, expansive, restrained, and acting in its strife upon the smaller particles of bodies. But the expansion is thus modified—while it expands in all ways, it has at the same time an inclination upwards—but the struggle in the particles is modified also, it is not sluggish, but hurried and with violence.'—*Bacon's Works*, Spedding's Translation, vol. iv.

Count Rumford's paper read before the Royal Society, January 25, 1798, entitled, 'An Enquiry concerning the Source of the Heat which is excited by Friction,' contains the results of his experiments made at Munich on the boring of brass cannon. He shows that by friction so much 'heat was generated' that the water in which the cannon during the operation of boring was placed, gained heat so rapidly that 'at two hours and twenty minutes it was 200°, and at two hours and thirty minutes it *actually boiled*.' He finds by careful estimates that the total heat produced was sufficient to raise 26·58 lbs. of ice-cold water to its boiling point, or through 180° F.; and that this heat is equal to that given out by the combustion of 2303·8 grains (or $4\frac{8}{10}$ oz. troy) of wax. Considering this interesting subject Count Rumford asks, 'What is heat? Is there any such thing as an *igneous fluid*? Is there anything that can with propriety be called *caloric*?' He then continues, 'We have seen that a very considerable quantity of heat may be excited by the friction of two metallic substances, and given off in a constant stream or flux in *all directions*, without interruption or intermission, and without any signs of diminution or exhaustion. . . . It is hardly necessary to add, that anything which any insulated body or system of bodies can continue to furnish without limitation cannot possibly be a material substance; and it appears to me to be extremely difficult, if not quite impossible, to form any distinct idea of anything capable of being excited and communicated in those experiments, except it be *motion*.'

Locke says, 'Heat is a very brisk agitation of the insensible parts of the object which produces in us that sensation from whence we denominate the object heat; so what in our sensation is *heat*, in the object is nothing but *motion*.'

Sir H. Davy wrote in 1812: 'The immediate cause of the phenomena of heat, then, is motion, and the laws of its communication are precisely the same as the laws of the communication of *motion*.'

These are the views entertained by those who do not believe heat to be matter. The *dynamical*, or as it is often called, the *mechanical theory*, of heat, assumes all heat to be a *motion of the ultimate particles of matter*.

The material hypothesis of heat, which held possession of the minds of most experimental philosophers—especially of Lavoisier and of Black—embraced the view which is well expressed by Gmelin in his 'Hand-book of Chemistry.' He says: 'Heat is *the substance* whose entrance into our bodies causes the sensation of warmth, and its egress the sensation of cold.' That is, heat was regarded as an infinitely subtile agent—a positive entity—which interpenetrated matter, in which it lay hidden, or latent, until it was by some exciting powers disturbed. This differs little, if anything, from the hypothesis of an all-pervading ether, which, being disturbed, produces one or the other of the so-called physical forces.

Heat can be produced by the effect of *gravitation*—a falling body, for example—but for all practical purposes water is really the only body we can employ to produce the motion necessary for the production or development of heat. A cataract or a river may be regarded as a constant means of obtaining the required motion. But this water has been lifted from the sea-level by the action of the solar heat, which has been produced in the sun, by, it would appear, the actual combustion of some material substances. Therefore, the heat which we obtain by the influence of the motion produced by the gravitating power of water, is really due to the emission of heat from the sun. By the influence of *Life*—vital force—we may produce motion and heat; but here again, as life is dependent upon solar heat, we have to look to the sun as its source. *Electricity* is another agent by means of which heat can be developed, but this power has a similar origin, in all probability, to heat itself. *Chemical action* in a vast number of cases produces the disturbance which is manifested as heat; and the combustion of all kinds of fuel may be considered to be but examples of chemical change. It is the operation especially of this source of heat, which we have to consider.

All the substances used by man for the production of Fire are chiefly of vegetable origin, as wood, peat, turf, and coal. Some few may possibly be derived from the animal kingdom, as some of the native bitumens. But either vegetable or animal fuel has originally gathered its heat from the sun—in the process of growth—and it has held that heat stored until a peculiar disturbance has liberated it for the use of man.

Numerous excellent experiments have been made for the purpose of determining with exactness the heating values of fuels of different kinds. Lavoisier and Laplace, in an extensive examination carried out by them, used their well-known *Calorimeter*, by which they determined the value of the heat by the quantity of ice melted in a given time. Count Rumford subsequently measured the quantity of heat by the increase of temperature in a given quantity of water. The quantity of heat which will melt 1 lb. of ice at 0° Cent. being just sufficient, according to Laplace, to raise the temperature of a pound of water to 75° Cent. or, according to the experiments of Regnault to 79° Cent. Clement and Desormes have also shown, that an equal weight of aqueous vapour, whatever may be its temperature and tension, is always produced by one and the same amount of heat.

As far as we can within the limits of the present work, we shall endeavour to present a full practical view of the subject, giving each class of fuels under their several heads.

1. *Wood*, which is divided into hard and soft. To the former belong the oak, the beech, the alder, the birch, and the elm; to the latter, the fir, the pine of different sorts, the larch, the linden, the willow, and the poplar.

Under like dryness and weight, different woods are found to afford very different degrees of heat and combustion. Moisture diminishes the heating power in three ways: by diminishing the relative weight of the ligneous matter, by wasting heat in its evaporation, and by causing slow and imperfect combustion. If a piece of wood contain, for example, 25 per cent. of water, then it contains only 75 per cent. of fuel, and the evaporation of that water will require $\frac{1}{28}$th part of the weight of the wood. Hence the damp wood is of less value in combustion by $\frac{8}{28}$ or $\frac{2}{7}$ than the dry. The quantity of moisture in newly-felled wood amounts to from 20 to 50 per cent.; birch contains 30, oak 35, beech and pine 39, alder, 41, fir 45. According to their different natures, woods which have been felled and cleft for 12 months contain still from 20 to 25 per cent. of water. There is never less than 10 per cent. present, even when it has been kept long in a dry place, and though it be dried in a strong heat, it will afterwards absorb 10 or 12 per cent. of water. If it be too strongly kiln-dried, its heating powers are impaired by the commencement of carbonisation, as if some of its hydrogen were destroyed.

The following Table, compiled from the researches of Count Rumford, will place these points clearly before us:—

One pound of the following woods when burnt will heat:	Pounds of water from 0° to 100° C.		
	Ordinary condition	Slightly dried	Strongly dried
Lime tree	34·708	38·833	40·131
Beech	33·798	...	36·746
Elm	30·205	...	34·083
Oak	25·590	29·210	29·838
Ash	30·666	33·720	35·449
Sycamore	...	...	36·117
Fir	30·322	34·000	37·379
Poplar	34·601	...	37·161

From every combustible the heat is diffused either by radiation or by direct communication to bodies in contact with the flame. In a wood fire the quantity of radiating heat is, to that diffused by the air, as 1 to 3; or it is one-fourth of the whole heating power.

II. *Charcoal.*—The different charcoals afford, under equal weights, equal quantities of heat. We may reckon, upon an average, that a pound of dry charcoal is capable of heating 75 pounds of water from the freezing to the boiling point; but when it has been for some time exposed to the air, it contains at least 10 per cent. of water, which is partially decomposed in the combustion into carburetted hydrogen, which causes flame, whereas pure dry charcoal emits none.

Winkler gives the following as the results obtained by him with charcoal from various sources:—

Charcoal from:	Pounds of water heated from 0° to 100° Cent. by 1 pound of charcoal	Air required by perfect combustion	Pounds of lead reduced by 1 pound of charcoal
Poplar	On an average 75·7.	On an average 293·5 cubic feet at 19° Cent.	33·56
Sycamore			33·23
Fir			33·51
Ash			33·23
Birch			33·71
Oak			33·74
Elm			33·26
Willow			33·49
Pine			33·53

A cubic foot of charcoal from soft wood weighs upon an average from 8 to 9 pounds, and from hard wood 12 to 13 pounds; and hence the latter is best adapted to maintain a high heat in a small compass. The radiating heat from charcoal fires constitutes one-third of the whole emitted. See Charcoal.

The following Table gives the approximate values of given weights of wood.

According to Landet, 'Polyt. Centr. 1854,' the value of fuel bought by volume corresponds to the product of the absolute heating power of fuel into the weight of a certain volume.

These two factors have the following value with various kinds of fuel:—

Kind of Fuel	Absolute heating power	Weight of 1 cubic mètre in kilos.
Holm oak (wood in large pieces or logs)	10,000	380
Red beech (logs)	9,941	380
Oak, both varieties in mixture (logs)	9,763	371
White beech (logs)	9,490	370
Oak (logs)	9,448	359
White beech (pieces and stumps in mixture)	9,392	338
Birch (logs)	9,260	381
Birch (pieces and stumps, &c., in mixture)	9,224	332
Birch (stumps)	8,836	318
Pine (stumps)	8,587	312
Oak (both varieties in mixture)	8,342	317
Red beech (stumps)	8,214	314
Alder (log-wood)	8,127	293
Alder (pieces and stumps in mixture)	8,070	291
White beech (stumps)	8,030	313
Red beech (branches)	7,953	304
Pine (branches)	7,898	287
Alder (stumps)	7,849	283
Pine (stumps)	7,808	283
Pine (branches)	7,752	281
White beech (branches)	7,644	298
Pine (logs)	7,624	377
Willow (pieces and stumps in mixture)	7,584	285
Birch (branches)	7,473	269
Willow (branches)	7,344	276
Aspen (pieces and stumps)	7,290	273
Oak (both varieties in mixture)	7,288	277
Pine (logs)	7,064	256
Charcoal	7,000	...
Turf dried at 100° C.	4,800	...
Turf containing 20 per cent. of water	3,600	...
Turf charcoal	5,800	...
Mineral coal of a medium quality	7,500	...
Do., containing 15 per cent. of ash	6,000	...
Wood dried at 100° C.	3,600	...

III. *Turf or peat.*—One pound of this fuel will heat, according to its quality, from 18 to 42 pounds of water from freezing to boiling. Its value depends upon its compactness and freedom from earthy particles; and its radiating power is to the whole heat it emits in burning as 1 to 3.

According to Berthier, the following results were obtained from peat:—

Source of the Peat.	Pounds of water heated by 1 pound of peat from 0° to 100° Cent.
From Troyes	18·1
„ department de la Somme	27·9
„ „ de la Marne	29·2
„ „ de la Vosges	34·9
„ „ des Landes	34·6

Winkler gives 26·9 as the evaporative power of the worst Hanoverian peat, and 42·6 as that of the best.

Peat obtained from the Bog of Allen gave, according to Griffith (the discrepancies between the results we do not understand):—

	Pounds of water heated from 0° to 100° Cent.
Upper peat	62·7
Lower peat	56·6
Pressed peat	28·0

See PEAT.

IV. *Coal.*—The varieties of coal are almost indefinite, and give out very various quantities of heat in their combustion. The carbon is the heat-giving constituent, and it amounts, in different coals, to from 75 to 95 per cent. One pound of good coal will, upon an average, heat 60 pounds of water from the freezing to the boiling point. Small coal gives out three-fourths of the heat of the larger lumps. The radiating heat emitted by burning pitcoal is greater than that by charcoal.

V. *The Coke of Coal.*—The heating power of good coke is to that of pitcoal as 75 to 69. One pound of the former will heat 65 pounds of water from 32° to 212°; so that its power is equal to nine-tenths of that of wood charcoal.

Berthier gives as the results of his trials:—

	Pounds of water heated by 1 pound of coal from 0° to 100° C.
Dowlais coal	72·0
Glamorgan „	70·7
Newcastle „	70·0
Derbyshire „	61·6
Lancashire „ (cannel)	53·2
Durham „	71·6
Coke (St. Etienne)	65·6
Do. gas from Paris	50·3

VI. *Carburetted Hydrogen or Coal Gas.*—One pound of this gas, equal to about 24 cubic feet, disengages in burning as much heat as will raise 76 pounds of water from the freezing to the boiling temperature.

In the following table the fourth column contains the weight of atmospheric air, whose oxygen is required for the complete combustion of a pound of each particular substance:—

Species of combustible	Pounds of water which a pound can heat from 0° to 212°	Pounds of boiling water evaporated by 1 pound	Weight of atmospheric air at 32°, to burn 1 pound
Perfectly dry wood	35·00	6·36	5·96
Wood in its ordinary state	26·00	4·72	4·47
Wood charcoal	73·00	13·27	11·46
Pitcoal	60·00	10·90	9·26
Coke	65·00	11·81	11·46
Turf	30·00	5·45	4·60
Turf charcoal	64·00	11·63	9·86
Carburetted hydrogen gas	75·00	13·81	14·58
Oil Wax Tallow	78·00	14·18	15·00
Alcohol of the shops	52·60	9·56	11·60

The quantity of air stated in the fourth column, is the smallest possible required to burn the combustible, and is greatly less than would be necessary in practice, where much of the air never comes into contact with the burning body, and where it consequently never has the whole of its oxygen consumed. The heating power stated in the second column is also the maximum effect, and can seldom be realised with ordinary boilers. The draught of air usually carries off at least one-seventh of the heat, and more if its temperature be very high when it leaves the vessel. In this case it may amount to one half of the whole heat, or more; without reckoning the loss by radiation and conduction, which however may be rendered very small by enclosing the fire and flues within proper non-conducting and non-radiating materials.

It appears that, in practice, the quantity of heat which may be obtained from any combustible in a properly-mounted apparatus, must vary with the nature of the object to be heated. In heating chambers by stoves, and water boilers by furnaces, the effluent heat in the chimney, which constitutes the principal waste, may be reduced to a very moderate quantity, in comparison with that which escapes from the best constructed reverberatory hearth. In heating the boilers of steam-engines, one pound of coal is reckoned adequate to convert 7½ lbs. of boiling water into vapour; or to heat 41¼ lbs. of water from the freezing to the boiling point. One pound of fir of the usual dryness will evaporate 4 pounds of water, or heat 22 lbs. to the boiling temperature; which is about two-thirds of the maximum effect of this combustible. According to Watt's experiments upon the great scale, one pound of coal can boil off with the best built boiler, 9 lbs. of water; the deficiency from the maximum effect being here $\frac{10}{57}$, or nearly one-sixth. *See the Tables at the end of this article.*

In many cases the hot air which passes into the flues or chimneys may be beneficially applied to the heating, drying, or roasting of objects; but care ought to be taken that the draught of the fire be not thereby impaired, and an imperfect combustion of the fuel produced. For, at a low smothering temperature, both carbonic oxide and carburetted hydrogen may be generated from coal, without the production of much heat in the fireplace.

Calorimeters.—To determine exactly the quantity of heat disengaged by any fuel in the act of burning, three different systems of apparatus have been employed: 1, the calorimeter of Lavoisier and Laplace, in which the substance is burned in the centre of a vessel whose walls are lined with ice, and the amount of ice melted measures the heat evolved; 2, the calorimeter of Watt and Rumford, in which the degree of heat communicated to a given body of water affords the measure of temperature; and 3, by the quantity of water evaporated by different kinds of fuel in similar circumstances.

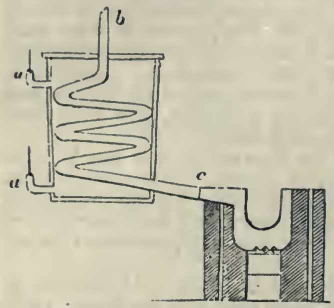
Lavoisier's.—The first and most celebrated, though probably not the most accurate apparatus for measuring the quantity of heat transferable from a hotter to a colder body, consisted of three concentric cylinders of tin plate, placed at certain distances asunder; the two outer interstitial spaces being filled with ice, while the innermost cylinder received the hot body, the subject of experiment. The quantity of water discharged from the middle space by the melting of the ice in it, served to measure the quantity of heat given out by the body in the central cylinder. A simpler and better instrument on this principle would be a hollow cylinder of ice of proper thickness, into whose interior the hot body would be introduced, and which would indicate by the quantity of water found melted within it the quantity of heat absorbed by the ice. In this case the errors occasioned by the retention of water among the fragments of ice packed into the cylindric cell of the tin calorimeter, would be avoided. One pound of water at 172° F., introduced into the hollow cylinder described, will melt exactly one pound of ice; and one pound of oil heated to 172° will melt half a pound. One constant source of error in this instrument is the *regelation* of the water from the liquified ice in passing through the ice, which still maintains a temperature below 32° F.

Meyer's Method of Refrigeration, contrived at first by Meyer, was brought to great perfection by Dulong and Petit. It rests on the principle, that two surfaces of like size, and of equal radiating force, lose in like times the same quantity of heat when they are at the same temperature. Suppose, for example, that a vessel of polished silver, of small size, and very thin in the metal, is successively filled with different pulverised substances, and that it is allowed to cool from the same elevation of temperature; the quantities of heat lost in the first instant of cooling will be always equal to each other; and if for one of the substances, the velocity of cooling is double of that for another, we may conclude that its capacity for heat is one half, when its weight is the same; since by losing the same quantity of heat, it sinks in temperature double the number of degrees.

The Method of Mixtures.—In this method two bodies are always employed: a hot body, which becomes cool, and a cold body, which becomes hot, in such manner that all the heat disengaged by the former is expended in heating the latter. Suppose, for example, that we pour a pound of quicksilver at 212° F., into a pound of water at 32°; the quicksilver will cool and the water will heat, till the mixture by stirring acquires a common temperature. If this temperature was 122°, the water and mercury would have equal capacities, since the same quantity of heat would produce in an equal mass of these two substances equal changes of temperature, viz., an elevation of 90° in the water and a depression of 90° in the mercury. But in reality, the mixture is found to have a temperature of only 37½°, showing that while the mercury loses 174½°, the water gains only 5½°; two numbers in the ratio of about 32 to 1; whence it is concluded, that the capacity of mercury is $\frac{1}{32}$ of that of water. Corrections must be made for the influence of the vessel and for the heat dissipated during the time of the experiment.

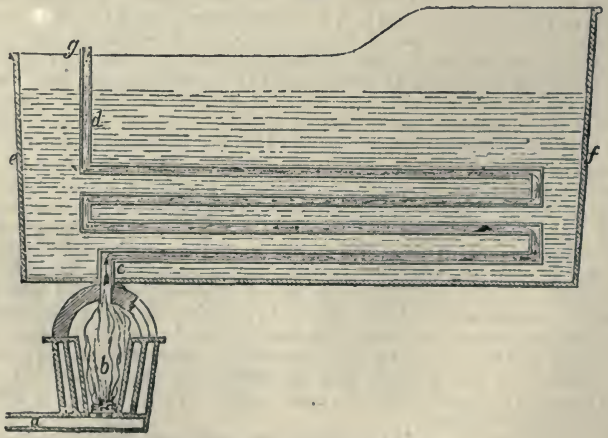
If our object be to ascertain the relative heating powers of different kinds of fuel, we need not care so much about the total waste of heat in the experiments, provided it be the same in all; and therefore they should be burned in the same furnace, and in the same way. But the more economically the heat is applied, the greater certainty will there be in the results. The apparatus, *fig.* 1004, is simple and well adapted to make such comparative trials of fuel. The little furnace is covered at top, and transmits its burned air by *c*, through a spiral tube immersed in a cistern of water, having a thermometer inserted near its top, and another near its bottom, into little side orifices, *a a*, while the effluent air escapes from the upright end of the tube *b*. Here also a thermometer-bulb may be placed. The average indication of the two thermometers gives the mean temperature of the water. As the water evaporates from the cistern, it is supplied from a vessel placed alongside of it. The experiment should be begun when the furnace has acquired an equability of temperature. A throttle valve at *c* serves to regulate the draught, and to equalise it in the different experiments by means of the temperature of the effluent air. When the water has been heated the given number of degrees, which should be the same in the different experiments, the fire may be extinguished, the remaining fuel weighed, and compared with the original quantity. Care should be taken to make the combustion as vivid and free from smoke as possible.

1004



The following calorimeter, founded upon the same principle as that of Count Rumford, but with certain improvements, may be considered as an equally correct instrument for measuring heat with any of the preceding, but one of much more general application, since it can determine the quantity of heat disengaged in combustion, as well as the latent heat of steam and other vapours.

1005



Scale about ½ inch to the square foot.

It consists of a large copper bath, *e, f* (*fig.* 1005), capable of holding 100 gallons of water. It is traversed four times, backwards and forwards, in four different levels, by a zig-zag horizontal flue or flat pipe *d*, *c*, nine inches broad and one deep, ending below in a round pipe at *c*, which passes through the bottom of the copper bath *e*, *f*, and receives there into it the top of a small black-lead furnace *b*. The innermost crucible contains the fuel. It is surrounded at the distance of one inch by a second crucible, which is enclosed at the same time by the sides of the outermost furnace; the strata of stagnant air between the crucibles serving to prevent the heat from being dissipated into the atmosphere round the body of the furnace. A pipe *a*, from a pair of cylinder double bellows, enters the ash-pit of the furnace at one side, and supplies a steady but gentle blast, to carry on the combustion, kindled at first by half an ounce of red-hot charcoal. So completely is the heat which is disengaged by the burning fuel absorbed by the water in the bath, that the air discharged at the top orifice *g* has usually the same temperature as the atmosphere.

The vessel is made of copper, weighing 2 lbs. per square foot; it is 5½ feet long, 1½ wide, 2 deep, with a bottom 5½ feet long, and 1¾ broad, upon an average. Including the zig-zag tin plate flue, and a rim of wrought iron, it weighs altogether, 85 lbs. Since the specific heat of copper is to that of water as 94 to 1,000, the specific heat of the vessel is equal to that of 8 lbs. of water, for which, therefore, the exact correction is made by leaving 8 lbs. of water out of the 600 or 1,000 lbs. used in each experiment.

In the experiments made with former calorimeters of this kind, the combustion was maintained by the current or draft of a chimney open at bottom, which carried off at the top orifice of the flue a variable quantity of heat, very difficult to estimate.

When the object is to determine the latent heat of steam and other vapours, they may be introduced through a tube into the top orifice *g*, the latent heat being deduced from the elevation of temperature in the water of the bath, and the volume of vapour expended from the quantity of liquid discharged into a measure glass from the bottom outlet *c*. In this case, the furnace is of course removed.

The heating power of the fuel is measured by the number of degrees of temperature which the combustion of one lb. of it raises 600 or 1,000 lbs. of water in the bath,—the copper substance of the vessel being taken into account.

It must be borne in mind that a coal which gives off much unburnt carburetted hydrogen gas does not afford so much heat, since in the production of the gas a great deal of heat is carried off in the latent state.

The economy of fuel, as exhibited in the celebrated pumping engines of Cornwall, will be dealt with under the proper head. See STEAM ENGINE. And in reference to the ordinary uses of fuel for domestic and other purposes, see STOVES.

Prof. T. S. Hunt, in the 'Canadian Naturalist,' July 1861, gives the results of the analyses by various chemists, taken chiefly from Bischof's 'Chemical Geology,' showing the relative proportions of the elements in wood, peat, coal, asphalte, and petroleum.

He states that 'the nitrogen, which in most cases was included with the oxygen in the analysis, has been disregarded, and the oxygen and hydrogen, for the sake of comparison, have been calculated for twenty-four equivalents of carbon.'

1. Vegetable fibre or cellulose	C^{24}	H^{20}	O^{20}
2. Wood, mean composition . . .	C^{24}	$H^{18\cdot4}$	$O^{16\cdot4}$
3. Peat (Vaux)	C^{24}	$H^{14\cdot4}$	O^{10}
4. ,, (Regnault)	C^{24}	$H^{14\cdot4}$	$O^{9\cdot6}$
5. Brown Coal (Schrötter)	C^{24}	$H^{11\cdot3}$	$O^{10\cdot6}$
6. ,, ,, (Woskresensky) . . .	C^{24}	H^{13}	$O^{7\cdot6}$
7. Lignite (Vaux)	C^{24}	$H^{11\cdot3}$	$O^{6\cdot4}$
8. ,, passing into mineral resin (Regnault)	C^{24}	H^{15}	$O^{3\cdot3}$
9. Bituminous coal (Regnault) . . .	C^{24}	H^{10}	$O^{3\cdot3}$
10. ,, ,, ...	C^{24}	H^{10}	$O^{1\cdot7}$
11. ,, ,, ...	C^{24}	$H^{8\cdot4}$	$O^{1\cdot2}$
12. ,, ,, ...	C^{24}	H^{6}	$O^{0\cdot9}$
13. ,, (Kühner and Gräger) .	C^{24}	$H^{7\cdot4}$	$O^{1\cdot3}$
14. ,, mean comp. (Johnston) .	C^{24}	H^{9}	$O^{2\cdot}$—$O^{4\cdot}$
15. Albert coal (Wetherell)	C^{24}	$H^{15\cdot9}$	$O^{1\cdot6}$
16. Asphalt, Auvergne.	C^{24}	$H^{17\cdot7}$	$O^{2\cdot2}$
17. ,, Naples	C^{24}	$H^{14\cdot6}$	O^{2}
18. Elastic bitumen, Derbyshire (Johnston) .	C^{24}	H^{22}	$O^{0\cdot3}$
19. Bitumen of Idria	C^{24}	H^{8}	...
20. Petroleum and naphtha	C^{24}	H^{24}	...

These analyses are very valuable as showing the variations which the different kinds of fuels exhibit in their passage from vegetable matter to bituminous coal.

The following Table, which has been constructed from the Reports made to the Admiralty by Sir Henry de la Beche and Dr. Lyon Playfair, gives

The Mean Composition of average Samples of Coals.

Name of Coal	Specific Gravity	Carbon	Hydrogen	Nitrogen	Sulphur	Oxygen	Ash	Percentage of Coke left by each Coal
South Wales :—								
Ebbw Vale	1·275	89·78	5·15	2·16	1·02	0·39	1·50	77·5
Merthyr	1·30	90·12	4·33	1·00	0·85	2·02	1·68	86·53
Bedwas	1·32	80·61	6·01	1·44	3·50	1·50	6·94	71·7
Plymouth Work	1·35	88·49	4·00	0·46	0·84	3·82	2·39	82·25
Resolven	1·32	79·33	4·75	1·38	5·07	included in ash	9·41	83·9
Neath Abbey	1·31	89·04	5·05	1·07	1·60	...	3·55	61·42
Llynvi	1·28	87·18	5·06	0·86	1·33	2·53	3·04	72·94
Llangennech	1·312	85·46	4·20	1·07	0·29	2·44	6·54	83·69
Pontypool	1·32	80·70	5·66	1·35	2·39	4·38	5·52	64·8
Newcastle :—								
Willington	...	86·81	4·96	1·05	0·88	5·22	1·08	72·19
Haswell Wallsend	1·286	83·47	6·68	1·42	0·06	8·17	0·20	62·70
Hedley's Hartley	1·31	80·26	5·28	1·16	1·78	2·40	9·12	72·31
Carr's Hartley	1·25	79·83	5·11	1·17	0·82	7·86	5·21	60·63
N. Percy Hartley	1·25	80·03	5·08	0·98	0·78	9·91	3·22	57·18
Broomhill	1·25	81·70	6·17	1·84	2·85	4·37	3·07	59·20
Derbyshire :—								
Elsecar	1·296	81·93	4·85	1·27	0·91	8·58	2·46	61·6
Park Gate	1·311	80·07	4·92	2·15	1·11	9·95	1·80	61·7
Butterley Portland	1·301	80·41	4·65	1·59	0·86	11·26	1·23	60·9
Staveley	1·27	79·85	4·84	1·23	0·72	10·96	2·40	57·86
Lancashire :—								
Ince Hall Arley	1·272	82·61	5·86	1·76	0·80	7·44	1·53	64·0
Balcarres Arley	1·26	83·54	5·24	0·98	1·05	5·87	3·32	62·89
Pemberton Yard	1·348	80·78	6·23	1·30	1·82	7·53	2·34	60·6
Rushy Park Mine	1·28	77·76	5·23	1·32	1·01	8·99	5·69	56·66
Cannel Wigan	1·23	79·23	6·08	1·18	1·43	7·24	4·84	60·33
Balcarres, 5-feet	1·26	74·21	5·03	0·77	2·09	8·69	9·21	55·90
Moss Hall New Mine	1·278	77·50	5·84	0·98	1·36	12·16	3·16	57·7
Scotch :—								
Wallsend Elgin	1·20	76·09	5·22	1·41	1·51	5·05	10·70	58·45
Dalkeith Coronation	1·316	76·94	5·20	trace	0·38	14·37	3·10	53·5
Eglinton	1·25	80·08	6·50	1·55	1·38	8·05	2·44	54·94
Dalkeith Jewel Steam	1·277	74·55	5·14	0·10	0·33	15·51	4·37	49·8
Grangemouth	1·29	79·85	5·28	1·35	1·42	8·58	3·52	56·6
Sundry :—								
Bagillt	1·269	88·48	5·62	2·02	1·36	0·86	1·62	55·8
Ewlowe	1·275	80·97	4·96	1·10	1·40	8·20	3·37	54·5
Ibstock	1·291	74·97	4·83	0·88	1·45	11·88	5·99	50·8
Borneo :—								
Labuan	1·28	64·52	4·74	0·80	1·45	20·75	7·74	...
Three-feet Seam	1·37	54·31	5·03	0·98	1·14	24·22	14·32	...
Eleven-feet Seam	1·21	70·30	5·41	0·67	1·17	19·19	3·23	...
Van Diemen's Land :—								
Tingal	...	57·21	3·58	1·20	1·32	7·80	29·09	...
Tasman's Peninsula	...	65·54	3·36	1·91	1·03	1·75	26·41	...
Whale's Head	...	65·86	3·18	1·12	1·14	7·20	21·50	...
Adventure Bay	...	80·22	3·05	1·36	1·90	4·80	8·67	...
Sydney	...	82·39	5·32	1·23	0·70	8·32	2·04	...
Formosa	1·24	78·26	5·70	0·64	0·49	10·95	3·96	...
Vancouver's Island	...	66·93	5·32	1·02	2·20	8·70	15·83	...
Conception Bay	1·29	70·55	5·76	0·95	1·98	13·24	7·52	...
Trinidad	...	65·20	4·25	1·33	0·69	21·69	6·84	...

Most persons interested in the uses of coal for manufacturing purposes will be able to calculate readily the value of any of those coals as fuel.

The following Table will show in a yet more satisfactory manner the value of varieties of coal as fuel.

Report of Trials of Coals at Woolwich Dockyard, between February 9, 1848, *and March* 31, 1858.

Description of the Fuel tried	Number of Trials from which the Average Results are deduced	Pounds of Water evaporated to 1 lb. Coal consumed, calculated from 100° constant Temperature of the Feed Water	Cubic Feet of Water evaporated per Hour, calculated from 100° constant Temperature of the Feed Water	Percentage of Clinker	Percentage of Ash	Percentage of both Clinker and Ash	Smoke
WELSH COALS:—							
Abercarn Black Vein	1	9·01	46·49	1·25	4·46	5·71	No record
Aberdare Steam Coal	1	8·98	48·81	1·72	5·93	7·65	Light smoke
,, Fothergill's	1	9·44	47·6	1·79	4·37	6·16	Lightbrownsmoke
,, Bwllfa	2	9·4	50·28	1·43	5·75	7·19	Light smoke
Bedwas	1	8·35	45·3	2·08	6·16	8·25	Black smoke
Birchgrove Graigola	3	8·53	48·37	1·43	9·13	10·55	Nearly smokeless
Blaendare Big Seam	1	8·28	43·76	3·34	5·1	8·44	Black smoke
,, Merthyr	1	9·06	47·68	3·12	6·14	9·26	Light smoke
Blaengwaur Merthyr	7	9·38	49·44	1·53	5·84	7·37	Light brown
Brymbo Main	2	8·52	44·24	·95	6·4	7·35	No record
,, 2-yard Vein	1	8·45	45·02	1·13	6·49	7·62	,,
,, 4-feet Vein	1	8·34	43·03	1·08	5·7	6·78	,,
,, Steam Coal	2	7·95	50·47	1·57	4·81	6·4	Black smoke
Bute Merthyr	5	9·2	48·39	3·07	5·19	8·26	Light brown
Camnethan	2	8·21	51·91	·55	3·99	4·54	Brown, moderate quantity
Carr's Merthyr	3	9·14	49·21	1·99	5·23	7·21	Black smoke
Charcoal Vein	1	8·98	46·79	1·95	5·06	7·01	No record
Coed Talon	5	7·68	52·11	·96	5·4	6·36	Light smoke
Coleshill Coal	1	7·68	52·06	·25	3·11	3·36	No record
,, Bagillt	2	7·92	49·33	·62	3·57	4·19	,,
Cwm Ammon	4	8·6	45·02	1·75	3·61	5·36	Light smoke
,,	6	8·93	45·93	2·01	5·27	7·28	,,
Cwmfrood Rock Vein	1	8·72	46·88	2·11	4·18	6·29	Black smoke
Ebbw Vale	3	9·26	38·79	1·78	6·78	8·56	Lightbrownsmoke
,,	1	9·09	43·82	2·51	6·41	8·92	No smoke
Elled's Vein	3	9·1	51·21	1·55	5·29	6·84	Brown, large quantity
Elsecar Hard Steam Coal	3	8·27	45·99	·73	5·33	6·06	No record
Enloe Colliery	2	8·28	48·36	1·31	3·71	5·02	Little smoke
Garden Edge Colliery Coal	3	8·41	50·87	·98	5·14	6·12	Black, moderate quantity
Gellia Cadaxton Steam Coal	2	8·91	49·97	·68	5·7	7·38	Very light smoke
,, Steam Coal	2	8·54	43·83	·87	6·21	9·09	No record
Golynos	1	9·02	42·62	·69	3·91	5·6	Black smoke
Graigola Steam Coal	3	8·89	35·59	·42	6·69	8·11	No smoke
,, ,, (handpicked)	1	8·84	41·02	·71	5·52	6·23	No record
Gwythen Charcoal Vein	1	8·21	47·55	·95	4·4	6·35	Light smoke
,, ,,	4	8·95	48·16	2·7	3·8	6·51	No smoke
Little Raith Lochgelly	2	7·27	46·68	·92	7·43	8·35	Much light smoke
Llanelly	1	8·43	46·43	1·96	6·8	8·76	No record
Llangennech	2	8·81	46·52	2·36	6·41	8·77	No smoke
,, (handpicked)	2	8·44	44·92	2·03	5·73	7·76	,,
Lochgelly Coal	2	7·66	46·06	·1	4·12	4·22	Light smoke
Machen Black Vein	1	8·81	50·44	2·1	5·39	7·49	Black smoke
Machen Rock Vein	1	8·32	47·27	1·37	4·78	6·16	Much black smoke
Merthyr	28	8·78	45·42	1·02	5·54	6·56	Light smoke
,,	4	9·06	48·17	1·66	4·56	6·23	,,
,, Aberamon	1	8·63	47·72	1·49	3·97	5·46	,,
,, Aberdare	3	8·75	46·78	1·61	4·06	5·67	No record
,, ,, Fothergill's	43	8·51	44·79	1·47	4·53	6·	Light smoke
,, Crosfield	2	9·37	45·14	1·25	6·38	7·63	No record
,, ,, and Gadley's	1	8·66	46·12	·91	7·53	8·44	,,
,, (handpicked)	8	8·92	45·85	1·13	4·82	5·95	Light smoke
,, Nixon's	6	8·78	45·54	·98	4·34	5·32	,,
,, Wensleydale	1	8·91	45·84	·61	6·49	7·1	No record
,, Wood's.	1	8·87	43·7	·67	5·68	6·35	,,
Morfa Steam Coal	1	8·53	44·63	1·12	4·63	5·75	Black smoke
,, ,, Vivian's	2	8·6	44·94	1·3	5·23	6·54	Much black smoke
Nevill's Llanelly	2	8·56	47·59	2·03	5·8	7·83	Light smoke
New Black Vein Steam Coal	2	9·56	50·67	·79	5·75	6·54	Large quantity of brown smoke
Newelline	1	8·97	48·25	2·21	6·25	8·46	No record
Powell's Duffryn	1	9·08	48·26	1·35	6·81	8·16	Light smoke
Resolven	9	9·06	48·1	1·77	5·48	7·25	Light brown
,, (handpicked)	1	8·64	45·32	·54	4·35	4·89	No record
,, ,,	1	9·15	49·79	1·75	4·4	6·15	,,

Description of the Fuel tried	Number of Trials from which the Average Results are deduced	Pounds of Water evaporated to 1 lb. Coal consumed, calculated from 100° constant Temperature of the Feed Water	Cubic Feet of Water evaporated per Hour, calculated from 100° constant Temperature of the Feed Water	Percentage of Clinker	Percentage of Ash	Percentage of both Clinker and Ash	Smoke
WELSH COALS :—							
Risca Rock Vein . . .	1	8·26	46·67	1·87	5·22	7·09	No record
Rock Vein	2	8·6	48·11	2·39	5·89	8·28	,,
Squborwen Merthyr . . .	12	8·93	46·51	1·85	6·	7·85	Light smoke
Thomas' Merthyr . . .	2	9·28	49·99	1·84	4·61	6·45	No record
Tillery Big Vein . . .	2	8·89	51·99	1·07	4·57	5·64	,,
Wagnus' Merthyr . . .	2	8·79	47·25	1·76	6·48	8·24	,,
Waynes' Merthyr . . .	1	8·98	48·43	1·79	5·23	7·02	Very light smoke
Welsh Coal	2	9·33	48·62	1·75	6·16	7·92	No record
NORTH COUNTRY COALS :—							
Alloa Colliery	2	8·89	55·07	1·01	5·02	6·04	Little black smoke
Atherton Steam Coal . .	4	8·22	48·76	·74	4·93	5·67	Black smoke
Barlieth and Dollar's Steam Coal	1	7·95	49·45	·46	4·17	4·63	Black, moderate quantity
,, Steam Coal . . .	4	8·32	49·39	1·29	4·17	5·46	Light brown
Bates' Hartley	1	6·71	45·66	2·12	4·12	6·24	No record
,, West Hartley . . .	3	7·7	46·41	1·34	5·23	6·56	Black smoke
Bebside Colliery Coal . .	4	8·14	49·82	·95	4·6	5·55	,,
Bell's Primrose	3	9·46	45·67	2·4	6·68	9·08	No record
Bourtreehill Coal . . .	1	7·56	45·96	1·27	4·67	5·94	Much smoke
Buddle's Hartley . . .	23	7·79	47·98	1·49	4·08	5·58	Dark smoke
,, West Hartley . .	38	8·05	48·34	1·41	4·47	5·87	Black smoke
Carr's Hartley	9	8·05	48·63	1·71	3·76	5·47	Black, large quantity
Clackmannan	3	8·09	45·39	·67	4·76	5·43	Black smoke
Cuttlehill	1	7·72	42·57	..	5·74	..	No record
Derwentwater, Radcliffe Colly.	1	8·27	50·22	1·1	3·8	4·93	Black smoke
,, West Hartley .	1	7·69	48·23	1·67	4·72	6·39	No record
Earsdon's Hartley . . .	3	8·25	50·12	·71	4·88	5·59	Great quantity of black smoke
Garforth's Hartley . . .	2	8·06	50·11	·61	5·75	6·36	Heavy smoke
Garforth Steam Coal . .	2	7·12	40·33	1·26	5·6	6·86	Light smoke
Garswood Park	1	7·99	51·61	1·19	5·29	6·48	No record
Gawber Hall	2	8·14	42·49	1·05	4·11	5·16	,,
,, Steam Coal . .	5	7·84	43·01	1·25	5·8	7·05	Light smoke
Gower Coal	2	7·83	44·58	·92	5·28	6·21	Black smoke
Grey's Broomhill . . .	5	8·04	48·87	1·14	5·66	6·79	Heavyblacksmoke
Grimsby Coal, Sheffield Railway	1	7·46	45·84	1·69	4·24	5·93	No record
Halsnead Coal	3	7·48	47·23	1·24	3·69	4·93	Dark smoke
Hartley Coal	2	7·74	45·78	1·06	5·77	6·83	No record
,, Bates' West . .	1	7·39	48·27	·66	7·07	7·73	Heavyblacksmoke
,, Belmont . . .	2	8·4	46·3	1·43	3·97	5·41	No record
,, Buddle's . . .	4	7·8	45·61	1·15	4·11	5·27	Much smoke
,, ,, West . .	17	7·82	46·33	1·28	4·09	5·38	Black smoke
,, Carr's	15	8·19	45·45	1·22	3·93	5·14	Dark smoke
,, ,, West . .	1	8·35	48·43	1·	5·88	6·88	Heavy black
Hartley, Clifton's West . .	3	7·91	45·02	1·48	4·57	6·05	,,
,, Cowpen . . .	2	7·63	44·87	·73	5·94	6·68	No record
,, Fenham's . . .	21	8·53	43·47	2·07	5·1	7·17	Heavy black
,, ,, West . .	1	8·87	42·41	2·89	6·25	9·14	,,
,, Hedley's . . .	1	8·4	47·02	1·29	2·91	4·2	No record
,, Hetton West . .	3	8·45	47·39	1·18	6·98	8·16	,,
,, Howard's W. Netherton	2	7·67	46·22	1·35	6·8	8·15	,,
,, Jonassohn's . .	4	8·09	49·12	·88	5·34	6·23	Little black smoke
,, Longridge West . .	1	7·82	47·57	1·46	3·75	5·21	No record
,, ,, Best .	2	7·86	46·1	1·18	3·39	4·57	Light smoke
,, Morpeth . . .	6	7·87	47·58	1·52	4·7	6·22	Little black smoke
,, Newcastle . . .	2	8·49	45·41	2·07	5·73	7·81	No record
,, Wellington West .	1	8·89	42·48	1·37	5·09	6·46	Black smoke
,, Whitworth . . .	2	8·4	42·88	1·79	3·81	5·61	,,
,, Willington West . .	1	8·93	43·11	1·35	3·65	5·	No record
Hastings Hartley . . .	1	7·73	47·45	1·16	3·94	5·1	Heavyblacksmoke
Heaton Colliery . . .	3	8·79	46·2	2·38	6·29	5·67	Much smoke
Howard's West Hartley . .	17	8·08	49·58	1·24	4·69	5·93	Dark smoke
,, Netherton . .	6	9·58	58·36	2·22	5·14	7·36	,,
Hoyland Colliery . . .	2	8·7	48·98	·55	3·95	4·5	Black smoke
,, and Elsecar . .	3	8·15	45·78	·67	4·12	4·79	No smoke
Ince Hall Coal	2	7·72	45·22	1·44	5·4	6·85	Very smoky
,, ...	1	8·04	45·62	1·08	3·76	4·84	No record
Kilnhurst Hard . . .	1	7·74	45·77	1·21	3·24	4·45	Much black smoke
Land Engine Coal . . .	1	7·86	48·09	1·51	4·68	6·19	No record
Lindsay Mine	2	7·9	42·86	2·04	2·83	4·88	,,
Lord Rosslyn's Coal . . .	1	6·11	42·66	1·67	6·08	7·75	Black smoke
Lord Ward's Steam Coal . .	2	7·6	51·3	1·36	4·37	5·74	Brown, immoderate quantity
Lumley's Steam Coal . .	2	8·54	37·4	1·01	6·63	7·64	No record
Lundhill Hard Coal . . .	2	8·84	49·19	1·22	3·92	5·14	Black, in great quantity

Description of the Fuel tried	Number of Trials from which the Average Results are deduced	Pounds of Water evaporated to 1 lb. Coal consumed, calculated from 100° constant Temperature of the Feed Water	Cubic Feet of Water evaporated per Hour calculated from 100° constant Temperature of the Feed Water	Percentage of Clinker	Percentage of Ash	Percentage of both Clinker and Ash	Smoke
NORTH COUNTRY COALS :—							
Lundhill Soft Coal . . .	3	8·55	50·42	1·6	3·87	5·47	Black, in great quantity
Lyon's West Hartley . .	4	8·71	52·73	1·17	4·95	6·12	Black smoke
Midgeholme	2	9·25	44·26	·59	6·16	6·76	No record
North Country Coal . . .	1	8·16	50·14	1·47	5·03	6·5	Heavyblacksmoke
North Gawber Steam Coal .	1	7·71	45·04	·85	4·59	5·44	No record
Oaks Colliery	4	7·75	44·91	·42	6·03	6·46	Heavy smoke
Orrell Steam Coal . . .	2	8·78	42·61	1·54	6·82	8·37	No record
Ramsay's Adair's Main . .	3	8·65	43·1	1·01	5·35	6·36	Light brown
Ravensworth's Hartley . .	3	7·77	48·44	1·63	4·79	6·42	Heavyblacksmoke
Rochsole's Colliery . . .	3	7·76	46·54	1·67	2·82	4·49	Light smoke
Skerrington Coal . . .	3	7·81	47·6	1·03	3·63	4·66	Much smoke
,, Colliery. . .	2	8·69	52·45	1·67	5·73	7·41	Light smoke
Splint Coal	3	7·25	42·29	·67	4·2	4·87	,,
St. Helen's Tees . . .	3	9·19	54·15	·33	4·78	5·11	Black, in large quantity
Staveley Main Coal . . .	8	7·69	41·27	·71	4·26	4·96	Light smoke
Strangeways' Colliery, 3 ft. Seam	1	7·91	48·17	·87	5·28	6·15	Black, in small quantity
Walthen House, or New House	1	8·62	49·11	2·85	5·07	7·92	No record
Washington's West Hartley .	2	8·63	48·26	2·91	5·98	8·89	Black smoke
Wather House Steam Coal .	4	7·84	47·75	2·46	3·64	6·11	No record
Wellington Hartley . . .	1	7·84	49·92	1·51	4·09	5·6	Black smoke
Wellwood Colliery . . .	2	7·97	50·25	1·05	7·05	8·1	Heavyblack smoke
West Hartley	2	8·08	47·97	1·79	4·46	6·25	Heavy smoke
Whitefield Colliery . . .	2	9·49	52·17	·05	4·42	4·47	Littlebrownsmoke
Whitworth Park . . .	2	8·79	46·49	·92	5·14	6·07	No record
Wigan, 4 ft. Seam . . .	1	7·97	45·38	1·64	5·75	7·39	,,
Wombwell Main . . .	3	8·26	44·89	·81	4·5	5·31	,,
Yate Deep Vein	3	8·26	51·11	3·1	4·47	7·57	Much black smoke
ANTHRACITE COAL :—	2	9·58	35·43	1·48	10·32	11·81	No record
,, ,, ...	4	6·87	26·64	·18	2·42	2·6	Nearly smokeless
,, ,, Bonville's Court	3	8·35	31·19	1·02	5·57	6·59	No record
,, ,, Killgetty . .	6	9·02	42·68	·64	11·3	11·94	,,
,, ,, Watney's . .	4	8·87	41·44	1·48	6·58	8·06	Smokeless
CAMBRIAN STEAM FUEL . .	3	8·32	45·45	1·17	5·81	6·98	
CHILIAN COAL	1	7·29	38·83	2·8	3·33	6·13	Light smoke
COKE, CONSOLIDATED . . .	2	8·76	19·47	·14	19·11	19·25	No record
PATENT FUEL	1	8·59	48·85	1·97	4·21	6·18	,,
,, ...	3	9·11	48·2	2·4	3·86	6·26	Black smoke
,, Captain Cochrane's	1	4·01	22·09	7·76	32·5	40·26	No record
,, Holland's . .	6	7·94	39·51	1·7	6·3	8·	Light brown
,, Lyon's . . .	2	8·98	47·4	2·86	4·37	7·24	No record
,, Temperly's . .	3	8·5	42·45	·99	7·19	8·19	,,
,, Warlich's . .	8	8·7	44·12	2·4	7·64	10·04	Littlebrown smoke
,, ,, . . .	4	9·16	46·47	3·03	5·62	8·65	No record
PORT ADELAIDE	1	6·44	32·3	7·42	23·35	30·77	No smoke
SINGAPORE COAL . . .	1	6·97	48·67	..	9·99	..	No record
ST. DOMINGO (Samana) . .	1	1·29	10·59	..	18·	18·	Little smoke

The calorific values of a selected variety of coals, as tried under circumstances considered the most favourable for the development of heat, will be found in the Table at top of next page; the result being given in a somewhat different form from the result in the preceding Tables. See COAL; COKE.

On Liquid Fuel.—The proposal to substitute for the coal now used as fuel in steam-vessels some kind of liquid combustible, arose from the discovery of vast quantities of petroleum in America; and it was that material which was in the first instance recommended as the substitute for coal. A commission appointed in America to investigate the subject reported that petroleum was beyond doubt more than twice as effective as anthracite coal in the production of steam, and that steam could, by the use of this material, be produced in less than half the usual time.

It was an inference by no means unnatural that, if this were the case, and if coal could be superseded by this material as the fuel of steam-vessels, a very great portion of the space required in merchant steamers for the stowage of coal would be rendered available for more profitable cargo; that steam-packets might become independent of coal depôts at various points of their passage; and that ships of war would be enabled to keep the sea for a very much longer time than they now do with coal. Any prospect of such advantages as these being attainable might reasonably have been expected to justify a more thorough and searching investigation of this subject than it has yet received in this country.

Name or Locality of Coal	Actual Number of lbs. of Water converted into Steam by 1 lb. of Coal	Number of lbs. of Water converted into Steam by the Coke left by the Coal	Total Number of lbs. of Water convertible into Steam by 1 lb. of the Coal	Amount of Ammonia corresponding to the Nitrogen contained in the Coal	Amount of Sulphate of Ammonia corresponding to the Nitrogen contained in the Coal
	Practical	Theoretical	Theoretical		
Graigola	9·35	11·301	13·563	0·497	1·932
Anthracite, Jones and Co.	9·46	12·554	14·593	0·225	0·990
Old Castle Fiery Vein	8·94	10·601	14·936	1·590	6·175
Ward's Fiery Vein	9·40	..	14·614	1·238	4·808
Binea	9·94	11·560	15·093	1·586	6·741
Llangennech	8·86	10·599	14·260	1·299	5·044
Pontrepoth	8·72	10·873	14·838	0·218	0·848
Pontrefellin	6·36	10·841	13·787	a trace	..
Powell's Duffryn	10·14	11·134	15·092	1·76	6·835
Mynydd Newydd	9·52	9·831	14·904	1·808	7·340
Three-Quarter Rock Vein	8·84	7·081	13·106	1·299	5·044
Cwm Frood Rock Vein	8·70	8·628	14·788	1·347	5·232
Cwm Nanty Gros	8·42	8·243	13·932	1·919	7·448
Resolven	9·53	10·234	13·971	1·675	6·505
Pontypool	7·47	8·144	14·295	1·639	6·364
Bedwas	9·79	8·897	14·841	1·748	6·788
Ebbw Vale	10·21	10·441	15·635	2·622	10·185
Porth Mawr Rock Vein	7·53	6·647	12·811	1·554	6·033
Coleshill	8·0	6·468	12·799	1·785	6·930
Dalkeith Jewel Seam	7·08	6·239	12·313	1·214	0·471
Dalkeith Coronation	7·71	6·924	12·772	a trace	..
Wallsend Elgin	8·46	6·560	13·422	1·712	6·647
Fordel Splint	7·56	6·560	13·817	1·372	5·327
Grangemouth	7·40	7·292	13·692	1·639	6·364
Broomhill	7·30	7·711	14·863	2·234	8·674
Park End Lydney	8·52	6·567	13·257	1·477	9·617
Slievardagh	9·85	10·895	12·482	0·279	1·084

Besides petroleum, several other analogous materials have been proposed as substitutes for coal; for instance, the oil obtained by distilling particular kinds of coal, or the shale which occurs in coal formations, and more recently the oil known as 'dead oil,' which is one of the products obtained in rectifying the coal-tar of gas works. All these materials resemble each other closely in being composed chiefly of carbon and hydrogen, which are, in various proportions, the combustible and heat-producing constituents of all kinds of fuel. For the application of these materials and of liquid fuel generally, various methods have been proposed. It is desirable to consider in the first place, what is the evaporative power of these materials respectively, since that is a very important point to determine in regard to the question as to the relative merits of these different kinds of fuel.

The following table gives several examples of the total evaporative powers of some kinds of fuel, as calculated from their chemical composition:—

	C.	H.	O.	A.	E.	Evap. due to	
						C.	$H.—\frac{O}{8}$
Charcoal	·93	0	0	11·5	14·0	14·0	0
Coke	·88	0	0	10·6	13·2	13·2	0
Rock-oils $C^{18} H^{20}$	·84	·16	0	15·75	22·7	12·7	10·0
Rock-oils $C^{26} H^{28}$	·85	·15	0	15·65	22·5	12·66	9·84
Coal	·87	·05	·04	12·1	15·9	13·05	2·85
,,	·85	·05	·06	11·7	15·5	12·75	2·75
,,	·75	·05	·05	10·6	14·1	11·25	2·85
Peat, dry	·56	·06	·31	7·7	10·0	8·5	1·5
Wood ,,	·50	·05	·40	6·0	7·5	7·5	0

The first line refers to charcoal; the second to coke of average quality; the third and fourth lines give two examples of hydrocarbons, which comprise between them the chief ingredients of rock-oil. Lines 5, 6, and 7 give a few examples of coal. They differ from the kinds of fuel previously mentioned, in having some oxygen in them, which somewhat lessens the evaporative power. Here, too, the units of evaporation due to carbon and to hydrogen are distinguished; for example, line 6 shows 12¾ units of evaporation due to carbon, and 2¾ due to hydrogen. Then follow some results for peat and for wood, on which we need not enlarge. In the third, fourth, and fifth columns are stated the proportions of the chemical constituents, ranging for the rock-oils, between 84 per cent. of carbon to 16 of hydrogen, and 85 per cent. of carbon to

15 of hydrogen. The fifth column gives the net weights of air required for the oxidation of the fuel. In the sixth column the theoretical evaporative powers are set down: for rock-oils they are from 22·7 to 22·5, or, in round numbers, we may say 22½. In two additional columns are some figures to show how much evaporation is due to carbon and how much to hydrogen. In rock-oils those quantities are 12½ due to the carbon, and 10 to the hydrogen, out of the 22½ units of evaporation.

It is to be observed that the examples given in this table, which are only a few selections out of much more voluminous data, are all taken from good specimens. But it may be taken as the result of practical experience that the evaporative power of bad specimens of fuel from a particular district is about two-thirds that of good. This applies particularly to coal. The difference is chiefly due to refuse or ash. But it does not apply to mineral oils, because they can hardly contain anything else but combustible matter. They do not contain ash; they do not contain earthy matter. The statement, then, about qualities of fuel which have only two-thirds of the total evaporative power of those set down in the table, applies to coal and peat; but it does not apply to mineral oils.

We have gone at some length into the principles of the total evaporative power of different sorts of fuel, because it is of great practical importance to understand them. They show the theoretical limit towards which practice approaches in the course of improvement, but which practice cannot surpass nor even attain: the knowledge of those principles prevents people, on the one hand, from forming too small an estimate of the results which may be got from the economical use of fuel; and on the other hand from indulging in exaggerated estimates of those results. It shows us, indeed what is the actual waste, when we know the result attained in practice: it enables us to judge how far that result falls short of theoretical perfection, and what room there is for further economy by means of improvements.

The late Dr. W. J. Macquorn-Rankine, from whose work on 'The Economy of Fuel' we are about to quote, writes thus with regard to mineral oil:—

'I may make the following observations on what we may look forward to as the probable result of the introduction of such classes of fuel as mineral oil as substitutes for coal. Coal is a very complex kind of fuel. To ensure the best possible economy in the use of it requires the fulfilment of many different conditions, some of which conflict with each other. We have to burn fixed carbon, and we have to burn the gas that is disengaged from the coal. We may burn one very efficiently, and not burn the other. It is extremely difficult to manage the introduction of air, so that there shall at once be no risk of a deficiency of air, which causes imperfect combustion, and gives bad economy in one way; or a surplus of air, which carries heat to waste up the chimney, and causes bad economy in another way. On the one hand, we are exposed to the risk, from any little fault of construction or management of the furnaces, of the hydrogen going off unburned, and of its carrying off a large portion of the carbon unburned also. On the other hand, we are exposed to the risk of solid carbon being imperfectly burned, and going off as carbonic oxide. The contrivances for diminishing the causes of waste are somewhat difficult and complex to apply in practice; and above all, too much depends upon the skill of the fireman or stoker. We may say almost everything depends upon the way the furnace is managed. The very best furnaces, the very best boilers that were ever contrived, may be made extremely wasteful by a careless stoker. On the other hand, in using mineral oils, we are somewhat in the position of the chemist who has got a good burner for burning coal-gas. We have to contrive a suitable apparatus for introducing that oil into the furnace in such a way that it shall be thoroughly mixed with air—whether in the state of vapour, or in the state of fine spray, with or without the assistance of some porous substance to act as a wick. A steam-jet seems to be the most efficient apparatus for that purpose. Then if our apparatus is properly contrived and properly constructed, and works in the right manner and produces complete combustion at first, there is no reason to suppose that it will ever act badly if treated with ordinary care.

'It would seem to be no difficult matter with fuel of that sort to diminish the waste of heat through imperfect combustion to nothing, and the waste of heat through hot gases going up the chimney to something very small indeed. In fact, such an efficiency as 90 per cent. of the total evaporative power being realised, instead of being a very extraordinary thing, may be looked for as a very ordinary thing; so that, taking the theoretical evaporative power of some hydrocarbon compounds at 22½, we ought not to be surprised that, even with rude apparatus, in a merely experimental state, we get an evaporation of 19 or 20 times the weight of the fuel—say 19, at all events. I believe that has been realised in experiments that have been made, and that are now being continued.

'There is another phenomenon as to which I may say something—the mode of operation of steam-jets in cases of this kind. There can be no doubt that one use of the steam-jet is the mechanical action to which I have frequently referred—the thorough mixing of the gaseous fuel with the oxygen required for the purpose of combustion—the churning of the particles all together, so that they shall be brought thoroughly into contact. There may be another mode of operation of steam—a chemical action whose effect is to prevent the deposition of unconsumed carbon from gaseous fuel. All hydrocarbons have a tendency when raised to a high temperature to deposit the carbon, unless it be instantly burned. We see that in the smoke that a flame tends to give out, if there is anything to prevent immediate and free access of oxygen to the carbon. Now it is possible that besides its mechanical action, the steam-jet may also have a chemical action of the following kind:—The oxygen of the steam combines with the carbon of the hydrocarbon fuel, and the hydrogen of both is set free; there is a mixture thus produced of carbonic oxide and of hydrogen, which is sure to be completely burnt as soon as a sufficient quantity of air gets access to it, and thus the deposit of unconsumed carbon is entirely prevented.'

Dr. Paul, in a paper communicated to the Society of Arts, has the following valuable remarks upon the combustion of mineral oils:—

'The volumes of the air-supply and combustion-products for the extreme cases of carbon and hydrogen are as follow:—

	Air-Supply at 60° F.			Combustion-Products at 660° F.	
	lb.	lbs.	Cubic feet	lbs.	Cubic feet
Carbon . . .	1	24	320	25	630
Hydrogen . .	1	69	960	70	2044

'In the combustion of carbon there is no expansion of volume in the combustion-product, except that due to the heat generated, which would render the volume at the temperature of combustion (2,522° F.) rather more than six times that of the air supplied. By the transfer of heat to the boiler, to such an extent as to reduce the temperature to 660° F., the volume would be reduced again to about 630 cubic feet per pound of carbon burnt.

'In the combustion of hydrogen the supply of air required is about three times as large as that required in the combustion of an equal weight of carbon. There is also an expansion of the combustion-products, independent of the heat generated, and amounting to one-half the normal volume of the hydrogen burnt. The expansion due to heat is also greater than in the combustion of carbon, on account of the greater amount of heat generated, so that the volume of the furnace-gas at the temperature of combustion (2,791° F.) would be about 6½ times that of the air supplied, and the volume of gas discharged into the chimney would be about 3½ times as great as in the combustion of an equal weight of carbon. This larger quantity of gas will, however, contain nearly 4 times as much effective heat as that resulting from the combustion of an equal weight of carbon, and its temperature will be about 270° higher, so that in this respect the use of fuel containing a large amount of hydrogen, provided it can be perfectly and readily burnt, presents an advantage as compared with fuel consisting almost entirely of carbon. Rather more than one-fourth of a pound of hydrogen would give as much effective heat as one pound of carbon with a somewhat smaller volume of combustion-products. The extent to which this advantage affects the value or efficiency of fuel will, of course, depend on the amount of hydrogen it contains. Since no hydrocarbon available as fuel contains more than 15 per cent. of hydrogen, the actual evaporative efficacy of such a material, when used under the ordinary conditions, cannot, at the utmost, be more than about 40 per cent. greater than that of an equal weight of carbon. This, assuming it to be perfectly burnt, and the arrangement of boiler flues or tubes, &c., to be favourable for the transfer of heat, is the maximum effect to be looked for according to the data already given.

'The amount of hydrogen in petroleum is probably larger than in any of the other hydrocarbons proposed to be used as fuel, and that contains, on the average, about 13 per cent. In coal and shale oil the amount of hydrogen is less. Consequently, the evaporative efficacy of these materials, as compared with carbon, would not reach the above limit of 40 per cent. in excess. The ratio between these materials and ordinarily good coal is much about the same in regard to evaporative efficacy, since the hydrogen contained in coal compensates for the oxygen and ash it contains, unless the amount of these is very considerable.

'The following tables show the relation between the total heat of combustion and the available heat of hydrocarbons, containing respectively 14 and 25 per cent. of hydrogen, also the amounts of heat consumed in the furnace-gas, and the mode in which it is disposed of:—

'One pound of hydrocarbon, containing 14 per cent. of hydrogen, yields about 31 lbs. of furnace-gas, consisting of:—

	Furnace-Gas	Quantities of Heat in Furnace-Gas	Equivalent Evaporation of Water	
			at 212°	at 60°
	lbs.	heat units	lbs.	lbs.
Carbonic acid gas	3·16	411		
Water vapour	1·26	359		
Nitrogen gas	11·45	1,683		
Surplus air	14·37	2,124	2·2	
	30·74	4,577	4·8	
Total heat of combustion		21,154		
Latent heat of water vapour		1,217	1·3	
Available heat		19,937		
Waste heat of furnace-gas		4,577	4·8	
Effective heat		15,630	15·8	13.5
Theoretical evaporative power		...	21·9	
Relative evaporative efficacy as compared with carbon or coal = 1	1·39			

'One pound of hydrocarbon, containing 25 per cent. of hydrogen, yields about 36 lbs. of furnace-gas, containing:—

	Quantities	Quantities of Heat in Furnace-Gas	Equivalent Evaporation of Water	
			at 212°	at 60°
	lbs.	heat units	lbs.	lbs.
Carbonic acid gas	2·75	358		
Water vapour	2·25	641		
Nitrogen gas	13·39	1,968		
Surplus	17·39	2,483	2·6	
	35·78	5,450	5·6	
Total heat of combustion		26,283		
Latent heat of vapour		2,174	2·2	
Available heat		24,109		
Waste heat of furnace-gas		5,450	5·6	
Effective heat		18,659	19·3	16·6
Theoretical evaporative power		...	27·1	
Relative evaporative efficacy as compared with carbon or coal = 1	1·69			

'I am not aware of any liquid hydrocarbon applicable as fuel, which contains so much as 25 per cent. of hydrogen, so that an evaporative effect of about 16 lbs. of steam per pound of hydrocarbon burnt must be regarded as the maximum result to be attained with such material used as fuel. By burning these hydrocarbons with only just enough air for combustion, or half the quantities assumed to be supplied in the above estimations, the effect capable of being realised would be from 13 to 14 per cent. greater than in the case stated above, or about 18 lbs. of steam per pound of hydrocarbon containing 14 to 15 per cent. of hydrogen.

'The plan of using liquid fuel, which so far as I am aware has proved the most advantageous, is one which does, to some extent at any rate, secure the advantage to be gained by forcing air into the furnace. According to this plan the oil is supplied to the furnace through a small pipe, together with a jet of high-pressure steam, by which it is converted into spray, much in the same manner as, in the toy known as the perfume-vaporiser, a liquid is blown out of a bottle by a current of air. The steam-jet at the same time induces a current of air which mixes with the oil spray and supports its combustion. This is the arrangement used by Messrs. Field and Aydon, and it appears to work exceedingly well, effecting a very perfect combustion of the oil. The oil I have seen used in this way was the dead oil, or creosote oil, which is a refuse product in the refining of gas-tar. It possesses characters which render it much preferable to petroleum, or to the oil obtained by distilling coal at a low heat, for use as liquid fuel. In the first place, its density being greater than that of water—the gallon weighing about 12 lbs.—it takes less space for stowage than petroleum or coal-oil, the gallon of which weighs only from 8 to 8½ lbs. For the same reason it would not be so dangerous as the lighter oils in case of accident; for instead of floating on the surface of water and burning, it would sink harmlessly. Again, its very high boiling point, approaching to a red heat, and the great density of its vapour as compared with that of petroleum or coal-oil, are great advantages as regards risk of explosion in consequence of the oil-vapour becoming mixed with air and then catching fire. This could hardly take place with the dead oil, except at a very high temperature, while petroleum readily gives off vapour to the air at a moderate degree of heat.

'The use of this oil as fuel presents great advantages for gas-tar distillers, with whom it is a troublesome waste product. If it should come into demand as steam-fuel its value would of course rise above that of coal, to an extent proportionate to its greater efficacy and any other advantages resulting from its application as steam fuel. Such an application might therefore be a great advantage to gas companies.

'Unfortunately the quantity of this oil which is available is very small as compared with the requirements of steam navigation, probably not amounting to 100,000 tons a year in the whole country, and therefore its application must be very limited.

'In order now to arrive at some estimate of the advantage to be gained in a steam vessel, either in point of weight to be carried, or space occupied by liquid fuel as compared with coal, it is evident that 100 tons of petroleum, or coal-oil, would do the work of about 140 tons of good coal. But as coal is rarely burnt in such a way as to be rendered useful to its full capability, and as there is always a considerable waste in the shape of dust and cinders, which would not be the case with liquid fuel, a further allowance must be made for this. Assuming that one-fifth of the coal is wasted in this way, then the equivalent of 100 tons of oil would be 175 tons of coal, for taking the density of the oil as ·850, it would occupy about the same space as an equal weight of coals, or at the rate of about 53 lbs. per cubic foot. This difference would enable a vessel capable of carrying coal for 12 days' steaming, to carry oil for 21 days. In burning this oil there would be a saving of labour in stoking, and as it would not give any ashes, a great deal of trouble would be saved in that way.

'These results differ widely from the statements which have been made in reference to the relative efficiency of oil and coal, according to which it has been represented that one ton of oil was equal to from 4 to 5 tons of coal, and that in regard to stowage-room the saving was more than nine-tenths in bulk. I am not aware of any evidence having yet been brought forward, such as would call for, or justify, the abandonment of those well-established principles by which the heating power and efficacy of fuel is determined, as above stated.

'Mr. Trickett, the engineer-in-chief of the dockyard, gives, as the highest evaporative effect obtained with petroleum, 11·63 lbs. of water converted into steam per pound of oil burnt. In this case, however, the combustion was imperfect. But in the most successful trials with coal-oil and shale-oil, when very little smoke was given off, the evaporative effect was about 18 lbs. of steam produced per pound of oil burnt. In this case some deduction is required to be made for the steam applied as a blast to the fire, but the amount was not ascertained. This result was also obtained under peculiarly favourable circumstances as regards the proportion of heating surface of the boiler to the rate of evaporation.

'In regard to the supply of material capable of being used as liquid fuel, it is necessary to make a few remarks. First, as regards petroleum, I imagine it is now generally acknowledged that this material in its natural state is not well adapted for the purpose. In that state it contains a large amount of very volatile hydrocarbon, which, even at the ordinary temperature, vaporises by contact with air, and the mixture of this vapour with air is explosive. At the temperature of a steam vessel's stokehole this vaporisation would take place more readily, and if there were any leakage in the supply pipes or tanks, disastrous consequences might ensue. In order to remove this objection to the use of petroleum as liquid fuel, the more volatile portion of it must be separated by distillation, and that operation, when carried far enough to render the oil fit for use with safety, would reduce the quantity to about one-third.

'Another objection to petroleum in its natural state is its bulkiness, the gallon weighing only about 8 lbs. This is to some extent removed by the distillation; and by the reduction of the quantity to one-third, an oil is obtained which weighs about 8½ lbs. per gallon.

'According to the latest returns, the total production of petroleum in America—which is out of all proportion the most abundant source of this material—amounts to about 360,000 tons a year. It would be mere speculation to offer any opinion as to whether this rate of production is the maximum which is attainable, or as to the time it may continue; but the prevailing impression is that the sources from which this supply originates are subterranean accumulations, and, therefore, not to be depended on beyond a certain limit. The experience of oil-winning in America has confirmed this view, for it has been found that the wells which were at first what are termed "flowing wells," *i.e.*, yielding their oil spontaneously, have gradually ceased to flow; and that after pumping has been resorted to for bringing the oil to the surface, even that means gradually declined in its effect. It would, therefore, be unwise to rely upon the supply of petroleum as affording material for fuel.' See the articles Naphtha; Petroleum; Shale Oils.

Patent Fuel. Under this name a great many attempts have been made to utilise waste material. In countries where charcoal is abundant, charcoal-dust mixed with pitch has been employed, and attempts have been made to utilise the immense quantities of saw-dust produced in the north of Europe, by mixing it with clay and tar. Passing over the several kinds of artificial fuel which have been made on the Continent, the productions of this character made in this country must be described.

Wylam's patent fuel is small coal and pitch, moulded together into bricks by pressure. The pitch is obtained, by the distillation of coal-tar from which naphtha and a peculiar oil are separated, leaving the pitch. This pitch is ground fine and mixed with small coal, and in this state is passed, by a very ingenious application of the Archimedean screw, through a retort maintained at a dull red heat, by which it is softened for being moulded, which is effected by a kind of brick-making machine under enormous pressure.

Warlich's patent fuel is similar in character, but he adds a little common salt or alum to prevent the evolution of too much smoke, and the fuel bricks are subjected to a temperature of 400° F. for eight hours, by which the more volatile constituents are driven off.

Wood's fuel is prepared by mixing small coke or coal in a heated state with tar or pitch in a common pug-mill, after which it is moulded in the ordinary manner.

Bessemer's process consists merely in exposing coal-dust to a temperature of 600° F. By this the bituminous matter of the coal becomes softened, and the whole can be pressed into a firm block.

Grant's patent. This fuel is composed of coal-dust and coal-tar pitch: these materials are mixed together, under the influence of heat, in the following proportions:—20 lbs. of pitch to 1 cwt. of coal-dust, by appropriate machinery, consisting of crushing-rollers for breaking the coal in the first instance sufficiently small that it may pass through a screen, the meshes of which do not exceed a quarter of an inch asunder; 2ndly, of mixing-pans or cylinders, heated to the temperature of 220°, either by steam or heated air; and 3rdly, of moulding machines, by which the fuel is compressed, under a pressure equal to five tons, into the size of a common brick; the fuel bricks are then whitewashed, which prevents their sticking together, either in the coal bunkers or in hot climates. The advantages of this artificial fuel over coal may be stated to consist, first in its efficacy in generating steam; secondly, it occupies less space, that is to say, 500 tons of it may be stowed in an area which will contain only 400 tons of coal; thirdly, it is used with much greater ease by the stokers or firemen than coal, and it creates little or no dirt or dust, considerations of some importance when the delicate machinery of a steam-engine is considered; fourthly, it produces a very small proportion of clinkers, and thus it is far less liable to choke and destroy the furnace bars and boilers than coal; fifthly, the ignition is so complete that comparatively little smoke, and only a small quantity of ashes, are produced by it; sixthly, from the mixture of the patent fuel, and the manner of its manufacture, it is not liable to enter into spontaneous ignition.

A great many other persons have either patented processes for the preparation of artificial fuel, or published suggestions. These are so nearly alike that a few of them only require any notice.

Cobbold agitates peat in water to separate the earthy matter, and then allows the peat to subside, and consolidates it.

Godwin makes brick of mud or clay with pitch or coal.

Oram employs tar, coals, and mud.

Hill takes the residuary matter after the distillation of peat, and mixes it with pitch.

Holland mixes lime or cement with tar and small coals.

Ransome cements small coal together by a solution of silicate of soda.

From the Admiralty Coal Inquiry's Report we obtain the following analyses of several of the more important artificial fuels:—

Name of Fuel	Specific Gravity of Fuel	Carbon	Hydrogen	Sulphur	Oxygen	Ash
Warlich's	1·15	90·02	5·56	1·62	...	2·91
Livingstone's . .	1·18	85·07	4·13	1·45	2·03	4·52
Lyon's	1·13	86·36	4·56	1·29	2·07	4·66
Bell's	1·14	87·88	5·22	0·71	0·42	4·90
Holland and Green's .	1·30	70·14	4·65	...	...	13·73
Wylam's	1·10	79·91	5·69	1·25	6·63	4·54

Monthly Return of the Quantities of Patent Fuel Exported to Foreign Countries during the Year 1872.

Months	Swansea	Cardiff	Newcastle	Liverpool
	tons	tons	tons	tons
January	14,305	3,649	...	...
February	9,257	7,989	...	61
March	12,989	5,909	...	...
April	12,369	4,657	...	...
May	12,113	7,115	...	435
June	7,747	4,201	...	10
July	9,322	4,338	...	10
August	12,546	3,665	58	...
September	11,659	5,445	...	25
October	15,049	4,784	43	38
November	8,455	3,264	...	...
December	11,965	7,708	184	305

Patent Fuel sent Coastwise to other Ports of the United Kingdom.

Ports from which shipped	1870	1871	1872
	tons	tons	tons
Cardiff	4,396	12,323	3,802
Swansea	18,673	19,398	8,628
Liverpool	4	...	...
Glasgow	...	250	6,631
Sunderland	...	...	...
Total . . .	23,073	31,971	19,061

Patent Fuel sent to Foreign Countries.

Ports from which shipped	1870	1871	1872
	tons	tons	tons
London	3,551	4,876	3,569
Newhaven	8	...	...
Bristol	...	3	...
Cardiff	52,762	57,127	58,260
Swansea	141,984	135,751	142,938
Newcastle	...	...	101
Sunderland	...	...	2,019
Liverpool	72	358	354
Total . . .	198,377	198,115	207,241

In connection with the consideration of the values of Fuel, as producers of mechanical power, the *Economiste Français* has published an article in which it examines the improvements that may be introduced into motive machines by the application of the science of the mechanical theory of heat. The writer thinks that the science itself is sufficiently advanced to afford important practical results, and, in support of that view, names the recent work of M. Léon Pochet, *La Nouvelle Mécanique Industrielle.*

Every thermal machine, which has for its object the conversion of heat into mechanical power, approaches perfection exactly in relation to the amount of heat which it transforms; this transformation has a maximum limit which cannot possibly be passed, but the machines at present in use are far from attaining the degree of perfection indicated by the theoretical limit. By calculating the heat necessary for converting water into steam at the proper temperature, in a supposed perfect machine, the consumption of fuel amounts to 0·17 kilogramme (of 2·204 avoirdupois lbs. of 7,000 grains) per horse-power per hour (see Horse Power); while the consumption of engines in industrial use is as follows:—The most perfect engines of large power, one kilogramme; those of moderate power, two; and small machines, four to six kilogrammes. This statement shows that many improvements are still to be looked for in our motive engines: and we may enquire in what direction and with what results the endeavour towards such amelioration has been pursued of late, with a special view to the economy of combustion.

The power of a boiler is measured by the weight of steam produced per hour for a given amount of heating surface, and its working power by the weight of steam produced by a given weight of fuel, for a boiler may give a large quantity of steam per unit of surface and by time, and yet utilise but a small portion of the heat emitted by the fuel. Thus, engineers are occupied at the present time with the question of the disposition of steam generators; the types employed in industry vary infinitely in their details, but they may all be referred to one or other of the seven heads following:—1. Waggon-head boilers; 2. Cylindrical boilers with exterior furnaces; 3. Cylindrical boilers with interior furnaces; 4. Boilers with hot-water tubes; 5. Tubular boilers; 6. Boilers with circulating arrangement; 7. Marine boilers.

According to the results of a considerable number of experiments made with various forms of apparatus, the weight of steam produced by a kilogramme of fuel oscillates between 4·30 (boiler with two lateral hot-water tubes, experimented on by M. Chavés on the Northern Railway of France) and 10·84 to 11·30 (cylindrical boiler, with a Wye-Williams' superheater), the exceptional limit yet arrived at. These figures, which indicate the economic value of each system, depend upon a great number of conditions, amongst which it must be remembered that the experience and care of the stokers are not the least important. From the economical point of view, little or no progress has taken place in boilers since the time of Watt. The old Cornish and London boilers gave about eight kilogrammes of steam for one kilogramme of fuel: modern apparatus only attain this result exceptionally. This arose in great part from the care with which the first boilers were constructed; precautions were taken in them to avoid loss of heat, which have unfortunately been neglected of late. The necessity for economising space aggravated the effects of this negligence. In diminishing the length of the boilers that of the flues was also lessened, and consequently the gases were allowed to escape at a higher temperature than before. What was gained in space was thus lost in economy.

In the present state of the art of construction, the maximum result to be looked for, under ordinary circumstances, from a good boiler, is that of seven kilogrammes of steam per kilogramme of coal of average quality, producing ten per cent. of cinders. In fixing at 8,000 units the heat disengaged by the combustion of a kilogramme of pure coal, we recognise the fact that the utilisation of boilers corresponds with a fraction equal to about fifty-seven per cent. More than a third of the heat is lost in our best steam generators. The care of a good stoker may easily augment the result by ten per cent.

Although this portion of our steam apparatus seems susceptible of notable improvements, still if we consider the stationary conditions of caloric effect since Watt's time, it would seem that these improvements are exceedingly difficult to bring about. The Siemens' furnaces appear to be the only apparatus introduced with the object of economising fuel, which deserve special notice; but their application is necessarily restricted to fixed engines.

Steam once produced, the next thing is to turn it to account, and in this case we can scarcely look for improvement in future but from amelioration in the details of the apparatus—and industry has almost arrived at perfection in this respect—steam-engines which consume a kilogramme of coal per horse-power effective and per hour, are not far removed from it.

It has been sought to replace steam in thermal engines by other vapours or by gas.

Trembley's engine, tried in 1840, and adopted for a boat which ran regularly between Marseilles and Algiers, was worked with steam and the vapour of ether. Sulphuric ether boils at a temperature of 37° Cent.; condensed steam preserves sufficient heat to convert ether into vapour which, by its expansion, adds a certain amount of power to that already produced. This experiment, however, was not successful, and the engines constructed upon this system were considered extremely dangerous. The substitution of chloroform for ether, proposed by M. Lafond, of the French Navy, was not more satisfactory.

Capt. Ericson, in his engine, which was remarkable from a theoretical point of view, constructed about 1852, appears to have been the first inventor who succeeded in utilising atmospheric air in thermic engines. But although his apparatus has been employed in America, under various circumstances, and especially for vessels, the hot-air engine, whether on the system of Ericson, Franchot, Lemoine (of Rouen), Belou or others, has not yielded really practical results or rendered any real service. It is well known that the effects of hot-air engines should far exceed those of good steam-engines. Our best motors actually consume, as already stated, a kilogramme of coal per horse per hour; if we admit that the heating apparatus of a hot-air engine transmits two-thirds of the heat developed in the furnace, that the mechanism utilises 60 per cent. of the possible mechanical power, and that the coal produces only 7,500 units of heat; lastly, if we estimate the absolute theoretical effect at 0·50, the consumption of a hot-air engine will, under these circumstances, be equal to 0·424 per horse per hour—a very reduced amount. It would be to despair of human ingenuity not to believe that such a result will some day be obtained. See Air Engine.

FULGURATION designates the sudden brightening of the melted gold and silver in the cupel of the assayer, when the last film of vitreous lead and copper leaves their surface.

FULLER'S EARTH. (*Terre à foulon, Argile smectique*, Fr.; *Walkererde*, Ger.) In geology this term is applied to the clayey deposit which intervenes between the calcareous strata commonly known as the Bath or Great Oolite, and the Inferior Oolite. A sandy argillaceous earth is met with in the upper part of the clay in question, to which the name Fuller's earth was given from its adaptability for *fulling* or cleansing cloth, when first woven, from grease or other impurities. The term thus limited originally to a particular stratum was subsequently applied to the entire formation by Dr. William Smith in his classification of the British strata, and has ever since retained its place in geological nomenclature. The fuller's earth above mentioned was formerly procured in considerable quantities from the Downs, to the south of Bath, whence it was sent to the cloth factories of Gloucestershire. Of late years, however, an artificial substitute has been found in a chemical preparation, and the demand for the natural production has decreased so far, that little or none of it is now procured in the West of England. The fuller's earth of Reigate is found in strata of a much more recent date than those alluded to above, and forms a part of the Lower Greensand. See Greensand.

From Reigate 12,000 tons of dried fuller's earth are raised annually. There are two varieties, called the blue and yellow; their analyses are respectively—

	Blue	Yellow
Alumina	18	11
Silica	42	44
Lime	4	5
Magnesia	2	2
Oxide of Iron	6	10
Soda	5	5

The other places from which fuller's earth has been obtained, are—Penenden Heath, Maidstone, Frome, Lonsdale, Coombe Hay, English Coombe, and Duncorn Hill in Gloucestershire, and at one locality in Bedfordshire.—H. W. B.

FULLERS' TEAZEL. *Dipsacus* (*δίψα, thirst*), so called because the bases of the leaves are, in many species, connate, so that they enclose a cavity which contains water ready to allay thirst. The fullers' teazel is the *Dipsacus fullonum*; the bracts of the head are very spiny, and are much used for carding cloth; consequently the teazel is cultivated in many parts. Many carding machines have been introduced, but the best cloth weavers still prefer the teazel for finishing their cloth.

FULLING. The art of cleansing, scouring, and pressing woollen manufactures. The object is to render them stronger and firmer. It is called also *milling*, because the cloths are scoured by a water mill.

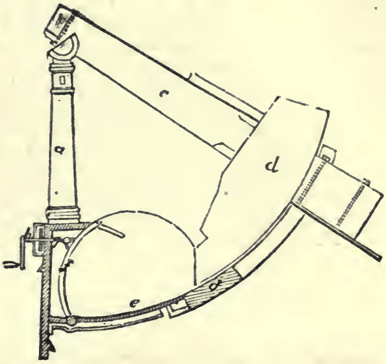
The principal parts of a fulling mill are the wheel with its trundle, which gives motion to the tree or spindle whose teeth communicate that motion to the stampers or beaters, which fall into troughs, wherein the cloth is put, with the fuller's earth.

William and Ogle introduced in 1825 some new fulling machinery, designed to act in a similar way to the ordinary stocks, in which cloths are beaten, for the purpose of washing and thickening them; but the standard and the bed of the stocks are made of iron instead of wood, as heretofore; and a steam vessel is placed under the bed, for heating the cloths during the operation of fulling, whereby their appearance is said to be greatly improved.

Fig. 1006 is a section of the fulling machine or stocks: *a*, is a cast-iron pillar, made hollow for the sake of lightness; *b*, is the bed of the stocks, made also of iron, and polished smooth, the side of the stock being removed to show the interior; *c*, is the lever that carries the beater *d*. The cloths are to be placed on the bed *b*, at bottom, and water allowed to pass through the stock, when by the repeated blows of the beater *d*, which is raised and let fall in the usual way, the cloths are beaten, and become cleansed and fulled.

A part of the bed at *e* is made hollow, for the purpose of forming a steam box, into which steam from a boiler is introduced by a pipe with a stopcock. This steam heats the bed of the stock, and greatly facilitates, as well as improves, the process of cleansing and fulling the cloths.

1006



The smoothness of the surface of the polished metal, of which the bed of the stock is constituted, is said to be very much preferable to the roughness of the surface of wood of which ordinary fulling stocks are made, as by these iron stocks less of the nap or felt of the cloth is removed, and its appearance when finished is very much superior to cloths fulled in ordinary stocks.

In the operation of fulling, the cloths are turned over on the bed by the falling of the beaters, but this turning over of the cloths will depend in a great measure upon the form of the front or breast of the stock. In these improved stocks, therefore, there is a contrivance by which the form of the front may be varied at pleasure, in order to suit cloths of different qualities; *f*, is a moveable curved plate, constituting the front of the stock; its lower part is a cylindrical rod, extending along the entire width of the bed, and being fitted into a recess, forms a hinge joint upon which the curved plate moves; *g*, is a rod attached to the back of the curved plate *f*, with a screw thread upon it; this rod passes through a nut *h*, and by turning this nut, the rod is moved backward or forward, and, consequently, the position of the curved plate altered.

The nut *h*, is a wheel with teeth, taking into two other similar toothed wheels, one on each side of it, which are likewise the nuts of similar rods jointed to the back of the curved plate *f*; by turning the central wheel, therefore, which may be done by a winch, the other two wheels are turned also, and the curved plate moved backward or forward. At the upper part of the plate there are pins passing through curved slots, which act as guides when the plate is moved.

FULMINATING MERCURY, $C^4N^2Hg^2O^4$ ($\mathbf{C^2N^2HgO^2}$). The well-known compound used for priming percussion caps. It was analysed many years ago by Liebig, and subsequently, by Gay-Lussac. Although chemists have long been acquainted with the true composition of fulminic acid, and the formula of fulminating mercury has also been rendered almost certain, no accurate analysis of the latter compound was made public until 1855, when M. Schischkoff published his celebrated paper on the fulminates. It is singular that Liebig and Schischkoff were independently engaged at the same time in investigating the products of decomposition of the fulminates. The formula of fulminic acid, and also that of fulminating mercury, had been deduced from the very accurate analyses of fulminating silver made by Gay-Lussac and Liebig. A great number of processes for the preparation of fulminating mercury have been published. The following are the best as regards economy and certainty:

1. One part of mercury is to be dissolved in 10 parts of nitric acid, sp. gr. 1·4; and the solution at a temperature of 130° F. is to be poured into 8·3 parts of alcohol, sp. gr. 0·830.—*Ure.*

2. One part of mercury is to be dissolved in 12 parts of nitric acid, of sp. gr. 1·3. To the solution (as soon as it has cooled to 55° F.). 8 parts of alcohol, sp. gr. 0·837, are to be added; the vessel containing the mixture is to be heated in boiling water

until thick white fumes begin to form. The whole is then set in a cool place to deposit the crystals of fulminate.—*Cremascoli.*

3. One part of mercury is to be dissolved in 12 parts of nitric acid, sp. gr. 1·340 to 1·345, in a flask capable of holding 18 times the quantity of fluid used. When the metal is dissolved, the solution is decanted into a second vessel containing 5·7 parts of alcohol, of 90° to 92° (*Tralles*), then immediately poured back into the first vessel, and agitated to promote absorption of the nitrous acid. In five to ten minutes gas-bubbles begin to rise, and there is formed at the bottom of the vessel a strongly refracting, specifically heavier liquid, which must be mixed with the rest by gentle agitation. A moment then arrives when the liquid becomes black from separation of metallic mercury, and an extremely violent action is set up, with evolution of a thick white vapour, and traces of nitrous acid; this action must be moderated by gradually pouring in 5·7 parts more of the same alcohol. The blackening then immediately disappears, and crystals of fulminating mercury begin to separate. When the fluid has become cold, all the fulminating mercury is found at the bottom. By this method not a trace of mercury remains in solution.—*Liebig.*

The fulminate in all these processes is to be collected on filters, washed with distilled water, and dried. The violent reaction which takes place when the solution of mercury reacts on the alcohol is essential to the success of the operation.

With regard to the economy of the above methods, it has been found that 1 part of mercury yields the following proportions of fulminate:—

1st process	1·30
2nd ,, ...	1·25
3rd ,, ...	1·53

C. G. W.

FULMINATING SILVER, $C^4N^2Ag^2O^4$ ($\mathbf{C^2N^2Ag^2O^2}$). This salt corresponds in constitution to the fulminate of mercury; it may also be prepared by analogous processes, merely substituting silver for mercury. *Preparation.*—1. 1 part of silver is to be dissolved in 24 parts of nitric acid, sp. gr. 1·5, previously mixed with an equal weight of water. To the solution is to be added alcohol equal in weight to nitric acid. *Produce,* 1·5 part of fulminating silver. 2. 1 part of silver is to be dissolved in 20 parts of nitric acid, sp. gr. 1·38. To the solution is to be added 27 parts of alcohol, sp. gr. 0·832. The mixture is to be heated to boiling, and, as soon as it shows signs of becoming turbid, it is to be removed from the fire, and a quantity of alcohol, equal in weight to the first, is to be poured in. The liquid is now to be allowed to become perfectly cold, when the fulminate will be found at the bottom of the vessel. *Produce,* equal to the silver employed. 3. 1 part of silver is to be dissolved in ten times its weight of nitric acid, sp. gr. 1·36. To the solution is to be added 20 parts of alcohol, sp. gr. 0·83. The mixture is to be treated as in the second mode of preparation, except that no more alcohol is to be added. The produce should be in fine crystals. Whichever mode of preparation be selected, it is absolutely necessary, in order to avoid fearful accidents, that the following precautions be attended to. The beakers or flasks employed must be two or three times larger than is required to hold the ingredients, for if, owing to frothing or boiling over, any of the fluid happened to find its way to the outside, and dry there, an explosion might ensue. Care must also be taken that the highly inflammable vapours given off during the preparation do not come near any flame. The salt, when formed, must be received on a filter, and well washed with cold water. It is safer to dry it spontaneously, or over oil of vitriol, for although it will endure a heat above that of boiling water before exploding, yet when warm, the slightest touch with a hard substance is often sufficient to cause a terrible detonation. A spatula of pasteboard or very thin wood should be employed to transfer it into its receptacle. Fulminating silver should not be kept in glass vessels, for fear of the salt finding its way between the cork or stopper, the slightest movement with a view of opening the vessel, being then sufficient to cause an accident. Small paper boxes are the safest to keep it in.

Fulminating silver gives a more violent detonation than the corresponding mercurial compound. The presence of roughness or granular particles on the substances with which it may be in contact assists greatly in causing it to explode.

Although giving so violent an explosion when alone, it may be burnt without danger when mixed with a large excess of oxide of copper, as in the ordinary process of organic analysis. It then gives off a mixture of two volumes of carbonic acid, and one volume of nitrogen. Gay-Lussac and Liebig made an analysis of the salt in this manner, with the annexed results:—

Experiment		Calculation		
Carbon	7·9	C^4	24	8·0
Nitrogen	9·2	N^2	28	9·3
Silver	72·2	Ag^2	216	72·0
Oxygen	10·7	O^4	32	10·7
	100·0		300	100·0

C. G. W.

FULMINIC ACID, $C^4N^2H^2O^4$ ($\mathbf{C^2N^2H^2O^2}$). The acid contained in fulminating mercury; it does not appear to exist in a free state.

FUMIGATION is the employment of fumes or vapours to purify articles of apparel, and goods or apartments supposed to be imbued with some infectious or contagious poison or fumes. The vapours of vinegar, the fumes of burning sulphur, or explosion of gunpowder, have been long prescribed and practised, but they have in all probability little or no efficacy. The diffusion of such powerful agents as chlorine gas, muriatic acid gas, or nitric acid vapour, should alone be trusted to for the destruction of morbific effluvia. See DISINFECTANTS.

FUMITORY. A bitter herb, *Fumaria officinalis.* It grows abundantly in this country, and was at one time used in medicine. The name is derived from the Latin word *fumus*, smoke, on account of its smoke-like smell. The French call it *fumeterre*, whence our name *fumitory.*

FUNGI. One of the orders into which the *Thallogenæ* are divided, comprehending the mushrooms. The fungi are cellular plants, which generally appear in the form of a more or less rounded *thallus* supported upon a stalk, and with spores or seeds on the under surface or gills, or, as it is called, the *hymenium.* Upwards of 4,000 species of fungi have been enumerated by botanists. All matter, and especially organic matter, may become productive soil for many species. The parasitic fungi are very serious agents of destruction, and the cereals and other useful plants are often entirely destroyed or rendered poisonous by their appearance. The mildew of wheat, *Puccinia graminis*; the smut, *Uredo segetum*; the bunt, *Uredo fœtida*; the ergot or cock's spur, *Spermœdia clarus*, which, without destroying the crops, renders the grain poisonous for food: the potato disease, which is intimately connected with the attack of a species of *Botrytis* (*Peronospora*) *infestans*, as are also diseases of many of the ordinary vegetables, are some of the minute and destructive kinds of fungi. Some of these parasitic fungi grow on living animals; the non-secretion of the silkworm is due to the fungus *Botrytis Bassiana.* A certain species of caterpillar is attacked by the fungus *Sphæria Sinensis*, and the animal becomes perfectly absorbed in the vegetable, and this substance is collected and used as a highly-prized drug among the Chinese. A very large class of fungi bears the name of mushroom; many of these species are edible, while others are more or less poisonous. The *Agaricus muscaria* is used by the natives of Kamtschatka and Korea to produce intoxication: of the edible kinds the *Agaricus campestris* is most used in this country as an article of food, and from it is obtained the sauce called Ketchup, or Catsup; this species is considered poisonous in Italy, while many others eaten in foreign countries are considered here unfit for food. The fairy-ring mushroom, *Agaricus pratensis*, is also an edible plant, and is used for mixing with rich sauces. The truffle, *Tuber cibarium*, is also a mushroom. The commercial value of this fungus is very great. Beyond these there are none of the fungi which have any practical uses in this country. In Rome it is stated that the yearly average of taxed mushrooms, from 1837 to 1847, was between 60,000 and 80,000 lbs. weight. The *Cyttaria Darwinii*, growing on the bark of the beech in Tierra del Fuego and in Australia; and species of the *Boletus*, especially one called native bread, *Mytittus Australis*, are much used by the respective natives as food. Some species of fungi are phosphorescent; the *Rhizomorpha*, one of these, is said to give to caves and mines where it abounds an indescribable splendour. Many of the smaller fungi are most destructive in their nature, as remarked previously. Fungous formations have been detected in our cotton goods sent to India, and the result has been most serious to our trade in these goods.

As many deaths have occurred by mistaking poisonous for edible fungi, it may be useful to point out the chief marks of distinction between the two classes. The characters have been thus contrasted by Prof. Bentley:—

Edible Mushrooms.	*Poisonous Mushrooms.*
1. Grow solitary, in dry, airy places.	Grow in clusters, in woods, and dark damp places.
2. Generally white or brownish.	Usually with bright colours.
3. Have a compact, brittle flesh.	Flesh tough, soft, and watery.

Edible Mushrooms.	*Poisonous Mushrooms.*
4. Do not change colour when cut, by action of air.	Acquire a brown, green, or blue tint, when cut and exposed to the air.
5. Juice watery.	Juice often milky.
6. Odour agreeable.	Odour commonly powerful, and disagreeable.
7. Taste not bitter, acrid, salt, or pungent.	Have an acrid, astringent, acid, salt, or bitter taste.

Further, all fungi should be avoided if insects will not touch them; if the fungi have scales or spots on their surfaces; or if they exhibit any signs of decomposition. It is said that some poisonous fungi are rendered innocuous by being cut in slices, macerated in vinegar and water for an hour, and then washed in boiling water before being dressed.

FUR. (*Fourrure*, Fr.; *Pelz*, Ger.) Fur may be strictly defined as the short fine soft hair of certain animals, growing thick on the skin, and distinguished from the hair, which is longer and coarser. The term is, however, used sometimes very loosely, and includes those skins which are covered with hair. Fur is one of the most perfect non-conductors of heat, and consequently we find the animals of the colder regions of the earth clothed with this substance, and hence man has adopted it as the warmest of clothing.

To the admirable report made by Messrs. J. A. Nicholay and James B. Bevington, on the Furs of the Great Exhibition, we are mainly indebted for the following particulars.

The Russian Sable (*Mustela zibellina*). In the reign of Henry VIII., by a law to regulate the expenses of different classes, and to distinguish them by peculiarity of costume, the use of sable was confined to the nobility above the rank of viscount. It is stated that 25,000 skins are annually collected in the Russian territories. The fur is brown, with some grey spots on the head; the darker varieties are the most valuable, a single skin of a fine dark colour being sold for as much as nine pounds, though the average value does not exceed two or three. The Russian sable is sometimes confounded with the Hudson's Bay sable, but to the furrier the former is easily distinguishable from the length and fullness, as well as the darker colour, of the fur.

Hudson's Bay Sable (*Mustela Canadensis*). As the natural colour of this skin is much lighter than the prevailing taste, it is the practice to dye many of them a darker colour, and the furs thus treated are scarcely inferior to the Russian or true sable. Not less than 120,000 skins are annually imported into this country.

Pine Marten or Baum (*Mustela abietum*). The animals producing this skin are found in extensive forests in the north of Europe. The skins are distinguished from the stone marten by the yellow colour of the throne. These skins are dyed to imitate real sable.

Stone Marten (*Mustela saxorum*). This is frequently called French sable, from the fact that the French furriers excel in dyeing this skin. The stone marten is distributed through most European countries. The under fur is a bluish white, with the top hairs a dark brown, the throat being generally a pure white, by which it is distinguished.

Fisher. These skins are larger than the sables, and the fur is longer and fuller; about 11,000 of these skins are annually brought from America. The tail, which is long, round, and gradually tapering to a point, was formerly used as the common ornament to a national cap worn by the Jew merchants of Poland.

Mink (*Mustela vison*).. There were 245,000 skins of this little animal brought to this country in 1850. The fur resembles sable in colour, but is considerably shorter and more glossy.

Ermine (*Mustela erminea*). This animal is similar in form and habit to the common weasel of this country; but in Siberia, Russia, and Norway, from whence the skins are imported, the little animal during winter becomes as white as the snowy regions it inhabits, and is esteemed the whitest fur known, though in summer its dress is a dingy brown. The tail of the skin, of which the lower half is jet black, is usually introduced as an ornament to the purely white fur. In Edward III.'s reign, the use of ermine was restricted to the royal family.

Fitch or Polecat (*Mustela putorius*), produced throughout Europe and in our own country. This animal has a soft black fur, with a rich yellow ground. The natural smell of this fur is unpleasant and difficult to overcome.

North American Skunk (*Mephitis Americana*). These skins are imported by the Hudson's Bay Company. The animal from which it is obtained is allied to the polecat of Europe. The fur is a soft black, with two white stripes running from the head to the tail. This fur is not much used in this country.

Kolinsky (*Mustela Siberica*). The Tartar sable, which is of a bright yellow colour. It is sometimes used in its natural state, but is more frequently dyed brown to imitate other sable, to which it bears a strong resemblance. It is remarkable for the uniformity of its colour, having no spot or difference of shade in any part of the body. The tail, which is of the same colour, is exclusively used for the best artist's pencils.

Musk Rat or Musquash (*Fiber zibethicus*), an inhabitant of the swamps and rivers of America. About a million skins are brought to this country annually. The fur resembles that of the beaver, and was used by hat manufacturers. The skins are also dyed by the furrier, and manufactured into many cheap and useful articles.

Nutria or Coypon (*Myopotamus coypus*). This animal is larger than, but somewhat similar to, the musquash; it inhabits the banks of rivers in Buenos Ayres and Chili. But few of these skins are now imported.

Hamster (*Cricetus vulgaris*), a native of Germany, where not less than 100,000 skins are annually collected. It has a poor, short, and coarse fur, which is almost exclusively used for cloak linings by the Greeks. The colour of the back is a reddish brown, the belly black, with a few light spots.

Perwitzky. The skin of this animal is marked like tortoise-shell; it is brought from the southern extremities of Asiatic Russia. It is chiefly used by the Russians for cloak lining.

Beaver (*Castor Americanus*). This beautiful fur is sometimes used for articles of dress. In order to prepare the skin for this appropriation, the coarse hairs are removed, and the surface cut by a very ingenious machine, somewhat similar to that used in dressing cloth. The skin thus prepared has a beautiful appearance, not unlike the costly South Sea otter, and has the advantage of durability and lightness.

Otter (*Lutra vulgaris, Lutra Canadensis*). Of the British otter about 500 skins are collected annually. The large quantity used by the Russians and Chinese is derived principally from North America.

Sea Otter (*Enhydra marina*). The sea otter has a very thick, soft, woolly fur, and is most highly prized by the Russians and Chinese, to whom most of the skins are exported. The animal is found in the North Pacific from Kamtschatka to the Yellow Sea, on the Asiatic coasts, and from Alaska to California on the American coasts.

Seal (*Phoca*). There are numerous varieties of these animals, which are found on the western coasts of these islands, and in immense numbers on the shores of Labrador, Greenland, and Newfoundland. The greater portions of the skins imported are tanned and enamelled with black varnish for ladies' shoes; other descriptions are well adapted for fur. Before they can be used as a fur, it is necessary to remove the very coarse hairs, which cover a beautifully fine and silky fur. By shaving the felt to half its natural substance, the roots of the coarse hairs are cut through, and they easily fall out, but the same effect is produced by the natural process of fermentation, which ensues when the skins are properly prepared and allowed to remain together. This fur is rarely used in its natural state, but is dyed a deep vandyke brown, when it has the appearance of the richest velvet.

Fox. Of foxes' skins brought to this country there are many varieties; the black and silver foxes (*Vulpes fulvus*, var. *argentatus*) from the Arctic regions are the most valuable. They are purchased for the Russian market, being highly prized in that country. The cross and red foxes are used by the Russians, Turks, and Greeks for cloak linings and collars. The blue and white foxes are used in this and other countries for ladies' dresses; the white foxes (*Vulpes lagopus*) are represented by arctic travellers as exceedingly numerous, and emigrating in troops over the frozen seas at the approach of the rigorous season.

Wolverine (*Gulo luscus*). The glutton of old writers. The fur is generally a dark brown, passing into a black in winter.

Bear (*Ursus*). The skin of the black bear is used for military purposes, for rugs and carriage hammercloths. The fur of the brown or Isabella bear (*Ursus Isabellinus*) has frequently been very fashionable in this country.

The skins of the hare and the rabbit scarcely require notice.

The Squirrel, especially the Siberian squirrel, is much sought for. It is said that 15,000,000 of these skins are annually collected in Russia, and of these, 3,000,000 are sent to this country.

Chinchilla (*Chinchilla lanigera*). There are two varieties of Chinchilla, the produce of South America. Our chief supply is from Buenos Ayres and Arica. The skins from the former locality are of a silvery grey. Those from Arica are the darkest and best coloured skins.

Racoon (*Procyon totor*), this fur is used for lining coats.

CAT (*Felis domesticus*). In Holland the cat is bred for its fur; it is fed on fish and carefully tended until the fur arrives at perfection.

CANADA LYNX (*Felis Canadensis*). This fur is not much used in this country, but it is prepared and exported for the American market.

Furs, Skins, and Pelts Imported.

	1868		1869		1870	
	Number	Value	Number	Value	Number	Value
		£		£		£
Bear	6,716	8,090	12,482	13,887	11,777	15,278
Beaver	150,640	69,023	153,853	58,727	205,695	94,548
Chinchilla	377,092	101,232	763,354	104,941	337,458	59,895
Coney	885,659	4,669	692,504	5,094	520,915	4,378
Deer, dressed and undressed .	64,160	8,385	60,940	6,509	40,987	4,704
Ermine	308,909	18,330	258,491	25,849	296,255	29,479
Fisher	8,501	15,059	13,699	21,682	8,614	13,377
Fitch	17,213	2,241	21,341	3,226	6,280	942
Fox, silver	2,443	8,256	5,904	26,939	1,117	3,021
„ other sorts	92,081	59,159	95,756	52,974	85,684	51,707
Goat, undressed	866,117	88,843	783,408	99,891	713,679	92,953
„ tanned or dressed . .	2,298,983	248,685	2,620,390	284,900	2,774,180	311,994
Kid, undressed	8,022	402	14,195	710	134,952	6,748
„ tanned or dressed . .	280,358	23,761	431,605	42,211	314,161	29,126
Kolinski	53,249	6,657	47,480	5,936	39,100	4,889
Lamb, undressed . . .	660,423	32,422	806,736	40,157	825,138	40,986
„ tanned or dressed . .	112,666	7,844	134,236	9,163	162,720	9,493
Lynx	68,206	24,109	44,055	11,413	24,982	7,088
Marten	119,626	89,315	91,684	78,367	79,674	91,642
Musquash	2,329,378	99,194	1,828,111	69,395	1,991,642	62,859
Nutria	13,396	616	24,112	1,240	167,140	6,254
Otter, common	14,651	14,341	18,225	21,050	22,802	24,949
„ sea	1,060	11,765	1,600	12,212	4,484	31,029
Racoon	297,504	27,857	385,721	31,868	324,438	24,358
Sable	3,845	5,755	6,918	12,948	52,063	67,183
Seal	780,477	243,679	736,336	314,653	731,913	270,024
Sheep, undressed . . .	3,913,392	303,702	3,595,914	253,555	5,179,806	413,931
„ tanned or dressed . .	2,154,387	116,284	2,687,859	141,186	2,800,888	171,870
Squirrel or Calabar . . .	244,674	4,077	275,282	4,587	150,668	2,512
Wolf	12,728	4,234	7,090	1,891	8,069	3,701
Unenumerated, being furs .	1,164,764	85,420	533,177	57,712	1,045,111	69,783
„ not being furs .	198,033	17,976	405,208	45,369	353,886	59,759

The importance of the trade in furs and skins will be rendered evident from the preceding accounts. It would have been desirable to have separated the furs, strictly so called, from the skins, but this has not been found practicable with anything like accuracy: the returns are therefore given under the heads adopted by the Customs, which have no been continued even in this form.

Furs are subject to injury by several species of moths, whose instinct leads them to deposit their eggs at the roots of the fine hair of animals.

Linnæus mentions five species that prey upon cloth and furs, of which *Tinea pellionella*, *T. vestionella*, and *T. tapelzella* are the most destructive. No sooner is the worm hatched than it eats its path through the fur, and continues increasingly destructive until it arrives at its full growth, and forms itself a silken covering, from which, in a short time, it again emerges a perfect moth.

Another cause of the decay of fur is, the moisture to which they are frequently exposed; the delicate structure of the fine under-fur cannot be preserved when any dampness is allowed to remain in the skin. This fact is well known to the leather manufacturer, who, having wetted his skins, allows them to remain in a damp cellar for a few days, for the purpose of removing the hair, which is pulled out with the greatest facility, after remaining only one week in a moist condition. It follows from these observations, that to preserve the furs it is necessary to keep them dry, and to protect them from moths; if exposed to rain or damp, they must be dried at a moderate distance from the fire: and when put by for the summer, should be combed and beaten with a small cane, and very carefully secured in a dry brown paper or box, into which moths cannot enter. During the summer they should be examined once a month, to be again beaten and aired, if the situation in which they have been placed be at all damp. With these precautions, the most valuable furs may be preserved uninjured for many years.

FUR. A deposit incrusting the interior of boilers, kettles, and other vessels in which water has been boiled. The fur generally consists of carbonate of lime. Its formation may be prevented by adding either soda-ash (carbonate of soda) or sal-ammoniac (chloride of ammonium) to the water. The addition of a small proportion of glycerine has also been recommended.

FURNACE. The construction of furnaces for the more important metallurgical operations will be found under the heads of the different metals, for the separation of which from their ores they have been employed. All the arrangements of the Blast Furnace, Puddling Furnace, and Reheating Furnace, will be found under Iron. Under the heads of Copper, Tin, Lead, Silver, Zinc, &c., will be described the furnaces used in the production of those metals.

In like manner, the several kinds of furnaces employed in Glass and other manufactures requiring the application of heat, are described in their respective places.

There remains, therefore, only one or two very ingenious forms of furnace, by which great heat can be obtained, for any purpose, to be mentioned in this place.

Furnace of Assay.—Under Assay a furnace constructed by Messrs. Anfrye and D'Arcet is mentioned, which gives some peculiar facilities and economy to the process by fire.

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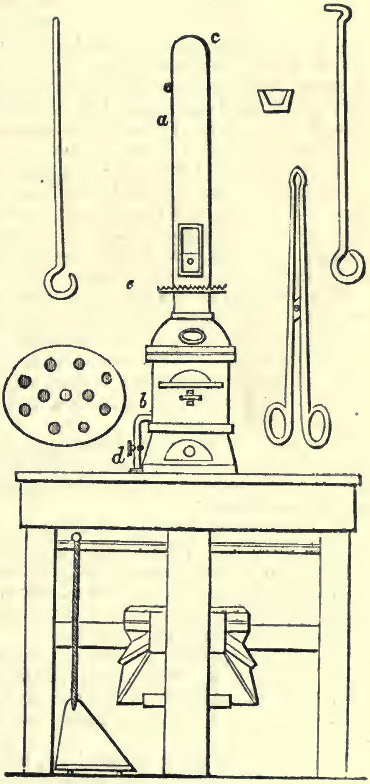


It had originally a small pair of bellows attached to it, for raising the heat rapidly to the proper vitrifying pitch. This is not shown in the previous figure.

The furnace is $17\frac{1}{2}$ inches high and $7\frac{1}{2}$ inches wide, made of pottery or fine clay, as represented in *fig.* 1007, supported on a table having a pair of bellows beneath it. The laboratory is at *b*, the blow-pipe of the bellows at *d*, with a stopcock, and the dome is surmounted by a chimney *a c*, in whose lower part there is an opening with a sliding door for the introduction of charcoal fuel. The furnace is formed in three pieces: a dome, a body, and an ash pit. A pair of tongs, a stoking hook, a cupel, are seen on the right hand; and the plan of the stoneware grate pierced with conical holes and a poker are seen to the left.

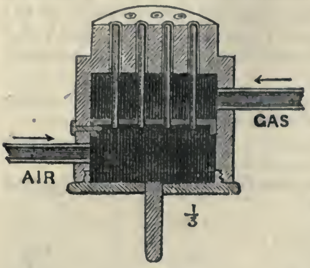
Gas Furnaces.—Gas has been employed, of late, with much advantage for heating crucibles, and many forms of burners have been introduced for the purpose of producing such jets as will yield the proper quantity of gas, and unite it with the right proportion of air, for producing the most intense heat; which can be applied in a convenient manner. The power of the burner, of whatever kind it may be, must be increased by surrounding the flame with a jacket of fire clay or some non-conducting substance, which will prevent the dissipation of heat by radiation. By attending to this a very high temperature may be produced with but a small expenditure of gas.

Griffin's Blast Gas-Furnace.—This is a more powerful apparatus, adapted for metallurgic operations, such as fusing considerable masses of metal, assaying, roasting, &c. It consists of two parts: first, of a particular form of *gas-burner*, which is supplied with gas at the usual pressure, and with a blast of common air, supplied by bellows or a blowing machine at about ten times the pressure at which the gas is supplied; and secondly, of a *furnace*, which is built up in a particular manner, round the flame produced by the gas-burner and the crucible exposed to ignition. The object of this particular construction is to accumulate and concentrate in a focus the heat produced by the gas flame, and to make it expend its entire power upon any object placed in that focus.

This apparatus can be made of various sizes, according to the amount of work required from it.

The *gas-burner* is a cylindrical iron reservoir shown in section in *fig.* 1008, which is drawn on a scale of one-third the full size. It contains two chambers, not in communication with one another. Into the upper chamber, gas is allowed to pass by the tube marked Gas. Into the lower chamber, air is forced by the tube marked Air. The upper part of this burner is an inch thick in the metal. Through this solid roof holes from 6 to 26 in number are bored for the escape of the gas. The number of holes depends, of course, upon the heating power required from the burners. The air passes from the lower chamber, through a series of metal tubes, placed in the centre of the gas-holes, and continued to the surface of the burner, so that the gas and air do not mix until both have left the gas-burner, and then a current of air is blown through the middle of each jet of gas. The bottom of the gas-burner is made to unscrew, and the division between the two chambers, which carries the air-tubes, is easily removable for the purpose of being cleaned. The gas and air pipes generally used in the inventor's experiments were each half an inch in the bore and ten inches long; the gas had usually a pressure of half an inch of water, and the blast of air about ten times that pressure. The quantity of gas used in an hour was about 100 cubic feet. The stopcock which supplied it had a bore of half an inch. The round rod represented at the bottom of the burner, *fig.* 1008, is intended to fit it to the support.

1008



When the gas is lighted and the blast of air is put on, the flame produced by the gas-burner is quite blue, and free from smoke. It is two inches in diameter and three inches high, and the point of greatest heat is about two inches above the flat face of the gas-burner. Above this steady blue flame there rises a flickering ragged flame, several inches in height, varying with the pressure of the gas. In the blue flame, thin platinum wires fuse readily.

When the gas is burning in this manner, and the apparatus is attached to flexible tubes, the burner may be inverted or held sideways, without disturbing the force or regularity of the flame, so that the flame may be directed into a furnace at the bottom, the top, or the side, as circumstances may require.

The following articles are used in building-up the gas-furnace for different experiments. They vary in size according to the volume of the crucible, or the weight of the metal to be heated:—

1. A circular plate of fire-clay, two inches thick, with a hole in the centre, exactly fitting the upper part of the gas-burner, which is made to enter into the hole three-quarters of an inch. In external diameter, this clay plate agrees with each size of the furnace.

2. A cylinder of fire-clay, of which two pieces are required to constitute the body of each furnace. In the middle of each cylinder a trial hole is made, one inch in diameter, to which a fire-clay stopper is adapted.

3. A fire-clay cylinder, closed at one end, and pierced near the open end with six holes of half an inch in diameter. The thickness of the clay is immaterial. This cylinder is three inches in diameter.

4. A circular plate of fire-clay, two and a half inches or three inches in diameter and one inch thick. Similar pieces half an inch thick are useful.

5. A cylinder of plumbago, to be used as a crucible support. It is three inches in inside diameter, one inch in height, and pierced with twelve holes of three-eighths of an inch bore.

6. A similar cylinder of plumbago, two or three inches high, pierced with twenty-four holes of three-eighths of an inch bore.

7. A thin plate of plumbago, three inches in diameter, viz. of the same diameter as the cylinder of 5 and 6. It has a small hole in the middle, and being of soft material, the hole can be easily cut or filed to suit crucibles of any desired size.

To suit the larger kind of crucibles and furnaces, cylinders are made resembling the above in form, but of greater diameter.

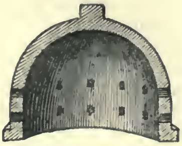
As in all cases the heating power of the gas-furnace spreads laterally and does not rise vertically, the most advisable form of the crucibles required for use in it, is *short* and *broad*, not tall and narrow, and the supporting cylinders must be shaped accordingly. No fire-bars or grates must be used to support the crucibles in this gas-furnace, because no material formed into narrow bars can sufficiently withstand its power of fusion and combustion.

8. A plumbago cylinder, or crucible jacket, two and a half inches high, two and a half inches in diameter, and a quarter of an inch thick in the walls. It has six holes of three-eighths of an inch diameter near one end.

9. A circular cover or dome (*fig.* 1009) flanged at the bottom, and having a knob or handle at the top. It is pierced with twenty-four holes of a quarter of an inch in diameter, arranged in two rows near the bottom. This dome, when of small size, is made of plumbago; when large, of fire-clay.

10. Plumbago crucibles made with a solid overhanging rim, the use of which is to suspend the crucibles over the gas-burner, by means of the cylinders Nos. 5 and 6. When the crucibles are too small to fit the cylinders, the flat-plate No. 7, is filed to fit the crucible, and is then placed on the cylinder, to whose diameter it is adapted.

1009



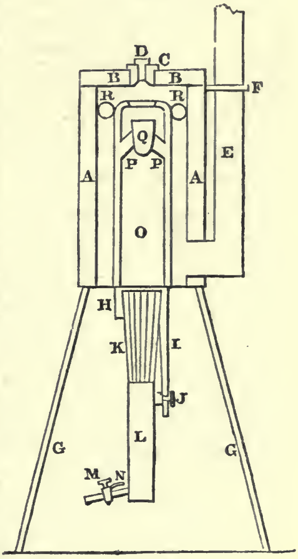
Besides these pieces of fire-clay and plumbago, it is necessary to be provided with a strong iron tripod, to sustain the furnace; an iron pan, in which to place the furnace; and a quantity of gravel, or rounded flints, not less than half an inch, nor more than one inch in diameter. These pebbles form an essential part of the gas-furnace.

Other forms of Griffin's gas-furnace will be found fully described in Watts's 'Dictionary of Chemistry.' See also Mr. Griffin's description of a gas-furnace for attaining a white heat without the aid of a blowing-machine, in Journ. of Chemical Soc., 1870, p. 280.

Mr. George Gore has patented a gas-furnace of great power, which he thus describes (*fig.* 1010):—A is a cylinder of fire-clay about nine inches high and six inches diameter, open at both ends, with a hole in its side near the bottom to lead into the chimney; it is covered by a moveable plate of fire-clay, B, with a hole in its centre for introduction or removal of the crucible, &c.; this hole is closed by a perforated plug of clay, C, for access to the contents of the crucible, and that again is closed by another clay stopper D. E is a chimney of sheet iron about five or six feet high, kept upright by a ring of iron, F, attached to the top of the furnace. The fire-clay cylinder is enclosed in a sheet-iron casing with a bottom of iron, to which are fixed three iron legs, G. An iron tube H, with a prolongation I, supports by means of the screw, J, the burner K, and its tube L, which is open at both ends. Gas is supplied to the burner by means of the tag, M, which has a small index, N, attached to it for assistance in adjusting the gas. Inside the larger cylinder is another fire-clay cylinder or cupola, O, with open ends, and with three projections of fire-clay, P, for supporting the crucible, Q; it is kept steady by means of three fire-clay marbles, R. The gas-burner is a thin metal cylinder, deeply corrugated at its upper end, with the corrugations diminishing to nothing at its lower end.

The action of this furnace is as follows:—Gas is admitted to the open tube, L, by the tap, M; it there mixes with air to form a nearly explosive mixture, which ascends through the burner, and burns in the clay cylinder, O, being supplied with the remainder of air necessary to complete combustion through the tube H, to the outer surface of the flame, by means of the spaces between the corrugations. The flame and products of combustion pass up through the cylinder O, and then downwards outside it to the chimney, the focus of greatest heat being at Q.

1010



It is important in using this furnace that the burner is placed quite in the centre of the bottom of the tube O; also that a crucible of not too large or not too small dimensions be selected. The most suitable way of supporting a smaller crucible is by placing it in a larger one that has had its upper parts broken off. If desirable, a little clay luting may be placed round the top edge of the iron casing to exclude air entering between it and the cylinder; also a little thin clay luting upon the part of the bottom of the furnace where the inner cylinder, O, rests.

In lighting the furnace, the plugs C and D are removed, a light held *inside* the opening, and the gas turned on full. Should the flame blow down to the bottom of the tube, L, on lighting (which, however, rarely occurs unless the furnace is already hot), the gas must be turned off, and the bottom of L momentarily closed whilst lighting the gas as before. Should the flame not burn down to the burner, but only burn at the orifice in the clay plate, B, it must at once be extinguished and relighted, otherwise some of the gaseous mixture will pass into the chimney unburned, and subsequently ignite and cause an explosion. A large flame now issues from the top orifice, and is white if too much gas is on, and chiefly violet or red with the proper quantity; it should now be coarsely adjusted until these appearances are presented. The annular plug, C, should now be inserted, which will compel it to pass downwards to the chimney, and as soon as the small remaining flame, now issuing, disappears or nearly disappears, as it will in a few seconds, the small stopper, D, should also be inserted. In lieu of this, the large flame may be deflected against the chimney by means of a piece of sheet-iron until it withdraws inwards as before mentioned; two plugs may then be reinserted. The gas-tap may now be partly adjusted. The crucible should be placed in the furnace after the act of lighting the gas, but not immediately after if the furnace is cold, or explosions may occur by unburned gaseous mixture passing the crucible into the chimney and igniting afterwards. After about five minutes the gas should be slowly adjusted, until a sound is heard inside like a series of small explosions. This sound is sometimes not very distinct, especially at high temperatures, and therefore requires a little experience in the use of the furnace in order to be detected. It is, however, a chief guide in determining the proper amount of gas, and should therefore be carefully studied. To assist in adjusting the gas, it will be found very useful to place a small piece of looking-glass beneath the tube, L, and to adjust the gas-tap until the flame between the burner and crucible appears wholly violet or slightly white; but this test is liable to fallacy if employed when the gas is just lighted, because the coldness of the part makes the flame much whiter than it otherwise should be. It is also fallacious, the flame appearing whiter than it really is when the crucible is very hot. It is, however, of great assistance, especially at intermediate temperatures. A rough deposit upon the outer edge of the crucible indicates an excess of gas: the deposit is carbon. Less gas is required with a crucible in the furnace than without one; also less is required when the small hole at the top of the furnace is open than when it is closed; and less is also required when the furnace is cold than after it has been lighted some time, because the draught gradually increases and draws in more air. After having accurately adjusted the gas, no further attention to the furnace is requisite.

Having once found the proper adjustment of gas under certain known conditions, it is well to notice the position of the index-pointer, N, in order to be able at once to adjust it to about the right point on other occasions.

Under ordinary circumstances, during daylight, I have found it best to set the gas nearly full on at first, and fully on at about five minutes afterwards, when the draught has become more powerful; but during twilight, when the supply of gas from the gas-works is more free, I have set the index-pointer at the numbers 2½ or 3. The gas should be supplied by a pipe of not less than three-eighths of an inch bore, with a main pipe of half an inch; but all depends upon the pressure of gas at the particular locality, which is very variable. The consumption of gas varies from thirty to forty cubic feet per hour, the value of which is about twopence.

The top of the chimney should be placed in a position where the products of combustion can pass freely away. If it is placed in an opening or pipe leading to another chimney, care must be taken not to have the draught too powerful, otherwise the heat will be drawn more into the chimney, and the supply of gas in the daytime may be found rather deficient. The furnace will act satisfactorily, though less powerfully, with the chimney standing in an open room without any special outlet for the products of combustion, provided the full height (6 feet) of chimney is employed. Under other circumstances I have generally used a chimney 4½ or 5 feet high.

This furnace will produce what is generally called 'a white heat;' it will readily melt half a pound of copper, or six ounces of cast iron. I have melted these quantities in it: it will melt as large a quantity of those substances as the largest sized crucible that can be introduced into it will contain, sufficient space being reserved around the crucible for draught. It requires from twenty to thirty minutes to acquire its highest temperature, and then *the entrance part of the chimney exhibits a faint red heat in daylight.* If it exhibits much more than this, the draught is too powerful, and if less, there is not sufficient gas.

When the small hole, D, is open, some air is drawn in that way, and less air passes up with the gas through the tube O, but the cold air does not much diminish the temperature of the crucible, because it combines with the excess of gas now passing over the edge of the inner cylinder; it, however, renders the flame round the crucible white by deficiency of air, and this should be partly corrected by lessening the gas. An excess of either gas or air renders the surface of melted copper dull.

When it is desirable to perfectly avoid contact of air with the fused substance during manipulation, a narrow crucible should be employed, and a thin and narrow ring of fire-clay should be placed upon the top of the tube O, to contract its opening; the flame then closes completely over the top of the crucible, and prevents access of air. A proper adjustment of gas, together with exclusion of air in this manner, enables a perfectly bright surface of melted copper, or even tin, to be continuously maintained, from which the images of parts above are clearly reflected. The clay ring may be withdrawn by lifting the plate B. A less perfect exclusion of air may be obtained by employing a narrow crucible placed rather low down in its support. A small iron dish should be placed beneath the tube L to receive any melted substance that may fall. The chief conditions of success in the use of this furnace are *sufficient gas, a suitable degree of draught*, and *proper regulation of gas to air*.

Several very ingenious furnaces for use in the laboratory or assay office are fully described in Watts's 'Dictionary of Chemistry.' See GAS-FURNACE.

FUR-SKIN DRESSING. Fur-skins are usually dressed by placing them in their dried state in closed tubs with a little salt butter, where they undergo a treading operation with men's feet until they are sufficiently soft, and bend easily. The skins if large are sewn up, the fur being turned inwards; but if small skins, such as ermine, are being dressed, they require no sewing. This sewing is preparatory to the greasing with butter or lard, and is intended to protect the fur from the grease, and to promote the softening in the succeeding treading operation. The skins are next wetted, and their flesh is removed; or they are fleshed. See CURRYING. They are again subjected to treading in tubs containing sawdust, that from mahogany being preferred; and afterwards in tubs containing plaster of Paris, or whitening, sprinkled between the skins. The main object of this is to remove the grease which has been used in the previous processes. They are then beaten with a stick and combed; when the dressing is completed. M. Pierre Thirion proposed to soften the skins, not by treading, but by beating stocks, of a construction like the fulling mill. They are next sewn up, and again filled in a strong vessel, where they are forced upwards by the beaters, turned over and over, and thus speedily softened. They are now fleshed, and then returned to the beating stocks, and mahogany or other sawdust is sprinkled upon the fur, before the beating is renewed. They are next placed in a heated barrel, furnished within with radial pins for turning the goods over and over, in order that they may be acted upon by various dry substances, which are thrown into the barrel, and absorb the fat from the skins. Through the hollow shaft of the barrel, steam is introduced, which heats the skins, softening the fat, which is then absorbed by sand, flour, or any other desiccative powder. It is proper to take the skins out of the barrel, from time to time, to comb them. Such as have been sufficiently acted upon may then be set aside. They are lastly freed from the dust by being subjected to a grated cylinder in a state of rotation, and then combed by hand.

FUSE. See FUZE.

FUSEES. A name given to a kind of lucifer-match which does not flame; this match is used exclusively by the smokers of tobacco. Bode of Vienna introduced them. A granule of powder, made of the same composition as the ordinary lucifer match, is placed at the end of a match, and a mixture of charcoal and nitrate of potash surrounds it. The granule is ignited by friction, and this fires the other mixture, which burns like quick-match.

FUSEL OIL. During the rectification of corn or grape spirits there is always separated a fiery fœtid oil of nauseous odour and taste. It is this substance which is the cause of the unpleasant effects which are produced upon most persons by even a small quantity of insufficiently-rectified whiskey or brandy. Any spirit which produces milkiness on the addition of four or five times its volume of water may be suspected to contain it. By repeated rectification every trace may be removed.

Fusel oil invariably consists of one or more homologues of the vinic alcohol, $C^4H^6O^2$ ($\mathbf{C^2H^6O}$), mixed with variable quantities of the latter substance and water. The nature of fusel oil varies much with the source from whence it is obtained. That which is ordinarily sold in this country for the purpose of yielding pear essence consists mainly of the amylic alcohol, $C^{10}H^{12}O^2$ ($\mathbf{C^5H^{12}O}$), mixed with from one-fourth to one-fifth of spirit of wine.

The progress of organic chemistry has been greatly assisted by the researches which have been made upon fusel oil, almost all the amylic compounds hitherto obtained having been directly or indirectly obtained from it.

To obtain fusel oil in a state of purity it is necessary, in the first place, to rectify it fractionally. By this means it will be found that much alcohol can be removed at once. If a great quantity of water and very little vinic alcohol be present, the simplest mode of purification is to shake it with water, by which means common alcohol is removed in solution, while the amylic alcohol, owing to its comparative insolubility, may be easily separated by the tap-funnel. After drying over chloride of calcium, it is to be again rectified once or twice, only that portion distilling at about 269°·6 Fahr. (132° Cent.) being received. The product of this operation is pure amylic alcohol, from which an immense number of derivations of the amylic series can be obtained. By treatment with sulphuric acid and bichromate of potash it is converted into valerianic acid. In this manner all the valerianic acid, now so much employed in medicine, is prepared. By distilling amylic alcohol with sulphuric acid and acetate of potash, we obtain the acetate of amyle, commercially known as jargonelle-pear essence.

The foreign fusel oils obtained from the grape-marc contain several homologues higher and lower in the series than the amylic alcohol. In fact, it would appear that during the fermentation of grapes there are formed, not only alcohols, but ethers and acids.

M. Chancel, by repeatedly rectifying the dehydrated and more volatile portions of the residues of the distillation of grape-marc alcohol, succeeded in isolating a fluid boiling at 205° Fahr. This proved to be true propionic alcohol. M. Wurtz has also been able to obtain the butylic alcohol by rectifying certain specimens of potato oil.

All fusel oils are not so complex. The author of this article has repeatedly examined specimens of English and Scotch fusel oil, which did not contain anything save the ethylic and amylic alcohols, accompanied by small portions of the acids, which are procured by their oxidation. M. Chancel has given the following equations, which explain the manner in which saccharine matters break up into homologous alcohols under the influence of ferments. I have reduced the unitary notation employed by him into the ordinary formulæ used in this country, in order to render the relations as clear as possible to the reader.

$$\underbrace{2C^{12}H^{12}O^{12}}_{\text{Glucose.}} = 8CO^2 + \underbrace{4C^4H^6O^2}_{\text{Alcohol.}}.$$

$$2C^{12}H^{12}O^{12} = 8CO^2 + C^4H^6O^2 + \underbrace{2C^6H^8O^2}_{\text{Propionic alcohol.}} + 2HO.$$

$$2C^{12}H^{12}O^{12} = 8CO^2 + \underbrace{2C^8H^{10}O^2}_{\text{Butylic alcohol.}} + 4HO.$$

$$2C^{12}H^{12}O^{12} = 8CO^2 + C^6H^8O^2 + \underbrace{C^{10}H^{12}O^2}_{\text{Amylic alcohol.}} + 4HO.$$

M. Chancel appears to consider the last equation as indicating the necessity of propionic alcohol being always formed wherever amylic alcohol is generated; but this is not in accordance with the results of those chemists who have examined crude amylic alcohol repeatedly for propionic alcohol, but without finding any. The formation of these interesting homologues appears therefore to depend upon special circumstances connected with the fermentation.

The caproic alcohol is also contained in certain varieties of fusel oil.

In order to assist those who may wish to examine the fluid alluded to, the following table of the physical properties of the alcohols, up as high as the caproic, has been inserted:—

Table of the Physical Properties of some Homologous Alcohols found in Fusel Oils.

Name	Observers	Formula		Boiling point	Specific Gravity	Vapour Density	
						Experiments	Calculation
Methylic .	Dumas and Peligot	$C^2H^4O^2$	CH^4O	152°	0·7980 at 68°	1·120	1·1072
Ethylic .	Gay-Lussac . .	$C^4H^6O^2$	C^2H^6O	172°	0·7938 at 60°	1·618	1·5916
Propionic .	Chancel . . .	$C^6H^8O^2$	C^3H^8O	205°	..	2·020	2·0760
Butylic .	Wurtz . . .	$C^8H^{10}O^2$	$C^4H^{10}O$	234°	..	..	2·5804
Amylic .	Balard and Dumas	$C^{10}H^{12}O^2$	$C^5H^{12}O$	270°	0·8184 at 59°	3·147	3·0448
Caproic .	Faget . . .	$C^{12}H^{14}O^2$	$C^6H^{14}O$	304°	0·8330 at 32°	3·530	3·5292

Fusel oil, in addition to these homologous alcohols, contains fatty acids. The following list contains the acids found in fusel oil, with the name of the observer:—

Name of Acid	Formula		Observer
Formic	$C^2H^2O^4$	$\mathbf{CH^2O^2}$	Wetherill
Acetic	$C^4H^4O^4$	$\mathbf{C^2H^4O^2}$	Kent
Valerianic	$C^{10}H^{10}O^4$	$\mathbf{C^5H^{10}O^2}$	Kent
Caproic	$C^{12}H^{12}O^4$	$\mathbf{C^6H^{12}O^2}$	Wetherill
Œnanthylic	$C^{14}H^{14}O^4$	$\mathbf{C^7H^{14}O^2}$	Mulder, Wetherill
Caprylic	$C^{16}H^{16}O^4$	$\mathbf{C^8H^{16}O^2}$	Wetherill
Capric	$C^{20}H^{20}O^4$	$\mathbf{C^{10}H^{20}O^2}$	Rowney
Margaric	$C^{34}H^{34}O^4$	$\mathbf{C^{17}H^{34}O^2}$	Kolbe

When 15 per cent. of fusel oil is found in alcohol it is admitted duty free; the determination of this is, therefore, a question of considerable importance. The method in use in the London Custom House for the determination of alcohol in fusel oil consists in shaking the liquid to be tested with an equal volume of water, and allowing it to stand twelve hours; at the expiration of which time it is found separated into two layers, the fusel oil being at the top. The specific gravity of the lower layer is taken, and from this the amount of proof spirit is calculated. This, Dr. Ulex says, leads to very false results, since crude fusel oil contains also ethylic, propylic, butylic, and amylic alcohol, which are variously soluble in water. He recommends the separation by fractional distillation, and the use of saturated solutions of sodic chloride (chloride of sodium). He places 100 c. c. of the fusel oil to be tested in a retort, and distils off 5 c. c., and shakes this with an equal quantity of a saturated salt solution. If, on standing, one half or more of the liquid is fusel oil we may be sure it contains less than 15 per cent. of proof spirit, which renders it free of duty in England. If less separates, shake some of the liquor with an equal quantity of brine, and allow it to stand; after separating, distil the spirit from the salt solution and determine.

Fusel oil has been patented as a solvent for quinine, but its odour, and more especially that produced by its oxidation, so persistently adheres to anything with which it has been in contact, that great care is requisite in the purification. It is remarkable, that at the first instant of smelling most specimens of fusel oil, the odour is not unpleasant, but in a very few seconds it becomes exceedingly repulsive, and provokes coughing.—C. G. W.

FUSIBILITY. That property by which solids assume the fluid state under the influence of heat. With a few exceptions, such as carbon and some organic bodies, all substances appear capable of assuming the fluid state. Although we do not appear to have actually fused charcoal by means of the voltaic battery, the diamond has been fused and converted from a crystalline gem into a mass of opaque coke.

Thénard has thus grouped the metals:—

1. Fusible below a red heat: *Mercury, potassium, sodium, tin, bismuth, lead, tellurium, arsenic, zinc, antimony, cadmium.*

2. Infusible below a red heat: *Silver, copper, gold, cobalt, iron, manganese, nickel, palladium, molybdenum, uranium, tungsten, chromium, titanium, cerium, osmium, iridium, rhodium, platinum, columbium.*

Pouillet has, in his admirable treatise on Heat, given the following table of the fusing points of various substances:—

Names	Centigrade
Mercury	— 39
Oil of Turpentine	— 10
Ice	0
Tallow	33 to 38
Acetic acid	45
Spermaceti	49
Stearine	49 to 43
Margaric acid	55 to 60
Unbleached wax	61
White wax	68
Stearic acid	70
Phosphorus	43
Potassium	58
Sodium	90
Iodine	107
Sulphur	114
Tin	230

Names	Centigrade.
Bismuth	202
Lead	320
Zinc	360
Antimony	432
Bronze	900
Silver, very pure	1000
Standard gold	1180
Very fine gold	1250
White cast iron, very fusible	1050
White cast iron, second fusion	1200
Grey cast iron, very fusible	1100
Grey cast iron, second fusion	1200
Manganesed cast iron	1250
The more fusible steels	1300
The less fusible steels	1400
Soft iron (French)	1500
English hammered iron	1600

FUSIBLE METAL. This alloy owes its peculiar property of melting at a comparatively low temperature to the presence of bismuth.

8	parts of bismuth,	5	of lead,	3	of tin	melt at 212° F.
2	do.	1	do.	1	do.	do. 201° F.
5	do.	3	do.	2	do.	do. 199° F.

8 do. 5 do. 4 of tin, and one of type metal is an alloy much used on the Continent for producing casts of metals by the *clichée* process. A mixture of bismuth, lead, tin, and antimony is used in this country for obtaining copies from wood-blocks. Mr. Cowper used 1 of bismuth and 2 of tin to make the alloy most suitable for rose engine and excentric turned pattern, to be printed from after the manner of letter-press. A good fusible alloy consists of—cadmium 2 parts, bismuth 8 parts, tin 2 parts, lead 4 parts; melts at 160° F.

The soft solders used by pewterers consist of tin, lead, and bismuth in various proportions; indeed, bismuth enters to a greater or a less extent into all the soft solders.

Fusible metal has also been employed as a sort of safety valve for steam-boilers. By adjusting the proportions of the above-named metals, an alloy can be made which will melt at any required temperature; therefore, when the boiler rose to this temperature, the metal plug gave way and the steam escaped. See Alloy.

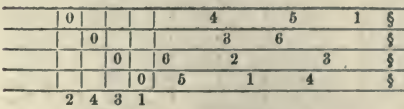
FUSTIAN is a species of coarse thick tweeled cotton, and is generally dyed of an olive, leaden, or other dark colour. Besides the common fustian, which is known by the name of pillow (probably pilaw), the cotton stuffs called corduroy, velveret, velveteen, and thickset, used for men's wearing apparel, belong to the same fabric. The commonest kind is merely a tweel of four, or sometimes five leaves, of a very close stout texture,, and very narrow, seldom exceeding 17 or 18 inches in breadth. It is cut from the loom in half pieces, or ends as they are usually termed, about 35 yards long, and after undergoing the subsequent operations of dyeing, dressing, and folding, is ready for the market.

The draught and cording of common fustian is very simple, being generally a regular or unbroken tweel of four or five leaves. Below are examples of a few different kinds, selected from those most general in Lancashire.

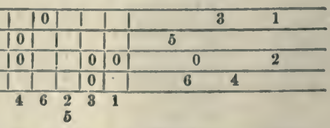
The number of leaves of heddles are represented by the lines across the paper, and the *cording* by the cyphers in the little squares, those which raise every leaf being distinguished by these marks, and those which sink them left blank, as more particularly explained in the article Textile Fabric.

When the material is silk, it is called velvet; when cotton, velveteen. A common tweeled cloth, when composed of silk is called satin; when of cotton, fustian or jean; of woollen, plaiding, serge, or kerseymere.

No. 1.—Pillow Fustian.



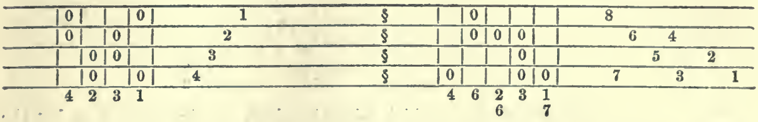
No. 2.—Plain Velveret.



Of the above, each contains four leaves of heddles or healds: that represented by No. 1 is wrought by four treddles, and that which is distinguished by No. 2, by five;

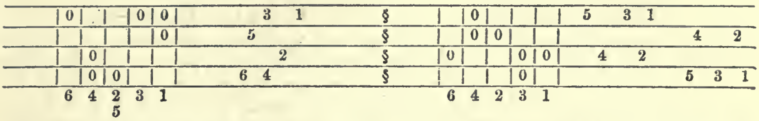
the succession of inserting the threads of warp into the heddles will be discovered by the figures between the lines, and the order in which the treddles are to be successively pressed down by the figures below.

No. 3.—Double Jean. No. 4.—Plain Thickset.



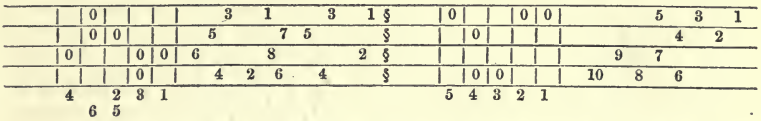
These, like the former, are wrought with leaves. No. 3 requires four, and No. 4 five treddles. The succession of inserting the threads of warp, and of working the treddles, are marked by the respective numbers between and under the lines, as in the former example. Both are fabrics of cloth in very general use and estimation as low-priced articles.

No. 5.—Best Thickset. No. 6.—Velvet Tuft.



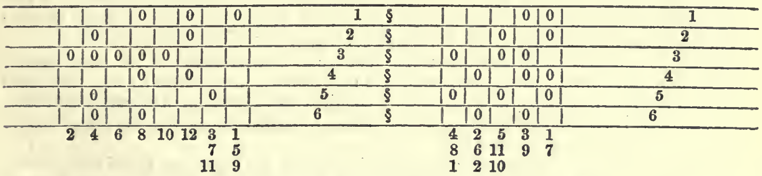
These are further specimens of what may be, and is, executed with four leaves, and in both examples five treddles are used. With two other specimens we shall conclude our examples of this description of work, and shall then add a very few specimens of the more extensive kinds.

No. 7.—Cord and Velveret. No. 8.—Thickset Cord.



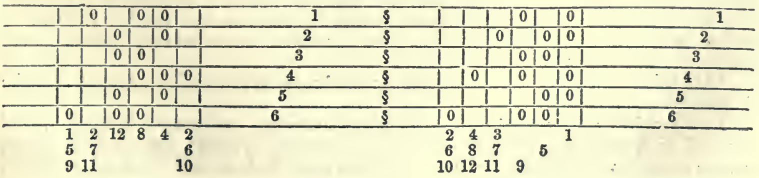
In these the succession of drawing and working are marked like the former. The next are examples of patterns wrought with six leaves. No. 9 has eight, and No. 10 five heddles.

No. 9.—Double Corduroy. No. 10.—Genoa Thickset.



In both these the warp is inserted into the heddles the same way. The difference is entirely in the application of the cords, and in the succession of pressing down the treddles. We now give four specimens of the flushed and cut work, known by the name of velveteen. They are also upon six leaves, and the difference is solely in the cording and in the treading.

No. 11. Queen's Velveteens. No. 12.



No. 13.—Plain Velveteen. No. 14.—Genoa Velveteen.

				0	1	§			0	0		0	1
0			0		2	§		0	0				2
				0	3	§	0	0		0			3
		0	0		4	§			0	0			4
				0	5	§		0	0		0		5
	0		0		6	§		0		0			6
1	3	2	4	8			2	4	8	12	3	1	
5	7	6					6				7	5	
							10				11	9	

The additional varieties of figure which might be given are almost endless, but the limits of this article will not admit a further detail. Those already given are the articles in most general use. The varieties of fancy may be indulged to great extent, but it is universally found, that the most simple patterns in every department of ornamental weaving, are those which attract attention and command purchasers. We shall therefore only add an example of king's cord or corduroy, and of Dutch cord, with one of Genoa and one of common velvet, to show the peculiarities.

No. 15.—King's Cord. No. 16.—Dutch Cord.

				0	0	1	§			0			4 1
		0			0	2	§		0			0	5 2
		0	0			7 3	§	0			0		6 3
			0	0		8 4	§		0	0			7
	0			0	0	5	§	0		0		0	8
0		0				6	§	0	0		0	0	9
1	3	8	6	4	2			6	4	2	3	1	
5	7									5			

No. 17.—Genoa Velvet. No. 18.—Plain Velvet.

		0			0	1	§						1
	0	0	0			2	§						2
0	0					3	§						3
		0	0			4	§						4
	0		0			5	§						5
0	0		0			6	§						6
2	4	8	12	3	1			1	3	4	2	8	
6				7	5			7	5				
10				11	9								

After the fustian cloth is taken from the loom-beam, it is carried to the cutter, who, rips up the surface-threads of weft, and produces thereby a hairy-looking stuff.

Preparatory to its being cut, the cloth is spread evenly upon a table about six feet long, upon each end of which a roller mounted with a ratchet-wheel is fixed: the one to give off, and the other to wind up the piece, in the above six-feet lengths.

The knife is a steel rod about two feet long, and three-eighths of an inch square, having a square handle at the one end; the other end is tapered away to a blade, as thin as paper. To prevent this point from turning downwards and injuring the cloth, its under side is covered by a guide which serves to stiffen it, as well as to prevent its lower edge from cutting the fustian.

The operative (male or female) grasps the handle in the right hand, and insinuating the projecting point of the guide under the weft, pushes the knife smartly forward though the whole length of six feet, with a certain dexterous movement of the shoulder and right side, balancing the body meanwhile, like a fencer, upon the left foot. This process is repeated upon every adhesive line of the weft.

The next process to which fustians are exposed is steeping in hot water, to take out the dressing paste. They are then dried, reeled, and brushed by a machine, &c. From twenty to thirty pieces, each eighty yards long, may be brushed in an hour. The breadth of the cloth is twenty inches. The maceration is performed by immersing the bundled pieces in tanks of water, heated by waste steam; and the washing by means of a reel or winch, kept revolving rapidly under the action of a stream of cold water, for an hour or longer.

After being thus ripped up, it is taken to the brushing or teazling machine, to make it shaggy.

This consists of a series of wooden rollers, turning freely upon iron axles, and covered with tin-plate, rough with the burs of punched holes; and blocks of wood, whose concave under surfaces are covered with card-cloth or card-brushes, and which are made to traverse backwards and forwards in the direction of the axes of the revolving rollers, during the passage of the cloth over them.

After they are brushed in the machine, the goods are singed by passing their cut surface over a cylinder of iron, laid in a horizontal direction, and kept red hot by a flue. They are now brushed again by the machine, and once more passed over the singeing surface. The brushing and singeing are repeated a third or even occasionally a fourth time, till the cord acquires a smooth polished appearance.

The goods are next steeped, washed, and bleached by immersion in solution of chloride of lime. They are then dyed by appropriate chemical means. After which they are padded (imbued by the padding machine of the calico-printers) with a solusition of glue, and passed over steam cylinders to stiffen them.

Smooth fustians, when cropped or shorn before dyeing, are called moleskins; but when shorn after being dyed, are called beverteen; they are both tweeled fabrics. Cantoon is a fustian with a fine cord visible upon the one side, and a satiny surface of yarns running at right angles to the cords upon the other side. The satiny side is sometimes smoothed by singeing. The stuff is strong, and has a very fine aspect.

FUSTIC, or *Yellow Wood.* (*Bois jaune*, Fr.; *Gelbholz*, Ger.) The *old fustic* of the English dyer. It is the wood of the *Morus tinctoria.* It is light, not hard, and pale yellow with orange veins; it contains two colouring matters, one resinous, and another soluble in water. Chevreul has given the name of *morin* to the colouring matter obtained from fustic. It is procured by boiling ground fustic in distilled water, passing the decoction rapidly through a filter, and allowing the liquid to stand for several days, when the colouring matter (*morin*) is precipitated.

The decoctions of fustic in water are brightened by the addition of a little glue, and still more so by curdled milk. This wood is rich in colour, and imparts permanent dyes to woollen stuffs, when aided by proper mordants. It unites well with the blue of the indigo vat, and Saxon blue, in producing green of various shades. Alum, tartar, and solution of tin, render its colour more vivid; sea-salt and sulphate of iron deepen its hue. From 5 to 6 parts of old fustic are sufficient to give a lemon colour to 16 parts of cloth. This wood is often employed with sulphate of iron in producing olive and brownish tints, which agree well with its dull yellow. For the same reason it is much used for dark greens.

The bichromates of potash and of lead have nearly superseded the use of fustic, but still it is employed for producing some green in cotton yarn, and in light cotton fabrics, as gauzes and muslins.

FUSTIC, YOUNG. (*Fustet*, Fr.) The wood of the *Rhus cotinus*, a shrub which grows principally in the south of France and in Italy, called also *Venetian sumach.* This wood contains a large quantity of yellow colouring matter, named *fusteric.* This colouring matter has a strong attraction for oxygen, which affects its use as a dye, rendering it very fugitive. It is rarely used alone, but as an assistant to strike some particular tint.

FUSTIN. A name given to the colouring matter of the *Rhus cotinus* or young fustic.

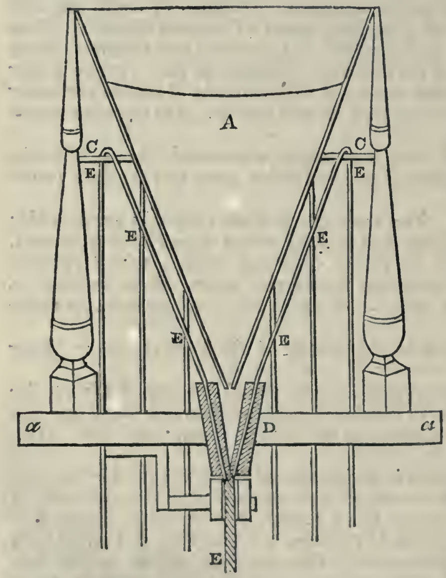
FUZE. Gunpowder, or some other explosive agent placed in a case or tube, to fire the powder placed in the cannon, or in the hole bored in rocks for blasting. See ELECTRICITY, BLASTING BY, for a description of Abel's fuzes. See also FUZE, SAFETY.

FUZE, SAFETY. The safety fuze is an instrument manufactured for the purpose of conveying fire to the charge in blasting. It is made of flax with a column of fine gunpowder in its centre, and appears like a hard, varnished cord. To use it—one end of the required length is placed in the charge, and the hole is tamped with any soft substance which will not cut the fuze. Fire must be applied to the fuze itself, which slowly and surely burns to the charge, if care has been taken to select that kind of fuze which the operation requires. It then affords the very best means of blasting ever devised, combining certainty, economy, and safety. The safety fuze was the invention of Mr. Bickford, who thus describes it in the specification of his process:—

'I embrace in the centre of my fuze, in a continuous line throughout its whole length, a small portion, or compressed cylinder, or rod of gunpowder, or other proper combustible matter prepared in the usual pyrotechnical manner of firework for the discharging of ordnance; and which fuze so prepared, I afterwards more effectually secure and defend by a covering of strong twine made of similar material, and wound thereon, at nearly right angles to the former twist, by the operation which I call countering, hereinafter described; and I then immerse them in a bath of heated varnish, and add to them afterwards a coat of whiting, bran, or other suitable powdery substance, to prevent them from sticking together, or to the fingers of those who handle them; and I thereby also defend them from wet or moisture, or other deterioration, and I cut off the same fuze in such lengths as occasion may require for use; each of these lengths constituting, when so cut off, a fuze for blasting of rocks and mining, and I use them either under water or on land, in quarries of stone and mines for detaching portions of rocks, or stone, or mine, as occasions require, in the manner long practised by, and well known to, miners and blasters of rocks.

‘At the left-hand end of an apartment which is 65 ft. long, is made an enclosed recess or closet of about 2 ft. square, and 6 ft. high, with a door or doors in front; in which closet, at about the height of 4 ft. 10 in., is placed a wooden shelf, about 1 in. thick at least, extending the whole length and breadth of such closet. In the centre of this shelf is made a hole, into which hole is inserted a collar. This collar is of metal, in form the frustum of a cone inverted. It is 3 in. long, 2 in. diameter at the upper end, and $1\frac{1}{4}$ in. at the bottom; through the centre of this is a hole of $\frac{3}{4}$ an inch diameter at the top, and $\frac{3}{16}$ths of an inch diameter at the bottom. Around this in a circle are twelve holes of about $\frac{1}{8}$th of an inch diameter, which converge towards a centre hole at the bottom, so as to be separated from it only by a fine edge of metal. *Fig.* 1011, D is a vertical section of the collar; this collar when placed in the hole in the shelf *a a*, projects both above and below the wooden shelf. In the upper projecting part of the cone or collar is then to be placed a common funnel, A, 12 in. high, and 10 in. in diameter at the top; around this funnel, at about 10 in. high from the before-mentioned shelf, is placed a ring made of cane, marked C C, and supported by a small frame of two or more pillars, resting on the before-mentioned shelf. At about 2 ft. 6 in. high from the floor of this room, and passing through the said closet, and extending the whole length of the said room, 65 ft. long, is a stage or shelf, or bench; the outside of this stage, or shelf, or bench, has a ledge or raised edge rising 1 in. above its surface, and on a similar raised edge on the inside, rising $1\frac{1}{2}$ in., is a line rack with teeth or cogs, twenty teeth to a foot. This stage, or shelf, or bench, is intended to support thereon a machine, being part of the apparatus thus used by me in my invention, called the monkey; which monkey consists, first, of a plane piece of board 20 in. long and 6 in. wide, supported by, and running on, three wheels of $1\frac{1}{2}$ in. diameter: on this board, supported by, and turning in, two centres, is a transverse axle placed quite across the plane bed of the monkey, supported by brackets, and turning round in holes made in the brackets, on the inside end of which is fixed a wheel of 10 in. diameter. Close to this wheel, and directly over the line rack, is placed on the said axle a pinion, which works on the cogs of the line-rack, on the side of which wheel at its outer edge are twenty-four teeth or cogs; these teeth or cogs work into corresponding teeth on the inner circle of another wheel, which has two circles of teeth or cogs, the inner and smaller circle working as already described, in those of the former wheel, and the outer circle of cogs working into a second pinion: connected with this pinion is a crook, and to the crook the threads of twine or other material are attached for twisting. A string or cord is fastened to the board of the monkey, and stretching along the stage, or shelf, or bench, passes over a pulley, and returning through holes made in the supports of the stage, or shelf, or bench, is attached to a winding roller; in this situation of the apparatus twelve balls of twine or other material intended to form the fuze are placed in the recess or closet on a floor raised there for that purpose 6 in. higher than the floor of the room, and the running threads from these balls are each led perpendicularly up through holes of 1 in. diameter, made for that purpose in a circle of 12 in. diameter in the shelf in which the before-mentioned collar is placed, and also perpendicular to and passed from the out-

1011



side to the inside over the said cane ring next to the funnel hereinbefore mentioned, and from thence the said threads are again led down by the side of the funnel to and through the holes in the upper and under sides of the aforesaid collar, which threads will then converge towards the lower point of the inner cone or collar, and there hang parallel and near to each other, and from thence they are to be led together to the pulley. Thence passing under the said pulley at a right angle they go to the monkey on the stage, or shelf, or bench, and are there made fast to the crook. The winding roller being now put in motion, communicates that motion to the monkey, which travels on the stage, or shelf, or bench, and at the same time by the pinion working on the line-rack; the cog-wheels before mentioned work the second pinion, and turning thereby the crook, completely twist the twelve threads (*Fig.* 1011) so made fast together, and continue that very twist up to the very point of the cone projecting downwards from under the funnel; at the very same time of putting the monkey in motion the funnel is charged with the gunpowder or other combustible matter for making the fuze, and then it is important to carefully watch the progress of the threads, and prevent or rectify any entanglement thereof; and also regulate the exit of the powder and prevent the dispersion of any surplus that falls to waste through the point of the cone or collar under the funnel during the operation of twisting. In this operation of twisting the powder passing the funnel lodges in the centre of the twelve threads, and is simultaneously embraced by all the threads, and the twisted part thus containing the powder is by the monkey drawn down and passes under the pulley, and continues its course with the monkey twisting the fuze along the stage, or shelf, or bench, to the end of the room. Here the monkey stops, and this part of the fuze so charged and twisted is then cut off, over a box placed on the said stage, or shelf, or bench, to receive any gunpowder or other combustible matter used therein that may fall from the ends when so cut asunder, the two ends thus separated are secured by a knot or tie made on each; the part so twisted and separated is put aside for the subsequent operation of "countering." By the monkey just described only one fuze could be spun at the same time, whereas it is desirable that several fuzes should be spun at once.

'Our second improvement in manufacturing fuzes relates to the mode of introducing the gunpowder. According to the method described in the said specification the gunpowder is not supplied from the funnel with the rapidity, regularity, and certainty which may be attained by our improvement. We introduce into the centre of the fuze a small strong thread or yarn, smaller and less fibrous than the yarns employed for the fuze. The thread or yarn which we employ is that known as No. 135 white-brown thread. This we supply from a reel or other source conveniently placed above the funnel containing the gunpowder. This thread or yarn is passed down through the gunpowder, and spun into the centre of the fuze by being attached to the monkey and drawn on with it as the fuze is spun. By means of this thread, so drawn on as the fuze is spun, the gunpowder in the lower part of the funnel is constantly kept in motion, and travels on with the threads so as to flow regularly down into the fuze. By this means the continuity and regularity of the cylinder of gunpowder is ensured.

'Our third improvement relates to the coating or varnishing applied to those fuzes which are to be used for blasting in dry ground, and in close or confined situations, or which are subject to considerable variation in temperature. The coating or varnishing heretofore applied, consisting of tar or resin, burns with a great deal of smoke and heat, and is affected by changes of temperature. Instead of a coating or varnish of either of those materials, we take 4 lbs. of best glue, and 2 lbs. of yellow soap, and having dissolved them in 12 gallons of water by a gentle heat, we add 56 lbs. of whiting, to give it a body. The varnish so made is applied to the fuzes by any suitable arrangement. The new varnish not being waterproof must not be employed for fuzes which are to be immersed in water; but, being less affected by temperature than the old varnish, and being non-inflammable, or burning with little smoke, is much preferable for general purposes. After the fuze has been coated or varnished with tar or resin varnish, and before the coating is hard or quite set, the fuze is fastened to crooks and made to revolve as if for countering, and a strip of brown paper is wound around the fuze in a spiral form, so as to completely envelope and cover the whole surface of the fuze. A thread is then wound round over the paper, which fixes the paper and prevents it shifting; another coat of tar or resin varnish is then applied to the paper, and by this means the fuze may be completely waterproofed, and protected against the action of the water.'

The following are the principal varieties of the safety fuzes in general use for special purposes:—

Common Safety Fuze.—This is the smallest kind of fuze which is made, and is only adapted for immediate use in dry ground, where the utmost care is taken in its application, and where the tamping is of a soft and homogeneous character, and is cautiously packed into the hole. In such circumstances it may be usefully employed.

Patent Safety Fuze.—This fuze is adapted for all blasting in dry ground, being made with an ample quantity of the best materials. When kept at a moderate temperature and carefully used, its operation is certain.

Ditto (2).—This is the same fuze as the preceding, and is only adapted to the same kind of blasting, but is specially varnished for any given climate. That varnish which is suitable for a cold country becomes soft and sticky if exposed to much heat; while that which is suitable for a hot country becomes hard and brittle if exposed to great cold. This inconvenience is remedied, as far as possible, by the special preparation of the varnish to suit any given temperature.

Patent Taped Sump Fuze.—This fuze is adapted for use in wet ground, and is specially protected so as to operate effectively even when the tamping is saturated with water. In such cases the charge of gunpowder should be placed in a cartridge, the end of the fuze should be inserted into the centre of the charge, and the junction of the fuze with the cartridge should be properly protected with a waterproof varnish. If employed in this manner, its certain operation is warranted.

Patent Double-Taped Sump Fuze.—This fuze is covered with a second coating of tape and varnish, and is intended for blasting in very wet ground.

Patent Gutta-Percha Fuze.—This fuze is adapted to sub-aqueous blasting.

Patent Taped Gutta-Percha Fuze.—This is the same fuze as the last, and is adapted to the same use and duty; but, having an exterior coating of tape and varnish which delays the oxidation of the gutta-percha, it retains its efficiency for a much longer time. It is therefore well adapted for service in distant countries.

In all sub-aqueous operations great care must be taken that the union of the fuze and cartridge be by a perfectly water-tight joint, and the fuze must be strengthened as much as possible both at and near the place of junction, else its swaying to and fro is very likely to break the joint, which would allow the water to soak into the charge.

G

GABBRO. An Italian name originally applied to a serpentine containing diallage, but now extended to a class of rocks consisting essentially of a triclinic felspar and an augite. The felspathic mineral is generally either labradorite or anorthite, but is in some cases represented by Saussurite; whilst the augitic constituent is either diallage or smaragdite. Hypersthene-rocks are also included by some writers under the term of gabbro.

GABIAN OIL. A mineral naphtha exuding from a bituminous shale at Gabian in Languedoc.

GABRONITE, is a yellowish stony substance of a greasy lustre. This mineral is distinguished by the large quantity of soda which it contains; its constituents being, silica, 54; alumina, 24; soda, 17·25; magnesia, 1·5; oxide of iron, 1·25; water, 2. It is most probably a variety of Scapolite.

GAD. A miner's tool; a pointed wedge having its sides of a parabolic figure.

GADIDÆ. The cod-fish family. This family of fishes is one of great importance to man. The value of the fisheries established in various parts of the northern seas is very great. The common cod, *Morrhua vulgaris*, is one of the most important species of this family. The catching and curing of this fish give employment to thousands. The haddock (*Morrhua æglefinus*) is nearly allied to, although smaller than, the cod. The coal-fish (*Merlangus carbonarius*) is much less valuable than either the cod or haddock. It is a coarse fish, and derives its name from the dusky pigment which tinges the skin, and soils the fingers like moist coal. The whiting (*Merlangus vulgaris*) is a well-known fish, forming a delicate article of food. The hake or stock fish (*Merlucius vulgaris*) is caught very abundantly on our southern coasts, and forms a valuable article of food; prejudice alone keeps it from taking its place at the tables of the wealthier classes. The ling (*Lota molva*) is caught in abundance around the Scilly Isles and the coast of Scotland, forming a considerable article of commerce. The torsk (*Brosmius brosme*) is found in great quantity around the Shetland Isles, where it is much prized. The best cod-liver oil is obtained from the livers of this fish. See COD.

GADOLINITE, called also *Yttrite* and *Ytterbyite*, is a mineral of a black, brownish, or yellowish colour, granular, or compact, with vitreous and conchoidal fracture; of sp. gr. 4·0 to 4·5, readily scratching glass; at the blowpipe it forms an opaque glass, sometimes with intumescence, but does not fuse into a bead. It is remarkable for containing from 45 to 55 per cent. of the earth yttria; its remaining constituents being silica, 25·8; oxide of cerium, 17·92; oxide of iron, 11·43. This mineral, which is very rare, is found in Sweden; also at Disko in Greenland; in the south of Norway; and near Galway. Its peculiar constituent was discovered by Professor Gadolin, after whom it is named.

GAGATES. The name by which jet was known to the ancients, derived probably from Gagis, a town in Lycia, where it was said to have been found. See JET.

GALACTITE, so called from its giving the colour of milk to water, when triturated with that fluid; analyses have shown it to be a variety of natrolite. See NATROLITE.

GALACTOMETER, or **LACTOMETER**, is an instrument to ascertain the quality of milk; an article often sophisticated in various ways. Fresh milk, rich in cream, has a less specific gravity than the same milk after it has been skimmed; and milk diluted with water becomes proportionally lighter. Hence, when our purpose is to determine the quantity of cream, the galactometer may consist merely of a long graduated glass tube standing upright upon a sole. Having filled 100 measures with the recent milk, we shall see, by the measures of cream thrown up, its value in this respect. A delicate long-ranged glass hydrometer, graduated from 1·000 up to 1·060, affords the most convenient means of detecting the degree of watery dilution, provided the absence of thickening materials has been previously ascertained by filtration. Good fresh milk indicates from 1·030 to 1·032; when the cream is removed, 1·035 to 1·037. When its density is less than 1·028, we may infer it has been thinned with water.

GALACTOSE. A saccharine substance obtained by boiling sugar of milk with dilute acids.

GALBANUM is a gum-resin, which exudes either spontaneously or from incisions made in the stem of a plant of the family of *Umbelliferæ*, which grows in Africa, particularly in Ethiopia. The source of this gum-resin is not distinctly known, but is believed to be the *Ferula galbaniflua*. Galbanum contains 67 of resin; 19·3 of gum; 6·4 of volatile oil and water; 7·5 of woody fibres and other impurities; with traces of acid malate of lime.

GALENA (*Plomb sulfuré*, Fr.; *Bleiglanz*, Ger.) is a sulphide (sulphuret) of lead. It is of a lead-grey colour, crystallises in the cubical system, and is susceptible of cleavages parallel to the faces of the cube; sp. gr. 7·7592; fusible at the blowpipe with exhalation of sulphureous vapours; is easily reduced to metallic lead. Nitric acid first dissolves it, and then throws down sulphate of lead as a white precipitate; the solution affording with plates of zinc brilliant laminæ of lead (*arbor Saturni*). It consists of sulphur, 13; lead, 85; with a little iron, and generally a small quantity of silver. This is the richest ore of lead, and it occurs in almost every geological formation, in veins, in masses, or in beds. Galena in powder, called *Alquifoux*, is employed as a glaze for coarse earthenware. See LEAD.

GALIPOT is a name of a white semi-solid viscid resin, found on fir-trees; or an inferior sort of turpentine, poor in oil.

GALL OF ANIMALS. A peculiar fluid, called also *bile*, secreted by the cells of the liver; it is taken up by the biliary ducts, which unite to form the hepatic duct, by which the secretion is either discharged directly into the duodenum, or is conveyed through the cystic duct into the gall bladder, wherein it becomes accumulated, and to some extent inspissated. Gall or bile from different animals finds several uses in the arts. It is used for cleansing woollen goods, and by artists it is employed to ensure the uniform spreading of water colours upon paper. For the constitution of the gall of different animals, see Watts's 'Dictionary of Chemistry.' See BILE.

GALL OF GLASS, called also *Sandiver*, is the neutral salt skimmed off the surface of melted crown glass; which, if allowed to remain too long, is apt to be reabsorbed in part, and to injure the quality of the *metal*, as the workmen call it. See GLASS.

GALLATES. Salts consisting of gallic acid combined with bases; the most important being that with oxide of iron, constituting a principal part of the black dye.

GALLERY, *in mining*, an underground horizontal excavation.

GALLIARD, a North of England term for a hard, smooth, flinty grit.

GALLIC ACID is the peculiar acid extracted from gall-nuts. See GALL-NUTS.

GALLIPOLI OIL is a coarse olive oil, containing more or less mucilage, imported from a seaport so named, of the province of Otranto, in the kingdom of Naples. See OLIVE OIL.

GALL-NUTS or **GALLS** (*Noix de Galle*, Fr.; *Galläpfel*, Ger.) are excrescences found upon the leaves and leaf-stalks of a species of oak, called *Quercus* *infectoria*, which grows in the Levant. They are produced in consequence of the puncture of the female of the gall-wasp (*Cynips folii quercus*), made in order to deposit her eggs; round which the juice of the tree exudes, and dries in concentric portions. When the insect gets fully formed, it eats through the nut and flies off.

The Levant galls are of two different appearances and qualities; the first are heavy, compact, imperforated, the insect not having been sufficiently advanced to eat its way through the shell; prickly on the surface; of a blackish or bluish green hue; about the size of a musket-ball. These are called *black*, blue, or Aleppo galls. The second are light, spongy, pierced with one or more holes; smooth upon the surface, of a pale greyish or reddish yellow colour, generally larger than the first, and are called *white* galls; but they are inferior to the former, and great care should be taken in the purchase of the best quality, for these are often dyed by dishonest traders to imitate the best blue Aleppo galls, but the fraud may be detected by the small hole made by the insect in the white galls, so that if the blue galls have holes, we may be sure they are not genuine.

Besides the galls of the Levant, others come from Dalmatia, Illyria, Calabria, &c.; but they are of inferior quality, being found upon the *Quercus cerris*; they are smaller, of a brownish colour, and of inferior value. The farther south the galls are grown, the better they are reckoned.

The galls of the *Quercus cerris* and common oak (*Galles à l'épine*, Fr.; *Knoppern*, Ger.) are of a dark-brown colour, prickly on the surface, and irregular in shape and size. They are used chiefly for tanning in Hungary, Dalmatia, and the southern provinces of the Austrian States, where they abound.

Galls consist principally of three substances: tannin, or tannic acid; yellow extractive; and gallic acid. Their decoction has a very astringent and unpleasant bitter taste. The following are their habitudes with various reagents:—

Litmus paper is powerfully reddened. Stannous chloride (protomuriate of tin) produces an Isabel-yellow precipitate. Alum: a yellowish grey precipitate. Acetate of lead: a thick yellowish white precipitate. Acetate of copper: a chocolate-brown precipitate. Ferric sulphate (red sulphate of iron): a blue precipitate. Sulphuric acid: a dirty yellowish precipitate. Acetic acid brightens the muddy decoction.

Tannin or tannic acid is prepared as follows: Into a long narrow glass adopter tube, shut at its lower orifice with a cotton wick, a quantity of pounded galls is put, and slightly pressed down. The tapering end of the tube being inserted into a matrass or bottle, the vacant upper half of the tube is filled with sulphuric ether, and then closed with a ground-glass stopper. Next day there will be found in the bottle a liquid in two distinct strata; of which the more limpid occupies the upper part, and the other, of a syrupy consistence and amber colour, the lower. More ether must be filtered through the galls, till the thicker liquor ceases to augment. Both are now poured into a funnel, closed with the finger, and after the dense liquor is settled at the bottom, it is steadily run off into a capsule. This, after being washed repeatedly with ether, is to be transferred into a stove chamber, or placed under the receiver of an air-pump to be evaporated. The residuary matter swells up in a spongy crystalline form of considerable brilliancy, sometimes colourless, but more frequently of a faintly-yellowish hue.

This is pure tannin, which exists in galls to the amount of from 40 to 45 per cent. It is indispensable that the ether employed in the preceding process be previously agitated with water, or that it contain some water, because by using anhydrous ether, not a particle of tannin will be obtained.

Tannic acid is a white or yellowish solid, inodorous, extremely astringent, very soluble in water and alcohol, much less so in sulphuric ether, and uncrystallisable. Its watery solution, out of contact of air, undergoes no change; but if, in a very dilute state, it be left exposed to the atmosphere, it loses gradually its transparency, and lets fall a slightly-greyish crystalline matter, consisting almost entirely of gallic acid. For procuring this acid in a perfectly pure state, it is merely necessary to treat that solution thus changed with animal charcoal, and to filter it in a boiling state, through paper previously washed with dilute muriatic acid. The gallic acid will fall down in crystals as the liquid cools.

If the preceding experiment be made in a graduated glass tube containing oxygen over mercury, this gas will be absorbed, and a corresponding volume of carbonic acid gas will be disengaged. In this case the liquor will appear in the course of a few weeks as if traversed with numerous crystalline colourless needles of gallic acid.

Tannin or tannic acid consists of carbon, 51·56; hydrogen, 4·20; oxygen, 44·24.

From the above facts it is obvious that gallic acid does not exist ready formed in gall-nuts, but that it is produced by the reaction of atmospheric oxygen upon the tannin of these concretions.

Gallic acid is a solid, feebly acidulous and styptic to the taste, inodorous, crystallising in silky needles of the greatest whiteness; soluble in about 100 times its weight of cold, and in a much smaller quantity of boiling water; more soluble in alcohol than in water, but little so in sulphuric ether.

Gallic acid does not dissolve the salts of protoxide of iron, but it forms, with the sulphate of the peroxide, a dark blue precipitate, much less insoluble than the tannate of iron.

Imports.

Places	1871		1872	
	Quantities	Value	Quantities	Value
	cwts.	£	cwts.	£
From Turkey	2,585	11,302	4,349	12,581
„ Persia	...	...	2,000	6,000
„ China	8,593	17,252	8,621	20,098
„ British India	...	...	2,126	3,330
„ other countries . . .	3,754	11,163	4,835	12,954
Total . .	14,932	39,717	21,931	54,963

GALMEI. German mineralogists usually recognise the silicate of zinc (Smithsonite) under this name. See Zinc.

GALVANISED IRON. This is the name, improperly given, first in France and subsequently adopted in this country, to iron coated with zinc by a peculiar patent process.

In 1837 Mr. H. W. Crawfurd patented a process for zincing iron. In the 'Repertory of Patent Inventions' his process is thus described:—Sheet iron, iron castings, and various other objects in iron are cleaned and scoured by immersion in a bath of water, acidulated with sulphuric acid, heated in a leaden vessel, or used cold in one of wood, just to remove the oxide. They are then thrown into cold water, and taken out one at a time to be scoured with sand and water with a piece of cork, or more usually with a piece of the husk of the cocoa-nut, the ends of the fibres of which serve as a brush, and the plates are afterwards thrown into cold water.

Pure zinc covered with a thick layer of sal-ammoniac is then melted in a bath, and the iron, if in sheets, is dipped several sheets at a time in a cradle or grating. The sheets are slowly raised to allow the superfluous zinc to drain off, and are thrown whilst hot into cold water, on removal from which they only require to be wiped dry.

Thick pieces are heated, before immersion, in a reverberatory furnace, to avoid cooling the zinc. Chains are similarly treated, and on removal from the zinc require to be shaken until cold to avoid the links being soldered together. Nails and small articles are dipped in muriatic acid, and dried in a reverberatory furnace, and then thrown altogether in the zinc, covered with the sal-ammoniac, left for one minute, and taken out slowly with an iron skimmer; they come out in a mass soldered together, and for their separation are afterwards placed in a crucible and surrounded with charcoal-powder, then heated to redness and shaken about until cold for their separation. Wire is reeled through the zinc, into which it is compelled to dip by a fork or other contrivance. It will be understood that the zinc is melted with a thick coat of sal-ammoniac to prevent the loss of zinc by oxidation.

Mr. Mallet coated iron with zinc by the following process:—

The plates are immersed in a cleansing bath of equal parts of sulphuric or muriatic acid and water, used warm; the works are then hammered and scrubbed with emery and sand to detach the scales, and to thoroughly clean them; they are then immersed in a 'preparing bath' of equal parts of saturated solutions of muriate of zinc and sal-ammoniac, from which the works are transferred to a fluid metallic bath, consisting of 202 parts of mercury and 1292 parts of zinc, both by weight, to every ton weight of which alloy is added above one pound of either potassium or sodium, the latter being preferred. As soon as the cleaned iron-works have attained the melting heat of the triple alloy, they are removed, having become thoroughly coated with zinc. At the proper fusing temperature of this alloy, which is about 680° Fahr., it will dissolve a plate of wrought iron of an eighth of an inch thick in a few seconds.

Morewood and Rogers's galvanised tinned iron is prepared under several patents. Their process is as follows:—

The sheets are pickled, scoured, and cleaned, just the same as for ordinary tinning. A large wooden bath is then half filled with a dilute solution of muriate of tin, prepared by dissolving metallic tin in concentrated muriatic acid, which requires a period of two or three days. Two quarts of the saturated solution are added to 300 or 400 gallons of the water contained in the bath. Over the bottom of the bath is first spread a thin layer of finely-granulated zinc, then a cleaned iron plate, and so on, a layer of granulated zinc and a cleaned iron plate alternately, until the bath is full; the zinc and iron, together with the fluid, constitute a weak galvanic battery, and the tin is deposited from the solution so as to coat the iron with a dull uniform layer of metallic tin in about two hours.

The tinned iron is then passed through a bath containing fluid zinc, covered with sal-ammoniac mixed with earthy matter, to lessen the volatilisation of the sal-ammoniac, which becomes as fluid as treacle. Two iron rollers immersed below the surface of the zinc are fixed to the bath and are driven by machinery to carry the plates through the fluid metal at any velocity previously determined. The plates are received one by one from the tinning bath, drained for a short time, and passed at once, whilst still wet, by means of the rollers, through the bath as described. The plates take up a very regular and smooth layer of zinc, which, owing to the presence of the tin beneath, assumes its natural crystalline character, giving the plates an appearance resembling that known as the *moirée metallique.*—See *Hunt's Handbook to the Great Exhibition.*

It is stated that galvanised iron plates cut with shears so as to expose the central iron become zinced round the edges, and at the holes where the nails were driven. We are also informed that *ungalvanised iron* will, if moist when near galvanised plate, become zinced, and that telegraph wires, where cut through, become coated by the action of the rain-water on the galvanised portion of the surfaces.

It has been stated that the galvanised iron is not more durable than unprotected iron; that, indeed, where the zinc is by any accident removed the destruction is more rapid than ordinary. We have made especial enquiries, and find that in forges where there is any escape of sulphur-vapour the galvanised iron does not stand well; but that under all ordinary circumstances it has the merit of great durability in addition to its other good qualities.

GALVANO-PLASTIC. The German name of Electro-metallurgy. See ELECTRO-METALLURGY.

GAMBIR, or **GAMBIER.** The Malayan name of an extract obtained from the *Uncaria Gambier.* It is the *Terra Japonica* of tanners.

Two methods of obtaining gambir are described: one consists in boiling the leaves in water, and inspissating the decoction; the other, which yields the best gambir, consists in infusing the leaves in warm water, by which a fecula is obtained, which is inspissated by the heat of the sun, and formed into cakes. The best gambir is made at Rhio, in the Isle of Brittany, in the Eastern Archipelago; and the next best is that of Lingin. It is principally imported from Singapore, and is used principally for tanning, under the name of *Terra Japonica.* The *Mimosa catechu* yields a different extract from the gambir, but catechu and gambir are often confounded.

Places	Quantities	Value	Quantities	Value
	cwts.	£	cwts.	£
From Turkey	2,585	11,302		
,, Straits Settlements . .	...	...	20,579	439,344
,, China	8,593	17,252		
,, United States of America .	...	...	557	12,073
,, other countries . . .	3,754	11,163	19	320
Total . .	14,932	39,717	21,155	451,737

GAMBIR CATECHU. See CATECHU.

GAMBOGE. (*Gomme gutte,* Fr.; *Gutti,* Ger.) Gamboge appears to have been first brought from China in 1603, and its oriental name was said to be *Ghittaiemon.*

It is generally supposed to be produced from the *Hebradendron cambogioides* of Graham and the *Xanthochymus ovalifolius* of Roxburgh; but different kinds of gamboge appear to have different botanical sources, several species of *Garcinia* and *Cambogia* yielding this substance. In Ceylon the gamboge is obtained by wounding the bark of the tree in various places with a sharp stone, when the flowers begin to appear. Gamboge is imported from Siam, by way of Singapore and Penang. It is known in three forms: in rolls or solid cylinders; in pipes or hollow cylinders; in cakes or amorphous masses. Gamboge in small quantities is also obtained in Ceylon. Gamboge consists of resin, 74·2; soluble gum, 21·8; moisture, 4·8.

Gamboge is employed as an artist's colour; it is used to colour varnishes and lacquers, and it is administered medicinally.

Our imports of gamboge were in 1863, 388 cwts., value 3,268*l.*; in 1864, 42 cwts., value 520*l.*; they have not been reported of late years.

GAMMAM. A dye-stuff, so called, from Tunis. Examples were sent to this country in 1851, but it does not appear to have been introduced since that time.

GANGUE. A word derived from the German *Gang*, a vein or channel. It signifies the mineral substance which either encloses or usually accompanies any metallic ore in the vein. Quartz, carbonate of lime, sulphate of baryta, sulphate of lime, and fluoride of calcium, generally form the gangues; but a great many other substances become such when they predominate in a vein. In mineral works the first thing is to break the mixed ore into small pieces, in order to separate the valuable from the useless parts, by processes called stamping, picking, sorting. Literally, *Gang* is a course or passage. See MINING.

GANNISTER. The name of a bed of highly siliceous fire-clay. It is usually extremely hard, and contains many Stigmaria roots. It is found beneath some of the seams of coal in Lancashire and other places. The gannister when crushed and, if necessary, mixed with a little more plastic clay, produces a brick of the most refractory description. It is also used for lining the Bessemer converters, and similar purposes.

GARANCEUX. See MADDER.

GARANCIN. See MADDER.

GARLIC. *Allium sativum.* This plant is well known, and is much used in flavouring sauces.

It is found by analysis to contain an acrid volatile oil, gum, woody fibre, albumen, water, with sulphur, starch, and saccharine matter. The *oil of garlic* is a sulphide of allyle, $AllS = C^6H^5S$. [$(\mathbf{C}^3\mathbf{H}^5)^2\mathbf{S}$.]

GARNET. (*Grenat*, Fr.; *Granat*, Ger.) Garnet is a double silicate of certain bases, such as alumina, lime, magnesia, oxide of iron, &c.

There are six sub-species of garnet, viz.:—

I. *Alumina-lime garnet*, consisting of the silicates of alumina and lime.

II. *Alumina-magnesia garnet*, consisting of the silicates of alumina and magnesia.

III. *Alumina-iron garnet*, consisting of the silicates of alumina and iron.

IV. *Alumina-manganese garnet*, consisting of the silicates of alumina and manganese.

V. *Iron-lime garnet*, consisting of the silicates of iron and lime.

VI. *Lime-chrome garnet*, consisting of the silicates of lime and oxide of chromium.

I. Lime-garnet, or grossular, is composed of silica, 40·1; alumina, 22·7; lime, 37·2 = 100·0. Colour, pale greenish, clear red, and reddish orange, cinnamon colour. Before the blowpipe, fuses to a slightly greenish glass or enamel; soluble, when powdered, in concentrated muriatic acid.

This section comprises cinnamon-stone or Essonite, grossular or Wiluite, Romanzovite, topazolite, and succinite.

II. Magnesia-garnet is of a deep coal-black colour, with a resinous lustre. The variety from Arendal is composed of silica, 42·45; alumina, 22·47; protoxide of iron, 9·29; protoxide of manganese, 6·27; magnesia, 13·43; lime, 6·53; = 100·44.—(*Wächtmeister.*) Before the blowpipe, easily fusible, forming with intumescence a dark greyish-green globule, which is non-magnetic.

III. Iron-garnet comprises the almandine or precious garnet, allochroite, and common garnet. It is composed of silica, 36·3; alumina, 20·5; protoxide of iron, 43·2 = 100·0. Before the blowpipe, fuses rather easily with an iron reaction.

IV. Manganese-garnet, or spessartine, is of a brownish-red colour, and is composed of silica, 35·83; alumina, 18·06; protoxide of iron, 14·93; protoxide of manganese, 30·96 = 99·78. (Analysis of M. garnet from Haddam, U.S., by *Seybert.*) Before the blowpipe, gives a manganese reaction.

V. Iron-lime garnet includes aplome, colophonite, melanite, and pyreneite. These vary in colour from dark red, brownish-black, to black, and possess a shining lustre, which is sometimes resinous, as in colophonite.

Analysis of the aplome of Altenau:—Silica, 35·64; lime, 29·22; protoxide of iron, 30·00; protoxide of manganese, 3·01; potash, 2·35 = 100·22.—*Wächtmeister.*

VI. Lime-chrome garnet, or ouvarovite, is of an emerald-green colour. Sp. gr., 3·418. Before the blowpipe it is infusible alone, but with borax affords a chrome-green glass. It occurs at Bissersk, in Russia.

Analysis by *Erdmann*:—Silica, 36·93; alumina, 5·68; peroxide of iron, 1·96; oxide of chrome, 21·84; magnesia, 1·54; carbonate of lime, 31·66; oxide of copper, a trace, = 99·58.

The garnet varies greatly in transparency, fracture, and colour; but when the colours are rich, and the stone is free from flaws, it constitutes a valuable gem, which may be distinguished by the following properties:—

The colour should be blood or cherry-red; on the one hand often mixed more or less with blue, so as to present various shades of crimson, purple, and reddish violet, and on the other hand, with yellow, so as to form orange-red and hyacinth-brown.

The stones vary in size from the smallest pieces that can be worked to the size of a nut. When above that size they are scarcely ever free from flaws, or sufficiently transparent for the purposes of the jeweller.

The garnets of commerce are procured from Bohemia, Ceylon, Pegu, and the Brazils. By jewellers they are classed as Syrian, Bohemian, or Cingalese, rather from their relative value and fineness, than with any reference to the country from which they are supposed to have been brought.

Those most esteemed are called Syrian garnets, not because they come from Syria, but after Syrian, the capital of Pegu, which city was formerly the chief mart for the finest garnets. The colour of the Syrian garnet is violet-purple, which, in some rare instances, vies with that of the finest oriental amethyst; but it may be distinguished from the latter by acquiring an orange tint by candle-light. The Syrian garnet may be also distinguished from all the other varieties of garnet in preserving its colour (even when of considerable thickness and unassisted by foil), unmixed with the black tint which usually obscures this gem. The Bohemian garnet is generally of a dull poppy-red colour, with a very perceptible hyacinth-orange tint when held between the eye and the light. When the colour is a full crimson it is called pyrope, or fire garnet, a stone of considerable value when perfect and of large size.

The best manner of cutting the pyrope, is *en cabochon*, with one or two rows of small facets round the girdle of the stone. The colour appears more or less black when the stone is cut in steps, but when cut *en cabochon*, the points on which the light falls display a brilliant fire-red.

Garnet is easily worked, and when facet-cut is nearly always (on account of the depth of its colour) formed into thin tables, which are sometimes concave or hollowed out on the under side. Cut stones of this latter description, when skilfully set, with a bright silver foil, have often been sold as rubies.

The garnet may be distinguished from corundum or spinel by its duller colour. Coarse garnets reduced to a fine powder are sometimes used as a substitute for emery in polishing metals.

Bohemian garnet. See Pyrope.—H. W. B.

GARNET, SOLUBLE (*Grenat soluble*). See Carbolic Acid.

GAS. (*Gas*, Fr.; *Gaz*, Ger.) The generic name of all such elastic fluids as are aeriform under a considerable pressure, at the zero of Fahrenheit. Oxygen, hydrogen, and nitrogen, are permanent gases; many of the other vaporiform bodies have been condensed by the joint power of cold and mechanical force. See Watts's 'Dictionary of Chemistry.'

GAS, AIR. The idea of carburetting air, or a gas of low illuminating power, is not by any means new, having been started almost at the same period that lighting by coal-gas in the ordinary way was introduced; but it was not until the opening up and working of the American oil-wells, by which a supply of very light petroleum oil or spirit was obtainable, that any scheme in this direction had any chance of success. In 1862 a patent was taken out in France by a M. Mongruel, which proposed to pass air through an exceedingly light and inflammable spirit, the air thus becoming charged with a certain amount of a highly luminous hydrocarbon-vapour, in such a quantity as to render the mixture inflammable, and to allow of its being burned as an ordinary combustible gas. This idea was introduced into England by a company known as the Photogenic Gas Company, which received some amount of support at the time, but from some cause or other did not prove a success.

The various inventions brought into notice since that time for the purpose of carburetting air and other gases have been based upon precisely the same principle, but have differed considerably in the apparatus employed.

Many erroneous statements have been made on this matter for the want of scientific knowledge; for instance, in most cases the patentees themselves have declared that a union takes place, other than mechanical, between the gases of the air and the vapours of certain hydrocarbons, which result in the production of such gases as olefiant gas, or acetylene; an utter absurdity which would be evident to anyone who would consider under what circumstances such gaseous mixtures are produced. A vapour of any hydrocarbon will, whether it exist by itself or whether it be diffused through another gas or gases, always be such a vapour, and will invariably exhibit the properties characteristic of it; and, if diffused through a gas, will be found condensible to the liquid from which it was formed, if proper means be applied. It is a matter of simple calculation from known data to ascertain the exact amount of hydrocarbon-vapour taken up by a given volume of air at certain temperatures. The following tables show this:—

Boiling points of light petroleum spirit of different specific gravity.

Specific Gravity	Boiling Point
0·600	4 deg. C.
0·628	30 ,,
0·669	68 ,,
0·699	92 ,,
0·726	118 ,,
0·741	136 ,,
0·757	160 ,,

Table of maximum vapour-tension of petroleum spirit of a Sp. Gr. ·650 *at different temperatures.*

Temperature.		Vapour-tension.
−10 deg. C.	(14 deg. F.)	43·5 mm.
0 ,,	(32 ,,)	81·0 ,,
+10 ,,	(50 ,,)	132·0 ,,
15 ,,	(60 ,,)	167·0 ,,
20 ,,	(68 ,,)	203·0 ,,
40 ,,	(104 ,,)	301·8 ,,

Table of percentage of vapour of petroleum spirit of a Sp. Gr. ·650 *present in air or other medium at different temperatures.*

Temperature.		Percentage.
−10 deg. C.	(14 deg. F.)	5·7
0 ,,	(32 ,,)	10·7
10 ,,	(50 ,,)	17·5
15 ,,	(60 ,,)	22·0
20 ,,	(68 ,,)	27·0
40 ,,	(104 ,,)	39·0

Now for an 'air-gas' scheme to be successful, the air must hold in solution a sufficient quantity of vapour to confer upon it inflammability and luminosity.

The liquid hydrocarbons, which at present are almost exclusively proposed to be employed for the purposes of carburation, are the light oils which form the first distillate in the preparation of paraffin oil from the crude American mineral oil. As this light oil is too volatile and inflammable to be burned in any sort of lamp at present in use, and no other commercial application has been discovered, very large quantities of it are disposed of as an entirely waste product, obtainable at a small cost.

The illuminating power of 'air-gas' when first obtained is very high, as high indeed as 30 candles, although this statement requires a slight qualification, as the illuminating power of the flame is not expressed by it, but only the fact that if it were possible (which it is not) to burn the gas at the rate required by the photometric test—viz. five cubic feet per hour, this illuminating power would be obtained, it being a fact that a very much smaller amount of air-gas can be burned from the ordinary argand burner, or from a batswing, to obtain the same rise of flame than in the case of coal-gas; this effect is no doubt due to the greater density of 'air-gas.' It may be mentioned that these air-gases do not burn well under pressure, and hence are only suited to burners which afford exceedingly free passage to the issuing gas, such as argands, there being a tendency with burners of the batswing and fishtail class for the air and vapour to separate, possibly explainable by the more rapid transpiration of the lighter substance through a narrow opening.

Mr. J. F. G. Kromschröder has spent nearly fourteen years in the endeavour to effect the mixture of common air with the hydrocarbonous vapours, so as to produce an 'air-gas' suitable for the illumination of small towns or dwelling-houses. He claims to have succeeded in his design, and he is probably the first man who has lighted a whole town upon a system of gas illumination which excludes the use of coal—Great Marlow in Buckinghamshire having been lighted by him with his air-gas. Mr. Kromschröder first applied his method to lighting the Battersea Water-works, and for five months he kept 104 burners supplied at a cost below that of ordinary gas. Farther, a quantity of his hydrocarbonised air was there stored over water for nearly four months, and at the end of that time it was said to be a far better illuminator than when first prepared, but this can scarcely be correct.

The experiments made at Great Marlow have been thus described:—

The generator is a kind of box, of sheet iron, in bulk not exceeding two cubic yards, standing upon a shallower box, holding a liquid hydrocarbon. A small dome on the upper surface covers an ingenious air- or force-pump, moved by clockwork, and capable of easy regulation. The liberation of a weight starts the operation, and a steady current of air is driven over the surface of the liquid in the receiver, which is kept at a constant level. An absorbent substance is employed to increase the evaporative surface, and to oppose a slight obstacle to the passage of the current, since it is found that, within certain limits, the slowest stream of air takes up the largest amount of combustible vapour. The hydrocarbon employed is a petroleum or shale-oil of specific gravity ·660, somewhat similar, we believe, to the cheap spirit burned in common sponge lamps. Seventy cubic feet of air, after complete saturation with the vapour, become a hundred cubic feet of 'gas,' of a density of 1·2, air itself being unity. The Kromschröder gas is thus about double the density of coal-gas, and contains nearly one-third its bulk of hydrocarbon-vapour. As to illuminating power, the trial by Bunsen's photometer proved satisfactory. Burning at the rate of 3½ cubic feet per hour, Sugg's improved argand being employed, a light equal to 18·1 candles was indicated, which, reduced to the standard of 5 feet per hour, is equal to about 26 candles, or nearly double the value of gas as usually burned.

Granting an equality in lighting power, there are three points in which any proposed substitute for coal-gas must satisfy consumers before it can come into use. First, its cost must not be greater; secondly, it must bear storage; thirdly, it must 'travel.' With regard to the first condition, Mr. Kromschröder makes no definite promises, but is confident that his gas can be generated more cheaply than coal-gas. Certainly the process is much less troublesome, and as the machine is self-acting, there can be but little expense for wages. One gallon of petroleum, worth about eighteenpence, will make about 700 cubic feet of gas, and this is alleged to burn as long as 1,200 feet of ordinary gas, giving a better light. As to storage and travelling power, Mr. Hastings, engineer at the Marlow Gasworks, having had full opportunity for three months of testing the gas in every possible way, and having, to begin with, a prejudice against it, reports favourably. In fact, he says that storage for a week or ten days improves the gas, his theory being that a chemical union takes place between its constituents. We could not, however, learn that the results of chemical examination confirmed this supposition. Mr. Hastings, we understood, mixes the new gas with the coal-gas supplied to the town in order to raise its light-giving power. The mains in the streets are nearly five miles in length, and the gas is said to bear travelling through this length of pipe very well. A considerable amount of cold is of course produced in the generator by the evaporation of spirit, but it does not follow that the farther cooling of the gas will not condense some of the hydrocarbonous vapour. Farther experience, therefore, is desirable to fully settle this point, though the home manufacture of gas in factories and large houses is a part of the inventor's scheme which does not entirely depend for success upon the power of the gas to travel. The inn, a mile and a quarter from the works, was lighted up on the occasion of a special trial during dinner, by coal-gas and Kromschröder gas in turns, and the greater brilliancy of the latter was thus rendered strikingly evident, even after at least two miles' conveyance, and in spite of a defect of pressure, arising from the hotel being at a 'dead end.'

The inventor does not claim to be able to supersede coal-gas in large towns and cities. He reckons that it may usefully and cheaply be applied to small towns consuming about a million cubic feet per annum, a consumption which would hardly justify the expense of erecting coal-gas works. The Great Marlow experiments have confirmed the confidence of himself and his co-workers in his system.—*Report made to 'Iron.'*

Messrs. Harrison are also the patentees of an 'Air-Gas.' This process is very simple, and consists merely in drawing air through light petroleum spirit, the air thereby becoming so charged with the inflammable vapour of the spirit, as to burn with a brilliant light. It is stated by the inventors that the mixture of air and vaporised spirit is perfectly permanent, and can be stored in holders, or passed through indefinite lengths of pipe, at varying temperatures, without suffering any condensation or diminution of lighting power. This statement is somewhat difficult of belief, as the gas produced by this process is a purely mechanical mixture, not the least combination (in a chemical sense) taking place, and there is every reason to think that variations of temperature, such as must necessarily occur in the ordinary distribution of such a gas, would cause a partial deposition of the petroleum spirit, and consequently much loss of illuminating power.

The air-gas invented by Mr. Wright, a plumber of Sheffield, must also be noticed here. His process is protected and involved by several patents: considerable mystery is made of the process by which his 'oil' is obtained, but it is, of course, essentially one of the liquid hydrocarbons. Mr. Thomas Wills, in his paper read before the Society of Arts, thus describes this patent:—

From the specification which is taken out in the name of Mr. William Wright, of Sheffield, we gather the following details. A light petroleum, or other spirit, is to be used, as in other cases; but the apparatus differs from any that has as yet been introduced. A number of cylinders of iron or other metal are placed side by side, each being supported in a perpendicular position by means of trunnions, or swivel-joints, which allow of the cylinder being reversed with ease; in the interior of these cylinders there are fitted a number of fixed pistons formed of cotton or other spongy material. The number of these pistons varies with the size of the apparatus; a hollow chamber at the top and bottom of each cylinder acts as a reservoir for the spirit, which, in the first instance, is poured in excess through the top, and gradually percolates through the cotton pistons, at the same time saturating them; the excess of spirit accumulates in the bottom reservoir, air is then driven through the cylinder, and consequently through the saturated cotton. This air enters through the swivel-joint, and passes to the bottom of the cylinder, where it enters just above the bottom chamber, and has to find its way up through the pistons, out at the top just below the upper chamber, and thence down to the opposite swivel-joint—much, in fact, in the same way as the steam passes into and out of the cylinder of an ordinary oscillating condensing engine. After so much air has passed as to carry away in suspension the greater quantity of the spirit in the cotton, the cylinder is reversed, when the liquid that had accumulated in the lower vessel percolates once more through the pistons from the top to the bottom. In this manner it is found possible to place into the cylinder a known quantity of spirit that shall be sufficient to charge a certain volume of air, and to work it completely out by successive reversals of the apparatus. The swivel-joints are made also to act as stopcocks, cutting off all communication between the inlet or outlet during the period occupied in reversing the cylinder. If a number of such cylinders are used, they are made to communicate with each other, so as to equalise the amount of spirit in each. The air used is supplied from two ordinary gas-holders, but so coupled together by pulleys that one rises as the other descends, a valve opening inwards being placed at the top of each for this purpose. Weights being added to the holder that is full, or, what comes to the same thing, some of the balance-weights being removed so as to allow the full weight of the holder to compress the air, this air is driven through the charging cylinders and can afterwards be used as an ordinary illuminating gas; at the same time the second holder is rising, and on the exhaustion of one the second is ready by a transference of the weights to supply a continuous stream of air. The work required to keep such apparatus in use does not seem to be great, an occasional reversing of the cylinders, and the removal or addition of weights to the holder, being all that is necessary. Doubtless even this would be found impracticable on the large scale, but it is only intended to use this process for isolated buildings and small districts.

With regard to the character of the gas produced, it is much the same as other air-gases, and subject to just the same laws; and, of course, this process can claim nothing more than an improvement in the apparatus used for carburetting the air. If air-gases are to come into use at all, and there seems to be no real obstacle to prevent their adoption to a limited extent, the direction for improvement must be looked for in the apparatus employed, and this new patent certainly deserves a fair trial, which no doubt in good time it will have. Probably some means will have to be taken to prevent the reduction of temperature which invariably occurs when evaporation goes on at all rapidly; but as it is generally accepted that almost the shortest possible contact of the air and spirit is sufficient to allow of the former taking up as much of the latter as it is possible for it to do, this cooling may be confined to a very small extent, and may be neutralised altogether, if proper means be applied. It appears to be rather a difficult matter for inventors to obtain the best spirit for the purposes of carburetting air, for we have seen several samples of spirit supposed to be effective for such purposes, which would have been found, if used, of very little if any good, consisting, as they did, almost entirely of a light paraffin oil. The truth is, that very little of the real *spirit* from the petroleum comes into this country, its exceeding volatility rendering it a very dangerous freight for a ship; it might, however, possibly pay to have the petroleum sent over in its rough state, and to distil the spirit here. The oil, which is valued as burning material, could be distilled afterwards, and it, and the pitch remaining, would have little difficulty in finding a ready market. If the promoters of any one of the recent schemes could command a continuous supply of the light spirit at a reasonable figure, a great advance towards success would be made. That very great interest is still taken in these new schemes by the public is undoubted, and this last one is not likely to form an exception. Meanwhile there is nothing that should be relied upon but a fair trial on such a scale as shall be satisfactory to all.

GAS, COAL. Although the employment of gas for illuminating purposes can be traced back to remote periods of antiquity, yet the substantial history of this application may be related in few words. In various places and at different times issues of inflammable gas from the earth have been observed; the holy fires at Baku on the shores of the Caspian Sea, and those of Pietra Mala in Italy are instances; but such issues have usually been only regarded with superstitious dread by the ignorant people who have observed them. The Chinese alone, if we are to believe the accounts of that boastful people, have many centuries ago turned these natural sources of inflammable gas to useful account, and have rendered them available both for heating and illuminating purposes. Abundant sources of inflammable gas exist in the coal districts of this country; and in some localities, as at Chat Moss in Lancashire for instance, so easy is this gas procurable, that it is only necessary to plunge an iron rod a few yards deep into the soft peat, and then on its withdrawal to insert a tin tube, in order to secure a copious discharge of gas, which is evolved in a continuous stream at a high pressure, and apparently for an unlimited period of time. But as this gas consists of nearly pure light carburetted hydrogen, and contains no luminiferous constituent, it yields scarcely any light when burnt in the ordinary manner, and cannot therefore be rendered available for illuminating purposes. It has, however, been successfully employed as a source of heat, and a jet of it was long made use of as the sole fuel to heat a four-horse boiler used for agricultural purposes. As early as the year 1659 Mr. Thomas Shirley communicated to the Royal Society a paper describing some experiments upon an inflammable gas issuing from a well near Wigan in Lancashire, and nearly a century later the Rev. John Clayton, having noticed the same phenomenon in the same locality, and finding on digging a few feet into the soil, that the gas issued from a bed of coal, he was led to try whether a similar gas could not be obtained artificially, by exposing coal to heat in close vessels. He succeeded in obtaining an illuminating gas, and amused his friends by collecting it in bladders and burning it from a hole pricked in the bladder. The particulars of these experiments Mr. Clayton communicated to the Royal Society in the year 1739. But he does not appear to have thought of applying his discovery to any practical purpose; and it was not until 1792 that the gas thus artificially obtained was used for illumination by Mr. Murdock, who first lighted his house and office at Redruth in Cornwall, and afterwards, having made several improvements in the apparatus, he lighted the factory of Messrs. Boulton and Watt at Soho about the year 1804, and in 1805 the large cotton mills of Messrs. Philips and Lee at Manchester; those of Mr. Lodge at Halifax having been lighted about the same time by Mr. Clegg, a gentleman to whose energy and scientific skill gas-lighting, in its earlier stages especially, is much indebted. In the year 1810 the Act of Parliament incorporating the London and Westminster Chartered Gas-light and Coke Company was passed, and, on the 31st of December 1813, Westminster Bridge was lighted with gas. This step was soon followed by the introduction of gas in the place of oil in several of the chief thoroughfares of the metropolis. From that period the progress of this branch of the chemical arts has been extremely rapid and satisfactory, so far at least as the extension of the manufacture and the improvement of the mechanical part of the processes are concerned. Nevertheless, although the methods employed for the generation and purification of gas have been rendered more economical, it can hardly be said that the average of the gas, supplied to consumers in London and the provincial towns, is either purer or better in quality than that furnished in the earlier years of the manufacture.

Before proceeding to describe the actual processes now employed for the generation of illuminating gas, it will be advisable to consider briefly the general scientific principles involved in those processes, and especially the chemical relations of the materials employed for the generation and purification of illuminating gas, together with the bearings of chemistry upon the operations of generating, purifying, and burning such gas.

The chemistry of gas manufacture.—The chief materials employed in the manufacture of gas for illuminating purposes are—coal, oil, resin, peat, and wood. These materials, though very dissimilar in appearance, do not essentially differ from each other in their chemical constituents; they may all be regarded as consisting chiefly of the elements, carbon, hydrogen, and oxygen, and their value for the production of illuminating gas increases with the increase of the proportion of hydrogen, and with the diminution of the relative amount of oxygen. Accordingly we find that oil and resin generally produce gas larger in volume and better in quality than coal, whilst peat and wood, owing to the large proportion of oxygen which they contain, are greatly inferior to coal for the purposes of the gas-manufacturer. The relative proportions of carbon, hydrogen, and oxygen, in the organic part of these substances, is seen from the following comparisons:—

	Percentage of Carbon	Percentage of Hydrogen	Percentage of Oxygen
Cannel (Boghead)	80·35	11·21	6·71
Cannel (Wigan)	85·95	5·75	8·14
Coal	88·15	5·26	5·41
Oil	78·90	10·97	10·13
Resin	79·47	9·93	10·59
Peat	60·41	5·57	34·02
Wood	50·00	5·55	44·45

In addition to the three essential constituents above mentioned most of these materials contain small and variable proportions of sulphur, nitrogen, and inorganic matter, the latter constituting, when the substance is burnt, what we term *ash*. When these substances are heated to redness, they undergo decomposition, a considerable quantity of inflammable gases and vapours being evolved, whilst a residue, consisting of carbon, or of carbon and ash, remains behind in the solid form. When atmospheric air has free access during this heating operation, the inflammable gases and vapours burn with a more or less bright flame, as in a common fire; whilst the carbonaceous residue continues afterwards to glow, until nearly the whole of the carbon is consumed. If, however, the application of heat be made without access of air, by inclosing the materials for instance in an iron retort provided only with an outlet for the escape of gases, the decomposition goes on in much the same manner as before, but the various products formed, being no longer exposed to the simultaneous action of atmospheric oxygen, do not undergo combustion; the inflammable gases and vapours are evolved through the outlet pipe in an unburnt condition, and the carbonaceous residue also remains unconsumed in the retort. Upon cooling the gases and vapours thus evolved, the latter condense more or less into liquids which separate into two layers, the lower one forming a dense black oily fluid, commonly known as tar, and containing several solid hydrocarbons partly in solution and partly in suspension; whilst the other one consists chiefly of an aqueous solution of salts of ammonia, if the organic matters operated upon contained nitrogen. Thus the volatile products of this process of *destructive distillation* consist of solids, liquids, and gases. These constituents may be thus tabulated:—

I. Gaseous.

Name	Chemical formulæ	
Hydrogen	H	$\mathbf{H}$
Light carburetted hydrogen	C^2H^4	$\mathbf{CH^4}$
Acetylene	C^4H^2	$\mathbf{C^2H^2}$
Carbonic oxide	CO	$\mathbf{CO}$
Olefiant gas	C^4H^4	$\mathbf{C^2H^4}$
Propylene	C^6H^6	$\mathbf{C^3H^6}$
Butylene	C^8H^8	$\mathbf{C^4H^8}$
Carbonic acid	CO^2	$\mathbf{CO^2}$
Sulphuretted hydrogen	SH	$\mathbf{SH^2}$
Nitrogen	N	$\mathbf{N}$

II. Liquid.

	Name	Chemical formulæ	
Aqueous layer:—	Water	HO	$\mathbf{H^2O}$
Oily layer:—	Bisulphide of carbon	CS^2	$\mathbf{CS^2}$
,,	Benzol	$C^{12}H^6$	$\mathbf{C^6H^6}$
,,	Toluol	$C^{14}H^8$	$\mathbf{C^7H^8}$
,,	Cumol	$C^{18}H^{12}$	$\mathbf{C^9H^{12}}$
,,	Cymol	$C^{20}H^{14}$	$\mathbf{C^{10}H^{14}}$
,,	Aniline	$C^{12}H^7N$	$\mathbf{C^6H^7N}$
,,	Picoline	$C^{12}H^7N$	$\mathbf{C^6H^7N}$
,,	Leucoline	$C^{18}H^8N$	$\mathbf{C^9H^8N}$
,,	Carbolic acid (Phenol)	$C^{12}H^6O^2$	$\mathbf{C^6H^6O}$
,,	Other hydrocarbons	$C_n\,H_n$ *	
,,	,, ,,	$C_n\,H_{n+2}$	
,,	,, ,,	$C_n\,H_{n-6}$	

* Here *n* means an even number, as 2, 4, 6, &c.

III. Solid.

	Name	Chemical formulæ	
In aqueous layer :—	Carbonate of ammonia	NH^4OCO^2	$\mathbf{2(NH^4)CO^3}$
,,	Hydrosulphate of sulphide of ammonium	NH^4S+HS	$\mathbf{2(NH^4)S+H^2S}$
,,	Sulphite of ammonia	NH^4OSO^2	$\mathbf{2(NH^4)SO^3}$
,,	Chloride of ammonium	NH^4Cl	$\mathbf{NH^4Cl}$
In oily layer :—	Paraffine	$C^{40}H^{42}$	$\mathbf{C^{20}H^{42}}$
,,	Naphthaline	$C^{20}H^8$	$\mathbf{C^{10}H^8}$
,,	Paranaphthaline (Anthracene)	$C^{28}H^{10}$	$\mathbf{C^{14}H^{10}}$
,,	Pyrene	$C^{30}H^4$	$\mathbf{C^{15}H^4}$
,,	Chrysene	$C^{32}H^{12}$	$\mathbf{C^{16}H^{12}}$

In practice, there is not such a perfect separation of the products as is represented in the above table: thus a small proportion of the gases dissolves in the liquid products, whilst most of the liquids, and even some of the solids, diffuse themselves in the form of vapour, to a certain extent, into the gases; and the solids are in most cases almost completely dissolved in the liquids. The relative proportions also in which these products occur greatly depend upon the temperature employed in the destructive distillation, and the length of time during which the volatile products are exposed to it; a low temperature and short exposure favouring the formation of solids and liquids, whilst a higher heat and longer exposure determine the production of a larger proportion of gases at the expense of the solids and liquids.

The usual process of gas-making consists in exposing coal or cannel to a bright-red heat, in close vessels of convenient size and shape, until all, or the greater part, of the volatile matter is expelled. Coke is the material left in the retort, and the matters volatilised consist of condensible vapours, and of permanent gases more or less saturated with these vapours. By a simple process of refrigeration nearly the whole of the vapours may be readily condensed, thus separating the gases more or less perfectly from the liquid and solid products of the distillation. But this preliminary process of purification leaves the gases still in a state totally unfitted for use in the production of artificial light. They still retain constituents, which are either noxious in themselves, or generate noxious compounds when they are burnt, such as sulphuretted hydrogen, sulphide of ammonium, carbonate of ammonia, and bisulphide of carbon. They also contain carbonic acid, which greatly diminishes the amount of light yielded by the illuminating gases with which it is mixed.

Besides these injurious ingredients, which may be conveniently included in the term *impurities*, there are others which do not contribute anything to the illuminating power of the mixture, and which may be denominated *diluents*. We can thus classify the constituents of gas-coal as follows:—

Illuminants	Diluents	Impurities
Olefiant gas. Acetylene. Propylene. Butylene. Hydrocarbon vapours of the formulæ $C_n H_n$ and $C_n H_{(n-6)}$. Vapours of hydrocarbons of the formula $C_n H_{(n-12)}$.	Hydrogen. Light carburetted hydrogen. Carbonic oxide.	Sulphuretted hydrogen. Hydrosulphate of sulphide of ammonium. Carbonate of ammonia. Carbonic acid. Vapour of bisulphide of carbon. Nitrogen. Oxygen. Aqueous vapour.

As the intelligent manufacture of gas for illuminating purposes requires a knowledge of the leading properties of the compounds included under the three heads just mentioned, we will now proceed briefly to describe them.

I. Illuminants.

Olefiant gas.—This gas has been proved by Berthelot to exist in coal-gas, and it is probably always a constituent of the illuminating gases from resin, oil, peat, and wood. It is occasionally, though rarely, met with in nature, as a product of the action of volcanic heat upon coal-bearing strata; it never occurs, however, in coal strata under ordinary circumstances, and no trace of it has ever been met with amongst the gases issuing from the coal strata of this country, and which have been investigated by Graham, Playfair, and others. Olefiant gas can be prepared nearly pure by heating in a glass retort a mixture of 1 part by weight of alcohol, and 6 parts oil of vitriol. The gas must be passed through solution of caustic soda, to remove sulphurous and carbonic acids with which it is generally contaminated.

Olefiant gas is colourless, and possesses a peculiar and slightly unpleasant odour. Its specific gravity is rather less than that of atmospheric air, being ·9784: 100 cubic inches, at 60° F. and 30 inches barometrical pressure, weigh 30·3418 grains. It consists of two volumes of carbon-vapour and four volumes of hydrogen, the six volumes being condensed to two. It contains, in a given bulk, exactly twice as much carbon as is contained in light carburetted hydrogen. Olefiant gas is inflammable, but does not support combustion: when inflamed as it issues from a jet into the atmosphere, it burns with a white flame, emitting a very brilliant light without smoke. In burning, it consumes three times its volume of oxygen, and produces twice its volume of carbonic acid. Exposed to a full red heat, as in passing through a red-hot tube, it is rapidly decomposed, carbon being deposited, whilst hydrogen and light carburetted hydrogen are produced; exposure to a full red heat consequently soon entirely destroys its illuminating power.

Acetylene.—This hydrocarbon may be formed synthetically by the direct union of its elements. Berthelot has shown that when the electric light is produced between carbon poles in an atmosphere of hydrogen, the high temperature thus produced determines the formation of acetylene. Among other modes of generating acetylene may be mentioned the incomplete combustion of gases and vapours containing carbon and hydrogen; the decomposition of olefiant gas, alcohol-vapour, or ether-vapour, by the action of heat, and the decomposition of marsh-gas by the passage of electric sparks from an induction-coil.

Acetylene is a colourless transparent gas, of peculiar odour. Its specific gravity is 0·92. The gas burns with an intensely luminous flame, much brighter than that of olefiant gas; for a given volume of acetylene contains the same bulk of carbon with only half as much hydrogen as in an equal volume of olefiant gas. Mixed with chlorine, acetylene explodes, even in diffused daylight, with separation of carbon as a dense black smoke. Acetylene passed through a solution of subchloride of copper (cuprous chloride) yields a red precipitate, which, when dried, forms an amorphous solid substance that readily explodes on being struck with a hammer, or on being suddenly heated to a temperature a little higher than that of boiling water. See ACETYLENE.

Propylene and Butylene.—The first of these highly-illuminating constituents of coal-gas may be obtained by passing the vapour of *fusel oil* through a red-hot tube, and the second by the electric decomposition of valerate of potash. Both these gases are colourless, possess a light ethereal odour, and burn with a brilliant white flame. Like olefiant gas, they are rapidly decomposed at a bright red heat, depositing much carbon, and being converted into the non-illuminating gases—hydrogen and light carburetted hydrogen. Propylene consists of three volumes of carbon-vapour, and six volumes of hydrogen condensed to two volumes. It therefore contains, in a given volume, one-half more carbon than olefiant gas. Its specific gravity is 1·4511.

Butylene consists of four volumes of carbon-vapour and eight volumes of hydrogen, the twelve volumes being condensed to two; it consequently contains, in a given volume, twice as much carbon as olefiant gas. Its specific gravity is 1·9348.

Vapours of hydrocarbons of the formula $C_n H_n$.—A considerable number of compounds having this formula are known to exist in coal-tar, and, as many of them are very volatile, they must be diffused as vapours in coal-gas; but as they have not yet been successfully disentangled from each other, no account of their individual properties can be given; they all, however, contain more carbon, in a given volume, than butylene, and must therefore contribute, proportionally to their volume, a greater illuminating power than any of the gaseous hydrocarbons. They are all readily decomposed at a bright red heat, chiefly into carbon and non-illuminating gases.

Vapours of hydrocarbons of the formula $C_n H_{(n-6)}$.—These consist chiefly of benzol, toluol, cumol, and cymol; compounds which, being components of the more volatile portions of the tar, diffuse themselves into the gaseous products of distillation, contributing in no inconsiderable degree to the total illuminating effect of the gas. The composition of these substances has been already given in the Table; and it is therefore only necessary here to remark that benzol-vapour contains, in a given volume, three times as much carbon as olefiant gas, whilst the vapours of toluol, cumol, and cymol contain respectively 3½, 4½, and 5 times the amount of carbon contained in olefiant gas. For a further account of these and other hydrocarbons, see NAPHTHA; COAL; DESTRUCTIVE DISTILLATION.

Vapours of hydrocarbons of the formula $C_n H_{(n-12)}$.—The only vapour of this composition known to be present in coal-gas is naphthaline, $C^{20}H^{8}$ ($\mathbf{C^{10}H^{8}}$), which, although a solid at ordinary temperatures, yet emits a considerable quantity of vapour; in fact, its presence occasions to a great extent the peculiar odour of coal-gas.

Naphthaline is a frequent source of serious annoyance to the gas-manufacturer, by condensing in the street mains and gradually blocking them up, or so narrowing their bore as to prevent the passage of the needful supply of gas. This effect can only be produced when the gas charged with naphthaline-vapour is allowed to leave the holder at a temperature higher than that of the mains through which it subsequently flows; but as this cannot always be avoided, the prevention of such deposits might perhaps be best effected by passing the gas over a large surface of coal-oil before it is led into the mains. The oil would absorb so much of the naphthaline as to prevent any subsequent deposition. The vapour of naphthaline contains, in an equal volume, five times as much carbon as olefiant gas. The amount of light yielded by these illuminating constituents is directly proportionate to the amount of carbon contained in an equal volume of each; taking, therefore, the illuminating power of olefiant gas as unity, the following numbers exhibit the relative illuminating values of equal volumes of the several luminiferous constituents of gas:—

Propylene	1·5	Benzol	3·0
Butylene	2·0	Toluol	3·5
Amylene	2·5	Heptylene	3·5
Hydride of amyl	2·5	Cumol	4·0
Hydride of hexyl	3·0	Cymol	5·0
Hexylene	3·0	Naphthaline	5·0

II. Diluents.

Hydrogen.—This element constitutes one ninth of the total weight of the waters of our globe, and with one or two unimportant exceptions, enters into the composition of all animal and vegetable substances and of the products derived from them, as peat, coal, oils, bitumen, &c. It is, however, very rarely met with in nature in a free or uncombined state; having hitherto only been thus found in the gases emitted from volcanoes.

Hydrogen gas may be obtained in abundance and nearly pure by passing steam over iron, zinc, and several other metals, in a fine state of division, at a full red heat. Mixed with carbonic oxide and carbonic acid gases, it is also generated in large quantity when steam is passed over charcoal, coke, or other carbonaceous substances at a red heat. In all these cases the watery vapour is decomposed, its hydrogen being liberated, whilst its oxygen unites with the metal or carbon, forming in the first case a solid non-volatile oxide, which encrusts the pure metal, and soon stops further action; in the second case a gaseous oxide of carbon is generated, and passes off along with the hydrogen, thus leaving the carbon freely exposed to the further action of the watery vapour. When carbon is used, that portion of the steam which is converted into hydrogen and carbonic oxide yields its own volume of each of these gases; and that portion which forms hydrogen and carbonic acid affords its own volume of hydrogen and half its own volume of carbonic acid. The amount of watery vapour which undergoes the latter decomposition decreases as the temperature at which the operation is conducted increases. At a white heat scarcely a trace of carbonic acid is produced.

Hydrogen is the lightest of all known bodies, its specific gravity being only ·0691: 100 cubic inches, at 60° Fahr. and 30 inches barometric pressure, weigh only 2·1371 grains. It has a powerful affinity for oxygen, but develops scarcely any light during combustion; when, however, solid substances, such as lime, magnesia, or platinum, are held in the flame of hydrogen, considerable light is emitted. Burnt in air or oxygen gas, it is entirely converted into watery vapour, which condenses upon cold surfaces held above the flame.

Light carburetted Hydrogen.—This gas consists of carbon and hydrogen in the proportion of 6 parts by weight of the former element combined with 2 parts of the latter. Owing to its being copiously generated in marshy swampy places, it is frequently termed *marsh gas*, and from certain considerations relative to its chemical constitution, it has more recently received the name of *hydride of methyl*. It enters largely into the composition of coal-gas, and is also a natural product of the slow decomposition of coal, and of putrefaction in general. Thus it occurs in enormous quantities in the coal strata, and bubbles up from stagnant pools and ditches which contain putrefying organic remains. As thus generated, it is mixed with small quantities of carbonic acid and nitrogen; it can, however, be artificially prepared perfectly pure, but the processes need not be described here.

Light carburetted hydrogen when pure is colourless, tasteless, and inodorous; it is neutral to test papers, and nearly insoluble in water; its specific gravity is ·5594, and 100 cubic inches, at 60° Fahr. and 30 inches barometric pressure, weigh 17·4166 grains. It does not support combustion or respiration, but is inflammable, burning with a blue, or slightly yellow flame, yielding scarcely any light. Mixed with a due proportion of atmospheric air or oxygen, and ignited, it explodes with great violence: the products of its combustion are water and carbonic acid.

When light carburetted hydrogen is exposed to a white heat, it is slowly decomposed, depositing carbon, and yielding twice its volume of hydrogen.

Carbonic Oxide.—This gas consists of 6 parts by weight of carbon, and 8 parts of oxygen. It is formed when carbon is consumed in a limited quantity of air or oxygen, and is also generated, as stated above, when steam is passed over ignited coke or charcoal, or when coal-tar and steam meet in a red-hot vessel. It is always a constituent of coal-gas.

Carbonic oxide is a colourless and inodorous gas, rather lighter than atmospheric air, and having exactly the specific gravity of olefiant gas, ·9727; it is very sparingly soluble in water, but is very soluble in ammoniacal solution of chloride of copper. Carbonic oxide is inflammable, burning with a beautiful blue flame almost devoid of light; the product of its combustion is carbonic acid. It is said to be very poisonous.

III. Impurities.

Sulphuretted Hydrogen.—This gas consists of sixteen parts of sulphur and one part of hydrogen; it may be produced by passing hydrogen along with the vapour of sulphur through a red-hot tube, but it is best prepared pure by decomposing protosulphuret of iron with dilute sulphuric acid, and collecting the evolved gas at the pneumatic trough or over mercury. It is always an ingredient in crude coal-, peat-, or wood-gas.

Sulphuretted hydrogen is a colourless gas, of a very nauseous odour, resembling that of putrid eggs: its specific gravity is 1·1747. It is highly inflammable, burning with a blue flame, destitute of light, and generating a large amount of sulphurous acid; it is chiefly this latter circumstance which renders its presence in coal-gas objectionable. It is readily absorbed by metallic solutions, by hydrated oxide of iron, and by lime both in the wet and dry states, and is easily recognised in coal-gas by exposing a strip of paper impregnated with acetate of lead to a stream of the gas; if the paper becomes discoloured, sulphuretted hydrogen is present.

Hydrosulphate of sulphide of Ammonium.—This compound is formed by the combination of equal volumes of ammonia and sulphuretted hydrogen. It consists of 14 parts by weight of nitrogen, 15 of hydrogen, and 32 of sulphur. It is always largely produced in the manufacture of coal-gas, but is almost completely condensed and retained in the aqueous layer of liquid products, contributing principally to the unbearable odour of *gas liquor*; a mere trace of this body is therefore present in crude coal-gas. When quite pure it is a colourless crystalline solid, very soluble in water, and volatile at ordinary temperatures. Its vapour, when present in coal-gas, is absorbed and decomposed by hydrate of lime both in the wet and dry states, ammonia being liberated. It is also decomposed by acids, but in this case the ammonia is retained by the acid, whilst sulphuretted hydrogen is evolved.

Carbonic Acid.—This gas is met with in nature as a constituent of atmospheric air, and is produced in large quantities during the earlier stages of the formation of coal in the earth's strata. Thus, in the lignite districts of Germany, it is copiously evolved, and meeting with water in its passage to the surface, it is absorbed, and forms those sparkling mineral springs commonly known as seltzer-water.

Carbonic acid is also formed during fermentation, by the combustion of carbon in air, and in the decomposition of water by carbon at a red heat.

At ordinary temperatures carbonic acid is a colourless and invisible gas, but it may be liquefied by very intense cold or pressure. It consists of 6 parts, by weight of carbon united with 16 parts of oxygen, and thus differs from carbonic oxide by containing twice as much oxygen as the latter gas. By passing carbonic acid over ignited coke, charcoal, or other carbonaceous matters, it takes up as much carbon as it already contains, and becomes converted into carbonic oxide; but it is impossible in this way to convert the whole of the carbonic acid into carbonic oxide unless the process be very frequently repeated. Carbonic acid is pungent, acidulous, and soluble in an equal bulk of water, to which it communicates that briskness which we so much admire in soda-water; it is considerably heavier than atmospheric air, its specific gravity being 1·524. This gas is uninflammable, and cannot support combustion or animal life. Its acid properties are not strongly developed, but it unites readily with alkaline bases, forming carbonates: it is upon this property that the removal of carbonic acid from coal-gas depends. On passing coal-gas containing this acid through slaked lime in fine powder, or through milk of lime, the whole of the carbonic acid disappears, having united with the lime. Quick-lime, slaked in such a manner as to be neither dust-dry nor very perceptibly moist, is most effective for the absorption of high percentages of carbonic acid, a layer three inches in thickness not allowing a trace of the acid gas to pass through it.

The presence even of a small percentage of carbonic acid in coal-gas is much to be deprecated, on account of the great loss of light which it occasions, 1 per cent. of carbonic acid diminishing the illuminating power of coal-gas to the extent of about 6 per cent.; the addition which it makes to the carbonic acid produced during combustion is, however, too minute to be of any importance.

Carbonate of ammonia.—During the destructive distillation of coal, a considerable proportion of the nitrogen contained in the coal is converted into carbonate of ammonia, the greater part of which condenses in the aqueous layer of liquid products; but as carbonate of ammonia is very volatile, even at ordinary temperatures, crude coal-gas always contains a small quantity of this compound. It is a volatile, white, crystalline solid, very soluble in water, and possessing a pungent smell like ammonia. Its vapour is decomposed by lime, which unites with carbonic acid, liberating ammonia. The presence of this salt, or of ammonia, in coal-gas is very undesirable, as it corrodes brass fittings, and is also partially converted into nitrous acid during the combustion of the gas.

Bisulphide of Carbon.—This compound consists of 6 parts, by weight, of carbon, and 32 parts of sulphur; it is formed whenever sulphur and carbonaceous matter are brought together at a bright red heat, and therefore, owing to the presence of sulphur in all varieties of coal, its vapour is generally, and probably always, present in coal-gas. Bisulphide of carbon is a colourless liquid, of a most insupportable odour resembling garlic; it is very volatile, boiling at 108°. It does not mix with water, but dissolves in alcohol and ether; it is also very soluble in solution of caustic soda or potash in methylic, ethylic, or amylic alcohol. It is very inflammable, and generates during combustion much sulphurous acid; on this account its presence in coal-gas is very injurious, and as there has hitherto been no known means of removing it on a large scale by any mode of purification, its non-generation in the process of gas-making becomes a problem of great importance. Few attempts have yet been made to solve this difficulty, but Mr. Wright, the eminent engineer of the Western Gas Company, has observed that its formation is greatly hindered, if not entirely prevented, by the employment of a somewhat moderate temperature. In corroboration of this observation it has frequently been noticed that the gas furnished by companies who use a high heat contains a very large quantity of this noxious material, whilst gas generated at lower temperatures, as for instance, that produced by White's hydrocarbon process, contains mere traces of this compound. Although no process for the absorption of bisulphide-of-carbon vapour from coal-gas is sufficiently cheap for employment on a large scale, yet advantage might be taken of its solubility in a solution of caustic potash in fusel oil (a by-product in spirit distilleries), or in methylated spirit of wine, for its removal from the gas supplied to private houses, where the damage done by the sulphurous acid is most annoying. By passing the gas over a considerable surface of this solution, contained in a small private purifier, the bisulphide-of-carbon vapour is completely removed.

A method of removing bisulphide of carbon from coal-gas has, however, been recently suggested by Mr. Vernon Harcourt, F.R.S. This chemist found that when impure gas was passed through an iron tube, 3 inches in diameter, filled with iron turnings and heated to low redness for a length of about two feet, the amount of bisulphide of carbon could be so far reduced that the gas, after purification from sulphuretted hydrogen, contained only 5 or 6, instead of about 30 cubic inches, in 100 cubic feet. A yet greater reduction in the amount of sulphur may be effected by heating the gas after, instead of before, purification, and then purifying the product a second time. In these experiments the sulphur of the bisulphide of carbon combines with hydrogen, perhaps with the aid of watery vapour, and forms sulphuretted hydrogen, which can be readily removed by the ordinary methods. Under certain circumstances, it appears that the illuminating power of the gas is actually increased by this process of heating to remove the bisulphide of carbon.

Bisulphide-of-carbon vapour can be readily detected in coal-gas by a very simple apparatus devised by Mr. Wright[1]; in this instrument the products of the combustion of a jet of gas are made to pass through a small Liebig's condenser; if the liquid dropping from this condenser strongly redden blue litmus paper, it is highly probable

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[1] This instrument can be had on application to Mr. Wright, 55 and 55A Millbank Street, Westminster, S.W.

that bisulphide of carbon is present. As a decisive test, 50 or 60 drops of the condensed fluid should be collected in a small test-tube, and a few drops of pure nitric acid added: on heating this mixture to boiling-point over a spirit lamp, and then adding a drop or two of a solution of chloride of barium, the liquid will become more or less milky if bisulphide of carbon has been present in the gas. It is necessary here to remark, that the absence of sulphuretted hydrogen must be first ascertained by the non-colouration of paper imbued with acetate of lead, and held for some minutes in a stream of the gas.

Nitrogen.—This gas is the chief constituent of atmospheric air, 100 cubic feet of air containing rather more than 79 cubic feet of this gas. It also enters into the composition of a large number of animal and vegetable substances. All descriptions of coal contain small quantities of this element. When nitrogen is eliminated from combination in contact with oxygen, it usually takes the form of nitrous or nitric acid; whilst in contact with an excess of hydrogen it generates ammonia. It is in this latter form that it is eliminated from coal in the process of gas-generation.

Nitrogen is a colourless, inodorous, and tasteless gas, of specific gravity 0·976. It is incombustible under ordinary circumstances, and instantaneously extinguishes burning bodies. Under certain conditions, however, nitrogen does undergo combustion, as when it is exposed to a very intense heat in the presence of oxygen. This occurs, for instance, when a small quantity of nitrogen is added to a mixture of hydrogen, with a somewhat larger proportion of oxygen than is requisite to form water, and the mixture then ignited: a loud explosion takes place, and a considerable quantity of nitric acid is formed, owing to combustion of the nitrogen, or in other words, its union with oxygen gas. This formation of nitric acid possibly occurs also to a limited extent during the burning of coal-gas; and as the temperature required to form nitric acid is very high, the greater the volume of gas consumed from one burner in a given time, the greater will be the relative quantity of nitric acid produced. The formation of such a corrosive material as nitric acid under these circumstances shows the importance of preventing the admixture of the products of the combustion of coal-gas with the atmosphere of the apartments in which it is consumed. The nitrogen contained in coal-gas is due entirely to the admission of atmospheric air, and not to the elimination of the nitrogen contained in the coal; for this latter nitrogen appears to be evolved only in combination with hydrogen as ammonia. As nitrogen is incombustible, it is not only a useless ingredient in coal-gas, but, owing to its abstracting heat from the flame of such gas, it causes a diminution of light, and is thus decidedly injurious. The admixture of this element ought therefore to be avoided as much as possible.

Oxygen.—This element is always present in coal-gas, although in very small quantity if the manufacture be properly conducted. It is never evolved from the coal itself, but it makes its way into the gas through leaky joints, and also to a certain extent through the water in which the holders are immersed. Its presence is highly injurious to the illuminating power of the gas; and since, when once introduced, it cannot be abstracted by any practicable means, its admixture ought to be carefully guarded against.

Oxygen is a colourless, invisible, and inodorous gas, very sparingly soluble in water, and which has hitherto resisted all attempts to liquefy it by cold or pressure. It is evolved from the leaves of plants under the influence of light, and constitutes about one fifth of the bulk of our atmosphere. By far the largest amount of oxygen, however, exists in combination with other elements; thus eight out of every nine tons of water are pure oxygen, and it forms at least one third of the total weight of the mineral crust of our globe. It is therefore the most abundant of all elements. Oxygen gas is heavier than atmospheric air; 100 cubic inches, at 63° Fahr. and 30 inches barometric pressure, weighing 34·193 grains, whilst 100 cubic inches of the latter weigh only 31·0117 grains. The specific gravity of oxygen is 1·1026. It eminently supports combustion, all combustible bodies when introduced into it burning much more vividly than in common air; indeed it is owing to the presence of this gas in our atmosphere, that common air possesses the property of supporting combustion.

Aqueous Vapour.—Water is volatile at all natural temperatures, and therefore its vapour always exists to a greater or less extent diffused in coal-gas, even as delivered to the consumer. The percentage amount of aqueous vapour thus present in coal-gas is always small, even when the gas is saturated; nevertheless the presence of even this small proportion of aqueous vapour diminishes to a certain extent the light produced by the combustion of gas. This effect is no doubt owing to the action of aqueous vapour upon carbon at a high temperature, by which action hydrogen, carbonic oxide, and carbonic acid gases are produced. The presence of aqueous vapour therefore tends to reduce the number of particles of carbon floating in the gas flame, and consequently the light is diminished. The following table shows the maximum percentages of aqueous vapour which can be present in gas at different temperatures. As a general rule the gas will contain the maximum amount at the lowest temperature to which it has been exposed in its passage from the retorts to the burners:—

Temperature	Percentage of aqueous vapour	Temperature	Percentage of aqueous vapour	Temperature	Percentage of aqueous vapour
32° F.	0·6	42° F.	0·9	52° F.	1·3
33	0·6	43	0·9	53	1·3
34	0·7	44	1·0	54	1·4
35	0·7	45	1·0	55	1·4
36	0·7	46	1·0	56	1·5
37	0·7	47	1·1	57	1·5
38	0·8	48	1·1	58	1·6
39	0·8	49	1·1	59	1·7
40	0·8	50	1·2	60	1·8
41	0·9	51	1·2		

Aqueous vapour has a specific gravity of ·6201, and one cubic foot of it contains one cubic foot of hydrogen and half a cubic foot of oxygen. In contact with ignited carbon, or carbonaceous substances, it is decomposed; producing a mixture of hydrogen, carbonic oxide, and carbonic acid gases. When passed over ignited iron, it yields its own volume of nearly pure hydrogen.

Having thus described the more important properties of the constituents of coal-gas, we are now prepared to discuss the conditions involved in the generation, purification, and combustion of gas.

On the generation of illuminating gas.—The production of gas for illuminating purposes whether derived from coal, peat, wood, or oil, depends, as we have seen, upon a re-arrangement of the elements composing the material employed. The nature of this re-arrangement is dependent upon the temperature employed. The lower the heat at which it can be effected, the less the weight of coke or carboniferous residue left in the retort, and, consequently, the greater the amount of carbon remaining combined with the hydrogen; the hydrocarbons thus formed being chiefly solids and liquids. On the other hand, the higher the temperature employed, the greater is the weight of carbonaceous residue, and, therefore, the smaller is the amount of carbon contained in the volatilised matters, whilst the proportion of gases in these latter becomes larger as the temperature increases. By employing a very low temperature for the destructive distillation, the production of gas may be almost entirely prevented, whilst by the employment of a very high temperature the three chief constituents of coal might without doubt be completely converted into coke, carbonic oxide, and hydrogen. Now the results produced by both these extremes of temperature are valueless to the gas manufacturer, and it is therefore necessary to employ a heat sufficiently high to prevent as much as possible the volatile substances from escaping in the form of condensible vapours, but not high enough to decompose the luminiferous constituents of the evolved gas. If coal were a definite and single chemical compound, and could be so exposed to heat as to suddenly raise the temperature of every particle to a uniform and definite degree, it is highly probable that the results of the distillation would be far less complex than they are in the present mode of gas manufacture; and it might even be possible to find such a degree of temperature as would convert the whole of the hydrogen into one or more of the higher gaseous compounds of carbon, thus giving results of maximum value to the gas manufacturer. In the ordinary processes of gas-making, where a charge of several cwts. of coal, often in large lumps, is thrown into an ignited retort, it is impossible to attain any such uniform temperature. The heat is conducted very gradually to the interior of the mass of coal, and therefore various portions of the charge are exposed to very unequal temperatures, especially in the earlier stages of the distillation. The natural consequence of these conditions is the production, on the one hand, of products resulting from excessive temperature, viz. hydrogen and light carburetted hydrogen, and, on the other, of tar, which may be regarded as the consequence of deficient heat. Notwithstanding several attempts, these disadvantages have not yet been successfully overcome; but the importance of a practical process which would secure a tolerably uniform temperature during the whole course of distillation, is seen from the remarkable results obtained with Clegg's revolving web retort: a form of apparatus undoubtedly the most ingenious yet invented for the production of gas, and which, although in its present form too complicated for successful practical use, yet embodies, when we consider the early date of its invention, in a remarkable manner, the true scientific principles of gas-making. This retort, of which a description will be found at p. 578, obviated to a great extent the inequality and uncertainty of temperature in the ordinary gas-retorts, and the result was an increase of from 30 to 40 per cent. in the quantity of gas produced, the quality being also improved, whilst scarcely any tar was formed.

But besides the great influence exercised by the temperature to which coal is exposed in the process of gas-making, *the length of time,* during which the volatile products of decomposition are exposed to that temperature, is a most important circumstance as regards the successful manufacture of gas. If we take into consideration the behaviour of the luminiferous constituents of gas when exposed to a bright red heat, and which has been described above, it will be evident that a second most important condition in the manufacture of gas is the rapid removal of these luminiferous constituents from the destructive influence of the red-hot retort as soon as they are generated: every second during which these gases are allowed to remain in their birthplace diminishes their value as illuminating agents. The only method hitherto employed for the rapid removal of the gases from the retorts is White's process, the mechanical details of which are fully described below. This process consists essentially in transmitting a current of *water-gas* through the retorts in which coal or cannel gas is being generated. The water-gas is produced by transmitting steam through retorts filled with coke or charcoal, and consists of a mixture of hydrogen, carbonic oxide, and carbonic acid gases. These gases, which are not in themselves luminiferous on combustion, necessarily become mixed with the coal or cannel gas, and thus diminish the illuminating power of the latter whilst they increase its volume. Nevertheless, if the admission of water-gas be properly managed, the luminiferous constituents saved from destruction by their rapid removal from the retorts, compensate for the dilution of the gas, so as to render the diluted gas equal in illuminating power to the gas produced from the same coal or cannel in the ordinary process of manufacture. When cannels yielding very highly luminiferous gas are employed, it is desirable to dilute them to a much greater extent, and this can be easily effected by admitting into the coal-retort a larger proportion of water-gas. In some cases the total amount of light yielded by the gas from a given weight of coal when treated according to White's process is more than double that obtained by the ordinary process, and in all cases the gain in total amount of light is very large, thus showing the importance of removing the gases from the red-hot retorts as rapidly as possible. This remark applies especially to gases very rich in luminiferous hydrocarbons, because such gases suffer relatively much more deterioration than those containing a larger proportion of diluents. In addition to these advantages, such a dilution of rich cannel-gases with any of the non-luminous constituents, hydrogen, carbonic oxide, or light carburetted hydrogen, increases the illuminating power of the gas in another way: this is effected by their forming a medium for the solution of the vapours of such hydrocarbons as exist in the liquid or even solid state at the ordinary temperature of the atmosphere, and they thus enable us to convert an additional quantity of illuminating materials into the gaseous form, which they retain permanently, unless the temperature fall below the point of saturation. The gain in illuminating power which is thus obtained will be perhaps better seen from the following example:—Suppose 100 cubic inches of olefiant gas were allowed to saturate itself with the vapour of a volatile hydrocarbon, containing three times as much carbon in a given volume of its vapour as that contained in an equal volume of olefiant gas, and that it took up or dissolved 3 cubic inches of this vapour; then, if we express the value of 1 cubic inch of olefiant gas by unity, the illuminating power of the 103 cubic inches of the mixture of olefiant gas and hydrocarbon-vapour will be 109. Now if we mix these 103 cubic inches with 100 cubic inches of hydrogen, the mixture will be able to take up an additional 3 cubic inches of hydrocarbon-vapour, and the illuminating power of the 206 cubic inches will then become 118; thus the hydrogen produces a gain in illuminating power equal to 9 cubic inches of olefiant gas, or nearly 4·5 per cent. upon the volume of mixed gases. When we consider that coal-naphtha contains hydrocarbons of great volatility, and that these are the surplus remaining after the saturation of the gas from which they are condensed, the importance of this function of the non-illuminating class of combustible gases will be sufficiently evident. It may here be remarked that incombustible gases could not be employed for this purpose, since their cooling influence upon the flame during the subsequent burning of the gas would diminish the light to a greater extent than the hydrocarbon-vapour could increase it.

It is evident that all the three non-illuminating gases, forming the class of diluents, would perform both the offices here assigned to them perfectly well, and therefore we have as yet seen no reason for giving our preference in favour of any one of these diluents; if, however, we study their behaviour during combustion, we shall find that where the gas is to be used for illuminating purposes, hydrogen has qualities which give it a very decided preference over the other two. When gas is used for lighting the interior of public buildings and private houses, it is very desirable that it should deteriorate the air as little as possible, or, in other words, it should consume as small a quantity of oxygen and generate as little carbonic acid as possible. The oppressive heat which is so frequently felt in apartments lighted with gas also shows the advantage of the gas generating a minimum amount of heat.

The following is a comparison of the properties of the three non-illuminating gases in reference to the points just mentioned:—

One cubic foot of light carburetted hydrogen, at 60° Fahr. and 30 inches barometrical pressure, consumes 2 cubic feet of oxygen during its combustion, and generates 1 cubic foot of carbonic acid, yielding a quantity of heat capable of heating 5 lbs. 14 oz. of water from 32° to 212°, or causing a rise of temperature from 60° to 80°·8 in a room containing 2,500 cubic feet of air.

One cubic foot of carbonic oxide, at the same temperature and pressure, consumes, during combustion, ½ a cubic foot of oxygen, generates 1 cubic foot of carbonic acid, and affords heat capable of raising the temperature of 1 lb. 14 oz. of water from 32° to 212°, or that of 2,500 cubic feet of air from 60° to 66°·6.

One cubic foot of hydrogen, at the same temperature and pressure, consumes ½ a cubic foot of oxygen, generates no carbonic acid, and yields heat capable of raising the temperature of 1 lb. 13 oz. of water from 32° to 212°, or that of 2,500 cubic feet of air from 60° to 66°·4.

This comparison shows that light carburetted hydrogen is very objectionable as a diluent, not only on account of the carbonic acid which it generates, but also by reason of the very large quantity of oxygen which it consumes, and the very great amount of heat which, in relation to its volume, it evolves on combustion; the consumption of oxygen being four times, and the absolute thermal effect more than three times as great as that of either of the other gases.

The quantity of heat evolved by the combustion of equal volumes of carbonic oxide and hydrogen is nearly, and the amount of oxygen consumed quite, the same; but the carbonic acid evolved from the first gives a decided preference to hydrogen as the best diluent.

The same comparison also shows that when the gas is to be used for heating purposes, and the products of combustion are carried away, light carburetted hydrogen is by far the best diluent.

The experiments of Dulong on the absolute thermal effects of hydrogen, light carburetted hydrogen, and carbonic oxide are taken as the basis of the foregoing calculations. Dulong found that—

1 lb. of hydrogen	raised the temperature of	1 lb. of water	through	62,471° F.
1 lb. of carbonic oxide	„	„	„	4,505° F.
1 lb. of light carburetted hydrogen		„	„	24,244° F.

These considerations indicate the objects that should chiefly be regarded in the generating department of the manufacture of gas for illuminating purposes. They are—

1st. The extraction of the largest possible amount of illuminating compounds from a given weight of material.

2nd. The formation of a due proportion of illuminating and non-illuminating constituents, so that on the one hand the combustion of the gas shall be perfect, and without the production of smoke or unpleasant odour, and on the other, the volume of gas required to obtain a certain amount of light shall not be too large.

3rd. The presence of the largest possible proportion of hydrogen amongst the non-illuminating constituents, to the exclusion of light carburetted hydrogen, and carbonic oxide; so as to produce the least amount of heat and atmospheric deterioration in the apartments in which the gas is consumed.

For some time previous to the strike of the gas-stokers, and to the temporarily-diminished illumination which it produced, a number of ingenious persons were busy with endeavours to improve and cheapen the manufacture of gas; and the strike had the good effect of attracting to their labours more attention than these would otherwise have commanded. About that time two new methods were brought prominently before the public—one of them being the process of Messrs. Porter and Lane, the property of the Gas Generator Company, and the other being the process of Mr. Ruck, which is now vested in the New Gas Company. See Gas, Water.

The method of Messrs. Porter and Lane consists essentially in an improved arrangement of the retorts, by which the distillation of coal is greatly facilitated. It has now been experimentally in use, upon a working scale, in the manufactory of the Chartered Gas Company in the Horseferry-road, and is established on a larger scale at their principal works at Beckton. Instead of the usual horizontal retorts, which are charged and emptied with great difficulty by severe labour, Messrs. Porter and Lane use vertical retorts, within which a screw, with an oblique blade, slowly revolves on a vertical axis. The coal is placed in a chamber or hopper above, and trickles down into the retort as room is made for it by the subsidence of that which is below. The apparatus is, therefore, self-feeding, and only requires that the hopper should be supplied at proper intervals by easy labour, such as can be done by anyone who can handle a spade and a barrow. The revolution of the screw keeps a spiral line of coal in constant contact with the inner side of the retort; and the intervals between the turns of the blade allow room for the disengagement of the gas. By the time the coal reaches the bottom of the screw it is exhausted, and it falls as coke into a vertical chamber below, which is continuous with the retort, but beneath the furnace, and in which it is instantly quenched. The coke-chamber can be emptied by one man, as often as necessary, in one minute; and the whole process requires scarcely any interference from those in charge of it. By establishing a proper relation between the length of the screw, the speed of its rotation, and the heat of the furnace, the distillation of the coal can be carried exactly to the most desirable point, so as to obtain from it all the gas it can yield, and to stop short of the evolution of a variety of noxious products. In the horizontal retorts the outer crust of the mass of enclosed coal becomes over-burnt long before the inner portion is exhausted, and in this way many sulphur compounds are produced, even although the charge, as a whole, is withdrawn flaming and manifestly unexhausted. In Porter and Lane's process, on the contrary, the charge falls out bit by bit in a glowing condition, and yields a coke which is said to be much better adapted for household purposes than that ordinarily made. It is said to be lighter and more spongy in texture, and to kindle readily when placed on a common fire; but it burns out with great rapidity.

The results hitherto obtained by this method at the works of the Chartered Gas Company seem to show a constantly-increased production of gas to the extent of 2,000 cubic feet for each ton of coal, and also an increased production of coke. Moreover, the division and distribution of coal by the screw exposes it so completely to the action of heat that the retorts may be kept at a lower temperature than in the ordinary method, and thus the life of each retort will be proportionately prolonged. The saving of labour, of course, speaks for itself; and the quality of the gas, especially with reference to the presence of sulphur-compounds, is very superior to that made in the usual way. The retorts remain free from carbonaceous deposit, and their vertical arrangement has admitted of improvement in the furnace, by which a considerable saving in repairs, fuel, and labour is effected.

The following remarks on the manufacture of gas for illuminating purposes are mainly derived from a paper read by Mr. Thomas Wills before the Society of Arts. After a few remarks on the constitution of wood, lignite, and coal, and the products of their gradual resolution into simpler compounds, their more rapid decomposition by heat was illustrated by the following table, showing the proportion of hydrogen and carbon in coal-gas as distilled at different temperatures, the hydrogen being maintained constant:—

Temperature	Hydrogen	Carbon	Name of gas
Dull red heat . .	100	614	Principally olefiant gas (C_2H_4).
Red heat . . .	100	580	
Bright red heat .	100	472	Olefiant gas (C_2H_4) mixed with marsh gas (CH_4).
White heat . .	100	325	Marsh gas (CH_4).
Continued white heat	100	7	Nearly pure hydrogen, carbon deposited.

The number of well-known intermediate products obtained during the destructive distillation of coal is very large, and coal-gas itself not only contains certain permanent gases, but also a large quantity of the vapours of volatile hydrocarbons, which contribute in no small degree to its luminosity. Still, the greater bulk of the gas is composed of hydrogen, the flame of which is without any light-giving properties whatever, and marsh gas, a gas possessing the least light-giving power of any hydrocarbon, as it contains the smallest proportion of carbon to the largest of hydrogen.

Average Composition of Coal-Gas supplied by the following Companies:—

	Great Central	Imperial	Chartered
Illuminating hydrocarbons	3·56	3·67	3·53
Marsh gas	35·28	40·66	35·26
Hydrogen	51·24	41·15	51·80
Carbonic oxide	7·40	8·02	8·05
Carbonic acid	0·28	0·29	
Nitrogen	1·80	5·01	0·38
Oxygen	0·44	1·20	0·08
	100·00	100·00	100·00

There can be no question that a great advance in the manufacture of coal-gas would be made if, by any means, applied either with primary distillation of the coal or to the gas after its production, whereby the amount of acetylene (C^2H^2) or of olefiant gas (C^2H^4) could be increased; for olefiant gas contains, in a given bulk, just twice as much carbon as marsh gas, and acetylene a still larger quantity. The value of this increase is not to be measured only by the increased quantity of carbon contained in a given bulk of gas, for a small portion of either of the above compounds, diffused through a non-illuminating gas, is much more than equivalent to a similar quantity of carbon combined in some less condensed compound. An illustration of this occurs in the case of marsh gas. If marsh gas, possessing, it will be remembered, only a small amount of luminosity, be decomposed, either by its passage through a heated tube, or by the electric spark, the carbon it contains will be deposited, while the amount of hydrogen set free will occupy double the volume of the original gas. Yet the flame of this nearly pure hydrogen will be found to possess a greater luminosity than the flame of the original marsh gas, although it has lost nearly the whole of its light-giving material, accounted for by the presence of a very small quantity of acetylene, produced during the decomposition.

In 1871 a patent was taken out for 'Improvements in the manufacture and purification of gas, and in certain parts of the apparatus employed therein.' This process is carried out by distilling the coal at a much lower temperature than usual—in the original scheme from 600° to 1,000° Fah. is mentioned, but in practice from 1,300° to 1,400° Fahr. will probably be employed; at this temperature, from a ton of gas-coal about 8,500 cubic feet of gas are obtained, together with a greater than ordinary yield of tar and oil: this tar is condensed, by special means employed for securing a greater rapidity in the process, and collected as free from water as possible, with a view to its being re-distilled in a separate and peculiar retort.

The following are some of the more important points brought out by examination of this process by Messrs. Keates and Odling. The highest yield of gas obtained directly from the coal was 9,775 cubic feet, the temperature of distillation being between 1,300° and 1,400° Fahr. The quantity of oil and tar obtained from one ton of coal varied considerably with the nature of the coal used; thus, Silkstone coal-gas 16·4 gallons of tar and oil per ton, Clay Cross main 11·9 gallons, and Pelaw main 13·9 gallons, or a mean of 14 gallons. The highest yield of gas which was obtained by the continued distillation and redistillation of the oily tar was 29 cubic feet per gallon. The mean lighting power of the gas produced from coal was 23·0 candles, and of that obtained from the tar 25·0 candles. The quantity of coke used to maintain the heat in the various parts of the apparatus was about 33 per cent. of that produced, and in the event of the distillation being repeated until complete separation into pitch and vaporisable matters takes place, this amount would be much exceeded. It is a generally-accepted fact that the quicker coal be carbonised in gas-making, provided it be done effectually, the more successful will be the operation. A plan for effecting this has recently been brought forward, the principle of which is as follows:—The retort in this case is set in a vertical position, and through its centre revolves a broad and somewhat deep screw, placed together in sections, the thread of which is placed at an angle of 45°, and which comes nearly into contact with the sides of the retort. Through a nipple at the top, coal is supplied, in pieces of small but regular size; the inclination of the thread of the screw impels the pieces against the heated sides, where comparatively rapid carbonisation takes place, and the rate of revolution of the screw is so regulated, that by the time the fuel has arrived at the bottom of the retort the process is complete, and coke of a somewhat inferior quality is discharged into a suitable receptacle. The yield of gas is greater by this means, and of higher illuminating power, the amount of tar being correspondingly less; the difficulties in this case appear to be chiefly mechanical. That the process is successful, will be seen from the following results:—

Coal carbonised	Quantity of Gas obtained	Illuminating power of Gas	Amount of Tar
ton		candles	gallons
1	11,040	16	85
1	10,160	17	
1	12,000	16	

The fact of the existence of a large number of hydrocarbons of great volatility, the vapours of which, when ignited, burn with exceedingly luminous flame, has been a very great incentive with inventors to produce some scheme whereby these vapours might be used to confer luminosity upon a combustible non-luminous gas, or further inflammability, coupled with luminosity, upon a non-combustible and negative gas.

Another process which has claimed some attention is that of Dr. Eveleigh, which has been used by the Patent Gas Company, and investigated, and reported on, by Dr. Odling and Mr. Keates.

The process consists in the distillation of coal in iron retorts of double the ordinary capacity, at a lower temperature than that usually employed. A smaller yield of gas is thus procured of comparatively high lighting power, together with a certain quantity of oily tar, which is subsequently submitted to destructive distillation in a peculiarly-constructed apparatus, in which the oil suffers a partial conversion into permanent gas. These two processes are, in practice, carried on simultaneously, the resulting gases mixing during their passage to the holder. The combined result of the distillation of the coal and oil by this method gives a larger yield of gas per ton of coal, it is of considerably higher lighting power, and is comparatively free from sulphur-compounds.

The apparatus used for the distillation of the oil consists of three vessels placed at increasing distances from the source of heat. The oil flows into that having the lowest temperature (about 900° F.), where the fixed portion of the oil remains as pitch, while the more volatile vapour, after becoming further heated by passing through the second chamber, enters the last or hottest vessel. This is an iron pan filled with charcoal, and heated to about 1,300° F. The highly-heated vapour of the oil, during its passage through the incandescent charcoal, is partially converted into permanent gas. This gas, after leaving the oil-still, enters a tank containing a little water, through which it passes, in order to condense any undecomposed oil: it is then conducted along a pipe, where it meets with the gas from the coal, the mixture going through the purifiers to the holder in the usual way.

The highest yield of gas obtained by this method from ordinary Norfolk Silkstone coal, during the experiments of Mr. Keates and Dr. Odling, was 10,500 cubic feet of 25-candle gas to the ton, the sulphur being as low as 6 grains per 100 cubic feet. This is certainly a striking result, as compared with the ordinary yield of the same coal, which is about 9,300 feet of 14-candle gas, frequently containing over 30 grains of sulphur per 100 feet.

Although it has been proved possible to obtain the above favourable result by Dr. Eveleigh's process, it is to be feared that the extra amount of plant, labour, and fuel required, necessitates such increased expenditure as to more than compensate for the increased yield.

On the purification of illuminating gas.—If we except the insignificant quantities of nitrogen and oxygen, which become mixed with illuminating gas through imperfections in the joints of the apparatus employed, and by the transferring power of the water of the gasholder, all impurities arise from the presence of the three elements sulphur, oxygen, and nitrogen in the generating material used.

The sulphur, uniting with portions of the hydrogen and carbon of the coal, generates, with the first-named element, sulphuretted hydrogen, and with the second, bisulphide of carbon. It is also probable that volatile organic compounds of sulphur are produced by the union of this element with carbon and hydrogen simultaneously, although we have as yet no positive evidence of their presence in illuminating gas. The oxygen, uniting with another portion of carbon, forms carbonic acid, whilst the nitrogen unites with hydrogen to form ammonia, which, by combination with sulphuretted hydrogen, produces hydrosulphate of sulphide of ammonium, and, with carbonic acid and water, carbonate of ammonia. With the exception of bisulphide of carbon and the organic sulphur-compounds just mentioned, the removal of all these impurities is not difficult. Slaked lime, either in the form of moist powder, or suspended in water as milk of lime, absorbs the whole of them; whilst it has no perceptible effect upon the other constituents of the gas. By this process of purification the sulphuretted hydrogen and caustic lime are converted into sulphide of calcium and water; the former being non-volatile, does not mix with the gas. Hydrosulphate of sulphide of ammonium is in like manner converted into sulphide of calcium, water, and ammonia: part of the latter is retained by the moisture present in the purifying material, but the remainder mixes with the gas, from which, however, it can be removed by contact with a large surface of water. Carbonic acid unites with caustic lime with great energy, forming carbonate of lime, a perfectly non-volatile material; and thus the acid gas is effectually retained. Carbonate of ammonia is under similar circumstances decomposed, carbonate of lime being formed and ammonia liberated; the last, as before, being only partially retained by the moisture present, and requiring, when 'dry lime' is used, a subsequent application of water for its complete removal. Although in the wet-lime purifying process a given weight of lime can remove a much larger volume of impurities, yet the dry-lime process possesses so many manipulatory advantages that it is now all but universally employed where lime is used as the purifying agent. The maximum amount of sulphuretted hydrogen or of carbonic acid which can be absorbed by 1 lb. of quick-lime, in the so-called dry and wet states respectively, is seen from the following table:—

	Cubic feet of Sulphuretted hydrogen	Cubic feet of Carbonic acid
1 lb. of quick-lime used as dry lime absorbs	6·78	3·39
1 lb. of quick-lime used as wet lime absorbs	6·78	6·78

In practice, however, the absorption actually effected is, even under the most favourable circumstances, considerably less than here indicated. As a substitute for lime in the purification of gas a mixture of hydrated peroxide of iron and sulphate of lime has lately come into extensive use. This material is prepared in the first place by mixing slaked lime with hydrated peroxide of iron, the composition being rendered more porous by the addition of a certain proportion of sawdust. This mixture is now in a condition to remove those impurities from coal-gas which are abstracted by lime. The peroxide of iron absorbs sulphuretted hydrogen and sulphide of ammonium, and becomes converted into sulphide of iron. The slaked lime absorbs carbonic acid and carbonate of ammonia until it is converted into subcarbonate of lime. When the absorbing powers of the mixture are nearly exhausted, the covers of the purifiers are removed and the mixture is exposed to the air. The following change is then said to take place. The sulphide of iron rapidly absorbs oxygen and becomes converted first into sulphate of protoxide of iron and finally into sulphate of peroxide, which latter is decomposed by the carbonate of lime, carbonic acid being evolved as gas, whilst sulphate of lime and peroxide of iron are produced; the mixture is thus again rendered available for the process of purification; the peroxide of iron acts as before, but in the place of quick-lime we have now sulphate of lime, which is quite effectual for the removal of carbonate of ammonia, with which it forms carbonate of lime and sulphate of ammonia; but the mixture is incapable of removing free carbonic acid, and it is therefore necessary to provide a separate dry-lime purifier for the removal of this gas. When the purifying material is again saturated with the noxious gases, another exposure to atmospheric oxygen restores it again to its active condition, the only permanent effect upon it being the accumulation of sulphate of ammonia within its pores. If this latter salt be occasionally dissolved out with water, the mixture may be used over and over again to an almost unlimited extent. It has been found that this process can be much simplified; and Mr. Hills, who has brought gas-purification to great perfection, recommends that hydrated peroxide of iron should be merely mixed with a considerable bulk of sawdust and placed in the purifiers. After the gas has passed through this mixture for 18 hours, it is shut off and replaced by a current of air forced through by a fanner for 3 hours. The sulphide of iron is thus oxidised, sulphur being separated and hydrated peroxide of iron regenerated; and the purifying material being now revivified, the gas may be passed through it again as before. In this way it is only found necessary to remove the material once a month in order to separate the lowest stratum of about an inch in thickness, which has become clogged up with tar. A proportional quantity of fresh mixture of hydrated peroxide of iron and sawdust having been added, the whole is again returned to the purifier. It is difficult to conceive a more simple and inexpensive process of purification than this. It does not, however, remove carbonic acid. Several other materials have been proposed for the separation of sulphuretted hydrogen from coal-gas, such as sulphate of lead, and chloride of manganese, but they possess no peculiar advantages, and have never been extensively adopted.

It has been already mentioned that, in addition to sulphuretted hydrogen and carbonic acid, which are readily removed by the processes just described, there also exist in coal-gas, as impurities, various quantities of bisulphide of carbon and probably sulphuretted hydrocarbons. Now all these sulphur-compounds produce sulphurous acid during the combustion of the gas, and where the quantities of these impurities is considerable, as is the case with much of the gas now manufactured, the atmosphere of the apartments in which such gas is used becomes so strongly impregnated with sulphurous acid, as to be highly offensive to the senses and very destructive to art decorations, bindings of books, &c. It becomes, therefore, a matter of considerable importance to prevent, as far as possible, the occurrence of these injurious constituents; in fact, until this is effected, gas will never be more than very partially adopted as a means of illumination in dwelling-houses. When once generated with coal-gas all attempts to remove these constituents have hitherto proved ineffectual; and there seems little ground for hope that any practicable process will be devised for their abstraction. Attention may, therefore, more profitably be directed to the conditions which tend to diminish the amount generated in the retorts, or altogether to prevent their formation. Mr. Wright, who has paid considerable attention to this problem, finds that the employment of a moderate heat for the generation of the gas has the effect of greatly reducing the relative quantity of these noxious ingredients, and thus by simply avoiding excessive heat in the retorts, and rejecting the last portions of gas, he has, to a great extent, prevented their formation. Unfortunately, however, this remedy is not likely to find favour amongst gas-manufacturers in general, inasmuch as it considerably reduces the yield of gas. A few well-directed chemical experiments could scarcely fail to discover the conditions necessary for the non-production of these sulphuretted compounds. Probably the proper admixture of salt or lime with the coals before carbonisation would have the desired effect. The subject is one of so much importance to the future of gas illumination, that it ought not to be suffered to rest in its present unsatisfactory condition.

On the consumption of gas.—The proper consumption or burning of illuminating gas depends upon certain physical and chemical conditions, the due observance of which is of great importance in the development of a maximum amount of light. The production of artificial light depends upon the fact that, at certain high temperatures, all matter becomes luminous. The higher the temperature the greater is the intensity of the light emitted. The heat required to render matter luminous in its three states of aggregation differs greatly. Thus solids are sometimes luminous at comparatively low temperatures, as phosphorus and phosphoric acid. Usually, however, solids require a temperature of 600° or 700° Fahr. to render them luminous in the dark, and must be heated to 1000° Fahr. before their luminosity becomes visible in daylight. Liquids require about the same temperature. But to render gas luminous, they must be exposed to an immensely higher temperature; even the intense heat generated by the oxyhydrogen blowpipe scarcely suffices to render the aqueous vapour produced visibly luminous, although solids, such as lime, emit light of the most dazzling splendour when they are heated in this flame. Hence it has generally been maintained that those gases and vapours only can illuminate which produce, or deposit, solid or liquid matter during their combustion. This dependence of light upon the production of solid matter is strikingly seen in the case of phosphorus, which when burnt in chlorine produces a light scarcely visible, but when consumed in air or oxygen emits light of intense brilliancy. In the former case the *vapour* of chloride of phosphorus is produced, in the latter, *solid* phosphoric acid.

Several gases and vapours possess this property of depositing solid matter during combustion, but a few of the combinations of carbon and hydrogen are the only ones capable of practical application; these latter compounds evolve during combustion only the same products as those generated in the respiratory process of animals, viz. carbonic acid and water. The solid particles of carbon which they deposit in the interior of the flame, and which are the source of light, are entirely consumed on arriving at its outer boundary; their use as sources of artificial light, under proper regulations, is therefore quite compatible with the most stringent sanitary rules.

The constituents of purified coal-gas have already been divided into illuminating and non-illuminating gases; amongst the latter will be found light carburetted hydrogen, which, although usually regarded as an illuminating gas, has been proved by the experiments of Frankland to produce, under ordinary circumstances, no more light than hydrogen or carbonic oxide, and therefore for all practical purposes it must be regarded as entirely destitute of illuminating power. This is owing chiefly to the temperature required for the deposition of its carbon being higher than that attained in an ordinary gas burner; for Frankland has proved that, if the temperature of the light carburetted hydrogen flame be increased by previously heating the gas and air nearly to redness, then the flame becomes luminous to a considerable degree. It is not improbable that when gas is consumed in very large burners this necessary temperature is attained, and the light carburetted hydrogen contributes considerably to the aggregate illuminating effect; a view which is, to a certain extent, confirmed by the fact, that a relatively much larger amount of light is obtained from coal-gas when the latter is consumed in a large flame than when it is allowed to burn in a small flame.

Omitting light carburetted hydrogen and carbonic oxide, the remaining carboniferous constituents of coal-gas yield, during combustion from suitable burners, an amount of light directly proportionate to the quantity of carbon which they contain in a given volume.

In order to understand the nature of the combustion of a gas flame, it is necessary to remember that the flame is freely permeable to the air, and that according to the well-known laws of gaseous mixture, the amount of air which mixes with the ignited gases will be increased, first, by an increase of the velocity with which the gas issues from the orifice of the burner; and secondly, by the velocity of the current of air immediately surrounding the flame. It is well known that a highly luminiferous gas may be deprived of all illuminating power either by being made to issue from the burner with great velocity, or by being burnt in a very rapid current of air produced by a very tall glass chimney.

The foregoing considerations indicate the conditions best adapted for obtaining the maximum illuminating effect from coal-gas. The chief condition is the supply of just such a volume of air to the gas flame as shall prevent any particles of carbon from escaping unconsumed. Any excess of air over this quantity must diminish the number of particles of carbon deposited within the flame, and consequently impair the illuminating effect.

Dr. Frankland has shown that the luminosity of a flame is materially modified by the pressure of the atmosphere in which it burns; the denser the air the more brilliant the light, the carbon combining more rapidly with the increased quantity of oxygen. Hence the illuminating effect of the same gas will vary in different localities; thus, a quantity of gas which gives in London the light of 100 candles would give in Munich (1,700 feet above the sea-level) only the light of 91 candles, and if the same gas were burned in the city of Mexico (about 7,400 feet above the level of the sea) it would yield the light of only 61½ candles.

The following remarks on increasing the illuminating power of coal-gas by carburetting or naphthalising, are derived from the Rev. W. R. Bowditch's work on 'The Analysis, Technical Valuation, Purification, and Use of Coal-gas':—

'Carburetting gas signifies adding to it vapours of hydrocarbons, which contain a large proportion of carbon in comparison of their other constituent, hydrogen; and as coal-naphtha was first used for this purpose, and is yet the chief substance employed, the process was named naphthalising, from the fluid employed. Coal-naphtha is a mixture of hydrocarbons, and is made up of a solid (carbon) and a gas (hydrogen), which, when united, form a fluid that contains a far higher percentage of carbon than gas does. It is to this high percentage of carbon it owes its use in improving the light of gas, to which its vapour is added. In fact, the light-giving power of gas supplied to us for combustion is largely due to the pressure in it of vapours which, when they are condensed into a fluid we call naphtha. We need not be chemists to ascertain that naphtha is much richer in carbon than coal-gas is; for if we light gas it burns with a luminous, but not with a smoky flame, whereas if we apply a light to a little naphtha in a saucer, it burns with a red flame, which affords but little heat, and deposits large quantities of carbon in the well-known form of soot. The proportion of carbon is so large that there is not heat enough to burn it, and hence the smoke. The cause of this is obvious. When the naphtha-vapour is fired, both of its constituents burn, but the heat-producing constituent, hydrogen, is relatively so small in quantity that its heat cannot raise the carbon to the temperature required for its union with oxygen or, as it is popularly called, burning, and therefore the unburnt carbon is deposited in visible black particles, instead of being converted into an invisible gas (carbonic acid), as it would have been had the hydrogen been in sufficient quantity to heat up the carbon to the temperature requisite for its combustion. Had this been the case the flame would have been smokeless instead of smoky, and white instead of red. The case of gas is very different. When that is lighted much more than enough heat is produced to burn its carbon perfectly. The richness of naphtha in carbon may also be inferred from the fact that while a cubic foot of common gas weighs but about 224 grains, a cubic foot of naphtha weighs more than 370,000 grains. Now, this naphtha is composed of carbon and hydrogen only. Hydrogen is the lightest substance known in nature, and a cubic foot of it weighs but 37·1 grains, from which it is easy to see that the other constituent (carbon) gives the weight to the naphtha. Why is it necessary to add to gas these highly carburetted bodies? Because the solid carbon which they contain is required to give light. A gas which does not contain a solid gives but a mere trace of light, however great the heat produced by its combustion. This is well seen in the case of the gas hydrogen. When it burns, the heat produced is very intense. Solid substances held in the flame become strongly ignited and afford light; but without the solid the burning gas gives so little light that we cannot imagine a flame sufficiently large to afford us useful illuminations; and, if we could produce such a flame, the heat of it would be unbearable. Hydrogen does not contain a solid, and the sole product of its combustion is water. If we pass hydrogen over naphtha we find by the smell that it has carried with it a quantity of the vapour; and if we then burn the hydrogen so mixed with vapour, we obtain light, and the light increases as the quantity of vapour mixed with the hydrogen increases. In this case the hydrogen burns as soon as it comes into contact with the air, and produces intense heat. This heat decomposes the naphtha-vapour and sets free its carbon in the solid form, and then heats it to whiteness, at which temperature it affords light; the quantity of light being regulated, first, by the quantity of carbon present in the flame; and, secondly, by the temperature to which the solid carbon is raised. The greater the quantity of carbon and the higher its temperature, the greater the light. Another change is observed to take place when the hydrogen is mixed with the vapour. The flame of hydrogen alone is small in comparison of the flame produced by the same quantity of coal-gas, but if the hydrogen be passed over naphtha and burnt at the same rate as before, the flame is considerably expanded by the white-hot carbon contained in it. That which occurs in this case occurs universally. An increase of luminosity is always attended by an increased size of flame when the gases compared are burnt at the same rate.

'What has now been said applies to the case of coal-gas thus: The principal portion of coal-gas consists of heat-producing substances which do not give light, and which, like hydrogen, require to be mixed with bodies rich in carbon before they can be made useful. In gas itself we find some of these richly-carburetted bodies, but their quantity is small even in the best gas, and of course much smaller in gas of inferior quality. Professor Bunsen of Heidelberg has published an analysis of Manchester gas, in which he shows the percentage of illuminants and non-illuminants; and although the Manchester gas is made principally from cannel coal, and has an illuminating power of from 20 to 22 sperm candles for a consumption of five feet per hour, the quantity of non-illuminating gas is far larger than is suspected by persons not familiar with the subject. The following is Professor Bunsen's statement, ("Gasometry," p. 113):—

Analysis of Manchester gas. In 100 *parts.*

Non-illuminating heat-producers	Hydrogen	45·58	87·12 per cent.
	Marsh gas	34·90	
	Carbonic oxide	6·64	
Illuminants.	Elayl	4·08	6·46 per cent.
	Ditetryl	2·38	
Impurities.	Sulphuretted hydrogen	0·29	
	Nitrogen	2·46	
	Carbonic acid	3·67	
		100·00	

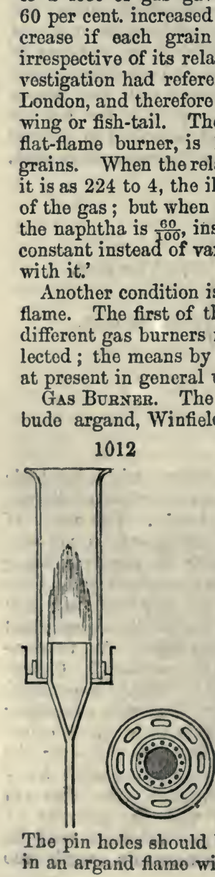
'This is cannel-gas. In common gas, such as that of London—which has little more than half the illuminating power of Manchester gas—the proportion of illuminants is smaller, and of non-illuminating heat-producers is larger. The mean of results obtained by many chemists shows that common 12-candle gas does not contain more than 4 per cent. of illuminating constituents, the other 96 per cent. being non-illuminating heat-producing compounds; that is, 4 feet in a hundred yield light and 96 feet yield heat. It seems extraordinary, that when we buy and burn 100 cubic feet of cannel gas we obtain and use only 6½ feet of useful illuminants, and are obliged to take 87 feet of gases which do not furnish any light. An unscientific person is apt to exclaim "Can this be? and if it be, is it necessary? Cannot the illuminants be made and sold without the heat-producers?" This is impossible. Gas cannot be made without its bulk being non-illuminating. But still something can be done to *increase the proportion* of illuminants, and this is what is called naphthalising or carburetting. We find by experiment if we pass gas over the highly-carburetted substance called naphtha, that every foot of gas carries away with it as vapour a part of the naphtha; that the naphtha-vapour burns with the gas; and that the light-giving power of the gas increases with the quantity of naphtha-vapour so removed and burnt. We can measure the gas, weigh the naphtha removed, determine the increase of light obtained, and thus ascertain exactly the illuminating value of each grain of naphtha burnt with the gas. The naphtha thus added to gas does not burn with a red flame, which gives off much smoke, as it does when burnt alone, but it gives a bright, white, smokeless flame. This result is due to the non-illuminating but heat-producing compounds of the gas. The naphtha contains so much carbon and so little heat-producing hydrogen, that when it is set on fire alone the carbon is not heated sufficiently to burn and still less to render it highly luminous; wherefore its light is feeble, and much of the carbon is deposited as soot. But when it is burnt with gas the heat-producers in the gas raise the carbon of the naphtha to a sufficient temperature to enable it to give off a brilliant light, and to burn without smoke. Thus, the heat-producers are rendered directly useful. They raise the carbon to the temperature required for illumination and combustion. The naphtha, on the other hand, remedies the want of luminosity in the gas by adding to it much carbon, in which it is deficient, and but little hydrogen, in which the gas itself abounds.

'But for the teaching of experiment we should expect that if a given quantity of naphtha added to a given quantity of gas raised it in illuminating value (a) candles, then double the quantity of naphtha added to the same quantity of gas would raise it ($2\,a$) candles, three times the quantity ($3\,a$) candles, and so on. In other words, we should expect the illuminating value of a grain of naphtha to be the same however it was burnt with gas. Experience shows this to be a mistake, and proves that the illuminating value of a grain of naphtha depends upon *the relation which it bears to the bulk of gas with which it is burnt*, and that within certain limits its illuminating value varies greatly. Dr. Letheby investigated the increase of illuminating power obtained by naphthalising, and his results are published in the "Chemical News," vol. vi. pp. 283–292. It is there stated that four grains of naphtha added to a foot of gas gave 25 per cent. increased light, whereas 8 grains per foot gave 60 per cent. increased light, instead of 50 per cent., which would have been the increase if each grain of carburetting material had a constant illuminating value irrespective of its relation to the bulk of gas with which it is consumed. The investigation had reference to the use of naphtha in the public lamps of the city of London, and therefore the results must have been obtained in flat-flame burners, bat's-wing or fish-tail. The average illuminating value of a foot of common gas burnt in a flat-flame burner, is 1·6 candle, and the weight of a foot of such gas is about 224 grains. When the relation between the weight of the gas and the naphtha burned with it is as 224 to 4, the illuminating value of the naphtha is $\frac{25}{100}$ of the illuminating value of the gas; but when the relation is altered to 224 to 8, then the illuminating value of the naphtha is $\frac{60}{100}$, instead of 50, as it would have been if its illuminating value were constant instead of variable, and depending much upon the quantity of gas consumed with it.' . . .

Another condition is the attainment of the highest possible temperature within the flame. The first of these conditions has been more or less perfectly obtained in the different gas burners now in use. The second has been hitherto almost entirely neglected; the means by which it may be attained will be discussed after the burners at present in general use have been described.

Gas Burner. The chief burners now in use are the bat's-wing, fish-tail, argand, bude argand, Winfield's argand, Guise's argand, Leslie's argand.

1012



The *bat's-wing* consists of a fine slit cut in an iron nipple, giving a flat fan-like flame.

The *fish-tail* consists of a similar nipple perforated by two holes, drilled so that the jets of gas are inclined towards each other at an angle of about 60°. A flat film of flame is thus produced, somewhat resembling the tail of a fish. This form of burner is especially adapted for the consumption of cannel and other highly illuminating gases.

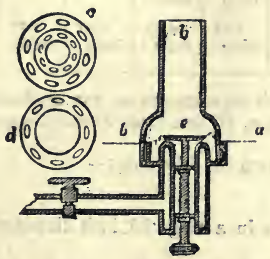
The *argand* consists of a hollow annulus (see *fig.* 1012), from the upper surface of which the gas issues through a number of small apertures, which are made to vary in diameter from $\frac{1}{32}$nd of an inch to $\frac{1}{50}$th of an inch, according to the richness of the gas; the most highly illuminating gases requiring the smallest apertures. The distances of the orifices for coal-gas should be ·16 to ·18 inch, and for rich cannel-gas ·13 inch. If the argand ring has 10 orifices, the diameter of the central opening should be $=\frac{4}{10}$ths of an inch; if 25 orifices, it should be one inch for coal-gas; but for oil-gas, with 10 orifices, the central opening should have a diameter of $\frac{1}{2}$ an inch, and for 20 orifices, 1 inch. The pin holes should be of equal size, otherwise the larger ones will cause smoke, as in an argand flame with an uneven wick.

The *Bude burner* consists of 2 or 3 concentric argand rings perforated in the manner just described. It is well adapted for producing a large body of very intense light with a comparatively moderate consumption of gas.

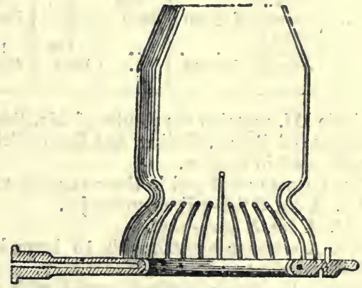
Winfield's argand.—The chief distinction between this and the ordinary argand burner consists in the introduction of a metallic button above the annulus, so as to cause the internal current of air to impinge against the flame. A peculiarity in the shape of the glass chimney, as seen in the figure, produces the same effect upon the outer current of air. See *fig.* 1013.

Guise's argand contains 26 holes in a ring, the inner diameter of which is ·6 inch, and the outer diameter 1·9 inch. Like the Winfield burner, it has a metal button ½ an inch in diameter, and 1 inch above the annulus. The glass chimney, which is cylindrical, is 2 inches in diameter and 6 inches long.

1013



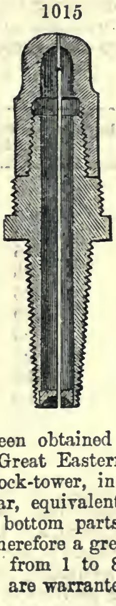
1014



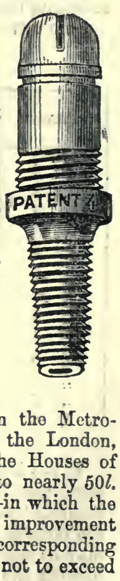
Leslie's argand consists, as seen in the figure (*fig.* 1014), of a series of fine tubes arranged, in a circle by which a more uniform admixture of air with the gas is effected. A sufficient current of air for all these argand burners can only be obtained by the use of a glass chimney, the rapidity of the current depending upon the height of the chimney. In the Leslie's argand the height of the chimney is especially adapted to the amount of light required, and in order to consume gas economically, this point must be attended to in all argand burners.

Brönner's burners, introduced by Messrs. Greene and Son, have lately attracted attention. The accompanying illustrations show the principle of this patent burner. *Fig.* 1015 is a section, and *Fig.* 1016 a full-sized drawing, from which it may be seen that, instead of the gas being admitted through a large opening and emitted through two small ones, as in the ordinary fish-tail burner, it is made to pass through a small aperture at the bottom into a circular chamber, and thence through a larger opening at the top, thus obviating all undue and variable pressure, the gas being fully consumed as it is emitted from the burner, instead of being forced through into the atmosphere partly unconsumed, to the injury of both health and furniture, &c. &c. By this method the disagreeable hissing noise, which is often noticed in the ordinary burner, is done away with, and the light given is pure, brilliant, and steady, of a whitish yellow instead of a bluish yellow flame, a very great improvement. That these burners, through improved combustion, produce a saving in the consumption of gas of from 20 to 40 per cent., is proved by the following facts :—

1015



1016



At the King's Cross station, Great Northern Railway, the saving in gas for six months was 1,072,000 cubic feet. A proportionately satisfactory result has also been obtained on the Metropolitan, the Great Western, the North London, the Great Eastern, the London, Chatham, and Dover, and other railways. At the Clock-tower, in the Houses of Parliament, 182,800 cubic feet were saved in one year, equivalent to nearly 50*l.* These burners are made of brass, having the top and bottom parts—in which the orifices are—of steatite, an incorrodible substance, and therefore a great improvement on the ordinary burners, and in eleven different sizes, from 1 to 8, corresponding to the number of cubic feet of gas per hour, while they are warranted not to exceed in consumption in any ordinary working pressure.

The following experiments made with different burners, by three eminent experimenters, upon the gas from three different kinds of coal, show the relative values of these burners for the gases produced from the chief varieties of coal used for the manufacture of gas in this country. (For Table I. see opposite page.)

TABLE II.—*Results of Experiments on Newcastle Cannel Gas by Mr. A. Wright.*

	1 foot per hour	1½ foot per hour	2 feet per hour	2½ feet per hour	3 feet per hour	3½ feet per hour	4 feet per hour	4½ feet per hour
Scotch Fish-tail, No. 1 :—								
One foot=candles . .	4·75	5·02						
„ =grains of sperm	585·0	602·0						
Scotch Fish-tail, No. 2 :—								
One foot=candles . .	5·05	5·77	5·95	5·84	5·53			
„ =grains of sperm	606·0	690·0	714·0	700·0	563·0			
Guise's Argand :—								
One foot=candles . .	..	1·08	1·85	3·12	4·85	4·95	5·77	6·74
„ =grains of sperm	..	129·0	222·0	374·0	582·0	594·0	692·0	808·0

Table III. contains the results of Mr. Barlow's experiments on gas produced from a mixture of Pelton, Felling, and Dean's Primrose, all first-class Newcastle gas-coals, largely used in London.

The burners employed in these experiments were the following:—

1st. A No. 3 fish-tail, or union jet.

2nd. A No. 5 bat's-wing.

3rd. A common argand, with 15 large holes in a ring ·85 inch diameter, and a cylindrical chimney-glass 7 inches high.

4th. A Platow's registered argand, with large holes in a ring, ·9 inch, with inside and outside cone, and cylindrical chimney-glass 8·5 inches high.

5th. A Bizzner patent No. 3 argand, with 28 medium-sized holes in a ring ·75 inch diameter, and cylindrical chimney-glass 8·65 inches high.

6th. A Winfield's registered argand, with 58 medium-sized holes in 2 rings of 29 holes in each, the mean diameter being 1 inch, with deflecting button inside and gauge below, bellied chimney-glass 8 inches high.

7th. A Leslie's patent argand, with 28 jets in a ring ·95 inch diameter, and chimney-glass 3·5 inches high.

8th. A Guise's registered shadowless argand, with 26 large holes in a ring ·85 inch diameter, and deflecting button, cylindrical chimney-glass 6·1 inches high, and glass reflecting cone to outside gallery.

On an average of numerous trials the annexed results were obtained:—

TABLE III.

Burner	Rate of consumption per hour in cubic feet	Value of cubic foot in grains of sperm	Standard candles per cubic foot
No. 2	4·9	289·0	2·4
„ 3	5·5	343·0	2·85
„ 5	5·5	374·0	3·11
„ 6	5·5	337·0	2·8
„ 8	5·5	350·0	2·91
„ 1	5·5	276·0	2·3
„ 2	5·0	290·0	2·41
„ 3	5·5	341·0	2·84
„ 4	5·5	348·0	2·9
„ 5	5·5	380·0	3·16
„ 6	5·5	335·0	2·79
„ 7	4·1	369·0	3·07
„ 8	5·5	364·0	3·03

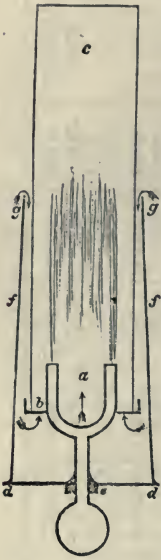
It has been stated that one of the conditions necessary for the production of the maximum illuminating power from a gas flame, is the attainment of the highest possible temperature, and that this condition has been almost entirely neglected in the burners hitherto in use. Dr. Frankland has, however, proved that this condition may be easily secured by employing the waste heat radiating from the gas flame, for heating the air previous to its employment for the combustion of the gas; and that the increased temperature thus obtained has the effect of greatly increasing the illu-

TABLE I.—*Experiments on Wigan Cannel-Gas, at different Rates of Consumption, by Mr. Alfred King.*

	½ foot	1 foot	1½ foot	2 feet	2½ feet	3 feet	3½ feet	4 feet	4½ feet	5 feet	5½ feet
Single Jet:—											
One foot = candles	2·15	2·6									
" = grains of sperm . . .	258·3	311·8									
Lancashire Fish-tail, No. 0:—											
One foot = candles	1·78	2·18	1·76								
" = grains of sperm . . .	214·1	262·5	211·9								
Lancashire Fish-tail, No. 1:—											
One foot = candles	1·76	2·65	2·55	2·53							
" = grains of sperm . . .	211·3	317·9	306·5	303·7							
Lancashire Fish-tail, No. 2:—											
One foot = candles	2·26	3·11	3·5	3·76	3·79	3·66					
" = grains of sperm . . .	271·2	373·3	420·6	455·7	455·7	439·4					
Lancashire Fish-tail, No. 3:—											
One foot = candles	2·26	3·48	3·86	4·07	4·07	4·18	4·1	4·3			
" = grains of sperm . . .	285·5	419·5	484·4	500·5	566·7	539·9	530·1	516·6			
Bat's-wing:—											
One foot = candles	1·83	3·01	3·73	4·1	4·12	4·31	4·3	4·46	4·32	4·4	
" = grains of sperm . . .	220·0	361·6	448·3	492·3	494·8	578·1	516·2	535·1	519·0	528·9	
Sixteen-hole Argand, small holes in ring 0·82 inch in diameter:—											
One foot = candles	...	0·323	1·02	1·9	2·6	3·27	3·72	3·84	3·96		
" = grains of sperm . . .	...	38·76	123·3	228·7	313·0	393·3	446·4	461·7	479·2		
Winfield's 28-hole Argand, registered July 25th, 1848, with slightly conical chimney:—											
One foot = candles	...	0·344	1·16	2·26	2·71	3·5	3·72	3·84	4·0		
" = grains of sperm . . .	...	41·27	139·1	271·3	325·6	420·5	446·4	461·7	481·0		
Winfield's 58-hole Lucent Argand, registered March 20th, 1845:—											
One foot = candles	...	...	0·318	0·75	1·09	1·57	2·09	2·59	3·07	3·82	4·5
" = grains of sperm . . .	...	...	38·2	87·5	131·8	188·4	251·1	311·3	368·9	458·8	540·0

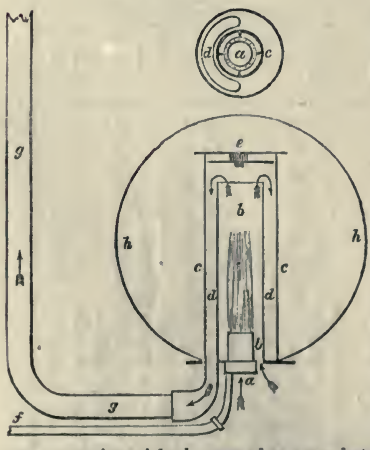
minating power of a given volume of the gas. *Fig.* 1017 shows the burner contrived by Dr. Frankland for this purpose. *a* is a common argand burner, or better, a Leslie's argand, furnished with the usual gallery and glass chimney *b*, *c*; the latter must be 4 to 6 inches longer than usual. *d d* is a circular disc of plate glass, perforated in the centre, and fixed upon the stem of the burner, about 1½ inch below the gallery, by the collar and screw *e*. *f f* is a second glass chimney, somewhat conical, ground at its lower edge so as to rest air-tight, or nearly so, upon the plate *d d*; and of such a diameter as to leave an annular space ¼ inch broad between the two cylinders at *g g*. The cylinder *f* should be of such a length as to reach the level of the apex of the flame. The action of this burner will now be sufficiently evident. When lighted, atmospheric air can only reach the flame by passing downwards through the space between the cylinders *f* and *c*; it thus comes into contact with the intensely-heated walls of *c*, and has its temperature raised to about 500° or 600° before it reaches the gas flame. The passage of this heated air over the upper portion of the argand burner also raises the temperature of the gas considerably before it issues from the burner. Thus the gases taking part in the combustion are highly heated before inflammation, and the temperature of the flame is consequently elevated in a corresponding degree. Experiments with this burner prove a great increase in light, due chiefly to the higher temperature of the radiating particles of carbon; but, no doubt, partly also to the heat being sufficiently high to cause a deposition of carbon from the light carburetted hydrogen; thus rendering this latter gas a contributor to the total illuminating effect, whilst, when burnt in the ordinary manner, it merely performs the functions of a diluent. The following are the results of Dr. Frankland's experiments with this burner:—

1017



	Rate of Consumption per Hour.	Light in Sperm Candles, each burning 120 grs. per Hour.
I. Argand burner without external cylinder.	3·3 cubic feet	13·0 candles.
	3·7 "	15·5 "
	4·2 "	17·0 "
II. Same burner with external cylinder.	2·2 "	13·0 "
	2·6 "	15·5 "
	2·7 "	16·7 "
	3·0 "	19·7 "
	3·3 "	21·7 "

1018



These results show that the new burner, when compared with the ordinary argand, saves on an average 49 per cent. of gas, when yielding an equal amount of light; and also that it produces a gain of 67 per cent. in light for equal consumptions.

Faraday's ventilating Burner.—This admirable contrivance, the invention of the late Prof. Faraday, completely removes all the products of combustion, and prevents their admixture with the atmosphere of the apartments in which the gas is consumed. The burner consists of an ordinary argand, *fig.* 1018, *a*, fitted with the usual gallery and chimney, *b b*. A second wider and taller cylinder, *c c*, rests upon the outer edge of the gallery which closes at bottom the annular space, *d d*, between the two glass cylinders. *c c*, is closed at top with a double mica cap, *e*. *f* is the tube conveying the gas to the argand; *g g* is a wider tube 1½ inch in diameter, communicating at one extremity with the annular space between the two glass cylinders, and at the other, either with a flue or the open air. The products of combustion from the gas flame are thus compelled to take the direction indicated by the arrows, and are therefore prevented from contaminating the air of the apartment in which the gas is consumed, *h* is a ground glass globe enclosing the whole arrangement, and having only an opening below for the admission of air to the flame. In order to dispense with the descending tube, to which there are some objections, Mr. Rutter has constructed a ventilating burner in which the ordinary glass chimney is made to terminate in a metal tube, through which the products of combustion are conveyed away. Mr. Dixon has also constructed a modification of Faraday's burner, the peculiarity of which consists in the use of a separate tube bringing air to the flame from the same place, outside the building, to which the products of the burner are conveyed; this contrivance is said to prevent downward draughts through the escape-pipe, and a consequently unsteady flame.

ON THE ESTIMATION OF THE VALUE OF ILLUMINATING GAS.

There are two methods in use for estimating the illuminating value of gas, viz.—

1st. The photometric method.

2nd. Chemical analysis.

The photometric method consists in comparing the intensity of the light emitted by a gas flame, consuming a known volume of gas, with that yielded by some other source of light taken as a standard. The standard employed is usually a spermaceti candle, burning at the rate of 120 grains of sperm per hour. A spermaceti candle of six to the pound usually burns at a somewhat quicker rate than this; but in all cases the consumption of sperm by the candle during the course of each experiment ought to be carefully ascertained by weighing, and the results obtained corrected to the 120-grain standard. Thus, suppose that during an experiment the consumption of sperm was at the rate of 130 grains per hour, and that the gas flame being tested gave a light equal to 20 such candles, and it is required to know the light of this flame in standard 120 grain candles, then—

$$120 : 130 :: 20 :: 21{\cdot}7,$$

or, 20 candles burning at the rate of 130 grains per hour, are equal to 21·7 candles burning at the rate of 120 grains per hour.

There are two methods of estimating the comparative intensity of the light of the gas and candle flames, both founded upon the optical law that the intensity of light diminishes in the inverse ratio of the square of the distance from its source. Thus, if a sheet of writing paper be held at the distance of one foot from a candle, so that its surface is perpendicular to a line joining the centre of the sheet and the flame, it will be illuminated with a light four times as intense as that which would fall upon a sheet of paper held in the same position at a distance of 2 feet; whilst at a distance of 3 feet the light would have but $\frac{1}{9}$th of the intensity which it possessed at 1 foot. One method of estimating the comparative intensity of the gas and candle flames, consists in placing the two lights and an opaque rod nearly in a straight line, and in such a way as to cause each light to project a shadow of the rod upon a white screen placed at a distance of about 1 foot behind the rod. The two shadows must now be rendered of equal intensity by moving the candle either nearer to the rod or further from it. The shadows will be of equal intensity when the light falling upon the white screen from both sources is equal; and if now the respective distances of the candle and gas flame from the screen be measured, then the square of the distance of the gas flame divided by the square of the distance of the candle will give the illuminating power of the gas in candles. Thus, if equally intense shadows fall upon the screen when the candle is 3 feet distant and the gas flame 12 feet, the illuminating power of the gas flame will be—

$$\frac{12^2}{3^2} = \frac{144}{9} = 16 \text{ candles.}$$

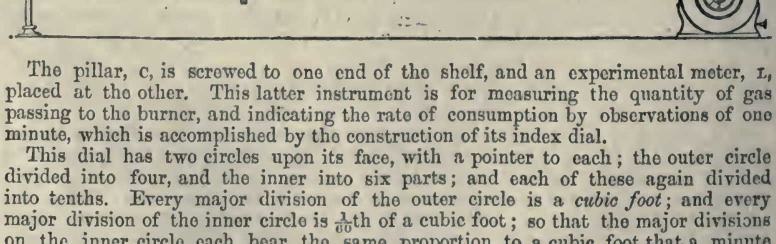
This method of estimating the illuminating power of a gas flame, known as the *shadow test*, is very easy of execution, and would appear from the description to be capable of yielding results of considerable accuracy; nevertheless, an unexpected difficulty arises from the great difference in colour of the two shadows; that of the gas being of a bluish brown, whilst that of the candle is of a yellow-brown tinge. This difference of tint renders it exceedingly difficult for the observer to ascertain when the two shadows possess equal intensity; and, consequently, the limits of error attending determinations by this test are probably, even in the hands of an experienced operator, never less than 5 per cent., and frequently even as much as 10 per cent. The shadow test has, therefore, been all but superseded by the *Bunsen's Photometer*, which consists of a graduated metal or wooden rod about 8 or 10 feet long, and sufficiently strong to be inflexible. At one extremity of this rod is placed the gas flame, and at the opposite end the standard candle. A stand which slides easily along the rod supports a small circular paper screen, at the same height as the two flames, and at right angles to the rod. This screen consists of colourless, moderately thin writing paper, saturated with a solution of spermaceti in spirit of turpentine, except a spot in the centre, about the size of a shilling, which is to be left untouched by the solution. The spirit of turpentine soon evaporates, and the paper is now ready for use. Being more transparent in the portion which has been saturated with the spermaceti solution, it becomes a delicate test of equality of light when placed between two luminous bodies; for if the light of one of the bodies impinge with greater intensity upon one side of the screen than the other light does upon the opposite side, the difference of the transparency of the two portions of the screen will become distinctly visible; the spot in the centre appearing comparatively opaque on the less illuminated side. When the screen is brought into such a position between the two sources of light as to render the central point nearly or quite invisible on both sides, the illuminating effect of both lights at that point may be regarded as equal; and all that now remains to be done is to measure the respective distances of the candle and gas from the screen, and divide the square of the distance of the gas by the square of that of the candle; the quotient expresses the illuminating power of the gas in candles. One of the most convenient forms of this instrument has been contrived by Mr. Wright, and may be had at 55 Millbank Street, Westminster. It consists of the following parts:—

1. A wooden rod, exactly 100 inches long (*fig.* 1019) from the centres of sockets at its ends, A B.
2. An upright pillar, C.
3. A candle holder, D.
4. A mahogany slide, E, having a metal socket, F, on its top, to hold the circular frame G, and a small pointer in its front.
5. A circular metal frame, G, made to hold a prepared paper.
6. A blackened conical screen, H, diminishing in size from its centre, where it opens with a hinge towards its ends, with two holes in front.

The long rod is graduated in accordance with the laws of distribution of light, from its centre each way into squares of distances in divisions numbered respectively 1, 2, 3, &c., to 36; to measure smaller differences than those amounting to 1 candle in value, each major division to 9 is subdivided into 10 parts, each, of course, representing $\frac{1}{10}$th of an increment. From thence to 20, the subdivisions indicate $\frac{1}{2}$. Beyond that point no subdivisions are made, because the major divisions become so small that, practically, such divisions would be useless.

The manner of fitting the apparatus together will be understood by reference to the annexed sketch.

1019



The pillar, C, is screwed to one end of the shelf, and an experimental meter, L, placed at the other. This latter instrument is for measuring the quantity of gas passing to the burner, and indicating the rate of consumption by observations of one minute, which is accomplished by the construction of its index dial.

This dial has two circles upon its face, with a pointer to each; the outer circle divided into four, and the inner into six parts; and each of these again divided into tenths. Every major division of the outer circle is a *cubic foot*; and every major division of the inner circle is $\frac{1}{60}$th of a cubic foot; so that the major divisions on the inner circle each bear the same proportion to a cubic foot that a minute does to an hour. If, therefore, the number of these divisions and tenths of divisions, which the hand passes over in a minute, is observed, it will evidently only be necessary to read them off as feet and tenths of a foot to obtain the hourly rate of consumption.

Thus, suppose the pointer passes from the upper figure 6 to the fifth minor division beyond the figure 4, it would read off as $4\frac{5}{10}$ths and $\frac{5}{600}$ths of a cubic foot in $\frac{1}{60}$th of an hour. Multiplying these quantities by 60, and we obtain the quantity of gas consumed in the hour.

A pillar, J, having a pressure gauge, and two cocks at K, one with a micrometer movement, screws on to the top of the meter, and is intended for receiving burners when experimenting. The graduated rod is supported in an exactly horizontal position by the pillars C and J, and screwed together by its binding screws.

The candle socket D is screwed on to the top of C, and the mahogany slide C placed on the rod, with its pointer to the scale, carrying the frame G, containing a prepared paper, and covered by the cone H.

The prepared paper is made by coating white blotting-paper with sperm, so as to render it semi-transparent, leaving a small spot in the centre plain, and therefore opaque. See G in the figure.

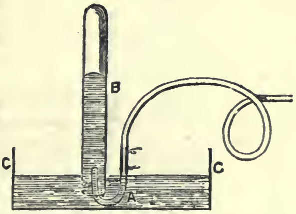
All that now remains to render the apparatus ready for experimenting, is to put a piece of candle into the socket, and consume the gas through a proper burner over the meter, taking care that the *centres* of the *candle-flame, paper, and gas flame*, are in one *horizontal line*, and adopting the precautions previously laid down.

Unfortunately the determination of the exact point of equality of the two lights, is by no means easy, even after considerable practice; and the maximum amount of error to which even the practised operator is liable in such estimations of illuminating power, cannot be set down at less than 5 per cent. It is scarcely necessary to add, that all photometric experiments must be conducted in an apartment from which all light from other sources is excluded, and the walls of which are rendered as absorbent as possible, by being coated with a mixture of lampblack and size, or by being hung with black lustreless calico.

Analytical method of estimating the value of illuminating gas.—Frankland has shown that the resources of chemical analysis place in our hands a method for the determination of the illuminating value of gas considerably more accurate than the photometric process just described, although the execution of the necessary operations requires more skill, and is usually much more troublesome. As the determination of the illuminating power of a sample of gas by the analytical method necessitates most of the operations required for the performance of a complete analysis of coal-gas, we shall here include in our description of the former process the additional details necessary for the latter.

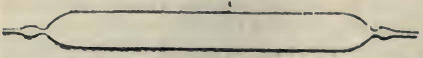
1. *Collection of the sample of gas.*—In all analytical operations upon gases, it is of the utmost importance, that the latter should be preserved from all admixture with atmospheric air. This can only be done, either by collecting the samples of gas over mercury, or by enclosing them in hermetically sealed tubes. When the sample of gas is collected at the place where the analysis is to be made, the former plan is usually most convenient, but when the sample has to be obtained from a locality at some distance from the operator's laboratory, the latter plan is usually adopted. To collect a sample of gas over mercury, attach one end of a piece of vulcanised India-rubber tube to the gas pipe, and insert into the other extremity a piece of glass tube bent, as shown at A, *fig.* 1020, allow the gas to stream through these tubes for two or three minutes, and then suddenly plunge the open extremity of the glass tube beneath the surface of the mercury in the trough C. Then fill the small gas jar B completely with mercury, taking care to remove all air-bubbles from its sides by means of a piece of iron wire, and closing its mouth firmly with the thumb, invert it in the trough C, introducing the end of the bent tube A into its open extremity, in such a way as to bring the mouth of A above the level of the surface of the mercury in C. The gas will then flow into B, until the level of the mercury in B is somewhat lower than that of the metal in the trough. If now, the tube A being removed, a small cup be filled with mercury and brought beneath B, the latter may be removed from the trough, and will be thus preserved from any appreciable atmospheric intermixture for several months.

1020

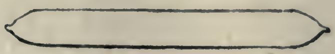


To collect samples of gas in hermetically-sealed tubes, proceed as follows: take a piece of glass tube about $\frac{7}{8}$ths of an inch internal diameter, and 1 foot long; draw it out at both ends before the blowpipe, as shown in *fig.* 1021; attach one extremity, A *fig.* 1022, to a vulcanised India-rubber tube, communicating with a source of the gas, and the opposite extremity B, to a similar flexible tube about three feet long, and which is allowed to hang down perpendicularly from B. After the gas has streamed through this system of tubes for about three minutes, so as to ensure the complete expulsion of atmospheric air, the flame of a mouth blowpipe is directed against the narrow portion of the glass tube, at *c*, so as to fuse it off. With as much expedition as possible, the same operation is performed at the opposite extremity of the tube *d*, which is thus hermetically sealed, and assumes the appearance shown in *fig.* 1023.

1021



1023



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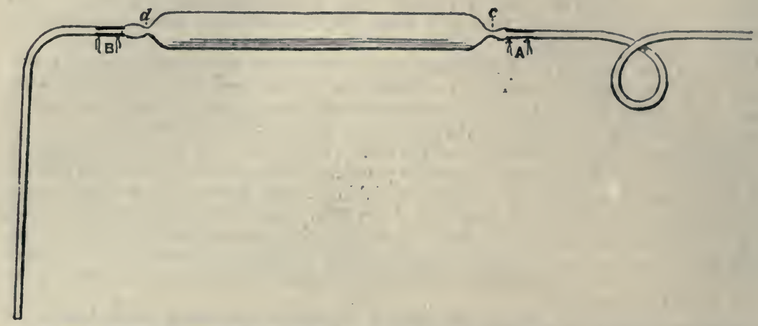
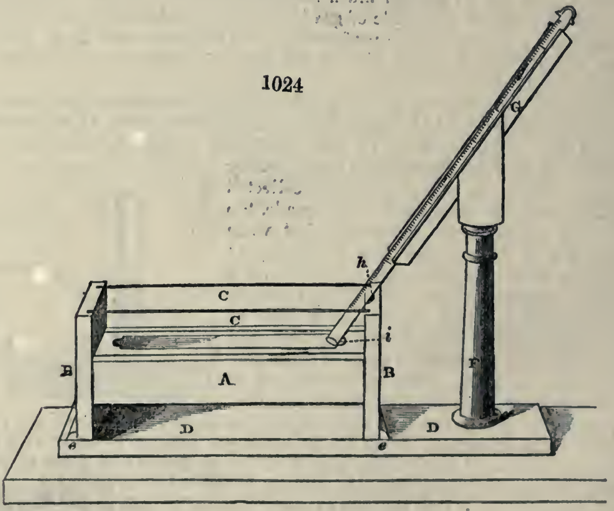


The gas having been thus carefully collected, the necessary analytical operations must be conducted over mercury in a small wooden pneumatic trough, with plate-glass sides, the construction of which is shown in *fig.* 1024. A is a piece of hard well-seasoned wood, 12 inches long and 3 inches broad, hollowed out, as shown in the figure; the cavity is 8¾ inches long, 1¾ inch broad, and 1¾ inch deep. The bottom of this cavity is rounded, with the exception of a portion at one end, where a surface, 1 inch broad, and 1½ inch long, is made perfectly flat, a piece of vulcanised India-rubber, $\frac{1}{10}$th of an inch thick, being firmly cemented upon it. Two end pieces, B B, ¾ths of an inch thick, 3¼ inches broad, and 5 inches high, are fixed to the block A; these serve below as supports for A, and above as the ends of a wider trough, which is formed by the pieces of plate glass C C, cemented into A and B B. The glass plates C C, are 10½ inches long, and 1⅞ inch high; they are slightly inclined, so that their lower edges are about 2⅜ inches, and their upper edges 2⅞ inches apart. This trough stands upon a wooden slab D D, upon which it is held in its place by two strips of wood *e e*. An upright column F, which is screwed into D, carries the inclined stand G, which serves to support the eudiometer during the transference of gas. *h* is a circular inclined slot in B, which allows of the convenient inclination of the eudio-

1024



meter in the stand G. *i* is an indentation in which the lower end of the eudiometer rests, so as to prevent its falling into the deeper portion of the trough A. When in use the trough is filled with quicksilver to within an inch of the upper edge of the glass plates C C, about 30 to 35 lbs. of the metal being necessary for this purpose.

The eudiometers or measuring-tubes, should be accurately calibrated and graduated into cubic inches and tenths of a cubic inch, the tenths being subdivided by the eye into hundredths, when the volume of gas is read off; this latter division is readily attained by a little practice. At each determination of volume, it is necessary that the gas should either be perfectly dry, or quite saturated with moisture. The first condition is attained by placing in the gas, for half an hour, a small ball of fused chloride of calcium, attached to a platinum wire[1]; the second condition, by introducing a minute drop of water, into the head of the eudiometer, before filling it with quicksilver. The determinations of volume must either be made when the mercury is at the same level inside and outside the eudiometer, or, as is more frequently done, the difference of level must be accurately measured and allowed for in the subsequent reduction to a standard pressure. The height of the barometer and the temperature of the surrounding atmosphere must also be observed each time the volume of gas is measured, and proper corrections made for pressure, temperature, and also the tension of aqueous vapour, if the gas be moist. As tables and rules for these corrections are given in most treatises on chemistry, they need not be repeated here.

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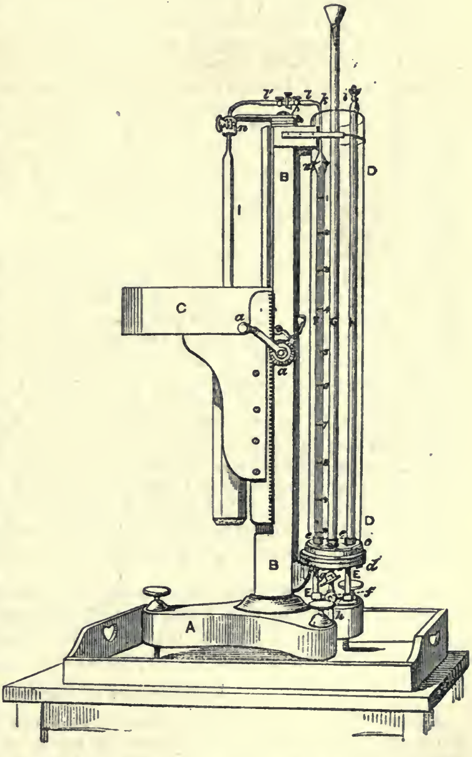

These troublesome corrections and calculations can be avoided by employing an instrument invented some years ago by Dr. Frankland and Mr. W. J. Ward, and which not only does away with the necessity for a room devoted exclusively to gaseous manipulations, but greatly shortens and simplifies the whole operation. This instrument, which is represented by *fig.* 1025, consists of the tripod A, furnished with the usual leveling screws, and carrying the vertical pillar B B, to which is attached, on the one side, the moveable mercury trough C, with its rack and pinion *a a*, and on the other, the glass cylinder D D, with its contents. This cylinder is 36 inches long, and 4 inches internal diameter; its lower extremity is firmly cemented into an iron collar *c*, the under surface of which can be screwed perfectly watertight upon the bracket plate *d* by the interposition of a vulcanised caoutchouc ring. The circular iron plate *d* is perforated with three apertures, into which the caps *e*, *e*, *e*, are screwed, and which communicate below the plate with the T-piece E E. This latter is furnished with a double-way cock *f*, and a single-way cock *g*, by means of which the tubes cemented into the sockets *e*, *e*, *e*, can be made to communicate with each other, or with the exit pipe *h* at pleasure.

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[1] These balls, which should be of the size of a large pea, are required constantly in operations upon gases; they are readily prepared, when the substances of which they are formed is fusible by heat, as chloride of calcium or caustic potash, by melting these materials in a crucible and then pouring them into a small bullet-mould, in which the curved end of a platinum wire has been placed; when quite cold the ball attached to the wire is readily removed from the mould. Coke bullets are made by filling the mould containing the platinum wire with a mixture of two parts of coke and one of coal, both finely powdered, and then exposing the mould and its contents to a heat gradually increased to redness, for a quarter of an hour.

F, G, H, are three glass tubes, which are firmly cemented into the caps *e*, *e*, *e*. F and H, are each from 15 to 20 millimeters internal diameter, and are selected of as nearly the same bore as possible, to avoid a difference of capillary action. The tube G is somewhat wider, and may be continued to any convenient height above the cylinder. H is accurately graduated with a millimeter scale, and is furnished at top with a small funnel *i*, into the neck of which a glass stopper, about 2 millimeters in diameter, is carefully ground. The tube F terminates at its upper extremity in the capillary tube *k*, which is carefully cemented into the small steel stopcock *l*. F has also fused into it at *m*, two platinum wires, for the passage of the electric spark. After this tube has been firmly cemented into the cap *e*, its internal volume is accurately divided into 10 perfectly equal parts, which is effected without difficulty by first filling it with mercury from the supply-tube G, up to its junction with the capillary attachment, and then allowing the mercury to run off through the nozzle *h* until the highest point of its convex surface stands at the division 10, previously made so as exactly to coincide with the zero of the millimeter scale on H; the weight of the mercury thus run off is carefully determined, and the tube is again filled as before, and divided into 10 equal parts, by allowing the mercury to run off in successive tenths of the entire weight, and marking the height of the convexity after each abstraction of metal. By using the proper precautions with regard to temperature, &c., an exceedingly accurate calibration can, in this way, be accomplished.

The absorption tube I is supported by the clamp *n*, and connected with the capillary tube *k*, by the stopcock and junction-piece *l l′ p*, as shown in the figure. When the instrument is thus far complete, it is requisite to ascertain the height of each of the nine upper divisions on the tube, above the lowest or tenth division. This is very accurately effected in a few minutes by carefully levelling the instrument, filling the tube G with mercury, opening the cock *l*, and the stoppered funnel *i*, and placing the cock *f* in such a position as to cause the tubes F H to communicate with the supply-tube G. On now slightly turning the cock *g*, the mercury will slowly rise in each of the tubes F and H; when its convex surface exactly coincides with the ninth division on F, the influx of metal is stopped, and its height in H accurately observed; as the tenth division on F corresponds with the zero of the scale upon H, it is obvious that the number thus read off is the height of the ninth division above the zero point. A similar observation for each of the other divisions upon F completes the instrument.[1]

Before using the apparatus, the large cylinder D D is filled with water, and the internal walls of the tubes F and H are, once for all, moistened with distilled water, by the introduction of a few drops into each, through the stopcock *l*, and the stoppered funnel *i*. The three tubes being then placed in communication with each other, mercury is poured into G until it rises into the cup *i*, the stopper of which is then firmly closed. When the mercury begins to flow from *l*, that cock is also closed. The tubes F and H are now apparently filled with mercury, but a minute and imperceptible film of air still exists between the metal and glass; this is effectually got rid of by connecting F and H with the exit tube *h*, and allowing the mercury to flow out until a vacuum of several inches in length has been produced in both tubes; on allowing the instrument to remain thus for an hour, the whole of the film of air above mentioned will diffuse itself into the vacuum, to be filled up from the supply-tube G. These bubbles are of course easily expelled on momentarily opening the cock *l* and the stopper *i*, whilst G is full of mercury. The absorption-tube I being then filled with quicksilver, and attached to *l* by the screw-clamp, the instrument is ready for use.

In illustration of the manner of using the apparatus, a complete description of an analysis of coal-gas by this instrument will be given below.

For the analysis of purified coal-gas by means of the mercury trough and eudiometer, the following operations are necessary:—

I. *Estimation of Carbonic Acid.*

A few cubic inches of the gas are introduced into a short eudiometer, moistened as above described; the volume is accurately noted, with the proper corrections, and a bullet of caustic potash is then passed up through the mercury into the gas; it is allowed to remain for at least one hour; the volume of the gas being again ascertained and subtracted from the first volume gives the amount of carbonic acid which has been absorbed by the potash.

II. *Estimation of Oxygen.*

This gas can be very accurately estimated by Liebig's method, which depends upon the rapid absorption of oxygen by an alkaline solution of pyrogallic acid. To apply

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[1] This instrument may be obtained from Mr. Oertling, philosophical instrument maker.

this solution, a small test tube is filled with quicksilver, and inverted in the mercury trough; a few drops of a saturated solution of pyrogallic acid in water are thrown up into this tube by means of a pipette, and then a similar quantity of a strong solution of potash; a coke bullet attached to a platinum wire is introduced into this liquid, and allowed to saturate itself; it is then withdrawn, and conveyed carefully below the surface of the mercury into the eudiometer containing the residual gas of experiment No. 1; every trace of oxygen will be absorbed in a few minutes, when the bullet must be removed, and the volume being again measured, the diminution from the last reading will represent the amount of oxygen originally present in the gas. It is essential that the coke bullet, after saturation with the alkaline solution of pyrogallic acid, should not come in contact with the air before its introduction into the gas.

III. *Estimation of the Luminiferous Constituents.*

Various methods have been employed for the estimation of the so-called olefiant gas (luminiferous constituents) contained in coal-gas. The one which has been most generally employed, depends upon the property which is possessed by olefiant gas, and most hydrocarbons, of combining with chlorine, and condensing to an oily liquid: hydrogen and light carburetted hydrogen are both acted upon in a similar manner when a ray even of diffused light is allowed to have access to the mixture; but the condensation of the olefiant gas and hydrocarbons takes place in perfect darkness, and advantage is therefore taken of this circumstance to observe the amount of condensation which takes place when the mixture is excluded from light. The volume, which disappears during this action of the chlorine, is regarded as indicating the quantity of olefiant gas present in the mixture. There are many sources of error inseparably connected with this method of operating, which render the results unworthy of the slightest confidence; the same remark applies also to the employment of bromine in the place of chlorine; in addition to the circumstance that these determinations must be made over water, which allows a constant diffusion of atmospheric air into the gas, and *vice versâ*, there is also formed in each case a volatile liquid, the tension of the vapour of which increases the volume of the residual gas; and this increase admits of neither calculation nor determination. The only material by which the estimation of the luminiferous constituents can be accurately effected is anhydrous sulphuric acid, which immediately condenses the luminiferous constituents of coal-gas, but has no action upon the other ingredients, even when exposed to sunlight. The estimation is conducted as follows:—A coke bullet, prepared as described above, and attached to a platinum wire, being rendered thoroughly dry by slightly heating it for a few minutes, is quickly immersed in a saturated solution of anhydrous sulphuric acid, in Nordhausen sulphuric acid, and allowed to remain in the liquid for one minute; it is then withdrawn, leaving as little superfluous acid adhering to it as possible, quickly plunged beneath the quicksilver in the trough, and introduced into the same portion of dry gas, from which the carbonic acid and oxygen have been withdrawn by experiments I. and II.; here it is allowed to remain for about two hours, in order to ensure the complete absorption of every trace of hydrocarbons. The residual volume of gas cannot, however, yet be determined, owing to the presence of some sulphurous acid derived from the decomposition of a portion of the sulphuric acid: this is absorbed in a few minutes by the introduction of a moist bullet of peroxide of manganese, which is readily made by converting powdered peroxide of manganese into a stiff paste with water, rolling it into the shape of a small bullet, and then inserting a bent platinum wire, in such a manner as to prevent its being readily drawn out; the ball should then be put in a warm place, and allowed slowly to dry, it will then become hard, and possess considerable cohesion, even after being moistened with a drop of water, previous to its introduction into the gas. After half an hour, the bullet of peroxide of manganese may be withdrawn, and replaced by one of caustic potash, to remove the watery vapour introduced with the previous one; at the end of another half-hour, this bullet may be removed, and the volume of gas at once read off. The difference between this and the previous reading, gives the volume of the luminiferous constituents contained in the gas. This method is very accurate; in two analyses of the same gas, the percentage of luminiferous constituents seldom varies more than 0·1 or 0·2 per cent.

IV. *Estimation of the Non-Luminiferous Constituents.*

These are light carburetted hydrogen, hydrogen, carbonic oxide, and nitrogen. The percentages of these gases are ascertained in a graduated eudiometer, about 2 feet in length, and $\frac{3}{4}$ths of an inch internal diameter; the thickness of the glass being not more than $\frac{1}{10}$th of an inch. This eudiometer is furnished as its closed end with two platinum wires, fused into the glass, for the transmission of the electric spark. A drop of water, about the size of a pin's head, is introduced into the upper part of the eudiometer before it is filled with mercury and inverted into the mercurial trough: this small quantity of water serves to saturate with aqueous vapour the gases subsequently introduced. About a cubic inch of the residual gas from the last determination is passed into the eudiometer, and its volume accurately read off; about 4 cubic inches of pure oxygen are now introduced, and the volume (moist) again determined. The oxygen is best prepared at the moment when it is wanted, by heating over a spirit or gas flame a little chlorate of potash, in a very small glass retort, allowing, of course, sufficient time for every trace of atmospheric air to be expelled from the retort before passing the gas into the eudiometer. The open end of the eudiometer must now be pressed firmly upon the thick piece of India-rubber placed at the bottom of the trough, and an electric spark passed through the mixture; if the above proportions have been observed, the explosion will be but slight, which is essential if nitrogen be present in the gas, as this element will otherwise be partially converted into nitric acid, and thus vitiate the results. By using a large excess of oxygen, all danger of the bursting of the eudiometer by the force of the explosion is also avoided. The volume after explosion being again determined, a bullet of caustic potash is introduced into the gas, and allowed to remain so long as any diminution of volume takes place; this bullet absorbs the carbonic acid that has been produced by the combustion of the light carburetted hydrogen and carbonic oxide, and also renders the residual gas perfectly dry: the volume read off after this absorption, when deducted from the previous reading, gives the volume of carbonic acid generated by the combustion of the gas.

The residual gas now contains only nitrogen and the excess of oxygen employed. The former is determined by first ascertaining the amount of oxygen present, and then deducting that number from the volume of both gases; for this purpose a quantity of dry hydrogen, at least three times as great as the residual gas, is introduced, and the volume of the mixture determined; the explosion is then made as before, and the volume (moist) again recorded: one-third of the contraction caused by this explosion represents the volume of oxygen, and this deducted from the volume of residual gas, after absorption of carbonic acid, gives the amount of nitrogen.

The behaviour of the other three non-luminous gases on explosion with oxygen enables us readily to find their respective amounts by three simple equations, founded upon the quantity of oxygen consumed, and the amount of carbonic acid generated by the three gases in question. Hydrogen consumes half its own volume of oxygen, and generates no carbonic acid; light carburetted hydrogen consumes twice its volume of oxygen, and generates its own volume of carbonic acid; whilst carbonic oxide consumes half its volume of oxygen, and generates its own volume of carbonic acid. If, therefore, we represent the volume of the mixed gases by A, the amount of oxygen consumed by B, and the quantity of carbonic acid generated by C, and further, the volumes of hydrogen, light carburetted hydrogen, and carbonic oxide respectively by x, y, and z, we have the following equations:—

$$x+y+z=A$$
$$\tfrac{1}{2}x+2y+\tfrac{1}{2}z=B$$
$$y+z=C.$$

From which the following values for x, y, and z, are derived:—

$$x=A-C$$
$$y=\frac{2B-A}{3}$$
$$z=C-\frac{2B-A}{3}.$$

V.—*Estimation of the Value of the Luminiferous Constituents.*

We have now given methods for ascertaining the respective quantities of all the ingredients contained in any specimen of coal-gas, but the results of the above analytical operations afford us no clue to its illuminating power. They give us, it is true, the amount of illuminating hydrocarbons contained in a given volume of the gas, but it will be evident, from what has already been said respecting the luminiferous powers of these hydrocarbons, that the greater the amount of carbon contained in a given volume, the greater will be the quantity of light produced on their combustion; and therefore, as the number of volumes of carbon-vapour contained in one volume of the mixed constituents, condensible by anhydrous sulphuric acid, has been found to vary from 2·54 to 4·36 volumes, it is clear that this amount of carbon-vapour must be accurately determined for each specimen of gas, if we wish to ascertain the value of that gas as an illuminating agent. Fortunately this is easily effected; for if we ascertain the amount of carbonic acid generated by 100 volumes of the gas in its original condition, knowing from the preceding analytical processes the percentage of illuminating hydrocarbons, and also the amount of carbonic acid generated by the non-luminiferous gases, we have all the data for calculating the illuminating value of the gas. For this purpose a known volume of the original gas (about one cubic inch) is introduced into the explosion eudiometer, and mixed with about five times its volume of oxygen; the electric spark is passed, and the volume of carbonic acid generated by the explosion ascertained as above directed. If we now designate the percentage of hydrocarbons absorbed by anhydrous sulphuric acid by A, the volume of carbonic acid generated by 100 volumes of the original gas by B, the carbonic acid formed by the combustion of the non-luminous constituents remaining after the absorption of hydrocarbons from the above quantity of original gas by C, and the volume of carbonic acid generated by the combustion of the luminiferous compounds (hydrocarbons) by x, we have the following equation:—

$$x = B - C,$$

and therefore, the amount of carbonic acid generated by one volume of the hydrocarbons is represented by

$$\frac{B-C}{A}.$$

But as one volume of carbon-vapour generates one volume of carbonic acid, this formula also expresses the quantity of carbon-vapour in one volume of the illuminating constituents. For the purpose of comparison, however, it is more convenient to represent the value of these hydrocarbons in their equivalent volume of olefiant gas, one volume of which contains two volumes of carbon-vapour; for this purpose the last expression need only be changed to

$$\frac{B-C}{2A}.$$

Thus, if a sample of gas contain 10 per cent. of hydrocarbons, of which one volume contains three volumes of carbon-vapour, the quantity of olefiant gas to which this 10 per cent. is equivalent, will be 15.

By the application of this method we obtain an exact chemical standard of comparison for the illuminating value of all descriptions of gas; and by a comparison of the arbitrary numbers thus obtained, with the practical results yielded by the same gases when tested by the photometer, much valuable and useful information is gained.

Analysis of Coal-gas with Frankland and Ward's apparatus.—Introduce a few cubic inches of the gas into the tube I, *fig.* 1025, and transfer it for measurement into F, by opening the cocks *l l′* and placing the tube F in communication with the exit pipe *h*, the transference being assisted, if needful, by elevating the trough C. When the gas, followed by a few drops of mercury, has passed completely into F, the cock *l* is shut, and *f* turned, so as to connect F and H with *h*. Mercury is allowed to flow out until a vacuum of two or three inches in length is formed in H, and the metal in F is just below one of the divisions; the cock *f* is then reversed, and mercury very gradually admitted from G, until the highest point in F exactly corresponds with one of the divisions upon that tube; we will assume it to be the sixth division. This adjustment of mercury and the subsequent readings can be very accurately made by means of a small horizontal telescope placed at a distance of about six feet from the cylinder, and sliding upon a vertical rod. The height of the mercury in H must now be accurately determined, and if from the number thus read off, the height of the sixth division above the zero of the scale on H be deducted, the remainder will express the true volume of the gas. As the temperature is maintained constant during the entire analysis, no correction on that score has to be made; the atmospheric pressure being altogether excluded from exerting any influence upon the volumes or pressures, no barometrical observations are requisite; and as the tension of aqueous vapour in F is exactly balanced by that in H, the instrument is in this respect also self-correcting. Two or three drops of a strong solution of caustic potash are now introduced into I by means of a bent pipette, and mercury being allowed to flow into F and H by opening the cock *g*, the gas returns into I through *l l′*, and there coming into contact with an extensive surface of caustic-potash solution, any carbonic acid that may be present will be absorbed in two or three minutes, and the gas being passed back again into H for re-measurement, taking care to shut *l* before the caustic-potash solution reaches *l'*, the observed diminution in volume gives the amount of carbonic acid present.

The amount of oxygen is determined in like manner by passing up into I a few drops of a saturated solution of pyrogallic acid, which forms with the potash already present pyrogallate of potash. The gas being then brought back into I, oxygen, if present, will be absorbed in a few minutes. Its amount is of course ascertained by re-measuring the gas in F.

The next step in the operation consists in estimating the amount of olefiant gas and illuminating hydrocarbons. For this purpose, whilst the gas, thus deprived of oxygen and carbonic acid, is contained in F, the tube I must be removed, thoroughly cleansed and dried, and being filled with mercury, must be again attached to *l*. The gas must now be transferred from F to I, and a coke bullet, prepared as above described, being passed up into I, must be allowed to remain in the gas for one hour. After its removal, a few drops of a strong solution of bichromate of potash must be admitted into I in order to absorb the sulphurous acid and vapours of anhydrous sulphuric acid resulting from the previous operation. The gas is now ready for measurement; it is therefore passed into F, and its volume determined; the diminution which has occurred since the last reading represents the volume of olefiant gas and illuminating hydrocarbons that were present in the gas.

It now only remains to determine the respective amounts of light carburetted hydrogen, carbonic oxide, hydrogen, and nitrogen present in the residual gas. This is effected as follows:—As much of the residual gas as will occupy about 1½ inch of its length at atmospheric pressure is retained in F, and its volume accurately determined; the remainder is passed into J, and the latter tube removed, cleansed, filled with mercury, and re-attached. A quantity of oxygen equal to about three and a half times that of the combustible gas is now added to the latter, and the volume again determined; then the mixture having been expanded to about the sixth division, an electric spark is passed through it by means of the wires at *m*. The contraction resulting from the explosion having been noted, two or three drops of caustic-potash solution are passed into J, and the gas is then transferred into the same tube. In two minutes the carbonic acid generated by the explosion is perfectly absorbed, and its volume is determined by a fresh measurement of the residual gas. The latter must now be exploded with three times its volume of hydrogen, and the contraction on explosion noted. These operations furnish all the data necessary for ascertaining the relative amounts of light carburetted hydrogen, carbonic oxide, hydrogen, and nitrogen, according to the mode of calculation given here.

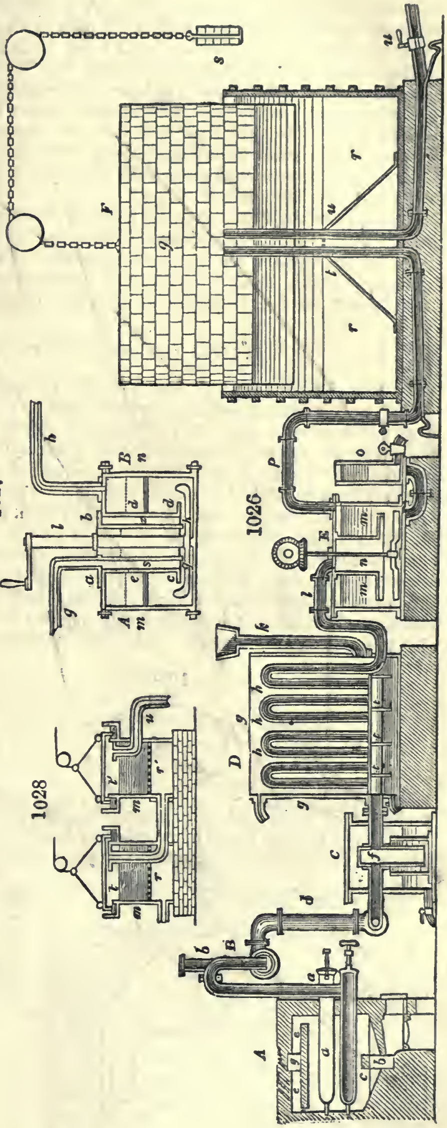
Finally, the value of the luminiferous constituents is obtained as before, by exploding about a cubic inch of the original specimen of gas with from four to five times its volume of oxygen, and noting the amount of carbonic acid produced.

On the Manufacture of Coal-Gas.

Coal-gas, as usually manufactured, is produced by exposing coal to a bright red heat in retorts. The gas as it issues from the retort cannot be directly employed for illumination, for it contains vapours of tar and naphtha, as also steam impregnated with carbonate of ammonia and hydrosulphate of sulphide of ammonium. These vapours would easily condense in the pipes through which the gas must be distributed, and would produce obstructions; they must therefore be so far removed by previous cooling, as to be liable to occasion no troublesome condensation at ordinary temperatures. The crude coal-gas contains moreover sulphuretted hydrogen, whose combustion would exhale an offensive sulphureous odour, that ought to be avoided as much as possible. Carbonic acid enfeebles the illuminating power of the gas, and should be removed. The disengagement of gas in the retorts is never uniform, but varies at the different stages of the process; for which reason the gas must be received in a gas-holder, where it may experience uniform pressure, and be discharged uniformly into the pipes of distribution, in order to ensure a steady discharge of gas, and uniform intensity of light in burners. A coal-gas apparatus ought therefore to be so constructed as not only to generate the gas itself, but to fulfil the above conditions.

In *fig.* 1026 such an apparatus is represented, where the various parts are shown connected with each other in section.

A is the furnace, with its set of cylindrical or elliptical retorts, five in number. From each of these retorts, a tube *b* proceeds perpendicularly upwards, and then by a curve or saddle-tube, it turns downwards, where it enters a long horizontal cylinder under B, shut at each end with a screw cap, and descends to beneath its middle, so as to dip about an inch into the water contained in it. From one end of this cylinder, the tube *d* passes downwards, to connect itself with a horizontal tube which enters into the *tar pit* or *cistern* C, by means of the vertical branch *f*. This branch reaches to near the bottom of the cylindrical vessel, which sits on the sole of the tar-cistern. From the other side of the vertical branch *f*, the main pipe proceeds to the condenser D, and thence by the pipe *l*, into the purifier E; from which the gas is immediately transmitted by the pipe *p* into the gasometer F.



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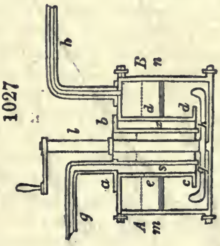

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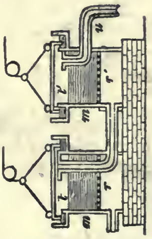

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The operation proceeds in the following way:—As soon as gas begins to be disengaged from the ignited retort, tar and ammoniacal liquor are deposited in the cylindrical receiver B, and fill it up till the superfluity runs over by the pipe *d*, the level being constantly preserved at the line shown in the figure. By the same tarry liquid, the orifices of the several pipes *b*, issuing from the retorts are closed; whereby the gas in the pipe *d* has its communication cut off from the gas in the retorts. Hence, if one of the retorts be opened and emptied, it remains shut off from the rest of the apparatus. This insulation of the several retorts is the function of the pipe under B, and therefore the recurved tube *b*, must be dipped as far under the surface of the tarry liquid as to be in equilibrio with the pressure of the gas upon the water in the purifier. The tube *b* is closed at top with a screw cap, which can be taken off at pleasure, to permit the interior to be cleansed.

Both by the overflow from the receiver B, and by subsequent condensation in the tube *d*, tar and ammoniacal liquor collect progressively in the cistern or pit under C, by which mingled liquids the lower orifice of the vertical tube *f* is closed, so that the gas cannot escape into the empty space of this cistern. These liquids flow over the edges of the inner vessel when it is full, and may, from time to time, be drawn off by the stopcock at the bottom of the cistern.

Though the gas has, in its progress hitherto, deposited a good deal of its tarry and ammoniacal vapours, yet, in consequence of its high temperature, it still retains a considerable portion of them, which must be immediately abstracted, as otherwise the tar would pollute the lime in the vessel E, and interfere with its purification. On this account the gas should, at this period of the process, be cooled as much as possible, in order to condense these vapours, and to favour the action of the lime in the purifier E, upon the sulphuretted hydrogen, which is more energetic the lower the temperature of the gas. The coal-gas passes, therefore, from the tube *f* into the tube *h* of the condenser D, which is placed in an iron chest *g*, filled with water, and it deposits more tar and ammoniacal liquor in the under part of the cistern at *t*, *t*. When these liquids have risen to a certain level, they overflow into the tar-pit, as shown in the figure, to be drawn off by the stopcock, as occasion may require.

The refrigerated gas is now conducted into the purifier E, which we will suppose to be filled with milk of lime, made by mixing 1 part of slaked lime with 25 parts of water. The gas, as it enters by the pipe *l*, depresses the water in the wide cylinder *n*, thence passes under the perforated disc in the under part of that cylinder, and rising up through innumerable small holes is distributed throughout the lime-liquid in the vessel *m*. By contact with the lime on this extended surface, the gas is stripped of its sulphuretted hydrogen and carbonic acid, which are condensed into the sulphide of calcium and carbonate of lime; it now enters the gas-holder F in a purified state, through the pipe *p t*, and occupies the space *q*. The gas-holder pressing with a small unbalanced force over the counter-weight, *s*, expels it through the main *u u*, in communication with the pipes of distribution through the buildings or streets to be illuminated.

Such are the chief and essential parts of the apparatus used in every gas-work for the generation, refrigeration, purification, and storage of coal-gas. The construction and mode of working these separate portions of the apparatus vary much, however, in different works, and it will therefore be necessary here to enter more minutely into the details of the four departments of the manufacture just enumerated.

I. Apparatus used in the Generation of Coal-Gas.

Retorts.—The use of this portion of the apparatus is to expose the coal to a high temperature, to exclude atmospheric air, and to deliver the gaseous and vaporous products of distillation into the refrigeratory portion of the apparatus. The materials composing the retorts should therefore possess the following properties:—1st, high conducting power for heat; 2nd, rigidity and indestructibility at a high temperature; and 3rd, impermeability to gaseous matter. The materials hitherto used in the construction of retorts are cast iron, wrought iron, and earthenware; but none of these materials possess the above qualifications in the high degree that could be wished. Thus cast iron, though a good conductor of heat, is not perfectly rigid and indestructible. At high temperatures it becomes slightly viscous, and at the same time undergoes rapid oxidation. Wrought iron is a still better conductor of heat, but its qualities of indestructibility and rigidity are even lower than those of cast iron; whilst earthenware, though rigid, and indestructible by oxidation, is a very bad conductor of heat, and is moreover very liable to crack from changes of temperature. Very various forms of retort have been employed at different times in order to secure as far as possible, the conditions just enumerated.

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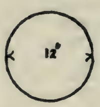

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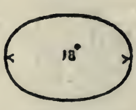

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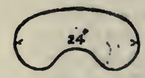

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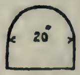

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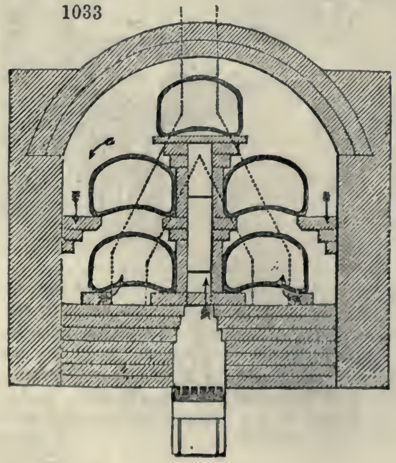
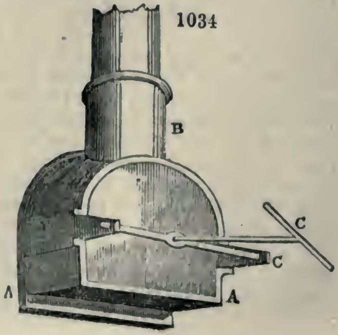


Cast-iron Retorts.—The chief forms of the cast-iron retorts are: First, the cylindrical, *fig.* 1029, used in the Manchester Gas Works, 12 inches diameter, and 6 to 9 feet long; second, the elliptical, 18 inches by 12 inches, by

1034



6 to 9 feet, *fig.* 1030; third, the ear-shape, *fig.* 1031, now little used, 2 feet 9 inches, and of the same length as before; fourth, the D-shaped retort, *fig.* 1032, 20 inches wide and 14 inches high. This form of retort is at present far more extensively used than any of the others.

Fig. 1033 shows a bed of 5 D-shaped iron retorts. The length is 7½ feet, and the transverse area, from one foot to a foot and a half square. The arrows show the direction of the flame and draught.

The charge of coals is most conveniently introduced in a tray of sheet-iron, made somewhat like a grocer's scoop, adapted to the size of the retort, which is pushed home to its further end, inverted so as to turn out the contents, and then immediately withdrawn.

All these retorts are set horizontally in the furnace, and they have a flanch cast upon their open end, to which a mouthpiece, A A, *fig.* 1034, can be securely bolted. The mouthpiece is provided with a socket, B, for the reception of the *standpipe*, and also with an arrangement by which a lid, C C, can be screwed gas-tight upon the front of the mouthpiece as soon as the charge of coal has been introduced. By applying a luting of lime mortar to that part of the lid which comes into contact with the mouthpiece, a perfectly tight joint is obtained.

Sometimes iron retorts are made of double the above length, passing completely through the furnace, and being furnished with a lid and standpipe at each end. Such is the construction of Mr. Croll's and of Lowe's reciprocating retorts. These retorts are charged from each end alternately, and there is an arrangement of valves by means of which the gas evolved from the coal recently introduced is made to pass over the incandescent coke of the previous charge, at the opposite end of the retort. It is highly probable that some advantage is derived from this arrangement during the very early stage of the distillation of the fresh coal; but on the whole, for reasons stated above, the principle is undoubtedly bad, for although it enables the manufacturer to produce a large volume of gas, the quality is so much inferior as to reduce the total illuminating effect obtainable from a given weight of coal.

Wrought-iron Retorts.—Mr. King, the eminent engineer of the Liverpool Gas Works, has for many years successfully used retorts of wrought iron. They are made of thick boiler plates, riveted together, and are of the D shape, 5½ feet wide, 6 feet long, and 18 inches high at the crown of the arch. About 1 ton of coal can be worked off in these retorts in 24 hours. Occasionally the bottoms are of cast iron, which materially prevents the great amount of warping to which wrought iron is subject when exposed to high temperatures.

Earthenware, or Clay Retorts.—These are usually of the D shape, although they are occasionally made circular or elliptical. Their dimensions are about the same as those of the cast-iron retorts commonly used, but their walls are necessarily thicker, varying from 2½ to 4 inches in thickness; this, added to the circumstance that clay is a very bad conductor of heat, undoubtedly causes the expenditure of a larger amount of fuel in heating these retorts; nevertheless, this disadvantage is, perhaps, less than might be supposed, since iron retorts soon become coated outside with a thick layer of oxide of iron, which also greatly hinders the free communication of heat to the iron beneath. Moreover, the lower price and much greater durability of clay retorts are causing their almost universal adoption in gas-works, especially since the removal of pressure by exhausters greatly reduces the amount of leakage to which clay retorts are liable.

The following is an extract relating to clay retorts, from the 'Reports of Juries' of the Great Exhibition of 1851:—

'The use of fire-clay is not of very ancient date, and has greatly increased within the last few years, It is found in England almost exclusively in the coal-measures, and from different districts the quality is found to differ considerably. The so-called 'Stourbridge clay,' is the best known, and will be alluded to presently; but other kinds are almost, if not quite, as well adapted for the higher purposes of manufacture, being equally free from alkaline earths and iron, the presence of which renders the clay fusible when the heat is intense. The proportion of silica and alumina in these clays vary considerably, the former amounting sometimes to little more than 50 per cent., while in others it reaches beyond 70, the miscellaneous ingredients ranging from less than ½ to upwards of 7 per cent.

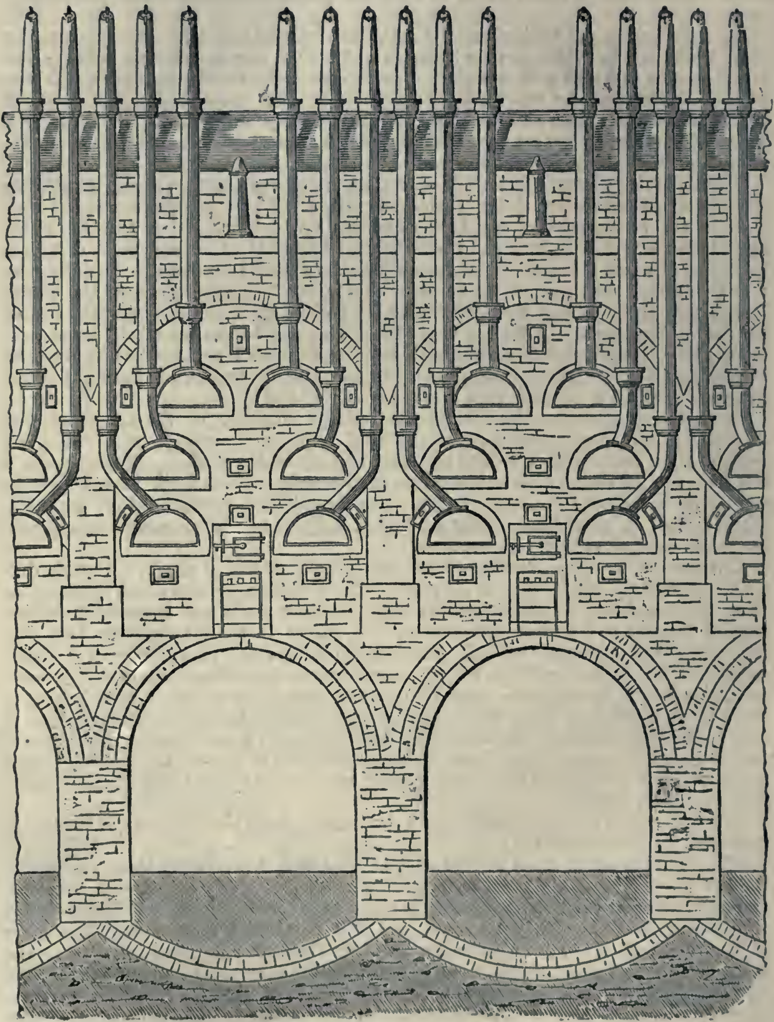
'The works of Messrs. Cowen and Co. are among the most extensive in England, and they obtain their raw material from no less than nine different seams, admitting of great and useful mixture of clay for various purposes.

'After being removed from the mine, the clay is tempered by exposure to the weather, in some cases for years, and is then prepared with extreme care. The objects chiefly made are fire-bricks and gas-retorts; the latter being now much used, and preferred to iron for durability.

'These retorts were first made by the present exhibitors in ten pieces (this being twenty years ago), and since then the number of pieces has been reduced successively to four, three, and two pieces, till in 1844 they were enabled to patent a process for making them in one piece, and at the present time they are thus manufactured of dimensions as much as 10 feet long by 3 feet wide in the inside, which is, however, more than double the size of the largest exhibited by them.

'Gas retorts of very fair quality are shown by Mr. Ramsay of Newcastle, who has also succeeded extremely well in the manufacture of fire-bricks. The retorts show a little more iron than is desirable, but the exhibitor has been considered worthy of honourable mention. Retorts of less creditable appearance are exhibited by Messrs. Hickman and Co. of Stourbridge, and Mr. A. Potter of Newcastle. The surface of both these retorts is cracked and undulating. When we consider the high and long-continued temperature to which these objects are exposed, the absolute necessity of attending to every detail in mixing the clay and moulding the retort will be at once recognised, and the apparently slight defects of some of those sent for exhibition require to be noticed as of real importance.

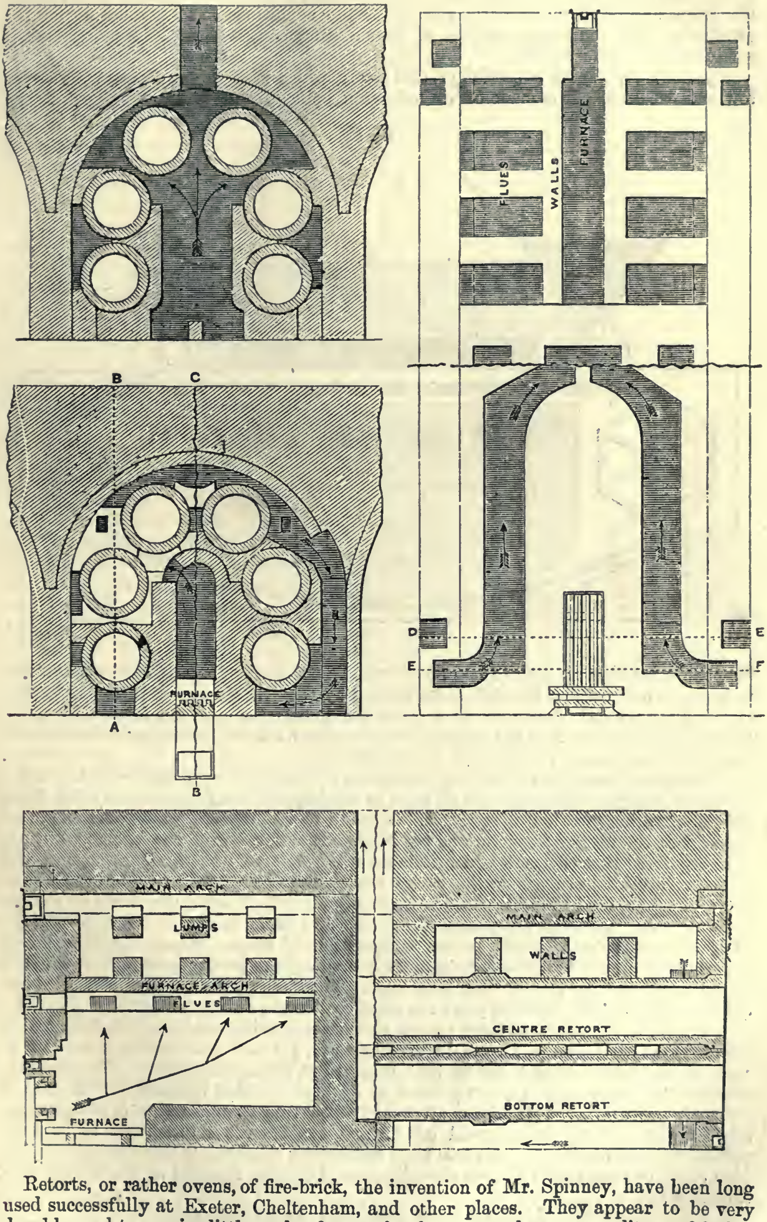
1035



'Next to England, the finest specimens of fire-clay goods on a large scale are from Belgium: the gas-retort sent from France is not remarkable for excellence.'

Fig. 1035 is an elevation of Mr. Wright's plan for a range of long clay retorts.
Fig. 1036 shows the plans and sections of the setting for these retorts.

1036



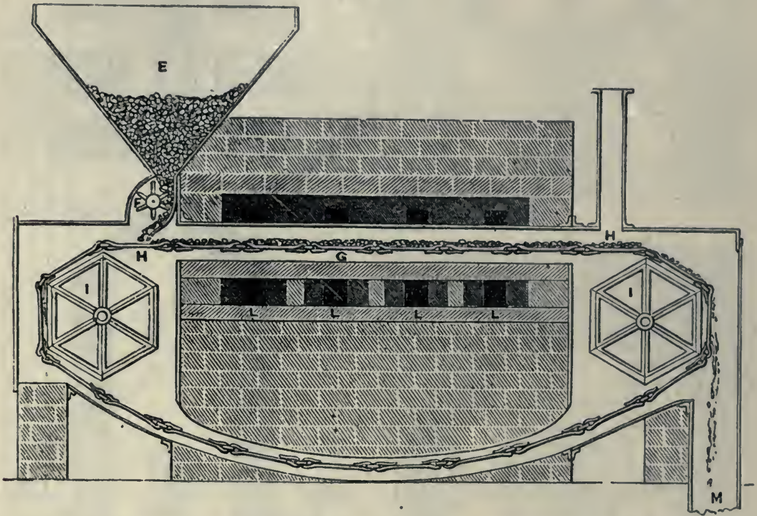
Retorts, or rather ovens, of fire-brick, the invention of Mr. Spinney, have been long used successfully at Exeter, Cheltenham, and other places. They appear to be very durable, and to require little outlay for repairs, but a very large expenditure of fuel is required for heating them. They are of the D shape, 7 feet long, 3 feet 2 inches wide, and 14 inches high at the crown of the arch. Each retort receives a charge of

5 or 6 cwts. of Newcastle or Welsh coal every 12 hours, and produces gas at the rate of 9,000 cubic feet per ton of Welsh, and 10,000 to 12,000 per ton of Newcastle coal.

Clegg's revolving Web Retort.—This retort, the invention of Mr. Clegg, sen., makes the nearest approach to a truly philosophical apparatus for the generation of gas; in it the coal is exposed to a sudden and uniform heat, in a thin stratum, by which means the gases are liberated at once, and under the conditions most favourable for the production of a maximum amount of illuminating constituents. Very little tar is produced from this retort.

Fig. 1037 represents a section of this retort, which is of the D shape, with a very low and flat arch. It is made of wrought-iron boiler plates riveted together. E is a hopper for holding the coal to be carbonised; F is a discharging disc; G is the retort; H is a web on to which the coal is discharged by the disc F; I I are revolving drums, carrying the wrought-iron web H; L L are the flues from a lateral furnace by which the retort is heated; M is the exit-pipe for the coke, its lower extremity is either closed by an air-tight door, or is made to dip into water.

1037



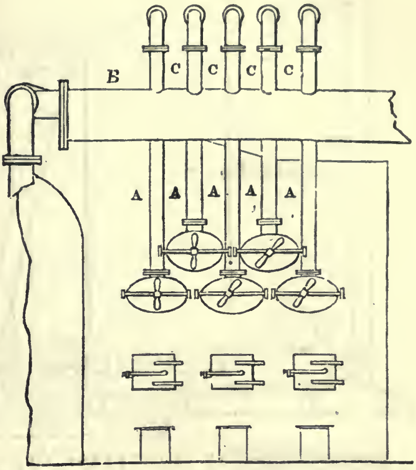
All the coal must be reduced to fragments about the size of coffee-berries, and a 24 hours' charge must be placed at once in the hopper, and secured by a luted cover. The discharging disc has 6 spurs, and is made to revolve uniformly with the drum below it at the rate of 4 revolutions per hour. The diameter of the hexagonal drums is so regulated that the coal, which falls upon the web from the discharging disc, will at one revolution have passed the entire length of the retort. The passage through the retort occupies 15 minutes, which is quite sufficient to expel the whole of the gas from the coal. In each revolution of the disc and drum 745 cubic inches of coal (or 21 lbs.) are distributed over a heated surface of 2,016 square inches. 18 cwts. of coal is carbonised in one of these retorts in 24 hours, and the production of gas is equal to 12,000 cubic feet per ton of Newcastle coal. The quality of the gas is also considerably superior to that obtained from the same coal in the ordinary retorts.

Although the first cost of these retorts and accompanying machinery is considerably greater than that of the retorts in ordinary use, yet the destructible parts can be replaced at about the same cost as that required to replace the latter. The coke produced is greater in quantity, but inferior in quality, owing to its more minute state of division. The minor advantages attendant upon this form are, that it occupies less space, requires much less manual labour, and enables the retort-house to be kept perfectly clean, wholesome, and free from suffocating vapour. If the principle of this plan could be combined with less complication of details, it would no doubt come into extensive use.

II. The Refrigeratory Apparatus.

From the moment that the gas leaves the retorts it is subjected to cooling influences, which gradually reduce its temperature, until, on leaving the so-called condenser, its temperature ought to be only a few degrees higher than that of the atmosphere, except in winter, when it is advisable to maintain a heat, relatively to the external air, greater than in summer. The gas leaves the retort by the *standpipes*, A A A, *fig.* 1038, which are of cast iron, 5 inches in diameter at their lower extremity, and slightly tapering upwards. Some of the least volatile products of decomposition condense in these pipes, but their proximity to the furnaces, and the constant rush of heated gas and vapour through them prevent more than a very slight amount of refrigeration. They conduct to the *hydraulic main*, which is shown at B, *fig.* 1038. It consists of a cylinder running the entire length of the retort-house, and fixed at a sufficient height above the mouths of the retorts to protect it from the flame issuing from the latter during the times of charging and drawing. The diameter varies from 12 to 18 inches, and the recurved extremities of the standpipes (*the dip-pipes*) C C C C, pass through it by gas-tight joints, and dip, to the extent of 3 or 4 inches, into the condensed liquids contained in the hydraulic main. The use of this portion of the apparatus is to cut off the communication in the reverse direction between the gas beyond the standpipes and the retorts, so as to prevent the former rushing back down the standpipe during the time that the lid of the retort is removed. Being maintained half full of tar it effectually seals the lower ends of the dip-pipes, and prevents any return of gas towards the retorts. The condensed products, consisting chiefly of tar, make their exit from the hydraulic main by the pipe D, which leads them to the tar-well. From the hydraulic main the gas passes to the *condenser*, the office of which, as its name implies, is to effect the condensation of all those vapours which could not be retained by the gas at the ordinary atmospheric temperature. The condenser has received a variety of forms, but the one which appears to unite in the highest degree simplicity and efficiency, is the invention of Mr. Wright, of the Western and Great Central Gas Companies. Its construction is shown in *fig.* 1039. A A A A, are 5 double concentric cast-iron cylinders, through which the air is made to circulate in succession by means of the tiepipes B B B B, whilst the inner cylinders being open above and below, a current of air, set in motion by their heated walls, rushes through them, thus securing both an internal and external refrigeratory action. It will be also seen by a reference to the figure that the heated gas enters these cylinders at the top, taking an opposite direction to that pursued by the external and internal currents of air, and thus securing the most perfect refrigeration, by bringing the gas constantly in proximity to air of increasing coldness. Each cylinder is furnished at bottom with a tar receptacle, C, for the collection of the condensed products, which are carried to the tar-well by a pipe not shown in the figure. The details of construction are sufficiently seen from the drawing, and require no further description.

1038

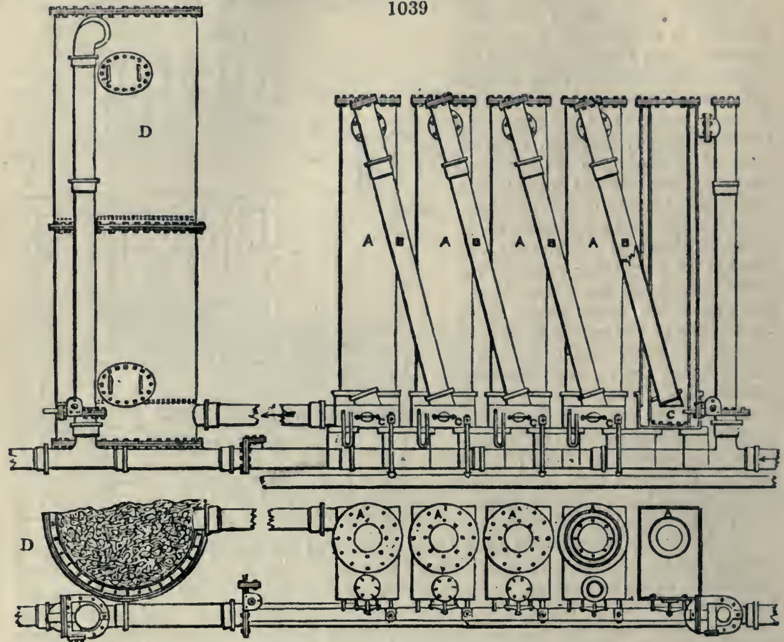


In some country works the condenser represented at D, *fig.* 1026 (p. 573) is used. It consists of a square chest, *g*, made of wrought-iron plates open at top, but having its bottom pierced with a row of holes, to receive a series of tubes. To these holes the upright four-inch tubes *h h* are secured by flanges and screws, and they are connected in pairs at top by the curved or saddle tubes. The said bottom forms the cover of the chest *t t*, which is divided by vertical iron partitions, into half as many compartments as there are tubes.

These partition plates are left open at bottom, so as to place the liquids of each compartment in communication. Thereby the gas passes up and down the series of tubes, in proceeding from one compartment to another. The condensed liquids descend into the box *t t*, and flow over into the tar cistern, when they rise above the level *t t*. The tar may be drawn off from time to time by the stopcock. Through the tube *k* cold water flows into the condenser chest, and the warm water passes away by a pipe at its upper edge.

The extent of surface which the gas requires for its refrigeration before it is admitted into the washing-lime apparatus, depends upon the temperature of the milk of lime, and the quantity of gas generated in a certain time.

1039



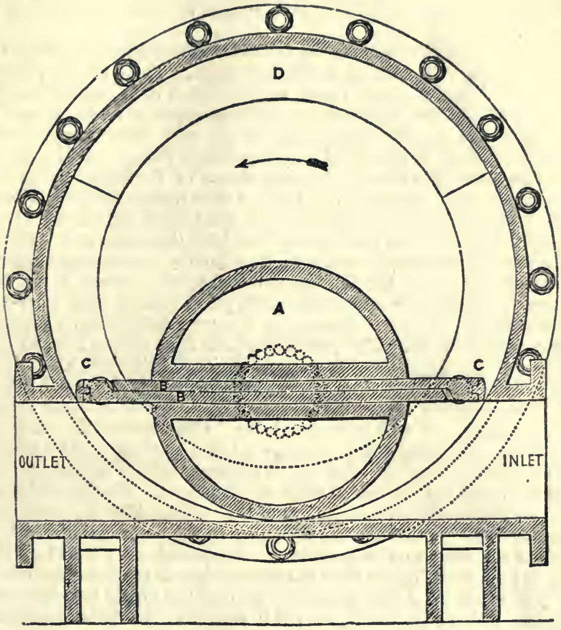
It may be assumed as a determination sufficiently exact, that 10 square feet of surface of the condenser can cool a cubic foot of gas per minute to the temperature of the cooling water. For example, suppose a furnace or arch, with 5 retorts of 150 lbs. of coal each, to produce in 5 hours 3,000 cubic feet of gas, or 10 cubic feet per minute, there would be required, for the cooling surface of the condenser, 100 square feet = 10 × 10. Suppose 100,000 cubic feet of gas to be produced in 24 hours, for which 8 or 9 such arches must be employed, the condensing surface must contain from 800 to 900 square feet.

After the action of the condenser, the gas still retains, chiefly in mechanical suspension, a certain quantity of tarry matter, besides a slight percentage of ammonia. To free it from these, it is passed through a *scrubber* D (*fig.* 1039), which consists of a tall cylinder filled with bricks, paving stones, or coke, and having an arrangement by which a stream of water can be admitted at top and removed at bottom. The chief use of the water is to remove ammonia from the gas, but as it also dissolves some of the luminiferous hydrocarbons, its use is objected to by Mr. Wright, and dry scrubbers are now used at the Western Gas Works. It is also considered by the same gentleman, that the detention of a certain percentage of ammonia by the gas is rather an advantage than otherwise, as it serves in part to neutralise the sulphurous acid which is inevitably produced by the combustion even of the best gas. It must, however, be borne in mind, that the presence of ammonia in gas gives rise to the formation of nitric acid during its combustion.

The Exhauster.—The passage of the gas through the liquid of the hydraulic main, and the other portions of apparatus between the retorts and gasholder, causes a very considerable amount of pressure to be thrown back upon the retorts, an effect which is productive of mischief in two ways: in the first place, if there be any fissure or flaw in the retorts, or leakage in the joints, the escape and consequent loss of gas is greatly augmented; and in the second place, it has been ascertained by Mr. Grafton, of Cambridge, that pressure in the retorts causes the decomposition of the illuminating hydrocarbons with greatly-increased rapidity. It is, therefore, very desirable to remove nearly the whole of this pressure by mechanical means, and this is now done in all well-arranged works, by the use of an apparatus termed an exhauster. Several forms of exhausters are in use, but it will be necessary only to describe that of Mr. J. T. Beale, which has been found by experience to be very effective and economical.

It is shown in section in *fig.* 1040. The axle A is reduced at each end, and passes into two cylindrical boxes bored to a larger diameter than the axle at those parts; and in the annular space between the axle and the box antifriction rollers are introduced, their diameter being equal to the width of the annular space; the box at one end is fitted with a stuffing box, through which the axle passes for the application of the driving power. Upon motion being given to the axle, the sliding pistons B B are carried with it. These sliding pistons are furnished at their ends with cylindrical pins, which project and fit into cylindrical holes bored in the guide blocks C C, which fit into annular recesses D in the end plates, and keep the slides in contact with the cylinder. The slides are fitted with metallic packing to allow of wear. The axle continuing to revolve, as one slide reaches the outlet and ceases to exhaust, the other comes into action, and the exhaustion is unceasing. Thus the pressure upon the retorts (which is indicated by a gauge) is reduced to about half an inch of water.

1040



III. Apparatus used in the Purification of Coal-Gas.

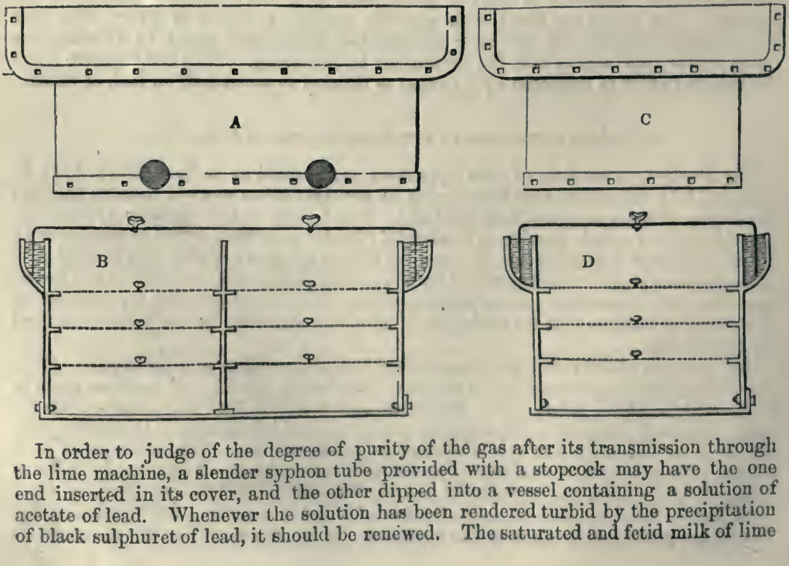
The Purifier.—One form of this apparatus, represented at E, *fig.* 1026 (p. 573), is composed of a cylindrical iron vessel, with an air-tight cover screwed upon it, through which the cylinder *n* is also fixed air-tight. The bottom of this cylinder spreads out like the brim of a hat, forming a horizontal circular partition, which is pierced with holes. Through a stuffing box, in the cover of this interior cylinder, the vertical axis of the agitator passes, which is turned by wheel-and-pinion work, in order to stir up the lime from the bottom of the water in the purifier. The vessel *o*, serves for introducing fresh milk of lime, as also for letting it off by a stopcock when it has become too foul for further use.

The quantity of lime should be proportioned to the quantity of sulphuretted hydrogen and carbonic acid contained in the gas. Supposing that in good coal-gas there is 5 per cent. of these gases, about one pound and a half of lime will be requisite for every hundred cubic feet of coal-gas generated, which amounts to nearly one-sixteenth of the weight of coal subjected to decomposition. This quantity of lime mixed with the proper quantity of water will form about a cubic foot of milk of lime. Consequently, the capacity of the purifier, that is, of the interior space filled with liquid, may be taken at four-sevenths of a cubic foot for every hundred cubic feet of gas passing through it in one operation; or for 175 cubic feet of gas, one cubic foot of liquor. After every operation, that is, after every five or six hours, the purifier must be filled afresh. Suppose that in the course of one operation 20,000 cubic feet of gas passes through the machine, this should be able to contain $\frac{20{,}000}{175} = 114$ cubic feet of milk of lime; whence its diameter should be 7 feet, and the height of the liquid 3 feet. If the capacity of the vessel be less, the lime-milk must be more frequently changed.

In some gas-works the purifier has the following construction, whereby an uninterrupted influx and efflux of milk of lime takes place. Three single purifiers are so connected together that the second vessel stands higher than the first, and the third than the second; so that the discharge-tube of the superior vessel, placed somewhat below its cover, enters into the upper part of the next lower vessel; consequently, should the milk of lime in the third and uppermost vessel rise above its ordinary level, it will flow over into the second, and thence in the same way into the first; from which it is let off by the eduction pipe. A tube introduces the gas from the condenser into the first vessel; another tube does the same thing for the second vessel, &c.; and the tube of the third vessel conducts the gas into the gasometer. Into the third vessel, milk of lime is constantly made to flow from a cistern upon a higher level. By this arrangement, the gas passing through the several vessels in proportion as it is purified, comes progressively into contact with purer milk of lime, whereby its purification becomes more complete. The agitator *c*, provided with two stirring paddles, is kept in continual rotation. The pressure which the gas has here to overcome is naturally three times as great as with a single purifier of like depth.

Fig. 1027 (p. 573) is a simple form of purifier, which has been found to answer well in practice. Through the cover of the vessel A B, the wide cylinder *e d* is inserted, having its lower end pierced with numerous holes. Concentric with that cylinder is the narrower one *s z*, bound above with the flange *a b*, but open at top and bottom. The under edge *g h* of this cylinder descends a few inches below the end *c d* of the outer one. About the middle of the vessel the perforated shelf *m n* is placed. The shaft of the agitator *l*, passes through a stuffing-box upon the top of the vessel. The gas-pipe *g*, proceeding from the condenser, enters through the flange *a b* in the outer cylinder, while the gas-pipe *h* goes from the cover to the gasholder. A stopcock upon the side, whose orifice of discharge is somewhat higher than the under edge of the outer cylinder, serves to draw off the milk of lime. As the gas enters through the pipe *g* into the space between the two cylinders, it displaces the liquor till it arrives at the holes in the under edge of the outer cylinder, through which, as well as under the edge, it flows, and then passes up through the apertures of the shelf *m n* into the milk-of-lime chamber; the level of which is shown by the dotted line. The stirrer, *l*, should be turned by wheel-work, though it is here shown as put in motion by a winch handle.

1041



In order to judge of the degree of purity of the gas after its transmission through the lime machine, a slender syphon tube provided with a stopcock may have the one end inserted in its cover, and the other dipped into a vessel containing a solution of acetate of lead. Whenever the solution has been rendered turbid by the precipitation of black sulphuret of lead, it should be renewed. The saturated and fetid milk of lime is evaporated in oblong cast-iron troughs placed in the ash-pit of the furnaces, and the dried lime is partly employed for luting the apparatus, and partly disposed of for a mortar or manure.

1042

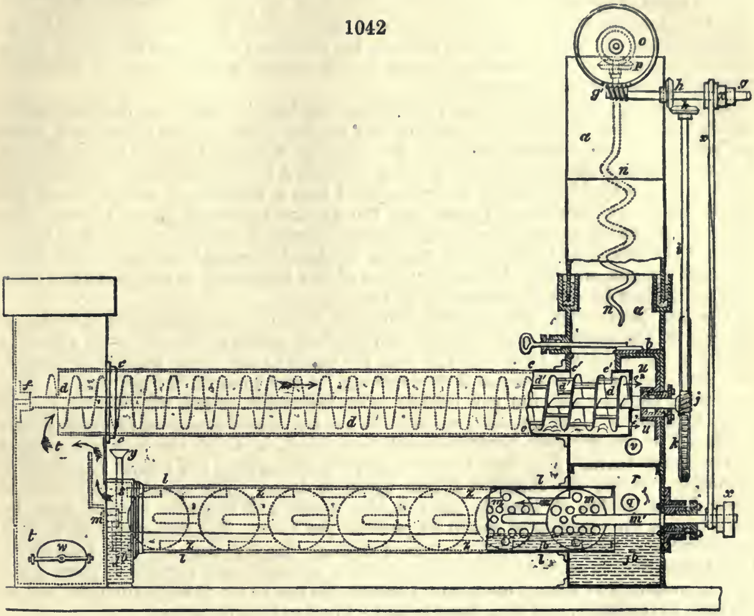
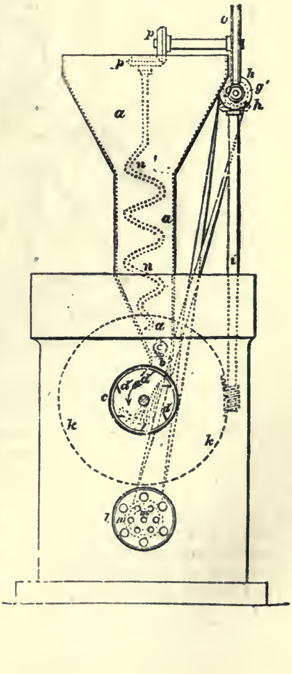


Fig. 1041 shows elevations and sections of dry-lime purifiers, which may also be used for other forms of dry purification. A is the longitudinal elevation; B ditto section; C transverse elevation; D ditto section.

Figs. 1042 and 1043 represent another form of dry purifier, combined with a washer or scrubber, patented by Mr. Lees of Manchester. *Fig.* 1042 is an elevation, partly in section of this apparatus, and *fig.* 1043 is another elevation, also partly in section, of the same. *a* is a hopper, into which the dry lime is fed; *b* is a damper, or sliding door, by which the supply of lime can be regulated; *c* is a sheet-metal tube, containing the worm or screw, *d*, the axis of which is supported at one end by the stuffing-box *e*, and at the other end by the bearing *f*. A slow revolving motion is given to the worm *d* from the driving shaft *g*, by means of the bevel-wheels *h*, upright shaft *i*, worm *j*, and worm-wheel *k*, fixed on the axis of the worm.

1043



The lime in the hopper *a*, is kept in motion by the screw *n*, which is turned slowly round by the worm *g*, the worm-wheel *o* and bevel-wheels *p*, one of which is fixed on the screw *n*. The tube *c* is open at *c'*, to admit the dry lime from the hopper *a*, and the worm or screw *d*, is furnished with cross pieces *d'* to agitate the lime which is gradually moved from the hopper to the other end of the tube *c*, by the revolving of the worm. Below the tube *c* is another tube *l*; *y* is a syphon, by which the washing fluid is supplied and conducted to the chamber *s*, which then flows down the tube *l* to the chamber *r*, keeping the level indicated by *j b*. *z* are two paddles, fixed upon the circular perforated plates, which are set to an angle, and secured to the shaft *m'*, and are revolved speedily by the strap and pulleys *x*. These agitators serve to increase the action of the washing fluid contained in the tube *l*, by which the gas is washed previous to passing through the dry-lime purifier.

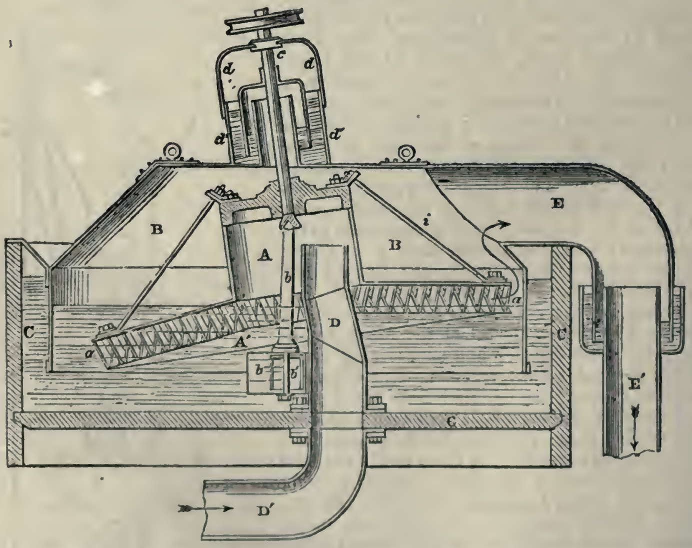
The mode of operation is as follows:—the gas to be purified is admitted through the pipe *q*, to the chamber *r*, from whence it passes along the tube *l*, as shown by the arrows, to the chamber *s*; it then rises into the chamber *t* and enters the tube *c*, along which it passes in the direction shown by the arrows, whence it may be conveyed, through the pipe *v*, to the gasometer.

It will be apparent, as the gas passes along the tube *l*, containing the agitators *m*, which are caused to revolve speedily by the motion given by the straps and speed pulleys *x*, that the washing fluid, which is passing regularly through the syphon *y*, and running into the chamber *s*, and along the tube *l*, into the chamber *r*, keeping the level as shown by *j b*, is caused to be revolved into a centrifugal motion round the tube *l*, by the two paddles *z*, placed upon the circular perforated plates, secured upon the shaft *m*, which are set to an angle, thereby causing a counter-motion from left to right of the tube *l*, and causing the washing fluid to be wrought into a complete spray amongst the gas, whereby the heavier parts of the impurities are carried away more effectually than by any other washers in use.

The gas then enters the chamber *t* through the tube *c*, passes along the coils or threads of the worm or screw *d*, and as the cross pieces *d′* are set to an angle, as shown in *fig.* 1043, the lime is raised from the lower to the upper part of the tube *c*, and then drops down to the gas that is making its way towards the openings c^2; consequently, the lime and the gas become most intimately mixed, whereby the lime is made to absorb a much greater proportion of the impurities contained in the gas than is effected by the dry-lime purifiers usually employed, in which the lime is supported on stationary trays. The lime dropping into the tube *c*, from the hopper *a*, is worked gradually towards the chamber *i*, into which it drops. The speed of the screw or worm *d*, the number of threads upon it, the length and diameter thereof must be made to suit the quantity of gas to be purified per hour. The lime which drops into the chamber *t*, may be removed therefrom through the man-hole *w*. Mr. Lees states that a considerable saving is effected in the lime, owing to each particle or atom being kept in motion, and falling repeatedly through the gas in its passage from one end of the tube to the other, and that there is also a great saving in labour.

Another form of wet purifier, which might also be advantageously used as a scrubber, or as a naphthaliser, has been invented by M. Colladon of Geneva, and is now in use in the gas-manufactory of that city. This apparatus, as shown in vertical section in *fig.* 1044, consists of a section of a very obtuse cone A′ the angle of inclination of which is 164°. Its upper and smaller end is joined to a metal cylinder A, placed on the same axis as A′, and about its own diameter in height. At top it is closed

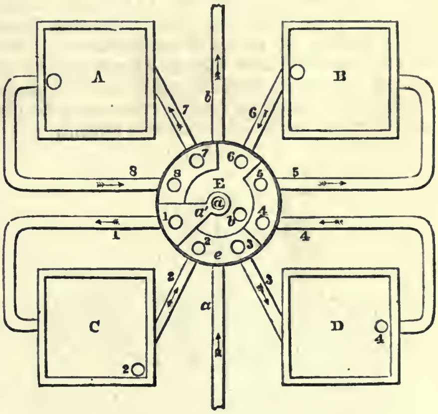
1044



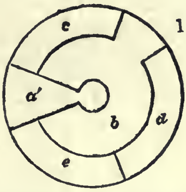
by a cast-iron plate K, through which the axle C passes: the latter communicates a rotary motion to the cylinder and cone A and A′. It is inclined 8° from the perpendicular, and rests upon the steel point of the centre pin *b*′, whilst at top it carries a pulley by which a circular motion is communicated to it. *a a* are a series of metal discs which stand vertically to the inner surface of the cone A′, with spaces of about one inch between them. The discs are arranged concentrically, and have spaces corresponding to the quantity of gas which has to pass through them. They are from 5 to 7 inches long. As the axle *c* and cylinder A are not vertical, but somewhat inclined, one side of the cone A′ will, during the revolution, be in a nearly horizontal position, whilst the opposite side will be immersed in the liquid to the extent of about 16°. The whole of this mechanism is enclosed in a sheet-iron lid B. The centre pin *b* is attached by a cross bar to the lower edge of B, whilst the axle *c* is supported by *d*, which is also attached to B. *d′ d′* is a water-joint permitting of the free motion of *c*. The lid B thus contains the whole of the washing apparatus, and it is held in its proper position in the trough C by lateral attachments. D is the inlet pipe opening into the cylinder A, from which it has to make its way through the discs *a a* to the outlet E. This apparatus gives no sensible pressure, and requires a very small motive power.

Fig. 1045 represents an arrangement of four of the dry purifiers shown in *fig.* 1041, worked by a central valve, as used at the present time in most large gas works; it is the invention of Mr. Malam, and is described in Mr. Peckston's treatise. A, B, C, D, are the four purifiers connected with the central valve E in such a way as to permit of three of them being at work whilst the fourth is emptied and re-charged. The outer case of the central valve E, is a cylinder of cast or wrought iron, 5 to 6 feet in diameter and 3 to 4 feet deep. Its floor receives the open ends of 10 pipes conducting the gas from the condenser or exhauster to the different purifiers, and then to the gas-holders; the ends of these pipes project upwards to the height of 14 inches, and the vessel E is filled with water to the height of 12 inches, thus leaving the orifice of the pipes 2 inches above the water-level. This cylinder has a cover which consists of a smaller cylinder, open below and closed above, fitting into E so as to form a water-lute. Its interior is divided into 5 chambers, as shown in *fig.* 1046; and when the cover is so far lowered into E as to immerse the edges of these chambers into the water, they each connect together a pair of pipes as shown in *fig.* 1045, at E, which exhibits a horizontal section through these chambers. The chambered cover being placed in the position shown in *fig.* 1045, the gas takes the following course: it enters the chamber *a*′ by the pipe *a a*, passes through the pipe marked 1, into the bottom of the purifier C, and after traversing the layers of purifying material in C, it returns to chamber *e* of the central valve by the pipe 2; thence by pipe 3, it enters the purifier D, and returns to chamber *d* of the valve by pipe No. 4. From this chamber it can only make its exit by pipe No. 5, which conducts it into B, whence it returns to chamber *b*, by pipe No. 6, and from this chamber it finally passes to the gasholder through the exit pipe *b b*. Thus the purifier A is left out of the circuit for the purpose of re-charging or revivification; but when the material in C has become exhausted, it can be replaced in the circuit by A, by slightly raising the cover of E, and turning it round so as to bring the chamber *a*′ over pipe 3, and again depressing it to its former position; by this arrangement D, B and A become the working purifiers, whilst C will be thrown out of the circuit. Thus, by the action of the central valve E, each of the four purifiers can in turn be excluded from the circuit, and recharged or revivified.

1045



1046



IV.—Apparatus for the Storage of Coal-Gas.

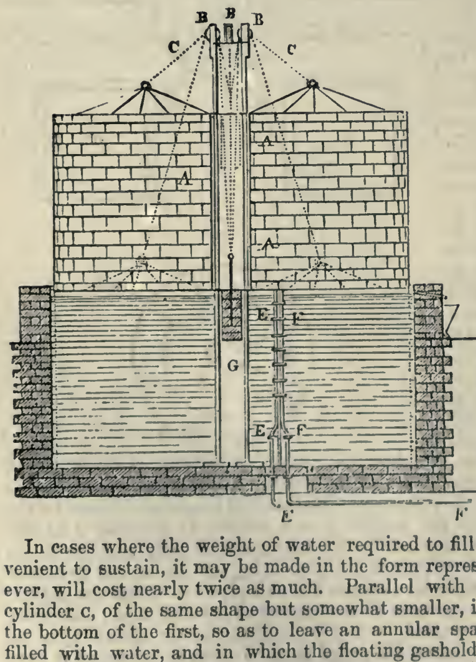
The gasholder serves as a magazine for receiving the gas when it is purified, and keeping it in store for use. It consists of two essential parts: 1, of an under cistern, open at the top and filled with water; and 2, of the upper floating cylinder or chest, which is a similar cistern, inverted, and of somewhat smaller dimensions (see F, *fig.* 1025, p. 573). The best form of this vessel is the round or cylindrical; both because under equal capacity it requires least surface of metal, and it is least liable to be warped by its own weight or accidents. Since a cylindrical body has the greatest capacity with a given surface when its height is equal to its semi-diameter, its dimensions ought to be such that when elevated to the highest point in the water, the height may be equal to the radius of the base. For example, let the capacity of the gasholder in cubic feet be k, the semi-diameter of its base be x, the height out of the water be h;

$h = x = \sqrt[3]{\dfrac{k}{3{\cdot}14}}$. This height may be increased by one or two feet, according to its magnitude, to prevent the chance of any gas escaping beneath its under edge, when it is raised to its highest elevation in the water.

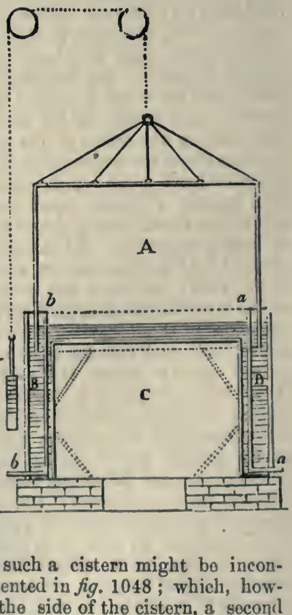
The size of the gasholder should be proportional to the quantity of gas to be consumed in a certain time. If 120,000 cubic feet be required, for instance, in 10 hours for street-illumination, and if the gas-retorts be charged 4 times in 24 hours, 30,000 feet of gas will be generated in 6 hours. Hence the gasholder should have a capacity of at least 70,000 cubic feet, supposing the remaining 50,000 cubic feet to be produced during the period of consumption. If the gasholder has a smaller capacity, it must be supplied from a greater number of retorts during the lighting period, which is not advantageous, as the first heating of the supernumerary retorts is wasteful of fuel.

The water cistern is usually constructed in this country with cast-iron plates bolted together, and made tight with rust cement.

1047



1048



In cases where the weight of water required to fill such a cistern might be inconvenient to sustain, it may be made in the form represented in *fig.* 1048; which, however, will cost nearly twice as much. Parallel with the side of the cistern, a second cylinder C, of the same shape but somewhat smaller, is fixed in an inverted position to the bottom of the first, so as to leave an annular space B B between them, which is filled with water, and in which the floating gasholder A plays up and down. The water must stand above the cover of the inverted cylinder. *a* and *b* are the pipes for leading the gas in and out. Through an opening in the masonry upon which the apparatus rests, the space C may be entered, in order to make any requisite repairs.

The water cistern may also be sunk in the ground, and the sides made tight with hydraulic mortar, as is shown in *fig.* 1047, and to make it answer with less water a concentric cylindrical mass of masonry may be built at a distance of 2 or 3 inches within it.

Every large gasholder must be strengthened interiorly with cross iron rods, to stiffen both its top and bottom. The top is supported by rods stretching obliquely down to the sides, and to the under edge an iron ring is attached, consisting of curved cast-iron bars bolted together; with which the oblique rods are connected by perpendicular ones. Other vertical rods stretch directly from the top to the bottom edge. Upon the periphery of the top, at the end of the rods, several rings are made fast, to which the gasholder is suspended, by means of a common chain which runs over a pulley at the centre. Upon the other end of the chain there is a counterpoise, which takes off the greater part of the weight of the gasholder, leaving only so much as is requisite for the expulsion of the gas. The inner and outer surfaces of the gasholder should be a few times rubbed over with hot tar, at a few days' interval between each application. The pulley must be made fast to a strong frame.

If the water cistern be formed with masonry, the suspension of the gasholder may be made in the following way:—A A, *fig.* 1047, is a hollow cylinder of cast iron, standing up through the middle of the gasholder, and which is provided at either end with another small hollow cylinder G, open at both ends, and passing through the top, with its axis placed in the axis of the gasholder. In the hollow cylinder G, the counterweight moves up and down, with its chain passing over the three pulleys, B, B, B, as shown in *fig.* 1048; E F are the gas-pipes made fast to a vertical iron rod. Should the gasholder be made to work without a counterweight, as we shall presently see, the central cylinder A A serves as a vertical guide.

In proportion as the gasholder sinks in the water of the cistern, it loses so much of its weight as is equal to the weight of the water displaced by the sides of the sinking vessel, so that the gasholder, when entirely immersed, exercises the least pressure upon the gas, and when entirely out of the water, it exercises the greatest pressure. In order to counteract this inequality of pressure, which, where no governor is used, would occasion an unequal velocity in the efflux of the gas, and of course an unequal intensity of light in its flame, the weight of the chain upon which the gasholder hangs is so adjusted as to be equal, throughout the length of its motion, to one-half of the weight which the gasholder loses by immersion. In this case, the weight which it loses by sinking into the water is replaced by the portion of the chain which, passing the pulley and hanging over, balances so much of the chain upon the side of the counterweight; and the weight which it gains by rising out of the water is counterpoised by the links of the chain which, passing over the pulley, add to the amount of the counterweight. The pressure which the gasholder exercises upon the gas, or that with which it forces it through the first main pipe, is usually so regulated as to sustain a column of from one to two inches of water, so that the water will stand in the cistern from one to two inches higher within than without the gasholder. The following computation will place these particulars in a clear light:—

Let the semi-diameter of the gasholder, equal to the vertical extent of its motion into and out of the water, $= x$; let the weight of a foot square of the side of the gasholder, including that of the strengthening bars and ring, which remain plunged under the water, $= p$; then

1. the weight of the gasholder in its highest position $= 3\,p\,\pi\,x^2$;
2. the weight of the sides of the gasholder which play in the water $= 2\,p\,x^2$;
3. the cubical contents of the immersed portion of the gasholder $= \frac{2\,p\,\pi\,x^2}{400}$;
4. its loss of weight in water $= \frac{112}{400}\,p\,\pi\,x^2$;
5. the weight of the gasholder in its lowest position =

$$p\,\pi\,x^2\left(3 - \frac{112}{400}\right) = 2{\cdot}72\,p\,\pi\,x^2;$$

6. the weight of n inches height of water $= \frac{56}{12}\,n\,\pi\,x^2$;
7. the amount of the counterweight $= \pi\,x^2\left(3\,p - \frac{56\,n}{12}\right)$;
8. the weight of the chain for the length $x = \frac{112}{800}\,p\,\pi\,x^2$.

If we reduce the weight of the gasholder, in its highest and lowest positions, to the height of a stratum of water equal to the surface of its top, this height is that of the column of water which would press the gas within the gasometer, were no counterweight employed; it consists as follows:—

9. for the highest position $= \frac{3p}{56}$;

10. for the lowest $= \frac{2{\cdot}72\,p}{50}$;

For the case when the height of the gasholder is different from its semi-diameter, let this height $= mx$; then the height of the water-level is

11. for the highest position $= p\left(\frac{1+2m}{56}\right)$;

12. for the lowest $= p\left(\frac{1+1{\cdot}72\,m}{6}\right)$;

13. the counterweight $= \pi x^2\left(p\,(1+2m)-\frac{56\,n}{12}\right)$;

14. the weight of the equalising chain $= \frac{112}{830}\,p\,\pi\,m\,x^2$.

For example, let the diameter of the gasholder be 30 feet, the height 15 (the contents in cubic feet will be 10,597), $p=4$ lbs.; then the counterweight for a height of 1½ inch of water-pressure = 3,532 lbs.; the weight of the chain for a length of 15 feet = 395 lbs. Were no counterweight employed, so that the gasholder pressed with its whole weight upon the gas, then the height of the equivalent column of water in its highest position = 2·56 inches; and in its lowest, 2·33. The counterweight may hence be lessened at pleasure, if the height of the pressing water column, *n*, be increased. The weight of the equalising or compensating portion of the chain remains the same. When $n=2$ inches, for instance, the counterweight = 1,886 lbs.

The velocity with which the gas passes along the mains for supplying the various jets of light may be further regulated by opening the main cock or slide valve in a greater or less degree.

Gasholders whose height is greater than their semi-diameter are not only more costly in the construction, but require heavier counterweights and equilibration chains.

The above estimate is made on the supposition of the gas in the gasholder being of the same specific gravity as the atmospherical air, which would be nearly true with regard to oil-gas under the ordinary pressure. But coal-gas, whose specific gravity may be taken on an average at about 0·5, exercises a buoyancy upon the top of the gasholder, which of course diminishes its absolute weight. Supposing the cubic foot of gas to be $=0{\cdot}0364$ lbs., the buoyancy will be $=3{\cdot}0364\,\pi x^3$ lbs., a quantity which deserves to be taken into account for large gasometers. Hence,

15. the weight of the gasholder in its highest position $= 3p\pi x^2 - 0{\cdot}1143\,x^3$;

16. the counterweight $= \pi x^2\left(3p-\frac{56\,n}{12}\right)-0{\cdot}1143\,x^2$;

17. the weight of the chain for the length $x, = \frac{112}{800\,p\pi}\,x^2\,\frac{0{\cdot}1143\,x^3}{2}$;

18. the weight of the water-pressure from the highest position, without the counterweight, $= \frac{3p\pi - 0{\cdot}1143\,x}{56\pi}$;

19. the same for the lowest position $= \frac{2{\cdot}72\,p}{56}$ in feet.

The preceding values of p and x, are,

(16) = 3147; (17) = 304; (18) = 2·44 inches; (19) = 2·33 inches.

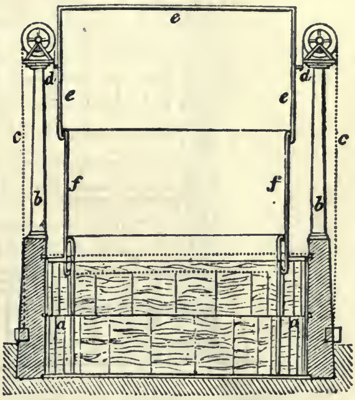
The water-columns in the highest and lowest situations of the gasholder here differ about 0·1 of an inch, and this difference becomes still less when p has a smaller value, for example, 3 lbs., or when the diameter of the gasholder is still greater.

It would thus appear that for coal-gasholders, in which the height of the gasholder does not exceed its semi-diameter, and especially when it has a considerable size, neither a compensation chain nor a counterweight is necessary. The only thing requisite is to preserve the vertical motion of the gasholder by a sufficient number of guide rods or pillars, placed either within the water cistern or round about it. Should the pressure of the gas in the pipe proceeding from the gasholder be less than in the gasholder itself, this may be regulated by the main valve, or by water valves of various kinds. Or, as is now usually done, a *governor* may be introduced between the great gasholder and the main pipe of distribution. With a diameter of 61 feet in the gasholder, the pressure in the highest and lowest positions is the same.

The gasholders employed in storing up gas until required for use, occupy, upon the old plan, much space, and are attended with considerable expense in erecting. The water-tank, whether sunk in the ground or raised, must be of equal dimensions with the gasholder, both in breadth and depth. The improved construction which we are about to describe, affords a means of reducing the depth of the tank, dispensing with the bridge of suspension, and of increasing at pleasure the capacity of the gasholder, upon a given base, thus rendering a small apparatus capable, if required, of holding a large quantity of gas, the first cost of which will be considerably less than even a small gasholder constructed upon the ordinary plan.

Mr. Tait, of Mile-End Road, the inventor, has, we believe, been for some years connected with gas-establishments, and is therefore fully aware of the practical defects or advantages of the different constructions of gasholders now in use. *Fig.* 1049 is a section of Mr. Tait's improved contrivance: *a a* is the tank, occupied with water; *b b* two iron columns with pulley wheels on the top; *c c* chains attached to a ring of iron, *d d*, extending round the gasholder, which chains pass over the pulley wheels, and are loaded at their extremities, for the purpose of balancing the weight of the materials of which the gasholder is composed.

1049.



The gasholder is formed by two or three cylinders, sliding one within the other, like the tubes of a telescope; *e e e* is the first or outer cylinder, closed at the top, and having the ring of iron, *d*, passing round it, by which the whole is suspended; *f f* is the second cylinder, sliding freely within the first, and there may be a third and fourth within these, if necessary.

When there is no gas in the apparatus, all the cylinders are slidden down, and remain, one within the other, immersed in the tank of water; but when the gas rises, through the water pressing against the top of the gasholder, its buoyancy causes the cylinder *e* to ascend. Round the lower edge of this cylinder a groove is formed by the turning-in of the plate of iron, and, as it rises, the edge takes hold of the top rim of the cylinder *f*, which is overlapped for that purpose. The groove at the bottom of the cylinder fills itself with water as it ascends, and, by the rim of the second cylinder falling into it, an air-tight hydraulic joint is produced.

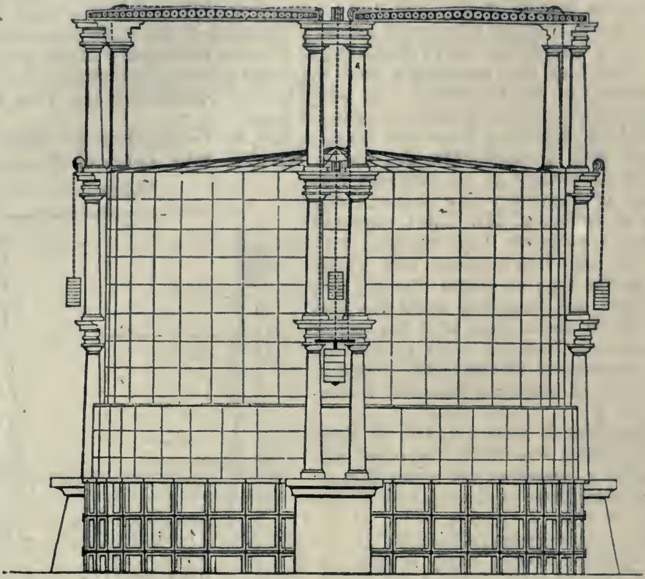
Thus several cylinders may be adapted to act in a small tank of water, by sliding one within the other, with lapped edges forming hydraulic joints, and, by supporting the apparatus in the way shown, the centre of gravity will always be below the points of suspension. A gasholder upon this plan may be made of any diameter, as there will be no need of frame-work or a bridge to support it; and the increasing weight of the apparatus, as the cylinders are raised one after the other, may be counterpoised by loading the ends of the chain *c c*.

Fig. 1050 is an elevation of a double or telescopic gasholder of a modern and approved form, with part of a tank.

The water in the gasholder need not be renewed; but merely so much of it as evaporates or leaks out is to be replaced. Indeed the surface of the water in the cistern gets covered with a stratum of coal-oil, a few inches deep, which prevents its evaporation, and allows the gas to be saturated with this volatile substance, so as to increase its illuminating power.

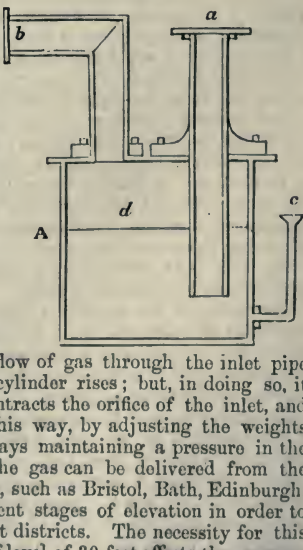
The gasholder may be separated from the purifier by an intermediate vessel, such as is represented by *fig.* 1051, with which the two gas-pipes are connected. A is the cylindrical vessel of cast iron, *a*, the end of the gas-pipe which comes from the purifier, immersed a few inches deep into the liquid with which the vessel is about two-thirds filled; *b* is the gas-pipe which leads into the gasholder, *c* is a perpendicular tube, placed over the bottom of the vessel, and reaching to within one-third of the top, through which the liquid is introduced into the vessel, and through which it escapes when it overflows the level *d*. In this tube the liquid stands towards the inner level higher, in proportion to the pressure of the gas in the gasholder. The fluid which is condensed in the gas-pipe *b*, and in its prolongation from the gasholder, runs off into the vessel A; and therefore the latter must be laid so low that the said tube may have the requisite declivity. A straight stopcock may also be attached to the side over the bottom, to draw off any sediment.

1050



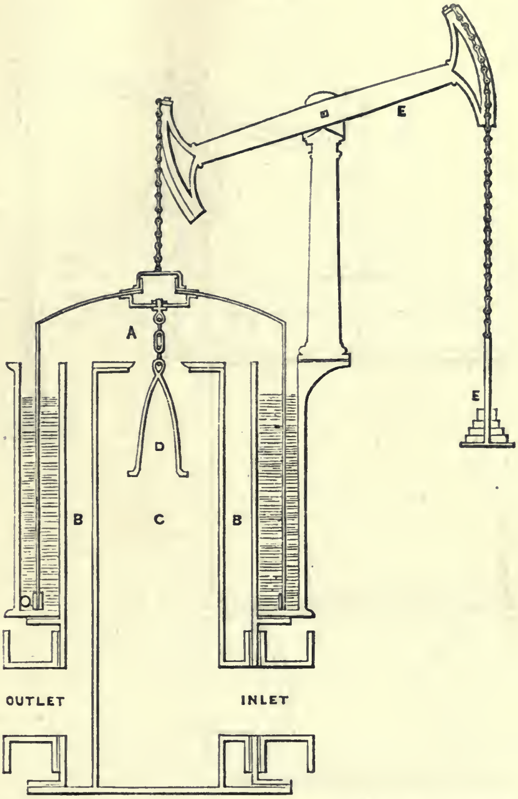
The governor.—Although the gasholder is, to a certain extent, a regulator of pressure, yet it is difficult, by its action alone, to maintain a pressure so steady and uniform as that required for the supply of gas consumers. It would be difficult, if not impossible, to alter the pressure upon the mains frequently during a single night, as is now usually done in towns with a large number of street lamps, without the intervention of an apparatus termed a *governor*. The governor, which occupies a position between the gasholder and supply mains, is a miniature gasholder A (see *figs.* 1052, 1053, and 1054, which represent Mr. Wright's improved governor), the interior of which, however, is nearly filled by the concentric inlet and outlet pipes B and C. Immediately over the mouth of the inlet pipe, and depending from the roof of the inner cylinder, is a parabolic piston D, which hangs within the contracted mouth of the inlet pipe C. The interior cylinder is counterpoised by the lever and weights E E. Now, when the pressure of gas in this small holder increases—that is, when the flow of gas through the inlet pipe exceeds that escaping from the outlet—the inner cylinder rises; but, in doing so, it carries with it the parabolic piston D, and thus contracts the orifice of the inlet, and consequently diminishes the ingress of gas. In this way, by adjusting the weights attached to the lever of the governor, and by always maintaining a pressure in the gasholder greater than is required in the mains, the gas can be delivered from the governor at any required pressure. In hilly towns, such as Bristol, Bath, Edinburgh, &c., it is necessary to employ governors at different stages of elevation in order to produce a tolerably uniform pressure in the different districts. The necessity for this will be obvious when it is stated that a difference of level of 30 feet affects the pressure of the gas in the mains to the extent of $\frac{2}{10}$ths of an inch of water.

1051

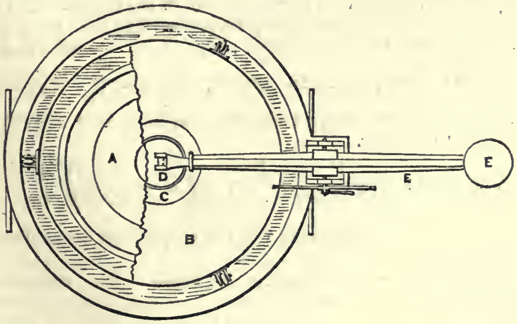


The gas mains.—The pressure by which the motion of the gas is maintained in the pipes is regulated by the governor. From the magnitude of this pressure, and the quantity of gas which in a given time, as an hour, must be transmitted through a certain length of pipes, depends the width or the diameter that the latter should have, in order that the motion may not be retarded by the friction which the gas, like all other fluids, experiences in tubes, whereby the gas might be prevented from issuing with the velocity required for the jets of flame. The velocity of the gas in the main pipe increases in the ratio of the square root of the pressing column of water upon the gasholder, and therefore by increasing this pressure the gas may be

1052

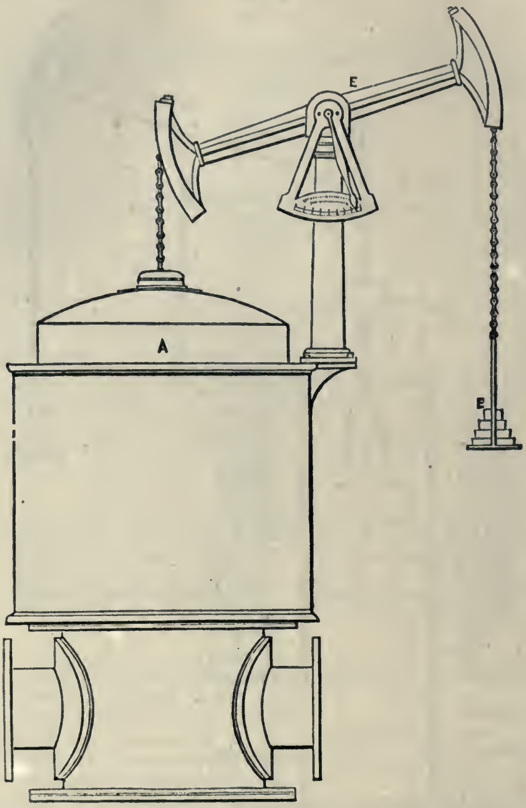


1053



forced more rapidly along the remoter and smaller ramifications of the pipes. Thus it happens, however, that the gas will be discharged from the orifices near the gasholder with superfluous velocity. It is therefore advisable to lay the pipes in such a manner, that in every point of their length, the velocity of discharge may be nearly equal. This may be nearly effected as follows :—

1054



From experiment it appears that the magnitude of the friction, or the resistance which the air suffers in moving along the pipes, under a like primary pressure, that is for equal initial velocity, varies with the square root of the length. The volume of gas discharged from the end of a pipe is directly proportional to the square of its diameter, and inversely as the square root of its length; or, calling the length L, the diameter D, the cubic feet of gas discharged in an hour k; then $k=\frac{D^2}{\sqrt{L}}$. Experience likewise shows, that for a pipe 250 feet long, which transmits in an hour 200 cubic feet of gas, one inch is a sufficient diameter.

$$\text{Consequently, } 200 : k :: \frac{1}{145\sqrt{250}} : \frac{D^2}{\sqrt{L}}; \text{ and } D = \frac{\sqrt{k\sqrt{L}}}{455{,}000}$$

From this formula the following table of proportions is calculated :—

Number of cubic feet per hour	Length of pipe, in feet	Diameter, in inches
50	100	0·40
250	200	1·00
500	600	1·97
700	1000	2·65

Number of cubic feet per hour	Length of pipe, in feet	Diameter, in inches
1000	1000	3·16
1500	1000	3·87
2000	1000	4·47
2000	2000	5·32
2000	4000	6·33
2000	6000	7·00
6000	1000	7·75
6000	2000	9·21
8000	1000	8·95
8000	2000	16·65

These dimensions are applicable to the case where the body of gas is transmitted through pipes without being let off in its way by burners, that is, to the mains which conduct the gas to the places where it is to be used. If the main sends off branches for burners, then for the same length the diameter may be reduced, or for like diameter the length may be greater. For example, if a pipe of 5·32 inches which transmits 2,000 cubic feet through a length of 2,000 feet, gives off, in this space, 1,000 cubic feet of gas; then the remainder of the pipe, having the same diameter, can continue to transmit the gas through a length of 2,450 feet $=\left(\frac{450{,}000}{k}\right)^2$, with undiminished pressure for the purposes of lighting. Inversely, the diameter should be progressively reduced in proportion to the number of jets sent off in the length of the pipe.

Suppose, for instance, the gasholder to discharge 2,000 cubic feet per hour, and the last point of the jets to be at a distance of 4,000 feet. Suppose also that from the gasholder to the first point of lighting, the gas proceeds through 1000 feet of close pipe the diameter of the pipe will be here 4·47 inches; in the second 1,000 feet of length, suppose the pipe to give off, at equal distances, 1,000 cubic feet of gas, the diameter in this length (calculated at 1,500 cubic feet for 1,000 feet long) = 3·87 inches; in the third extent of 1,000 feet, 600 cubic feet of gas will be given off, and the diameter (reckoning 700 cubic feet for 1,000 feet long) will be 2·65 inches; in the fourth and last space (for 200 cubic feet in 1,000 feet long) the pipe has a diameter of only an inch and a half, for which, in practice, a two-inch cast-iron pipe is substituted; this being the smallest used in mains, into which branch pipes can be conveniently inserted.

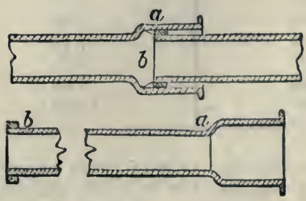
The same relations hold with regard to branch pipes through which the gas is transmitted into buildings and other places to be illuminated. If such pipes make frequent angular turnings, whereby they retard the motion of the gas, they must be a third or a half larger in diameter, The smallest tubes of distribution are never less than one fourth of an inch in the bore.

Where, from one central gas-work, a very great quantity of light is required in particular localities, there ought to be placed near these spots gasholders of distribution, which being filled during the slack hours of the day are ready to supply the burners at night without making any considerable demand upon the original main pipe. Suppose the first main be required to supply 8,000 cubic feet in the hour, for an illumination of 8 hours, at the distance of 2,000 feet, a pipe 10⅜ inches in diameter would be necessary; but if two or three gasholders of distribution, or station gasholders be had recourse to, into which the gas during the course of 24 hours would flow through the same distance continuously from the central gas-works, the quantity required per hour from them would be only one third of 8,000 = 2666·6 cubic feet; consequently, the diameter for such a pipe is only 6·15 inches.

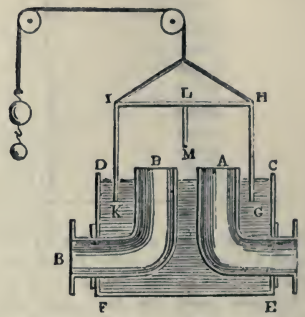
All the principal as well as branch pipes, whose interior diameter exceeds an inch and a half, are made of cast iron, from 6 to 8 feet long, with elbow pipes cast in them where it is necessary. These pipe-lengths are shown in *fig.* 1055, having at one end a wide socket *a*, and at the other a nozzle *b*, which fits the former. After inserting the one in the other in their proper horizontal position, a coil of hemp, soaked with tar is driven home at the junction; then a luting of clay is applied at the mouth, within which a ring of lead is cast into the socket, which is driven tight home with a mallet and blunt chisel.

The pipes should be proved by a force-pump before being received into the gas-works; two or three lengths of them should be joined before laying them down, and they should be placed at least two feet below the surface, to prevent their being affected by changes of temperature, which would loosen the joints. The tubes for internal distribution, when of small size, are made of lead, copper, wrought iron, or tin.

1055



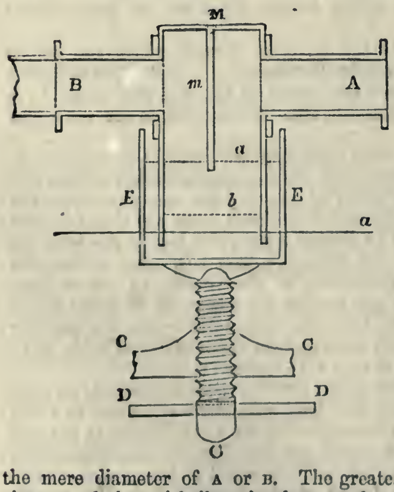
1056



Instead of a stopcock for letting-off the gas in regulated quantities from the gasholder, a peculiarly-formed water or mercurial valve is usually employed. *Fig.* 1056 shows the mode of construction for a water trap or lute, and is, in fact, merely a gasholder in miniature. C D E F is a square cast-iron vessel, in the one side of which a pipe A is placed in communication with the gasholder, and in the other, one with the main B. The moveable cover or lid H G I K has a partition, L M, in its middle. If this cover be raised by its counterweight, the gas can pass without impediment from A to B; but if the counterweight be diminished so as to let the partition plate L M sink into the water, the communication of the two pipes is thereby interrupted. In this case the water-level stands in the compartment A so much lower than outside of it, and in the compartment B, as is equivalent to the pressure in the gasometer; therefore the pipes A and B must project thus far above the water. In order to keep the water always at the same height, and to prevent it from flowing into the mouths of these pipes, the rim C D of the outer vessel stands somewhat lower than the orifices A B; and hence the vessel may be kept always full of water.

If a quicksilver valve be preferred, it may be constructed as shown in *fig.* 1057. A B are the terminations of the two gas-pipes, which are made fast in the rectangular iron vessel M. E is an iron vessel of the same form, which is filled with quicksilver up to the level *a*, and which, by means of the screw G, which presses against its bottom, and works in the fixed female screw C C, may be moved up or down so that the vessel M may be immersed more or less into the quicksilver. The vessel M is furnished with a vertical partition *m*; the passage of the gas from A to B is therefore obstructed when this partition dips into the quicksilver, and from the gradual depression of the vessel E by its screw, the interval between the quicksilver and the lower edge of the partition, through which the gas must enter, may be enlarged at pleasure, whereby the pressure of the gas in B may be regulated to any degree. The transverse section of that interval is equal to the area of the pipe, or rather greater; the breadth of the vessel M, from A to B, amonnts to the double of that space, and its length to the mere diameter of A or B. The greatest height to which the partition *m* can rise out of the quicksilver is also equal to the above diameter, and in this case the line *a* comes to the place of *b*. The vertical movement of the outer vessel E is secured by a rectangular rim or hoop which surrounds it, and is made fast to the upper part of the vessel M, within which guide it moves up and down. Instead of the lever D D, an index with a graduated plate may be employed to turn the screw, and to indicate exactly the magnitude in the opening of the valve.

1057



GAS-ENGINE (*Lenoir's patent*).—From time to time various forms of explosive engines have been introduced. Lenoir's is one of this description which has engaged the public attention; it differs in principle but little from those gas-engines by which it has been preceded.

It resembles a horizontal steam-engine in outward appearance, but the motive power is obtained by exploding a mixture of coal-gas and air on each side of the piston. The explosion is effected by means of a small galvanic battery, which is alternately put in circuit with wires at either end of the cylinder by means of an insulated conductor sliding on the cross head of the piston. Two slide valves are employed, driven by excentrics in the usual manner; one serving for the admission of the mixed gases, whilst the other covers the ports, for the removal of the gases produced by the explosion. The cylinder is kept cool by a current of water, which circulates about its outer surface.

From a report on the mechanical effect produced by this engine, published by M. Tresca, the following data have been obtained:—

The hourly consumption of gas per effective H. P. is 101·7 cubic feet. The ignition of the gases in the interior of the cylinder is effected at a temperature of 536° Fahr. and 175 gallons of water, at 64° Fahr. are employed per hour in cooling the cylinder, the temperature being raised by the contact of the heated metal to 105° Fahr.

It will therefore be seen that there is no economy to be obtained from the use of this engine in the place of steam-power, but it may be conveniently employed for the production of a small power in places where it is considered desirable to dispense with the use of steam boilers. Another, and perhaps more formidable objection, is pointed out by M. Tresca in the fact, that a trace of nitric acid is invariably found in the products of the explosion, which results from the oxidation of a minute quantity of the nitrogen in the air employed, and which is likely to exert a destructive influence on the interior of the cylinder.

The gas-engine known as the *moteur Lenoir*, which was imagined at the commencement of the present century by an engineer named Lebon, was intended to supply motive power in small workshops; the Lenoir engine has answered the end for which it was invented, and has carried motive power into the very residence of the workman. The Lenoir engine has no boiler; it is fed by a current of ordinary gas, mixed with a certain amount of air; an electric spark, produced from a Ruhmkorff coil, excited by the machine itself, sets fire to the mixture, and the heat which results is the true motive power of the engine. The Lenoir engines are of the force of one-half to three-horse and they occupy little space; amongst their advantages are, that they can be started and stopped instantaneously, and present no danger from explosion or fire. They require to be kept, however, in perfect condition, otherwise they are liable to sudden and apparently unaccountable stoppages.

With regard to their economy, according to experiments made with an engine having a cylinder 0·24 meter in diameter, and a stroke of 0·12 meter, the gas used amounted to from 2,699 to 5,352 litres per horse per hour, but the consumption in regular working is about 2,700 litres. The most economical employment corresponded with a little less than the force of one horse, the speed of the flywheel being 107 revolutions per minute. The consumption of water was equal to 120 litres per horse per hour; this water left the cylinder at a temperature inferior to 100° C.

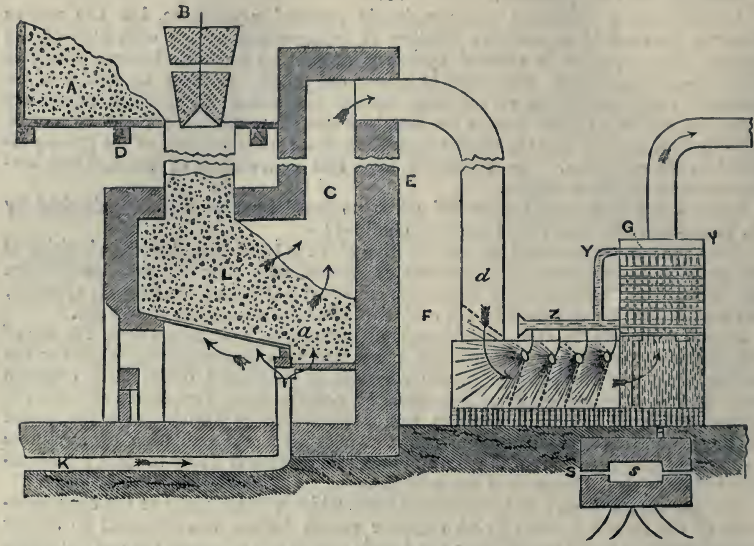
There is another class of machines about which a few words should be said; their applications are not yet numerous, but they doubtless have a great future before them; these are compressed air-engines which allow of work being carried on at the depth of thirty to forty meters below water, and even deeper, for the establishment of the tubular foundations of bridges, and for other purposes. The piercement of Mont Cenis offers an admirable example of the new and important means of employment of compressed air. The works of the grand Alpine tunnel have shown with what facility air compressed under six or seven atmospheres can be conveyed through pipes to great distances, as far as five miles or more, without any sensible loss of pressure to work motive machines similar to ordinary steam-engines. See AIR-ENGINE.

These results are very important, and may contain the germs of the solution of the problem of distributing motive power wherever it is required in towns. We have spoken of the Lenoir engine, but in spite of many improvements introduced into gas motors, they still have their inconveniences; their power, at the same time, is very limited.

GAS-FURNACE. *Lundin's Gas-Furnace.*—Puddling with wood is practised to a considerable extent in Sweden, the best furnace being that of F. Lundin, of Carlstadt Munkfors, *fig.* 1058, designed for the consumption of turf and peat without drying, and of wet sawdust or other moist fuel. A *fig.* 1058, is a pile of green sawdust; B, hopper and cone; D, gas generator for green sawdust; G, condenser; K, air blast; S, chimney, 43 feet high; Y Y, 3,500 lbs. of iron in bars, cooled by the water from pipe

Y Y, to cool the gas and precipitate the water; L sawdust containing 45 per cent. of water; Z water at 2°; at *s* the temperature is 300°, at *d* 350°, at C 400° to 450° C.

1058



The temperature used to burn the gas, calculated from the cold air, is about 2000° C.

At R lead melts slowly; at F lead melts easily; at E zinc sometimes melts.

The gas, before condensation, contains 33 parts by weight of water to 100 of dry gas.

Constituents of Gas.

11·8 vol.	carbonic acid	19·6 weight.
19·8 „	„ oxide	20·8 „
11·3 „	hydrogen	0·87 „
4·0 „	marsh gas	2·4 „
53·1 „	nitrogen	56·3 „

The furnace may be placed at a long distance from the condenser.

In this furnace the fuel is fed by a hopper into a reservoir, resting upon an inclined grate, supplied from below with air from a blower. The products of combustion thus produced pass through a condenser, where all the moisture in the gas is condensed. The gas then passes to the heating furnace, which is furnished with Siemens' regenerators. It is found easy to use fuel containing as much as 45 per cent of water, and the resulting gas contains about 33 lbs. of water to 100 lbs. of dry gas, whilst the water, after condensation, contains about 2 per cent. of its weight in gas, and 3 per cent. of its volume. The condensing apparatus consists of 3,500 lbs. of iron bars piled crosswise on each other, and kept cold by a jet of water from a tuyère. The heat of the gas before condensation of the water always melts lead easily, and sometimes zinc. In the Elkman furnace dry wood containing 8 per cent. of water produces in the generators gas of a temperature of 1394°, while in the Lundin furnace the temperature is 2666°, the combustion in both cases being produced by cold air. The gas produced by seasoned wood contains more water than that which proceeds from the Lundin condenser. The duration of the furnace is very remarkable, and is to be attributed probably to the fact that there is no cinder. In eight weeks the thickness of the roof, 4 in., was only diminished from $\frac{1}{4}$ to $\frac{3}{8}$ in., and the side walls were entirely uninjured. So great is the success of this system of condensation, in connection with the Siemens' regenerators, that in Sweden, and in fact everywhere where moist fuel is employed, the Lundin furnace will supersede every other. Abram S. Hewitt considers that it is available for any kind of fuel whatever.

Siemens' patent Regenerative Gas-Furnaces.—The advantagesof the regenerative gas-furnaces are stated to be—

1.—Saving of fuel, amounting to from 40 to 50 per cent. in the quantity, besides which, the most inferior qualities of fuel, such as slack, coke-dust, lignite, and peat, may be employed, producing a money saving, in many instances, amounting to 75 per cent.

2.—Increase of work done per day in a furnace of given dimensions amounting to 30 per cent. or more, owing to unlimited command of heat with low chimney-draught.

3.—Great purity and gentleness of flame, which greatly diminishes the oxidation, or deterioration, of the material heated in the furnace.

4.—Increased durability of furnace, owing to the absence of ashes, and a perfect uniformity of heat throughout the furnace.

5.—Saving of space within the works, and great cleanliness of operation, the fuel being converted into gas outside the works.

6.—Complete command of the intensity of the heat, and of the chemical nature of the flame, which may be arrested or changed from a reducing to an oxidising flame, or the reverse, at any one moment, tending to facilitate and improve all metallurgical operations.

7.—Complete absence of smoke from the stack, which renders this furnace beneficial to the public in large towns.

The late Professor Faraday, in his last public lecture at the Royal Institution, on the 20th June 1862, described these furnaces in the following terms:—

'The gaseous fuel is obtained by the mutual action of coal, air, and water, at a moderate red heat. A brick chamber, perhaps 6 ft. by 12 ft., and about 10 ft. high, has one of its end walls converted into a fire-grate, *i.e.*, about half-way down it is a solid plate, and for the rest of the distance consists of strong horizontal plate bars where air enters, the whole being at an inclination such as that which the side of a heap of coals would naturally take. Coals are poured, through openings above, upon this combination of wall and grate, and being fired at the under surface, they burn at the place where the air enters; but as the layer of coal is from 2 to 3 feet thick, various operations go on in those parts of the fuel which cannot burn for want of air. Thus the upper and cooler part of the coal produces a large body of hydrocarbons; the cinders or coke which are not volatilised, approach, in descending, towards the grate; that part which is nearest the grate burns with the entering air into carbonic acid, and the heat evolved ignites the mass above it; the carbonic acid, passing slowly through the ignited carbon, becomes converted into carbonic oxide, and mingles in the upper part of the chamber (or gas-producer) with the hydrocarbons. The water, which is purposely introduced at the bottom of the arrangement, is first vaporised by the heat, and then decomposed by the ignited fuel, and re-arranged as hydrogen and carbonic oxide; and only the ashes of the coal are removed as solid matter from the chamber at the bottom of the fire-bars.

'These mixed gases form the gaseous fuel. The nitrogen, which entered with the air at the grate, is mingled with them, constituting about a third of the whole volume. The gas rises up a large vertical tube, for 12 or 15 feet, after which it proceeds horizontally for any required distance, and then descends to the heat regenerator, through which it passes before it enters the furnaces. A regenerator is a chamber packed with fire-bricks, separated so as to allow of the free passage of air or gas between them. There are four placed under a furnace. The gas ascends through one of these chambers, whilst air ascends through the neighbouring chamber, and both are conducted through passage-outlets at one end of the furnace, where mingling, they burn, producing the heat due to their chemical action. Passing onwards to the other end of the furnace, they (*i.e.*, the combined gases) find precisely similar outlets down which they pass; and traversing the two remaining regenerators from above downwards, heat them intensely, especially the upper part, and so travel on in their cooled state to the shaft or chimney. Now the passages between the four regenerators and the gas and air are supplied with valves and deflecting plates, which are like four-way cocks in their action; so that by the use of a lever those regenerators and air-ways, which were carrying off the expended fuel, can in a moment be used for conducting air and gas into the furnace; and those which just before had served to carry air and gas into the furnace, now take the burnt fuel away to the stack. It is to be observed that the intensely-heated flame which leaves the furnace for the stack always proceeds downwards through the regenerators, so that the upper part of them is most intensely ignited, keeping back as it does, the intense heat; and so effectual are they in this action, that the gases which enter the stack to be cast into the air are not usually above 300° Fahr. of heat. On the other hand, the entering gas and air always pass upwards through the regenerators, so that they attain a temperature equal to a white heat before they meet in the furnace, and there add to the carried heat that due to their mutual chemical action. It is considered that when the furnace is in full order, the heat carried forward to be evolved by the chemical action of combustion is about

4000°, whilst that carried back by the regenerator is about 3000°, making an intensity of power which, unless moderated on purpose, would fuse furnace and all exposed to its action.

'Thus the regenerators are alternately heated and cooled by the outgoing and entering gas and air, and the time for alteration is from half an hour to an hour, as observation may indicate. The motive power on the gas is of two kinds: a slight excess of pressure within is kept up from the gas-producer to the bottom of the regenerator to prevent air entering and mingling with the fuel before it is burnt; but from the furnace, downward through the regenerators, the advance of the heated medium is governed mainly by the draught in the tall stack or chimney.

'Great facility is afforded in the management of these furnaces. If, whilst glass is in the course of manufacture, an intense heat is required, an abundant supply of gas and air is given; when the glass is made, and the condition has to be reduced to working temperature, the quantity of fuel and air is reduced. If the combustion in the furnace is required to be gradual from end to end, the inlets of air and gas are placed more or less apart the one from the other. The gas is lighter than the air; and if a rapid evolution of heat is required, as in a short puddling furnace, the mouth of the gas-inlet is placed below that of the air-inlet; if the reverse is required, as in the long tube-welding furnace, the contrary arrangement is used. Sometimes, as in the enameller's furnace, which is a long muffle, it is requisite that the heat be greater at the door-end, because the goods, being put in and taken out at the same end, those which enter last, and are withdrawn first, remain, of course, for a shorter time in the heat at the end; and though the fuel and air enter first at one end and then at the other alternately, still the necessary difference of temperature is preserved by the adjustment of the apertures at the ends.

'Not merely can the supply of gas and air to the furnace be governed by valves in the passages, but the very production of the gas fuel itself can be diminished, or even stopped, by cutting off the supply of air to the grate of the gas-producer; and this is important, inasmuch as there is no gasometer to receive and preserve the aeriform fuel, for it proceeds at once to the furnaces.

'Some of the furnaces have their contents open to the fuel and combustion, as in the puddling and metal-melting arrangements; others are enclosed, as in the muffle furnaces and flint-glass furnaces.

'The economy in the fuel is estimated practically as one-half, even when the same kind of coal is used either directly for the furnace or for the gas-producer; but, as in the latter case, the most worthless kind can be employed—such as slack, &c., which can be converted into a clean gaseous fuel at a distance from the place of the furnace, so, many advantages seem to present themselves in this part of the arrangement.'

Professor Faraday concludes his lecture with the following conclusive figures:—

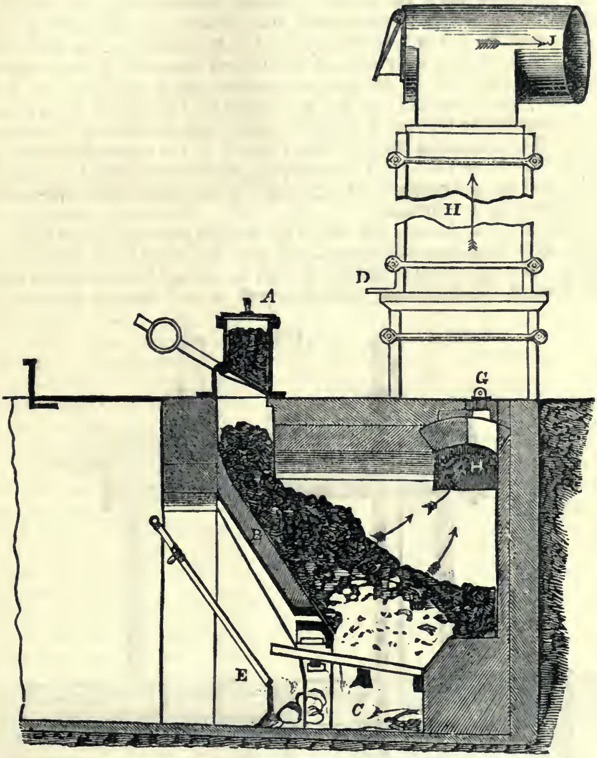
'Carbon burnt perfectly into carbonic acid in a gas-producer would evolve about 4000° of heat; but, if burnt into carbonic oxide, it would only evolve 1200°. The carbonic oxide, in its fuel form, carries on with it the 2800° in chemical force, which evolves when burning in the real furnace with a sufficient supply of air. The remaining 1200° are employed in the gas-producer in distilling hydrocarbons, decomposing water, &c. The whole mixed gaseous fuel can evolve about 4000° in the furnace, to which the regenerator can return about 3000° more.'

The following is a brief description of the regenerative gas-furnaces:—

The gas-producer is shown in *fig.* 1059. The producers are entirely separate from the furnace where the heat is required, and may be made sufficient in number and capacity to supply several furnaces. The fuel is supplied, at intervals of from two to four hours, through the charging boxes A, *fig.* 1059, and descends gradually on the inclined plane B, which is set at an inclination to suit the fuel used. The upper portion of the incline B is made solid, being formed of iron plates covered with firebricks; but the lower portion C is an open grate formed of horizontal flat steps. The large opening under the lowest flat step is convenient for drawing out clinkers, which generally collect at that point. The small stoppered holes F at the front, and G at the top of the producer, are provided to allow of putting in an iron bar occasionally to break up the mass of fuel and detach clinkers from the side walls. Each producer is capable of converting daily about two tons of fuel into a combustible gas, which passes off through the uptake H leading to the furnaces.

The action of the gas-producer in working is as follows:—The fuel descending slowly on the solid portion B of the inclined plane becomes heated, and parts with its volatile constituents, the hydrocarbon gases, water, ammonia, and some carbonic acid, which are the same as would be evolved from it in a gas-retort. There now remains from 60 to 70 per cent. of purely carbonaceous matter to be disposed of, which is accomplished by the current of air slowly entering through the grate C, producing regular combustion immediately upon the grate; but the carbonic acid (a non-combustible gas) thereby produced, in passing slowly on through a layer of incandescent fuel from 2 to 3 feet thick, takes up another equivalent of carbon, and is thus transformed into carbonic oxide (an inflammable gas), which passes off with the other combustible gases to the furnace. For every cubic foot or combustible carbonic oxide thus produced, taking the atmosphere to consist of 1-5th part by volume of oxygen and 4·5ths of nitrogen, two cubic feet of incombustible nitrogen pass also through the grate, tending greatly to diminish the richness or heating power of the gas. Not all the carbonaceous portion of the fuel is, however, volatilised on such disadvantageous terms; for water is brought to the foot of the grate by the pipe E, which, absorbing the spare heat from the fire, is converted into steam; and each cubic foot of steam in traversing the layer of from 2 to 3 feet of incandescent fuel is decomposed into a mixture consisting of one cubic foot of hydrogen and nearly an equal volume of carbonic oxide, with a variable small proportion of carbonic acid. Thus one cubic foot of steam yields as much inflammable gas as five cubic feet of atmospheric air; but the one operation is dependent upon the other, inasmuch as the passage of air through the fire is attended with the generation of heat, whereas the production of the water-gases, as well as the evolution of the hydrocarbons, is carried on at the expense of heat. The generation of steam from the water being dependent on the amount of heat in the fire, regulates itself naturally to the requirements; and the total production of combustible gases varies with the admission of air. And since the admission of air into the grate depends in its turn upon the withdrawal of the gases evolved in the producer, the production of the gases is entirely regulated by the demand for them. The production of gas may even be arrested entirely for twelve hours without deranging the producer, which will begin work again as soon as the gas-valve of the furnace is re-opened; since the mass of fuel and brickwork retain sufficient heat to keep up a dull red heat in the producer during that interval. The gas is, however, of a more uniform quality when there is a continuous demand for it, and for this reason it is best to supply several furnaces from a nest of gas-producers so as to keep them constantly at work. A damper D, shown

1059

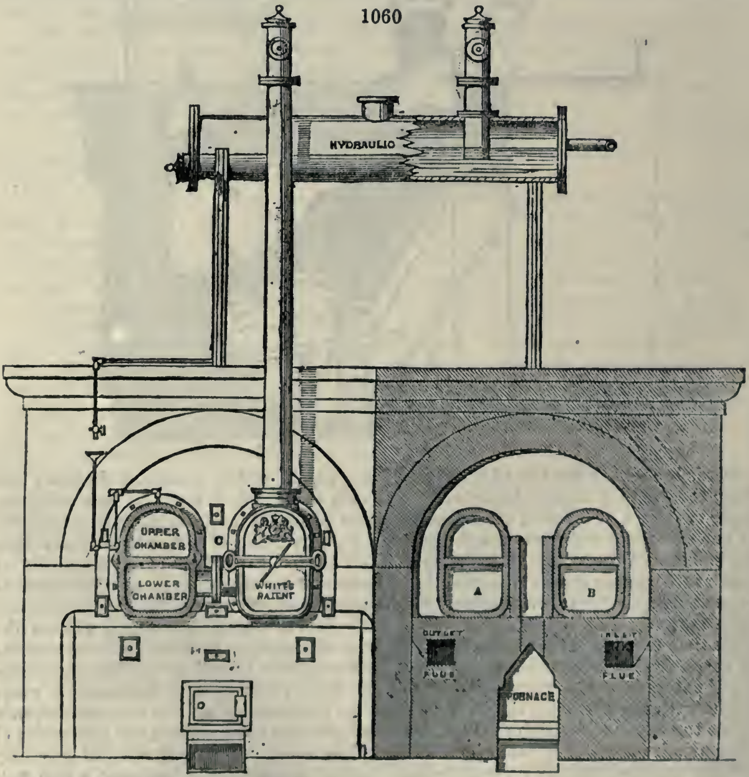


in *fig.* 1059, can be inserted in the uptake so as to shut off any gas-producer at pleasure.

It is important that the main gas-flue leading to the furnaces should contain an excess of pressure, however, slight, above the atmosphere, in order to prevent any inward draught of air through crevices, which would produce a partial combustion of the gas, and diminish its heating power in the furnace, besides causing a deposit of soot in the flues. It is therefore necessary to deliver the gas into the furnace without depending upon the chimney-draught for that purpose. This can be easily accomplished when the gas-producers are placed at a lower level than the furnaces; but as that is not always practicable, the following plan has been adopted. The mixture of gases on leaving the producers has a temperature ranging between 300° and 400° F., which must under all circumstances be sacrificed, since it makes no difference to the result at what temperature the gas to be heated enters the regenerators, the final temperature being in all cases very nearly that of the heated chamber of the furnace, or say 2500° F. The initial heat of the gas is therefore made available for producing a plenum of pressure by making the gas rise about 20 feet above the producers, then carrying it horizontally through a wrought-iron tube J, and letting it again descend to the furnace. The horizontal tube J, being exposed to the atmosphere, causes the gas to lose from 100° F. to 150° F. of temperature, which increases its density from 15 to 20 per cent., and gives a preponderating weight to that extent to the descending column, urging it forward to the furnace.

The regenerative gas-furnace consists of the heating chamber, below which are placed four regenerative chambers, which are filled with firebricks built up with spaces between them. The regenerative chambers work in pairs; the two under the left-hand end of the furnace communicating with that end of the heating chamber, while the other two communicate with the opposite end. The gas enters the heating chamber through one passage, and the air through the other passage whereby they are kept separate up to the moment of entering the heating chamber, but are then able immediately to mingle intimately, producing at once an intense and uniform flame.

1060



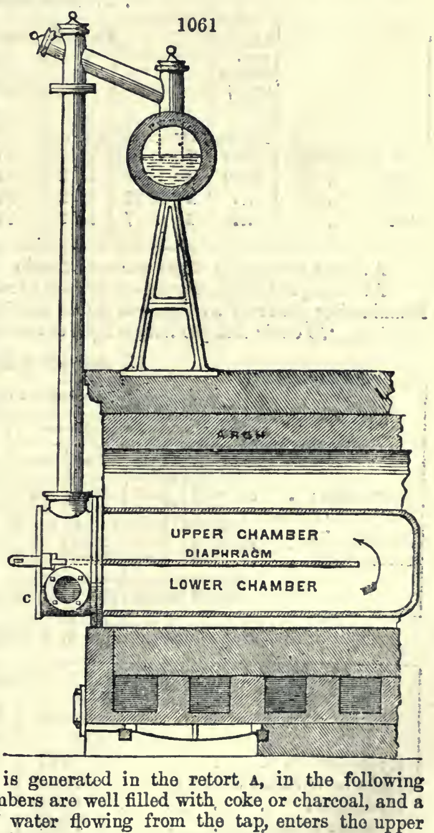
From the air-flue, the entering air is directed by the reversing valve into the air-regenerator, and there becomes heated ready for entering the furnace; at the same time the gas entering from the gas-flue is directed by the reversing valve into the gas-regenerator, where it also becomes heated to the same temperature as the air.

The products of combustion, on leaving the opposite end of the furnace, pass down through the second pair of regenerators (as shown by the arrows), and after being there deprived of their heat, are directed by the reversing valves into the chimney flue. When the second pair of regenerators have become considerably heated by the passage of the hot products of combustion, and the first pair correspondingly cooled by the entering gas and air, the valves are reversed by hand-levers, causing the currents to pass through the regenerators in the contrary direction, whereby the hot pair of regenerators are now made use of for heating the gas and air entering the furnace, while the cool pair abstract the heat from the products of combustion escaping from the furnace. The supply of gas and air to the furnace is regulated by the adjustable stop-valves, whereby the nature and volume of the flame in the furnace may be varied at pleasure, whilst a chimney damper is used to regulate the amount of pressure in the furnace in relation to the atmosphere, so as to allow the opening of the doors or working holes of the furnace.

For a further description of the applications of this gas-furnace and the regenerative system as applied in the Iron manufacture, see Iron and Steel.

GAS, HYDROCARBON. This title has been given to illuminating gas manufactured according to a patent granted some years ago to Mr. White of Manchester. The process of manufacture consists essentially in the generation of non-illuminating combustible gases by the action of steam upon charcoal, coke, or other deoxidising substances, in a separate retort, and the introduction of these gases, technically called water-gas, into the retort in which the illuminating gases are being generated, and in such a manner that these latter gases shall be swept out of the retort as rapidly as possible, so as to remove them from the destructive influence of a high temperature.

1061



The retorts used for the hydrocarbon-gas process may be of various shapes and sizes. The settings are similar to those for the ordinary retorts, and any number which is necessary may be placed in an oven. They differ only from the ordinary retorts by having a horizontal partition, or diaphragm, cast in the centre, dividing the retort into two chambers, and extending to within 12 inches of the back. This diaphragm is found in practice to strengthen the sides of the retorts, and thus to add to their durability. The water-gas retorts may be cast from the same pattern as the cannel retorts, and may be set in exactly the same manner. *Figs.* 1060 and 1061 represent a setting of two retorts in one oven, and show the same in elevation, transverse section, and longitudinal section. The retorts here shown have an internal cubical capacity of about 16 feet, and the bed of two is capable of producing about 10,000 cubic feet per diem of hydrocarbon-gas. The temperature at which the retorts are worked is about the average. The water-gas is generated in the retort A, in the following manner:—The upper and lower chambers are well filled with coke or charcoal, and a a very fine stream, or rapid drops of water flowing from the tap, enters the upper chamber through the siphon pipe, falling into a small steam-generating tube, which is placed inside to receive it, and instantly converts it into steam. The vapour, in passing backwards along the upper chamber, and forwards along the lower one, becomes to a great extent decomposed into hydrogen, carbonic oxide, and carbonic acid gases. The water-gas generated in the retort A, as described above, enters the lower chamber of the retort B, through the connecting pipe C C, cast on the mouthpiece. In the chambers of this retort the illuminating gas is generated, either from coal, cannel, resin, or other suitable material, and being rapidly carried forward by the current of water-gas, its illuminating principles are preserved from the destruction caused by prolonged contact with the incandescent surfaces in the retort, whilst at the same time its volume is increased. When very rich cannels or other materials are used, two, three, or even four water-gas retorts are made to discharge their gas into the cannel retort.

The hydrocarbon process has hitherto been applied only to resin, coals, and cannels. The following is a brief summary of the results of a series of experiments made by Dr. Frankland on the manufacture of hydrocarbon resin-gas. Each hundredweight of resin was dissolved by heat in 7½ gallons of the resin-oil of a former working, and the liquid, whilst still hot, was run into one of the retorts, by means of a siphon tube, in a stream about the thickness of a crowquill, whilst water-gas generated in the second retort, was admitted, as described above. The mixed gases were then made to stream through the usual form of condensing apparatus, and were afterwards compelled to pass successively through wet and dry lime-purifiers before they reached the gasholder. In order to secure a uniform mixture of the gas produced in each experiment, it was allowed to remain at rest in the gasholder for at least twelve hours before a specimen was withdrawn for analysis.

In the following Tables both the practical and analytical results are given.

I. *Practical Results.*

	Average evolution of gas per hour	MATERIALS CONSUMED									PRODUCTS OBTAINED		
		Resin			Coal		Charcoal	Lime	Water		Resin-oil	Gas	Gas per cwt. of resin
	cub. ft.	cwt.	qr.	lb.	cwt.	qr.	lb.	lb.	lb.		gals.	cb.ft.	
1st Experiment	930	2	1	17½	1	2	10	20	73		10·7	3340	1388
2nd ,,	1000	2	1	18	1	2	12	20	77		7·8	3800	1576
3rd ,,	...	2	0	17	1	2	12	28	85		4·5	4157	1932
4th ,,	...	2	0	7	1	2	10	28	62½		8·75	3090	1520

Average production of gas per ton of resin . . . 32,080 cubic feet.
Average production of resin-oil per ton of resin . . 70·3 gallons.
Illuminating power of average gas before purification, as ascertained by shadow test, ·75 cubic feet per hour = light of one short six spermaceti candle.

II. *Analytical Results.*

	COMPOSITION OF GAS BEFORE PURIFICATION								
	Actual amount in cubic feet				Per-centage amount				
	1st exp.	2nd exp.	3rd exp.	4th exp.	1st exp.	2nd exp.	3rd exp.	4th exp.	Average
Hydrocarbons . .	258·7	269·0	305·7	254·0	7·75	7·08	7·41	8·22	7·62
Light carbd. hydrogen	587·5	1527·7	895·9	961·0	17·58	40·20	21·71	31·09	27·64
Hydrogen . . .	1315·3	1274·8	1976·2	1297·8	39·38	33·54	47·90	42·06	40·72
Carbonic oxide . .	967·9	319·2	753·3	463·5	28·98	8·40	18·26	15·04	17·67
Carbonic acid . .	210·6	409·5	194·9	113·7	6·31	10·78	4·72	3·59	6·35
	3340·0	3800·2	4126·0	3090·0	100·00	100·00	100·00	100·00	100·00

Amount of carbon-vapour contained in 1 volume of hydrocarbons = 2·8 volumes.

	Composition of gas after purification				
	1st exp.	2nd exp.	3rd exp.	4th exp.	Average
Hydrocarbons	8·27	7·94	7·78	8·53	8·13
Light carburetted hydrogen .	18·76	45·06	22·79	32·25	29·71
Hydrogen	42·03	37·59	50·27	43·62	43·38
Carbonic oxide	30·93	9·41	19·16	15·60	18·78
	100·00	100·00	100·00	100·00	100·00

Specific gravity of average gas before purification = ·65886.
" " " after " = ·59133.

	Value of hydrocarbons expressed in their equivalent volume of olefiant gas	
	Value of actual amount	Value of percentage amount in purified gas
	cubic feet	cubic feet
1st experiment	362·2	11·58
2nd "	376·6	11·12
3rd "	428·0	10·89
4th "	...	11·94

This process is especially adapted for the manufacture of gas on a small scale, as in private houses or small manufactories. The necessary operations involve little trouble and unpleasant effluvia.

Dr. Frankland has also investigated the hydrocarbon process as applied to coals and cannels, and the following is a tabulated summary of his experimental results :—

Summary of Experimental Results.

Name of Coal	Cubic feet of gas per ton		Illuminating power per ton in sperm candles		Gain per ton by White's process		Gain per cent. by White's process	
	By old process	By White's process	By old process	By White's process	Quantity of gas in cubic feet	Illuminating power in sperm candles	Quantity of gas	Illuminating power
Wigan cannel, Ince Hall	10,900	16,120	4,816	6,448	5,220	1,632	47·9	33·9
" " Balcarres	10,440	15,500	4,156	5,920	5,060	1,764	48·5	42·4
Boghead " . .	13,240	38,160	11,340	21,368	24,920	9,988	198·2	87·8
" " 2nd exp.	..	51,720	..	20,688	38,480	9,308	290·6	81·8
Lesmahago cannel .	10,620	29,180	7,620	13,934	18,560	6,314	174·8	82·8
Methill " .	9,560	26,400	5,316	11,088	16,840	5,772	176·2	108·1
Newcastle " Ramsey	10,300	15,020	5,026	5,646	4,720	620	45·8	12·3

Table showing the quantity of Coal or Cannel requisite for producing light equal to 1,000 *Sperm Candles, each burning* 10 *hours at the rate of* 120 *grs. per hour.*

Name of Coal	Weight of Coal	
	By old process	By White's process
	lbs.	lbs.
Wigan cannel (Ince Hall)	465·1	347·4
" " (Balcarres)	539·0	378·4
Boghead "	197·5	104·8
Lesmahago cannel	293·9	160·7
Methill "	421·4	202·0
Newcastle "	445·7	396·7
" coal (Pelton)	745·7	

Table showing the quantity of Gas requisite for producing light equal to 1,000 *Sperm Candles, each burning* 10 *hours at the rate of* 120 *grs. per hour.*

Name of gas	Rate of consumption per hour	Quantity of gas
	cubic feet	cubic feet
Wigan cannel (Ince Hall)	5	2263
" by White's process . .	5	2500
Wigan cannel (Balcarres)	5	2512
" by White's process . .	5	2618
Boghead cannel	3	1168
" by White's process . .	3	1786
" " 2nd experiment	5	2500
Lesmahago cannel	4	1394
" by White's process . .	4	2094

	Name of gas	Rate of consumption per hour	Quantity of gas
		cubic feet	cubic feet
	Methill cannel	5	1798
	„ by White's process . .	5	2381
	Newcastle cannel (Ramsay) . . .	5	2049
	„ by White's process . .	5	2660
	Newcastle coal (Pelton)	5	3356
	Resin-gas by White's process . . .	calculated from analysis	3012
	Manchester gas (June 1851) . . .	„ „	3448
London gases	City Company's gas (July 15, 1851) .	5	3846
	Great Central Company's gas „ .	5	3546
	Chartered Company's gas „ .	calculated from analysis	3320
	Imperial Company's gas „ .	„ „	4099
	Western Company's gas „ .	„ „	1538

Dr. Frankland thus sums up the advantages which he conceives to result from the application of the hydrocarbon process to coals and cannels :—

1. It greatly increases the produce in gas from a given weight of coal or cannel. the increase being from 46 to 290 per cent., according to the nature of the material operated upon.

2. It greatly increases the total illuminating power afforded by a given weight of coal, the increase amounting to from 12 to 108 per cent., being greatest when coals affording highly illuminating gases are used.

3. It diminishes the quantity of tar, formed by converting a portion of it into gases possessing a considerable illuminating power.

4. It enables us profitably to reduce the illuminating power of the gases produced from such materials as Boghead and Lesmahago cannels, &c., so as to fit them for burning without smoke and loss of light.

Mr. Barlow has also experimented upon this process of gas-making, and finds that a very considerable gain in total illuminating results from its use.

Mr. Clegg's investigation of this process showed, that whilst Wigan cannel produces by the ordinary process of gas-making about 10,000 cubic feet of 20-candle gas per ton; 16,000 cubic feet of 20-candle gas, or 26,000 cubic feet of 12-candle gas, can be made from the same quantity of material by the hydrocarbon process. Also that by the application of the same process to Lesmahago cannel 36,000 cubic feet of 20-candle gas, or 58,000 cubic feet of 12-candle gas per ton can be obtained; whilst Boghead cannel yields 52,000 cubic feet of 20-candle gas, or 75,000 cubic feet of 12-candle gas. The following table presents in a condensed form Mr. Clegg's results as to comparative cost:—

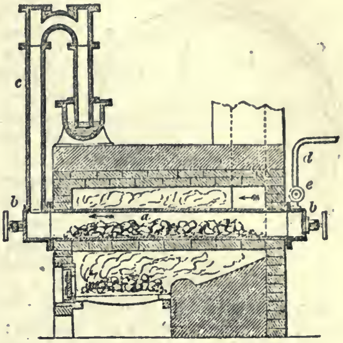
Name of coal	Cost of 1,000 ft. of 20-candle gas by old process	Cost of 1,000 ft. of 20-candle gas by hydrocarbon process	Cost of 1,000 ft. of 12-candle gas by hydrocarbon process
	s. *d.*	*s.* *d.*	*s.* *d.*
Wigan cannel at 14*s.* per ton	1 9¾	1 3½	0 11¼
Lesmahago cannel at 18*s.* per ton . . .	2 5½	0 11¾	0 9¼
Boghead cannel at 20*s.* per ton . . .	2 4½	0 11	0 9¼

The principle of the hydrocarbon process is also adopted by Messrs. Lowe and Evans in their patent process for the manufacture of gas for illuminating purposes.

In carrying out this latter improved manufacture of gas, the patentees pass gas obtained from any of the sources hereinafter specified, through heated retorts containing cannel coal, coal, lignite, resin, pitch, tar, oil, retinite, or other substance or substances capable of yielding carburetted hydrogen gas; by which means such a combination of rich and poor gases may be produced as will be exactly suited to the purposes of illumination. For this purpose, it is proposed to use retorts, open at both ends, as shown in the drawing given in *fig.* 1062, which represents a longitudinal vertical section of the apparatus employed in carrying out this part of the invention. Only one retort is exhibited;

but a similar arrangement of retorts may be adopted to that in general use in gasworks. *a* is the retort, set in a suitable furnace for heating the same; and *b b* are mouthpieces and lids, fitted to both ends of the retort. *c* is the pipe for carrying off the gaseous products generated in the retort; and *d* is a pipe for introducing into the retort the gas which is intended to mix with the gaseous products of the substances under distillation in the retort. As soon as the retort is charged with coal or other carbonaceous matter, a cock *e*, in the pipe *d*, is opened, which allows the gas to flow into the retort; and it then passes in the direction of the arrows, and mingles with the gas that is evolved from the carbonaceous matters contained in the retort: whereby a compound is formed, possessing a much higher illuminating power than could have been obtained had the combination taken place after instead of at the time of the generation of the gas in the retort *a*. The gas, which is brought to the retort by means of the pipe *d*, may be forced into the retort, so as to overcome the internal pressure put on the retort by means of the hydraulic main; or, instead thereof, an exhauster may be applied to draw off the gas from the retort. Should tar, oil, resin (previously melted), or any liquid hydrocarbon be employed for the generation of the gas, it is to be run into the retort in the way generally adopted for making oil- or resin-gas.

1062



The sources from which the patentees propose to obtain inflammable gases, to be applied as above indicated, are wood, sawdust in a damp or dry state, spent tanner's bark, and other like substances capable of yielding an inflammable gas. These substances must be put into a red-hot retort, and distilled like coal. The resulting gases may be either purified at once, or passed directly to the retort containing the coal or other carbonaceous materials. As a general rule, however, these gases are preferred to be stored in gasholders for use; as, in that case, a more uniform and constant supply to the coal-retort may be relied on.

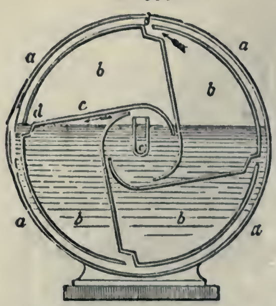
Another source of inflammable gas is from coal of an inferior description, or from peat. These substances having been distilled in a retort, the resulting gas can be then employed as above indicated. It is also proposed to conduct carbonic oxide gas into retorts containing carbonaceous matters under distillation. This gas the patentees obtain from carbonic acid, by passing the latter gas (which may be obtained from any convenient source) through a retort or furnace containing red- or white-hot coke. Or, they utilise a portion of the gases generated in furnaces, by collecting these gases and converting the carbonic acid they contain into carbonic oxide, by passing them through a retort or furnace, as described for treating carbonic acid; or the gases may be conducted directly into retorts, wherein carburetted hydrogen is being generated, for the purpose of effecting the desired combination. See Peat.

From the foregoing description, it will be understood, that the object of this part of the invention is to obtain gas of a uniform quality—that is, possessing a definite amount of illuminating power. Now, it is well known that if the gas be too rich in carbon it will burn with a dull flame, and give off a large amount of smoke; and that, if deficient in carbon, it will burn with a blue flame, and possess very little illuminating power. It is therefore proposed to mix the rich and poor gases, obtained as above described, in such proportions as will be needful to produce a highly-illuminating quality of gas. As the proportions will depend entirely on the quality of the gases to be combined, no rule can be laid down for the amount of the gas required to be passed into the retorts, wherein the distillation is proceeding. The mode, however, in which gas burns on issuing from the retort will be a sufficient test for the workmen in attendance.

GAS-METER. In order to measure the quantity of gas which passes through a pipe for lighting a factory, theatre, &c., the gas-meter is employed, of whose construction a sufficiently precise idea may be formed from the consideration of *fig.* 1063, which shows the instrument in a section perpendicular to its axis.

Within the cylindrical case *a*, there is a shorter cylinder *b b*, shut at both ends, and moveable round an axis, which is divided into four compartments, that communicate by the openings *d*, with the interval between this cylinder and the outer case. The mode in which this cylinder turns round its axis is as follows:—The end of the tube *c*, which is made fast to the side of the case, and by which the gas enters, carries a pivot or gudgeon, upon which the centre of its prop turns; the other end of the axis runs in the cover, which here forms the side of a superior open vessel, in which, upon the same axis, there is a toothed wheel. The vessel is so far filled with water, that the tube *c* rises just above it, which position is secured by the level of the side vessel. When the gas enters through the tube *c*, by its pressure upon the partition *e* it turns the cylinder from right to left upon its axis, till the exterior opening *d* rises above the water, and the gas expands itself in the exterior space, whence it passes off through a tube at top. At every revolution a certain volume of gas thus goes through the cylinder, proportional to its known capacity. The wheel on the axis works in other toothed wheels, whence, by means of an index upon a graduated disc or dial, placed at top or in front of the gas-meter, the number of cubic feet of gas which pass through this apparatus in a given time is registered.

1063



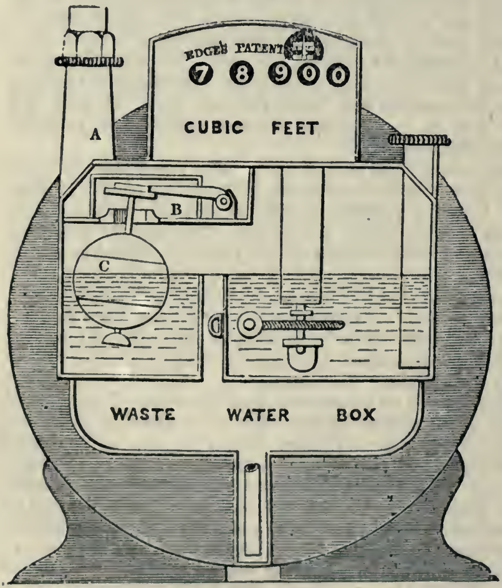
Mr. Thomas Edge, of Great Peter Street, Westminster, has contrived the following meter, of which drawings are annexed:—

Fig. 1064 is a front view of a three-light meter, the front plate being removed, and some of the parts shown in section.

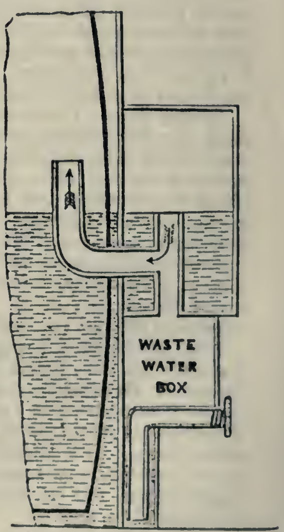
Fig. 1065 is a transverse section of the same.

The gas enters at A into the small chamber B, in the bottom of which is a lever valve (part of Mr. Edge's patent improvement), moving upon its axis and attached by the rod to a metal float C, which in the present drawing is buoyant. The object of this arrangement is to intercept the passage of the gas into the meter, unless a sufficient quantity of water is in it, that being necessary to its proper action; the gas then passes through the inverted siphon or tunnel into the convex cover, whence it passes into the chambers of the drum.

1064



1065

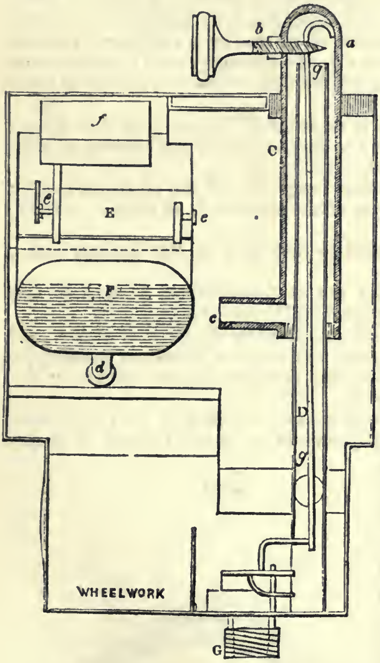


Another of Mr. Edge's improvements consists in the cutting down of this siphon pipe or tunnel to the proper water level, and connecting the bottom of it to a waste water box, into which any surplus water must fall. The importance of this precaution will be seen on investigating the drum, as an excessive height of water will materially interfere with the measurement, the quantity of gas delivered per revolution being considerably less. This, in connection with the lever valve and float, confines the variation of the water levels within such narrow limits, that the measurement may be considered perfectly just on all occasions.

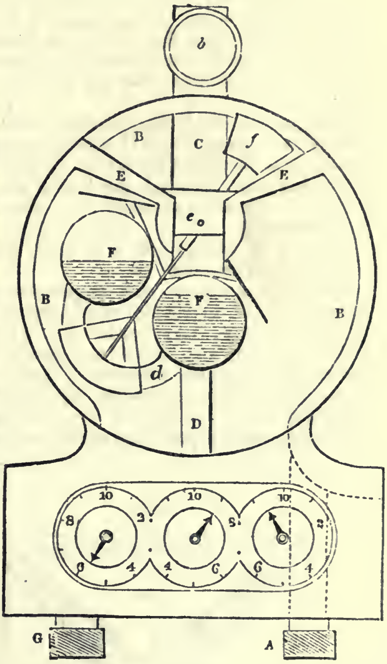
The hydraulic, or wet gas-meter in ordinary use, when properly constructed, measures with great accuracy, and requires only a very slight pressure of gas to work it; but it readily admits of fraudulent means being employed by the consumer, so as to cause the instrument to under-estimate the amount of gas consumed; whilst, on the other hand, the condensation of moisture within the meter may so far elevate the water-level as to cause an over-estimation of the consumption. The water in the hydraulic meter is also liable to freeze in winter, thus completely stopping the supply of gas; at other times, especially when the meter is fixed in a comparatively warm place, the gas, becoming saturated with aqueous vapour, subsequently deposits water during its passage through the cooler portions of the pipes of distribution. The water thus deposited collects in the lower portions of the pipes, breaking the flow of gas into a succession of bubbles, and causing that flickering or dancing of the gas flames which is so frequently a source of annoyance in winter.

These defects and inconveniences are all obviated by the *dry gas-meter*, several forms of which have of late years been invented. The first in point of date is Clegg's patent dry gas-meter, an instrument displaying great ingenuity, although it has never come into very extensive use. *Figs.* 1066 and 1067 show the construction of this meter: the letters of reference are the same in both.

1066



1067



B B, *fig.* 1067, represents a cylindrical vessel, about 3¾ inches in diameter and 4 inches deep, being the dimensions of a meter capable of measuring gas for three burners, called a three-light meter. In this vessel are two glass cylinders F F, connected together by the bent tube *d*. The cylinders being perfectly exhausted of air, and half filled with alcohol, are made to vibrate on centres *e*, *e*, and are balanced by the weight *f*. This instrument accurately indicates the excess of heat to which either cylinder may be exposed upon the principle of Leslie's differential thermometer.

C is a hollow brass box, called the heater, about 4 inches long and ½ an inch broad, projecting out of the meter about 1 inch. At *a* issues a small jet of gas, which, when inflamed, gives motion to the cylinders.

The gas enters the meter by the pipe A, and circulates throughout the double case B. Having passed round the case B, a portion of it enters the top of the box C, by the pipe D, and passes out again at the bottom of the tube *c*, into the meter; the rest of the gas enters the body of the meter through holes in the curved faces of the hoods E E, and, after blowing on the glass cylinders, passes to the burners through the outlet pipe.

To put the meter in action, let the jet *a* be lighted about an hour before the burners are wanted. In most cases this jet will be lighted all day as a useful flame. The hole *a* is so situated on the box C, that whatever be the size of the jet, a fixed temperature is given to the box, that temperature depending on the quantity of flame in contact with the box, and not at all on the length of the jet. The jet being lighted, and the box C thereby heated, the gas which passes through it is raised to the same temperature, and, flowing out at the tube *c*, impinges on the glass cylinder which happens for the time to be the lowest; the heated gas soon raises a vapour in the lower cylinder, the expansion of which drives the liquid into the upper one, until it becomes heavier than the counterpoise *f*, when the cylinders swing on their centre, the higher one descends, and comes in the line of the current of hot gas, and the lower one ascends; the same motion continues as long as the jet *a* burns. The same effect on the cylinder is maintained, however the outward temperature may change, by the cold gas, which, issuing from the curved side of the hood E E, impinges on the upper cylinder, and hastens the condensation of the vapour which it contains.

The cold gas and the heater vary in temperature with the room, and thus counteract each other.

The lighting of the jet *a* is essential to the action of the meters; in order to insure this, the supply of gas to the burners is made to depend on it in the following manner. The pipe G, by which the gas leaves the meter, is covered by a side valve, which is opened and shut by the action of the pyrometer *g*; the pyrometer is in communication with and receives heat from the jet, and opens the valve when hot, closing it again when cold.

The speed at which the cylinders vibrate is an index of the quantity of heat communicated to them, and is in exact proportion to the quantity of gas blowing on them through the pipe *c* and curved side of the hoods E E.

The gas passed through the heater is a fixed proportion of the whole gas passing the meter; therefore the number of vibrations of the cylinder is in proportion to the gas consumed.

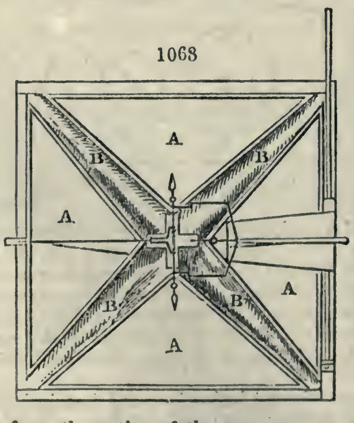
A train of wheel-work with dials, similar to that used in the common meter, registers the vibrations.

Simplicity, accuracy, and compactness are the most remarkable features of this instrument, and the absence of all corrosive agents will ensure its durability.

The most recently-constructed meters on the dry principle are those of Defries, and of Messrs. Croll and Richards. Both of these contrivances consist in causing the gas to fill expansible chambers of definite volume, and the alternate expansion and contraction of these is registered by wheel-work.

Defries' meter has three of these measuring chambers, separated from each other by flexible leather partitions which are partly covered by metallic plates, to protect them from the action of the gas. A A A A, *fig.* 1068, represent these metallic plates, fixed upon the leather diaphragm B B B B. As the gas enters, it causes the flexible partition to expand, which it does by assuming the form of a cone, as seen in *fig.* 1069. Three such chambers are attached to each meter, so as to insure a uniform and steady

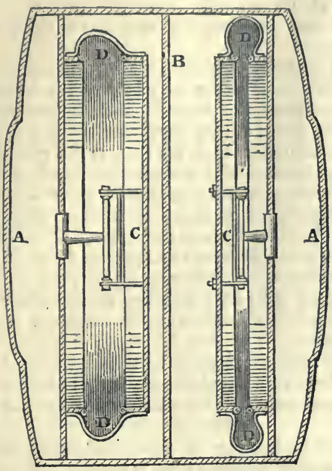
1068



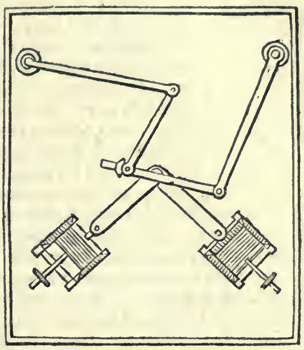
1069

supply of gas, and the motion of the chambers being communicated to clockwork, the consumption of gas is registered upon dials in the usual manner.

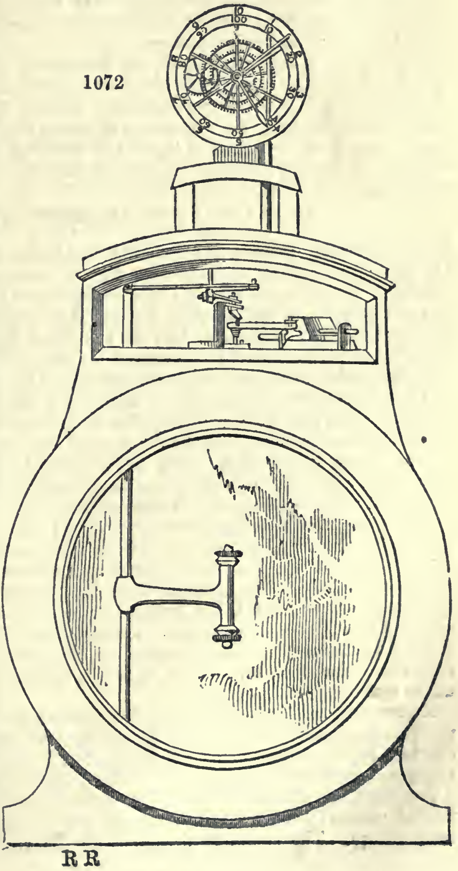
1070



1071



1072



The dry meter invented by Messrs. Croll and Richards is superior in construction and accuracy of measurement to that of Defries. It is shown in *figs.* 1070, 1071, and 1072. A A, *fig.* 1070, is a cylindrical case, divided into two cylindrical compartments by the inflexible metallic diaphragm B. These compartments are closed at opposite ends by the metal discs C C. The latter perform the functions of pistons, and are retained in their proper position by universal joints attached to each. The discs are restrained from moving through more than a fixed space by metallic arms and rods, shown in *fig.* 1072, and when this space has been once adjusted, it cannot afterwards vary. It will be seen that the principle of this meter is that of a piston moving in a cylinder; but, in order to avoid the friction which such an arrangement would cause if literally carried out, bands of leather, D D, are attached, which act as hinges, and allow of the motion of the discs without friction.

The gas enters the cylinder from the upper space containing the levers, valves, &c., *fig.* 1072; its pressure forces the discs forward through the space limited, as above described. The flow of gas is then reversed; that is, a passage to the burners is opened from the internal space, whilst the supply is now directed into the outer chamber, thus forcing the disc back to its original position, and expelling the first portion of gas through the pipes of distribution. Each motion of the disc thus evidently corresponds to a given volume of gas, and being registered by clockwork, indicates the consumption upon the usual dial plates.

Dry gas-meters are generally preferred, and consequently they have come into general use.

To the present system of registering the quantity of gas burnt by the consumer, many honest objections may be raised. Whichever meter may be used, the record of gas passing through it is entirely removed from the inspection of the consumer. The quantity is registered by a servant of the gas company supplying the meter, and whatever may be the number of cubic feet returned by him, for that is the consumer charged and obliged to pay. It seldom happens that the gas companies admit that any error can occur which tells against themselves, but they frequently discover errors in the other direction. Presuming that honesty of purpose actuates equally the supplier and the consumer of gas, it would be perfectly easy to arrange the dials of our domestic gas-meters so that the consumer might note the quantity indicated at any time, and from his knowledge of the number of burners used by him, within any given week or month, be enabled to tell if, as compared with any other period, the indicated result was near to, or far from, the truth, and direct the attention of the servant of the gas company to the circumstance.

GAS, WATER. Various methods have been from time to time introduced for decomposing water, and for employing the hydrogen liberated therefrom for the purposes of heating and lighting. Recently (1874) this 'water-gas' has been introduced to the public under the name of the 'New Gas.'

The possibility, without any great amount of trouble, of obtaining a quantity of hydrogen gas from water has always been a favourite theme with inventors, and many schemes for its practical utilisation have been introduced; and a patent has been obtained for the carbonisation of this gas with some light hydrocarbon liquid, so as to give it a high illuminating power.

The process is dependent upon the decomposition of steam by red-hot coal, coke, or metal. Hydrogen, carbonic oxide, and carbonic acid are produced. An analysis of the gas obtained by passing steam over red-hot charcoal for some hours gave as a mean: carbonic acid, 20 per cent.; carbonic oxide, 20 per cent.; hydrogen, 60 per cent. Any form of carbon is capable of effecting this decomposition if a metal, such as iron, be present; it adds to the quantity of hydrogen obtained according to the following action:—

$$4HO + 3Fe = Fe^3O^4 + 4H \quad (\mathbf{4H^2O + 3Fe = Fe^3O^4 + 4H^2}).$$

This mixture of gases is inflammable, and burns with a non-luminous but hot flame, the heat of which would be increased if the carbonic acid were previously removed, the flame of hydrogen having a temperature of 3,776° Fahr. This heat of the flame is an undoubted advantage when the gas is carburetted, as the particles of carbon are thereby heated to whiteness; but, on the other hand, the presence in the gas of a quantity of carbonic oxide is as great a disadvantage, on account of its injurious and exceedingly harmful character. Carbonic acid is an injurious gas, but its action upon the system is not that of an active poison, but rather that of preventing the necessary amount of oxygen from entering the lungs, and hence death from its effect will be death from suffocation. On the other hand, carbonic oxide is an active poison, and recovery from its effect is much more doubtful; indeed, it is calculated that 2 per cent. in an atmosphere would prove fatal, a result that should cause great caution in the use of a gas containing it in any quantity.

It is thought it will be possible to utilise this gas by itself, as a heating gas; but its chief use is for illumination, and the illuminating power is obtained in the same manner as with air-gas, the hydrogen gas obtained by any of the methods named being caused to bubble through some light spirit, any reduction of temperature by the rapid evaporation being avoided by maintaining the vessel containing it at a constant temperature by means of a steam-pipe. The illuminating power of the gas so obtained is equal to about sixteen or seventeen candles; and its permanent character is declared to be, and no doubt is, sufficient to render it of practical utility under some peculiar conditions.

A company, called the 'New Gas Company,' has been formed for working a patented process, the invention of Mr. Ruck. Instead of manufacturing gas by the distillation of coal, Mr. Ruck first obtains his hydrogen by the decomposition of water, and then charges it with the carbon necessary for illuminating purposes by passing it through a petroleum spirit of specific gravity 0·680. In the first part of the process, superheated steam is conveyed into retorts containing iron and coke raised to a high temperature. The steam is decomposed; the resulting oxygen combines with the iron and the carbon, and the hydrogen is given off, carrying with it a small proportion of carbon compounds. In this state it is valuable for heating purposes, but possesses very little illuminating power, rather resembling, when kindled, the flame of a Bunsen's burner. The various attempts which have been made to combine volatile hydrocarbons with coal-gas, in order to increase its illuminating power, have all failed on account of the speedy precipitation of the former; but Mr. Ruck claims to have discovered that petroleum of the specific gravity stated will remain in combination with the hydrogen. According to the report of Messrs. Quick and Spice, the engineers concerned in the matter, this claim has been subjected to crucial tests, and has withstood them all. The gas has been suddenly reduced in temperature from 60° to 30°, has been kept for a month in a closed vessel, has been passed through miles of iron pipes with many rectangular bends, without any consequent precipitation. The illuminating power appears to be exceedingly good, and it is said that it may be increased almost indefinitely by the removal of a small quantity of carbonic acid by a simple process. The petroleum can be added to the gas at any point between the manufactory and the burner, so that heating gas alone, it is proposed, might be supplied from the mains, say to the kitchens or the conservatories of a large establishment, and the illuminating agent only added to that portion of the supply which was to be used for lighting purposes. The mode of manufacture ensures the complete absence of the noxious sulphur- and ammonia-compounds with which we are familiar, but the gas, although in this sense 'pure,' is not dangerously inodorous. It has a distinct smell, pronounced by those interested in it to be agreeable, but which is certainly sufficient to lead to the discovery of any domestic leakage, and thus to obviate danger from explosions.

At the present price of coal, the discovery of a source of gas which is as plentiful as water, should manifestly have an important bearing on the cost of production. The report of the engineers on this head is to the effect that they can command millions of gallons of the petroleum spirit required, and that the illuminating gas can be made at the cost of 1*s.* 7¾*d.* per thousand cubic feet. They say also, that out of every thirty men required for the manufacture of coal-gas, twenty-nine may be dispensed with in working Mr. Ruck's process. These statements, if borne out by larger experience, cannot fail to attract the attention of the companies.

GAS, WOOD. Attempts were first made in France towards the close of the last century to manufacture an illuminating gas from wood. The Thermo-lamp of Lebon, a wood-gas apparatus, then and for some time afterwards excited considerable attention, especially in the districts of Germany, Sweden, and Russia, where coals are scarce. This mode of illumination, proved however, to be a complete failure, owing to the very feeble illuminating power of the gas produced, and as at this time the production of gas from coal was rapidly becoming better known, anything like a regular manufacture of wood-gas never in any case gained a footing. Subsequent trials only confirmed the failure of Lebon, so that it was universally considered impossible to produce a practically useful gas from wood by the usual process of gas manufacture. In the year 1849 Professor Pettenkofer of Munich had occasion to repeat these experiments, and he found that the gases evolved from wood at the temperature at which it carbonises consist almost entirely of carbonic acid, carbonic oxide, and light carburetted hydrogen; olefiant gas and the illuminating hydrocarbons being entirely absent. Such gas was therefore totally unfit for illuminating purposes.

The temperature of boiling quicksilver, at which coal is not in the slightest degree decomposed, is quite sufficient to carbonise wood completely. If small pieces of wood be placed in a glass retort half filled with mercury and the latter be heated to boiling, a black lustrous charcoal is left in the retort, whilst gas of the following composition is evolved:—

Carbonic acid	57·4
Carbonic oxide	36·6
Light carburetted hydrogen	7·0
	100·0

If however the gases and vapours produced by the above experiment be heated to a considerably higher temperature than that at which the wood is carbonised, Professor Pettenkofer found that a very different result is obtained: the volume of permanent gas is considerably augmented, whilst such an amount of illuminating hydrocarbons is produced as to render the gas actually richer in these constituents than coal-gas. Analysis of various samples of such superheated gas gave the following results:—

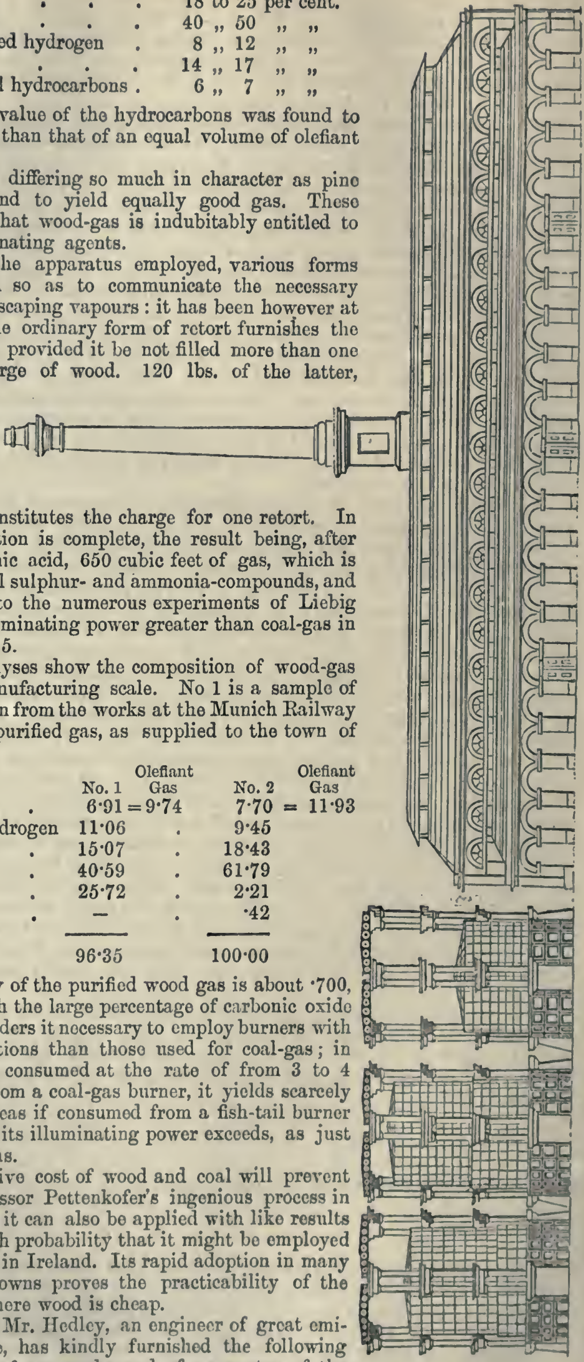
Carbonic acid	18 to 25 per cent.
Carbonic oxide . . .	40 ,, 50 ,, ,,
Light carburetted hydrogen .	8 ,, 12 ,, ,,
Hydrogen	14 ,, 17 ,, ,,
Olefiant gas and hydrocarbons .	6 ,, 7 ,, ,,

The illuminating value of the hydrocarbons was found to be one half greater than that of an equal volume of olefiant gas.

Varieties of wood differing so much in character as pine and beech were found to yield equally good gas. These observations prove that wood-gas is indubitably entitled to rank amongst illuminating agents.

With regard to the apparatus employed, various forms have been contrived so as to communicate the necessary temperature to the escaping vapours: it has been however at length found that the ordinary form of retort furnishes the necessary conditions, provided it be not filled more than one third with the charge of wood. 120 lbs. of the latter, thoroughly dried, constitutes the charge for one retort. In 1½ hour the distillation is complete, the result being, after absorption of carbonic acid, 650 cubic feet of gas, which is perfectly free from all sulphur- and ammonia-compounds, and possesses, according to the numerous experiments of Liebig and Steinheil, an illuminating power greater than coal-gas in the proportion of 6 : 5.

1073



The following analyses show the composition of wood-gas when made on a manufacturing scale. No 1 is a sample of gas before purification from the works at the Munich Railway Station and No 2 is purified gas, as supplied to the town of Bayreuth:—

	No. 1	Olefiant Gas	No. 2	Olefiant Gas
Hydrocarbons . .	6·91	= 9·74	7·70	= 11·93
Light carburetted hydrogen	11·06	.	9·45	
Hydrogen . . .	15·07	.	18·43	
Carbonic oxide . .	40·59	.	61·79	
Carbonic acid . . .	25·72	.	2·21	
Nitrogen . . .	—	.	·42	
	96·35		100·00	

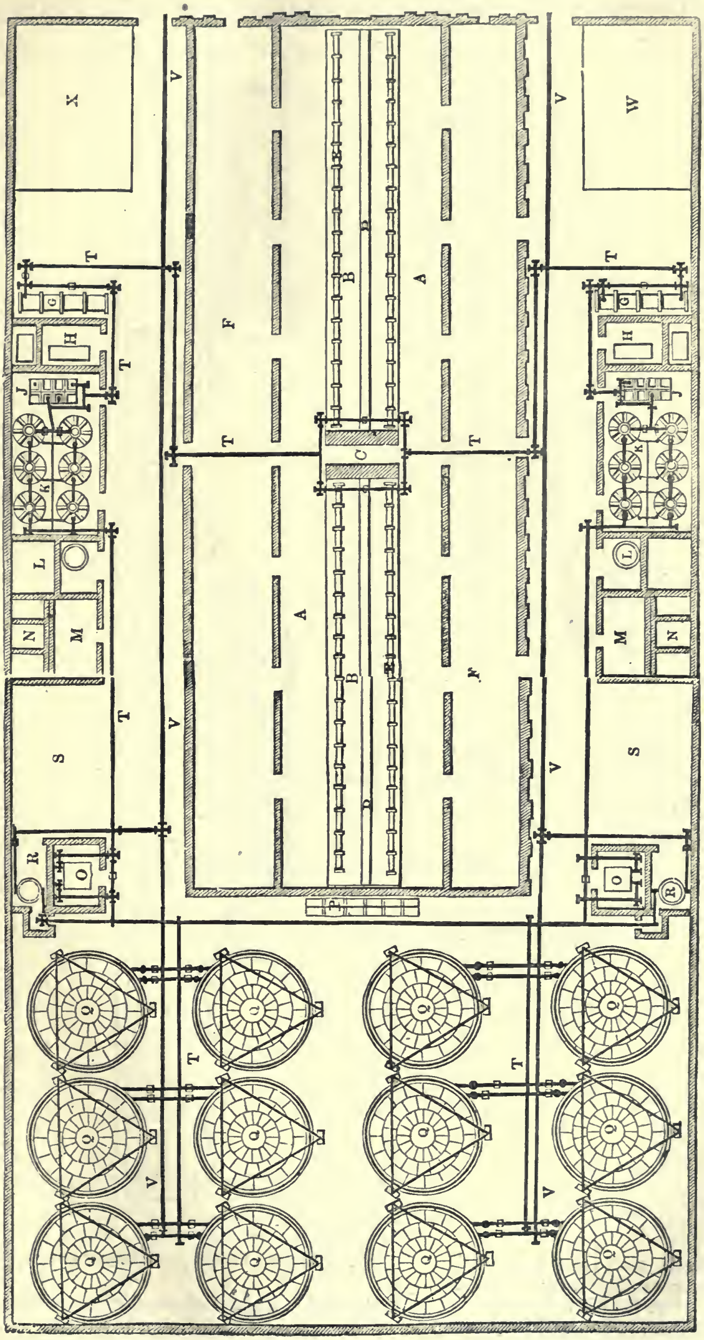
The specific gravity of the purified wood gas is about ·700, and this, coupled with the large percentage of carbonic oxide which it contains, renders it necessary to employ burners with much larger perforations than those used for coal-gas; in fact, if wood-gas be consumed at the rate of from 3 to 4 cubic feet per hour from a coal-gas burner, it yields scarcely any light at all, whereas if consumed from a fish-tail burner with wide apertures, its illuminating power exceeds, as just stated, that of coal-gas.

Although the relative cost of wood and coal will prevent the adoption of Professor Pettenkofer's ingenious process in this country; yet, as it can also be applied with like results to peat, there is a high probability that it might be employed with great advantage in Ireland. Its rapid adoption in many German and Swiss towns proves the practicability of the process in districts where wood is cheap.

GAS WORKS. Mr. Hedley, an engineer of great eminence and experience, has kindly furnished the following plans and drawings of gas-works and of apparatus of the most approved and modern construction, and on the very largest scale as to extent of business or manufacture; also plans and drawings of a gas-work on a smaller scale, with its corresponding apparatus. In the first, or large work, purification by wet lime, before described, is used; in the latter, by dry lime.

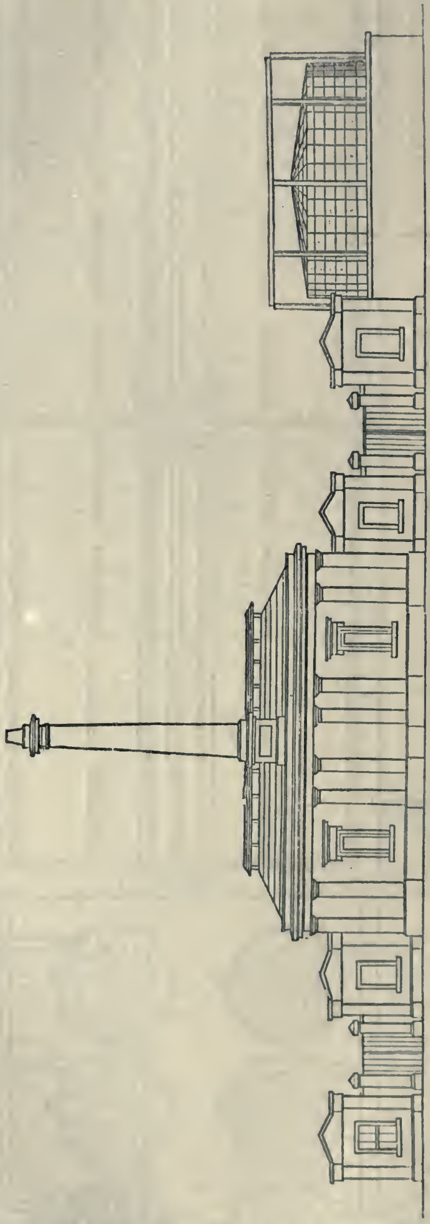
The large work referred to is calculated for, and is arranged to contain, 400 retorts,

1074



12 wet-lime purifiers, and 2 washers; 12 large double or telescopic gasholders, capable of storing 1,000,000 cubic feet of gas; and coal stores capable of holding 10,000 tons of coal.

The smaller work is calculated for, and will contain, 40 retorts, 2 dry-lime purifiers, and a wash vessel; 2 gasholders capable of storing 50,000 cubic feet of gas; and coal stores sufficient for 1,000 tons of coal.



1075

Fig. 1073 is the side elevation (front view) of a gas-work capable of containing 400 retorts, and all their dependencies.

Fig. 1074 is the plan of the retort house, coal, stores, tanks, gasholders, &c., on the largest scale, and most approved form, viz.: A the retort house, 300 feet long, 56 feet wide; B, retort beds; C, chimney stack; D, flues; E, hydraulic mains; F, coal stores, each 300 feet long, 30 feet wide; G, condensers; H, engine-houses; J, wash vessels; K, purifiers and connections; L, lime store and mixing tub; M, smiths' and fitters' shops; N, refuse-lime pits; O, meter houses; P, tar tank; Q, tanks, gasholders, bridges, columns, valves, and connections; R, governors; S, coke stores; T, inlet pipes; V, outlet pipes; W, house and offices; X, stores.

1076

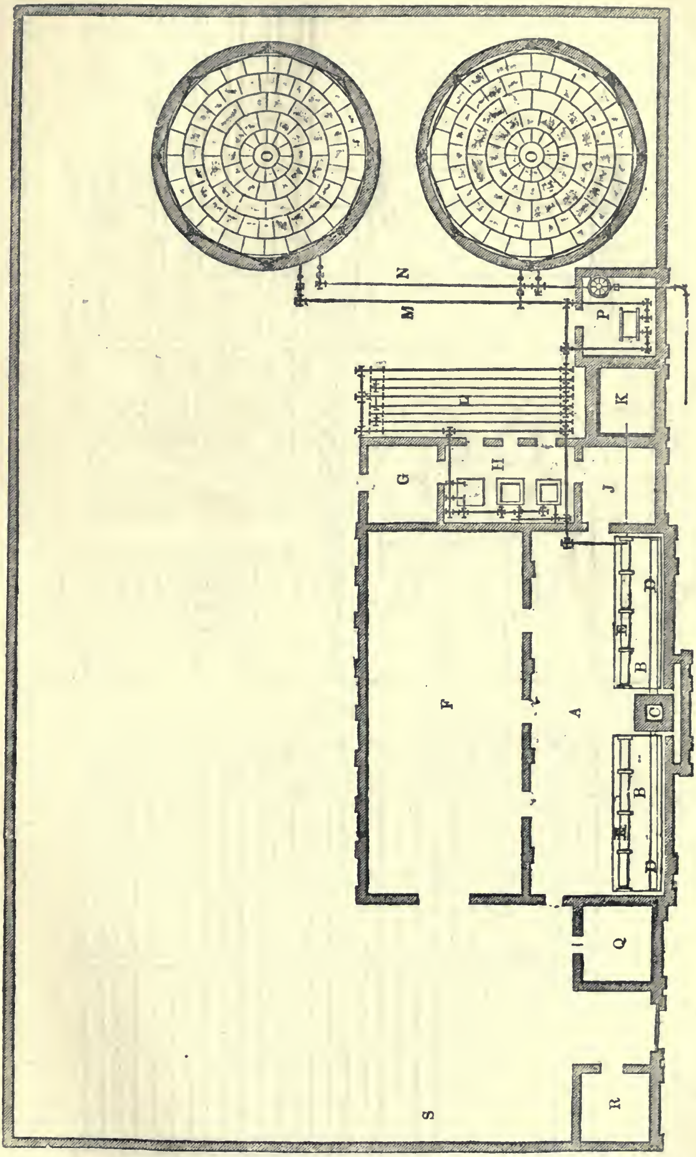
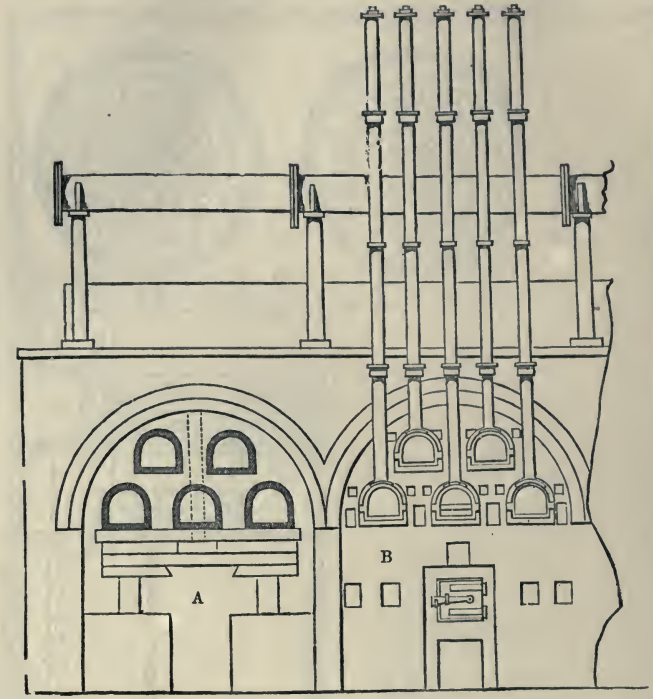


Fig. 1075. Front elevation of gas works on a smaller scale, where dry lime is used.

Fig. 1076. Plan of gas works, consisting of A, retort house; B, retort beds; C, chimney stack; D, flue; E, hydraulic main; F, coal store; G, lime store; H, washer and purifiers; J, store; K, tar-tank; L, horizontal condenser laid on the ground; M, inlet pipe, N outlet pipe; O, tanks and gasholders; P, meter and governor; Q, smiths' shop; R, office: S, coke store.

1077



1078

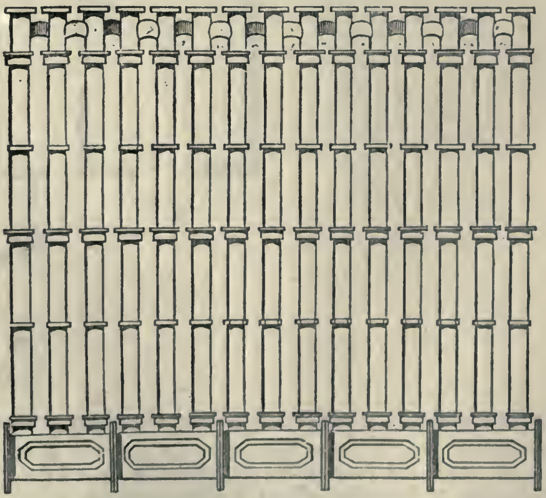
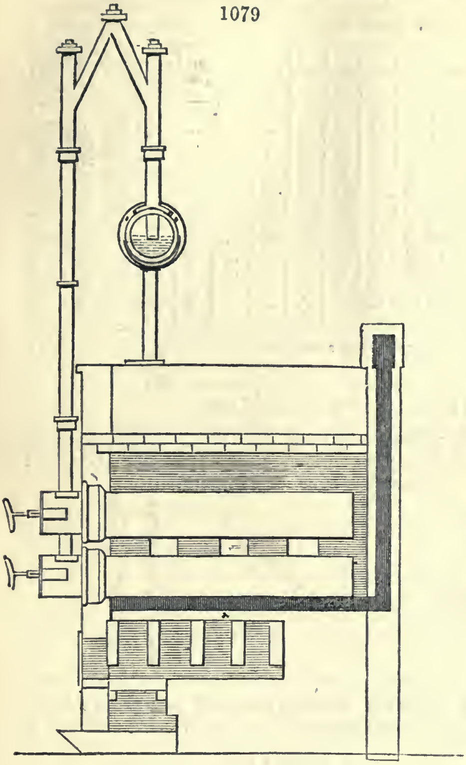


Fig. 1077. Transverse section and elevation of a bed of five retorts. A, transverse section; B, elevation.

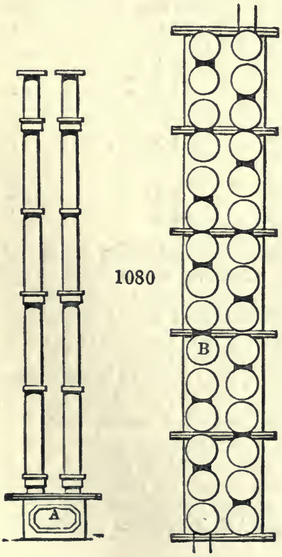
Fig. 1078. Elevation of an upright air condenser, consisting of five chambers, with a series of 10-inch pipes.

Fig. 1079. Longitudinal section of a bed of 5 D-retorts.
Fig. 1080. End elevation and plan of air condenser. A, end elevation; B, plan.
Fig. 1081. Set of three wet-lime purifiers and wash vessels, in elevation and section,

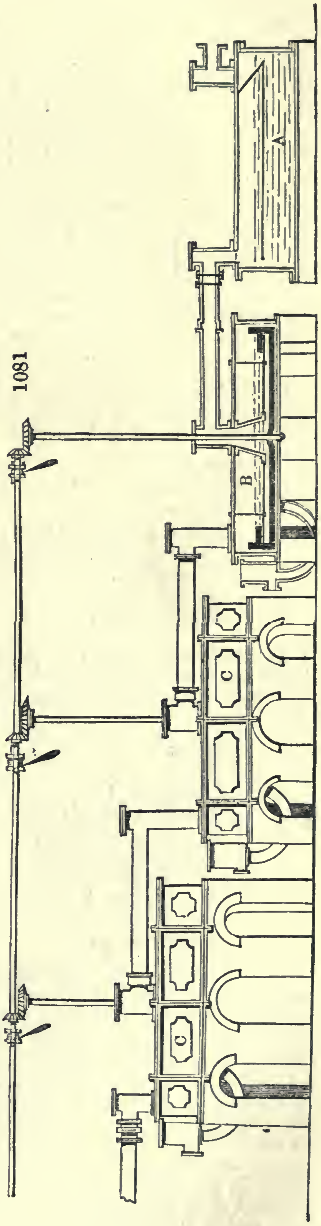
1079



1080



1081



with feed-heads, agitators, valves, and connections, raised for the lime-liquor to run from one purifier to the next below it, and ultimately into the refuse-lime pits; viz. A, section of wash vessel; B, section of purifier; C, elevation of purifier.

A Table of the number of hours Gas is burnt in each month, quarter, and year.

Time of burning	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April	May	June	Mid. quar.	Mic. quar.	Xms. quar.	Lady day quar.	Total of year
o'clock.																	
From dusk to 6	..	..	2	31	62	80	65	33	4	..	..	..	..	2	173	102	277
" 7	..	14	22	62	92	111	96	61	31	4	..	..	4	36	265	188	493
" 8	..	40	52	93	122	142	127	89	62	28	4	..	32	92	357	278	759
" 9	13	71	82	124	152	173	158	117	93	58	29	8	95	166	449	368	1078
" 10	44	102	112	155	182	204	189	145	124	88	60	38	186	258	541	458	1443
" 11	75	133	142	186	212	235	220	173	155	118	91	68	277	350	633	548	1808
" 12	106	164	172	217	242	266	251	201	186	148	122	98	368	442	725	638	2173
All night . .	217	307	345	421	473	527	512	411	382	295	242	195	732	869	1421	1305	4327
Morning from 4	..	16	48	80	110	137	137	98	71	28	2	..	30	64	327	306	727
" 5	..	..	18	49	80	106	106	70	40	3	..	..	3	18	235	216	472
" 6	..	..	..	18	50	75	75	42	9	..	..	..	..	..	143	126	269
" 7	..	..	..	..	20	44	44	14	..	..	..	..	..	..	64	58	122
For Sundays off, deduct one seventh.																	

ECONOMICAL AND SANITARY RELATIONS OF GAS.

In a lecture delivered at the Royal Institution in 1853, Dr. Frankland thus estimates the comparative cost of an amount of light from various sources equal to that yielded by 20 sperm candles, each burning 120 grains per hour for 10 hours:—

	s.	*d.*
Wax	7	2½
Spermaceti	6	8
Tallow	2	8
Sperm oil (Carcel's lamp)	1	0
London gases: City, Great Central, Imperial, and Chartered.	0	4¼
Western	0	2¼
Manchester gas	0	3

The following table exhibits the amount of carbonic acid and heat produced per hour from the above sources of light, the heat generated by tallow being assumed to be 100 for the purposes of comparison:—

	Carbonic Acid. Cubic Feet	Heat
Tallow	10·1 . .	100
Wax Spermaceti }	8·3 . .	82
Sperm oil (Carcel's lamp)	6·4 . .	63
London gases: City Great Central Imperial Chartered }	5·0 . .	47
Western	3·0 . .	22
Manchester gas	4·0 . .	32

Notwithstanding the great economy and convenience attending the use of gas, and in a sanitary point of view, the high position which, as an illuminating agent, coal-gas of proper composition occupies, its use in dwelling-houses is still extensively objected to. The objections are partly well founded and partly groundless. As is evident from the foregoing table, even the worst gases produce, for a given amount of light, less carbonic acid and heat, than either lamps or candles. But then, where gas is used, the consumer is never satisfied with a light equal in brilliancy only to that of lamps or candles, and consequently, when three or four times the amount of light is produced from a gas of bad composition, the heat and atmospheric deterioration greatly exceed the corresponding effects produced by the other means of illumination. There is, nevertheless, a real objection to the employment of gaslight in apartments, founded upon the production of sulphurous acid during its combustion; this sulphurous acid is derived from bisulphuret of carbon, and the organic sulphur-compounds, which have already been referred to as incapable of removal from the gas by the present methods of purification.

These impurities, which are encountered in almost all coal-gas now used, are the principal if not the only source of the unpleasant symptoms experienced by many sensitive persons in rooms lighted with gas. It is also owing to the sulphurous acid generated during the combustion of these impurities that the use of gas is found to injure the bindings of books, and impair or destroy the delicate colours of tapestry: therefore the production of gas free from these noxious sulphur-compounds is at the present moment a problem of the highest importance to the gas-manufacturer, and one which demands his earnest attention.

The high sanitary position which gas takes, with regard to the production of a minimum amount of carbonic acid and heat for a given amount of light, ought to stimulate the manufacturer to perfect the process, by removing all sulphur-compounds, and attaining the most desirable composition, so that this economical, and if pure, agreeable and sanitary light, may contribute to our domestic comfort to a much greater extent than it has hitherto done.

For the Royal Coal Commission (1869) circulars were issued to all the gas companies in the United Kingdom, public and private, so far as those could be ascertained. Replies, giving very full information, were received from 1,024 works. These used, in 1867, 3,612,954 tons of coal, and in 1868, 3,811,981 tons: the increase being about 200,000 tons for each year. This has been confirmed by subsequent enquiries, so that in 1873 the same number of gas-works would have used about 4,800,000 tons of coal. Those works which are not included in the return from which this quantity is estimated, will have used above 2,500,000 tons; consequently, we may estimate the quantity of coal now (1874) used is 7,300,000 tons.

The number of cubic feet of gas produced from each ton of coal, according to the returns referred to, were 8,300. The total produce of gas would therefore be

60,590,000,000 cubic feet.

The following description of the Brighton and Hove General Gas Company's Works, Portslade, Sussex, by Mr. John Biret Paddon, as it embraces the most recent improvements, (the paper was read on February 3, 1874, at the Institution of Civil Engineers), cannot fail to form a useful appendix to this article:—

'The site of these works was the wildest, most level, and highest part of a tract of shingle lying between the sea and the canal forming the eastern entrance to Shoreham Harbour. This shingle was formerly arrested in its eastward movement by the entrance works to the harbour; but since the construction of the present westerly entrance, it had been greatly wasted by the sea. Between 1865 and 1870, in front of the site of the gas-works, the high-water mark at ordinary spring tides advanced landwards 100 feet; and at high tides, during strong gales of wind, the waves broke over the greater portion of the land referred to. To obtain a deposit of shingle along the sea front as a protection, and to prevent the lighter portions of the waves passing over the bank, two groynes were constructed, one, in accordance with local custom, being at a right angle to the shore. With groynes so built there was an invariable scour and waste on the lee side, so that a repetition of such groynes along the coast to be protected became a necessity. The second groyne was designed to prevent this destructive action, and was projected towards the east at an angle of 45° to the shore. The result has been satisfactory, for soon after its completion a large bank of shingle accumulated on the east side, where it had since remained. A breastwork had also been constructed of creosoted Swedish timber; and although several times exposed to the coincidence of a high tide and a strong gale of wind, it has proved a suitable and efficient protection. At a depth of 14 feet the ends of the piles entered a stratum of sand and gravel of great density and holding-power. A supply of water had been obtained by sinking an iron cylinder to a depth of 50 feet below the ground line. The water from the chalk at this point held in solution 500 grains per gallon of salts (sea-water containing 2,700 grains per gallon), and was available for most of the purposes of the works, except for drinking. The water-tanks over the pump-room furnished storage for 20,000 gallons of water—a quantity sufficient for ordinary operations to an extent represented by the consumption of 100 tons of coal. Excellent material for concrete was found in the excavations, and the foundations of the walls were extended so as to make the proportion of the weight of the superstructure to the bearing surface, 15 cwt. per square foot. The concrete bed under the retort benches was 7 feet 6 inches thick.

'The retort-house was 284 feet 6 inches long and 80 feet wide, inside measurement. The chimneys were constructed with the lower parts of brick and the upper parts of wrought iron, and were sufficiently light to be placed on the benches, so that no floor space was occupied. They were 71 feet 6 inches high, 3 feet square at the bottom, and 3 feet in diameter, at the top, the least sectional area giving one square inch for each lineal foot of retort, a proportion which had been satisfactory. In consequence of the exposure of the roof to storms of great violence, and to rapid corrosion from the proximity of the sea, it was considered desirable that it should be of great strength, and that its parts should be few and accessible. Accordingly the roof was designed to sustain a weight equal to 60 lbs. per square foot of external surface, or 72 lbs. per square foot of plain covered. With that weight no piece of metal was subjected to a tensile strain exceeding five tons per square inch of section, and the strains on the parts in compression varied from two tons to four tons per square inch of section. The roof consisted of ten Warren trusses of 84 feet span and 14 feet deep, placed about 30 feet apart. Across the top beams were laid four lines of latticed purlins, and upon these purlins rested the bars carrying the skin of the upper portion of the roof. The lower portion of the roof was formed with the framed struts of trusses, and some lighter intermediate framed struts were joined to the bars immediately over them. Thrust on the walls was prevented by a series of ties, with screwed couplings, placed between the feet of the intermediate rafters and principal trusses. The laths were of channel-shaped section, and Duchess slates were fastened thereto with screwed clips, two to each slate. Four wrought-iron rudimentary shafts, 10 feet in diameter, enclosing the tops of the chimneys, allowed the smoke to escape; there was also a protected opening, 5½ feet wide, along the ridge for its entire length, for the same purpose. The roof was constructed by Messrs. Newton and Chambers, of the Thorncliffe Ironworks, and its cost, ready for slating, was 8*l.* 16*s.* per square of 100 feet. There was twenty-four benches of these retorts. Each bench had eight long retorts, and there being two mouthpieces to a retort, made 384 mouthpieces in all. The retorts were cylinders 16 inches in diameter and 20 feet long; and each would carbonise one ton of coal per day. Allowing one-sixth the number for reserve, the remainder would produce 1,500,000 cubic feet of gas every twenty-four hours, or 300 millions per annum. The ascension pipes were 6 inches diameter at the bottom, and 5 inches at the top. The hydraulic mains, two to each block of six benches, were of larger section than usual, and were fastened with separate outlets to the collecting main. The buckstaves were of rolled iron, with tie-rods fixed clear of the brickwork. The gas, as it was produced, passed with the tar and liquor from the collecting pipes of the hydraulic mains, at either end of the retort-house, into 12-inch mains carried along the inside, and uniting in the middle of the south wall of the retort-house, from which point they issued by a 16-inch main to the condensers. At the end of the horizontal condensers the tar and liquor were deposited in a tank, whence they were led to the tar-tanks under the coal stores. From this point the gas passed successively through the vertical condensers, exhausters, scrubbers, purifiers, station meters, and driving exhausters, in the main leading to the gasholders at Hove. The mains and connections were 16 inches in diameter throughout.

'The engine-house contained four exhausters, each exhauster being driven directly by an independent engine. Two of these exhausters were for the purpose of removing the gas from the hydraulic mains and driving it through the scrubbers and purifiers. A self-acting by-pass was carried from the inlet of the exhausters to the inlet of the purifiers, and each exhauster was connected with a governor, which also acted as a by-pass. Only one of these exhausters was in use at a time, the other being in reserve. The remaining exhausters were also used one at a time, and were for the sole duty of receiving the gas at the outlet of the station meter, and of delivering it into the mains leading to the gasholders at Hove, so that the works were relieved from all pressure from the weight of gasholders and resistance of the intervening mains. An hydraulic by-pass made to resist back pressure was placed between the meter and the main, and each exhauster being connected with a governor, a slight uniform pressure was maintained at the outlet of the meter.

'The scrubbers used at these works were the first of the kind erected. They consisted of a series of perforated discs or screens, which revolved slowly in a tank half filled with liquor, so that the gas might pass through the portions of the screens above water. The gas was in this way divided into a series of small streams, each stream being brought equally into repeated contact with a thoroughly wetted surface. The screens being fitted at the edge with an elastic fringe, made by preference of bass, there was but little friction against the circular portion of the tank, and as no advantage was gained by a speed of more than fifty revolutions per hour. the power to keep the screens in motion was very small. There was a slight difference in the heights of the bases of the scrubbers, the first being the lowest and the third the highest. In working, the gas passed through each scrubber from the lowest to the highest of the set. Water entered the highest scrubber and ran through the middle and lower scrubbers to the liquor tanks, the desired strength of the liquor being obtained by regulating the volume of water admitted to the highest scrubber. The scrubbers removed 95 per cent. of the ammonia, 50 per cent. of the sulphuretted hydrogen, and from 30 per cent. to 50 per cent. of the carbonic acid existing in the crude gas. They offered no preceptible resistance to the flow of gas and were free from the disadvantages of the vertical scrubbers in ordinary use. There were seven purifiers in a line with each other; each purifier was 36 feet long, 18 feet wide, and 5 feet deep, with water lutes 2 feet 3 inches deep. The covers were lifted at four points, two on each side, by a travelling lift passing on rails through the entire length of the shed. In consequence of the large surface of the covers, and the occasional heavy pressure to which they were subjected, each cover was held down by four Lewis fastenings, instead of by the usual bars and clips. As the purifiers were near high-water mark, they were placed on pile foundations 3 feet above the surface of the ground, and when the pipes and connections had been laid between the piles, the spaces under the purifiers were filled up. Tramways were laid at each side of the line of purifiers, and the purifying material was brought and removed from the oxide and lime sheds at either end in wagons. The shed covering the purifiers was of light construction, and was closed on the side next the sea and open on the other side. The revivifying sheds at either end were each 100 feet long and 50 feet wide, and were fitted with framed moveable louvres. The first three purifiers were for lime, the next three for oxide of iron, and the last was also for oxide of iron, to be used as a check purifier. The collective internal capacity of the purifiers amounted to 22,600 cubic feet. The station meter, one of the largest yet made, was erected by Messrs. Parkinson and Son, to pass 100,000 cubic feet of gas per hour, and was placed next to the engine-house. The gasholders were all at Hove, and their tanks were about 34 feet above the level of the works at Portslade.

'The entire cost of the works was about 72,000*l.*; and when the proposed second retort-house and coal store were erected upon the site allotted for them, the total expenditure would amount to 100,000*l.* The works would then be capable of producing 600 million cubic feet of gas per annum, at a cost of 166*l.* per million on the capital so expended.'

Gas-lighting by Electricity.—The following account is from the pen of Mr. W. L. Wise, A.I.C.E.:—

'Some curiosity has recently been excited relative to experiments made first in Germany and subsequently at Preston, in lighting gas by electricity, on the plan invented by Professor Klinkerfues, director of the Royal Observatory at Göttingen.

'Few persons will question that the art of lighting gas by electricity is as yet in its infancy, and has a great future before it as applied not only to buildings, but also to the lighting-up of large towns. The subtle agent, electricity, by which such marvels as instantaneous communication between points thousands of miles apart have been rendered possible, would seem to be peculiarly adapted as a medium for enabling operations to be simultaneously performed at many distant points, from any given place, and, on this account, has commended itself to many inventive minds as the best means for rapidly lighting gas in towns and large buildings, with what success remains to be seen.

The advantages to be derived from a practical system of igniting gas, without the use of an exposed flame for the purpose, will be fully appreciated by those acquainted with the difficulties and dangers attending the ordinary methods of lighting gas, and the frequent accidents arising from the careless use of matches and negligent ignitions, not only in private houses, but also in warehouses, magazines, cotton-mills, and workrooms, especially where the manufacture of inflammable materials is carried on. There is, also, considerable inconvenience and waste in connection with the lighting-up of turret clocks, and the ignition of gas in other places difficult of access, where, in some cases, to save the great trouble of lighting and extinguishing, the gas is kept constantly burning, instead of being extinguished during the day-time.

'Then, as to street lamps, several important points claim attention. The old-fashioned system of carrying a ladder with a lighted fuse from lamp to lamp, though still used in many towns, has, nevertheless, been somewhat improved upon by the introduction of the lighting staff; notwithstanding the use of which, however, our present mode of street lamp-lighting is a tedious, wasteful, and expensive process. Not only does it involve the employment in every considerable town of a large staff of lamp-lighters, but, in order that all the lamps may be lighted by dusk, the lighting operation has to be commenced some time before any lights are really wanted, so that gas is consumed to no purpose.

'Many plans have been from time to time proposed for igniting gas by electricity.

'Many years ago Admiral Sheringham made experiments in Portsmouth Harbour, with a view to the illuminating of buoys and beacons, &c., by gas ignited by electricity.

'Some years later Mr. Simon Petit proposed lighting several gas-jets simultaneously, or in very rapid succession, by providing each burner with a valve or cock, to be opened and closed by means of an electric current, acting directly upon it by means of an electro-magnet or coil, or indirectly by a releasing detent, an electric spark being passed through the issuing gas at the moment of opening the valve, or immediately afterwards.

'At about the same time Mr. Isham Baggs proposed certain arrangements for instantly igniting gas by the use of frictional or high-tension electricity, as also means for turning on and off the gas when required. The burner of each lamp was to be provided with a strip of glass, or other non-conducting material, placed horizontally, having a couple of wires passed through it, one at each side of the burner, the ends of the two wires being brought close to each other at a short distance above the aperture of the burner. To the lower ends of these wires others were to be attached, suitably insulated from the metallic portion of the lamp, and joined to wires connecting it to the other lamps in a given circuit. Several plans were suggested for turning the gas on and off, one being to provide several burners with a common tap, to be turned on and off by air pressure and vacuum in a small cylinder containing a piston connected to the lever of the gas-tap. For effecting the ignition, Mr. Baggs preferred to use an ordinary plate electrical machine and a Leyden jar, or combination of jars, for sending the requisite currents of electricity through the wires of each circuit.

'Another plan, proposed by Mr. Denny Lane, was the use of a portable battery, to be carried from lamp to lamp, a piece or pieces of platinum wire being suitably placed in proximity to the orifice of each burner.

'More recently Mr. Robert Cornelius has brought out a plan for igniting gas, by an electric spark generated by frictional electricity, at the point of a wire bent over the top of a gas-burner. A chain attached to this wire was carried to some accessible point, and upon being touched by a portable electric apparatus, or acted upon by a stationary battery fixed in any convenient position, a current of electricity was conveyed to the pointed wire over the burner, and the gas issuing from it thereby ignited. He proposed several kinds of small stationary frictional batteries suited to the purpose named, and also a small portable battery, in the form of a tube, with a metal rod, coated with vulcanite working loose in the inside. The tube was to be lined with lambs'-skin or other suitable material adapted for the purposes of frictional electricity, the depression or elevation of one end of the tube causing the metal rod to slide downwards by its own gravity, so as to generate sufficient electricity for lighting the gas issuing from the burner.

'Mr. Barbarin subsequently proposed two plans, one involving the combined use of electricity and clockwork, a very complex arrangement; the other dispensing with the clockwork and electric currents, and employing a quicksilver closing and hydrogen gas, in conjunction with spongy platinum, for igniting the gas.

'The following are the lighting arrangements at the Royal Albert Hall, South Kensington:—The lights are arranged in thirty clusters of five stars each, each star containing twenty-one jets or burners. A bichromate battery is made to work an inductorium, or induction coil, connected to which is a semicircular insulated arrangement. Attached to this are thirty wires, which lead off, one to each of the thirty clusters. The burners are arranged in sets of three, somewhat like a three-pronged fork, and the ends of a couple of platinum wires, connected with the battery, are fixed, within a short distance of each other, near the orifice of the centre burner of one set in each star, there being a special conducting wire from the battery to one of the stars in each cluster, or thirty wires in all. When the galvanic circuit is closed, by lowering the plates of the battery into the acid, a spark is caused to fly from the point of one platinum wire to the other, and thereby ignites the gas issuing from the burner. Since that burner is within lighting range of its neighbours at each side, they in turn with those next to them, and so on, the ignition of the gas proceeds from one to the other all round the star. The platinum wires are held by iron wires, attached by a small block of steatite to the stem of the burner, and are placed slightly below the horizontal line of the small burner orifice, so that when the gas is alight the upward draught draws the flame away, and so prevents deposit of carbon upon them. The gas is turned on and off by stopcocks in the mains in the ordinary way.

'Professor Klinkerfues' arrangements are based upon the use of compact platinum, in connection with a galvanic battery, without the intervention of any coil, the movement of the plates or of the electro-motive liquid by mechanical means, or by gas-pressure completing the galvanic circuit, the gas being at the same time brought into contact with the heated platinum wire, and thereby ignited. His experiments demonstrated that for this purpose less than a red heat was required, as a platinum wire inserted between the poles of a very small pair of zinc and graphite, without showing the slightest emission of light in a dark room, ignited a jet of gas almost immediately. For opening and closing the gas-passage leading to the burner, and lighting and extinguishing the gas as required, by simply altering the pressure in the main, he combines a bell-shaped compartment with the gas-pipe and the vessel containing the electromotive liquid in such a way that when the gas is at its lowest pressure the liquid seals the gas-pipe. By increasing the gas-pressure the passage to the burner is opened, and by a still farther temporary augmentation of the gas-pressure, the galvanic circuit is completed, so that the issuing gas, impinging upon the platinum wire between the poles of the battery, is ignited. In its most simple form his apparatus constitutes a hand-igniter, to be used in lieu of matches, spills, or tapers for lighting gas at any burner. It consists of a thin, hollow, glass vessel, several inches high, closed at the bottom, and provided with a cover which screws into a mounting attached to the neck of the vessel, so as to hermetically close it. The cover has fixed to it, and carries beneath it, the galvanic pair, consisting of a perforated tubular piece of zinc, and a cylindrical piece of graphite or carbon. Above the cover are the electrodes, connected by a piece of platinum wire. The electrodes consist of two brass wires, one of them screwed into the metal cover, which is in direct contact with the zinc; the other passes to the carbon through the cover, from which it is insulated. The electromotive liquid used is the well-known mixture of bichromate of potash with dilute sulphuric acid. In order to light gas with this simple apparatus, it is only necessary to incline it sufficiently to bring the liquid into contact with the zinc-and-carbon pair, and at the same time to hold the platinum wire in contact with the jet of gas issuing from the burner. When the apparatus is placed in an upright position, the zinc and carbon do not touch the liquid, consequently no galvanic action takes place, and no material is consumed.

'The street-lamp arrangement is designed to simultaneously light or extinguish a number of lamps from a single station. But Professor Klinkerfues, considering that galvanic batteries intended for the production of caloric would be of weak resistance, and therefore incompatible with great lengths of conducting wires and long duration of galvanic action, without frequent renovation of the liquid, decided to furnish each lamp-post with its own galvanic apparatus, and to make the galvanic pair touch the liquid only during the short time necessary for lighting up. In his apparatus for this purpose the vessel containing the liquid is provided with an internal tube leading to the burner, and having an enlargement at its lower part, as already mentioned. This tube is attached at its upper end to the cover. The gas-pipe enters the vessel at its lower part, and terminates within the tube. The carbon rests upon the enlargement of the tube leading to the burner; and the zinc, in the form of a ring, which is insulated from the tube, is attached to a screwed wire or rod, surrounded at its lower end by insulating material, and passing up through a suitable insulator in the cover to a connecting bar, upon which rests a nut, whereby the zinc is held and adjusted. One of the electrodes is attached directly to the connecting bar, and the other is insulated from the bar and attached to the cover. The upper end of the gas-pipe, situated within the tube leading to the burner, is perforated, and a cap, adjustable by a screw, which screws into the pipe, fits easily over it, the lower end of the cap passing down below the level at which the liquid stands when the gas is at its lowest pressure. An annular space is thus left between the cap and the gas-pipe, and the interior of the latter communicates by the apertures at its upper end with the annular space.

'The action of the apparatus is as follows:—When the gas is at its lowest pressure, and the surface of the liquid in the annular space between the gas-pipe and its cap is at or about its highest level, the liquid seals the lower part of that annular space, thereby preventing the passage of gas into the tube and thence to the burner. By slightly increasing the pressure of gas, it will force the liquid down in the annular space, thereby raising the level in the main vessel until the gas is permitted to pass by the tube to the burner, and then, by a still further augmentation of the gas-pressure for a few seconds, the liquid is temporarily forced up in the vessel into contact with the zinc, thereby completing the galvanic circle, and igniting the gas issuing from the burner as it comes in contact with the heated platinum wire. After this is effected, a slight remission of the gas-pressure causes the level of the liquid in the vessel to fall below the zinc, thereby breaking the galvanic circuit in order to avoid unnecessary exposure, but without shutting off the supply of gas to the burner. The extinction of the light is effected by reducing the pressure, so that the level of the liquid rises up within the annular space between the pipe and its cap, and thereby shuts off the communication to the burner. The apparatus is accommodated to variations of pressure at different altitudes, by adjusting the position of its cap, and the extent to which it dips in the liquid by means of its screw.

'The practicability of this apparatus was first publicly demonstrated by a three months' test in Göttingen, when it was applied to forty street-lamps in the principal thoroughfares; and the Gas Commission certified that the apparatus had worked continuously to their satisfaction. But the experiments more recently conducted at Preston were as follow:—

'The apparatus was fitted to a lamp near the Lady's Walk, Moor Park, a mile and a quarter distant from the gas works in Glover Street, whence the apparatus was to be operated. The times having been previously agreed upon at which the lamp should be lighted and the light extinguished, watches were carefully compared, so that the feasibility of at will almost instantaneously changing the gas-pressure in the lamp apparatus to a definite extent, by means of a regulator at works far removed from the lamps, might be demonstrated. The regulator in Glover Street being operated upon at the agreed times, the lamp a mile and a quarter distant was lighted with scarcely any perceptible lapse of time, left burning for five minutes, as had been previously arranged, and then was promptly extinguished. This process was repeated several times. Similar experiments were tried on a lamp in Ribblesdale Place, and on another in Fishergate, the two being in sight of each other, about a quarter of a mile apart, and the same distance from the gas-works. They were lighted simultaneously by one operation on the regulator at the agreed time, and both lights were extinguished promptly when the pressure was reduced. The several lamps used for the trial were taken at hap-hazard, none of the service-pipes having been tested for defects; nevertheless, the experiments were considered highly satisfactory.

'For lighting sunlights the foregoing arrangement is modified, only one battery being used for each cluster of lights. The vessel containing the liquid is placed in the middle, and is carried by a hollow centre-piece above it, from which the several arms or branches of the sunlight project radially. The centre-piece is screwed on to the gas-pipe, whose lower end passes down into the vessel containing the liquid, and is enlarged at its lower part, and leads to the centre-piece above. The lower end of the pipe is closed by the liquid when the gas is at its minimum pressure, and opened by increasing the pressure, the galvanic circuit being completed for igniting the gas by a temporary augmentation of pressure, as in the street-lamp apparatus. The electrodes are situated at each side of one burner only, across which the platinum wire passes, and all the burners being within lighting range of each other, the whole of the gas jets are rapidly ignited. The dip of the pipe into the liquid may be varied, as required, by simply turning the centre-piece. The requisite changes in the gas-pressure are effected by means of a suitable regulator, as well understood.

'The office desk, or table apparatus, is an ingenious modification, in which the battery resembles those of the street and sunlight arrangements, except that, there being a hydrostatic tap, and the electromotive fluid being brought into contact with the zinc by the pressure of the gas, the zinc is lowered into the acid by a mechanical arrangement, operated by hand-pressure upon a suitable knob, by which, at the same time, an ordinary gas-tap is opened, the platinum is moved over, and ignites the issuing gas. A spring returns the zinc and platinum wire to their original positions, on the removal of the pressure from the knob.'

GASEOUS. All permanently elastic fluids are usually so called. Oxygen, hydrogen, nitrogen, are gaseous bodies.

GASES, ABSORPTION OF. All bodies, liquid or solid, absorb gases, the amount of gases absorbed depending on some mechanical conditions which are by no means satisfactorily explained. This is not the place to enter into any examination of this most interesting and important question. Yet, as the consideration of the phenomena involved is continually pressing itself upon the manufacturer, some brief notice appears necessary.

Gases are absorbed by liquids under two distinct sets of laws, according as the gas enters into chemical combination with the liquid or not. The amount of gas absorbed by a liquid, on which it exerts no chemical action, depends on the specific nature of the gas and the liquid, on temperature, and on pressure.

Gases are absorbed by solids in virtue of some power residing upon their surfaces. The phenomena of 'catalytic' action, of 'capillary' attraction, and of 'exosmose' and 'endosmose,' appear to be all due to the force which compels the condensation of gases,—*and liquids*—upon the surfaces of all solids. Under CHARCOAL, many examples of this are given. The whole subject demands an investigation which it has not yet received, See Watts's 'Dictionary of Chemistry' for a very full description of all the important experiments which bear upon the subject.

GASES, DIFFUSION OF. All gases and all vapours, have a tendency to diffuse themselves through one another. The spontaneous evaporation of water is an example of vapour-diffusion. The way in which coal-gas mixes itself with the air of an apartment is one of gas-diffusion. The point to be remembered, however, is that this diffusion readily takes place in opposition to the law of gravity; as a light gas, contained in a vessel with an open mouth inverted, gradually descends—is diffused—into the heavier gas in which it may be placed, and eventually a mixture of the two is effected.

This subject was very carefully investigated by the late Professor Graham. See his 'Elements of Chemistry,' and Watts's 'Dictionary of Chemistry.'

GASES, OSMOSE OF. The phenomenon of the passage of a gas through membranaceous diaphragms is so called. See Graham's paper in the 'Philosophical Transactions of the Royal Society.'

GASES, TRANSPIRATION OF. The passage of gases through capillary tubes. All these phenomena are well explained in Watts's 'Dictionary of Chemistry.'

GAS-HOLDER. A vessel for containing and preserving gas, of which various forms are described by chemical writers.

GAS, LAUGHING. *Protoxide of Nitrogen; Nitrous Oxide; or Nitrogen monoxide,* NO (**N^2O**). This gas is always prepared from the nitrate of ammonia. When this salt is heated in the solid state, it is completely resolved into laughing-gas and water. The heat should be applied with caution so as to avoid too sudden a disengagement of gas. Laughing-gas was first described by Priestley in 1776, and carefully studied by Davy. This gas is chiefly remarkable for the peculiar intoxication which it produces when breathed. It is not to be used without much caution. If it is not very pure, serious consequences may ensue; and even when absolutely pure, the editor has seen the nitrous oxide produce very distressing effects. It has of late been extensively used as an anæsthetic by dentists.

GASOMETER, means properly a measurer of gas, though it is employed often to denote a recipient of gas of any kind. See GAS, COAL.

GAS-PIPES. When the illumination by gas was first introduced in the large way by Aaron Manby, Esq., then of the Horsley Iron Works, the old musket-barrels, laid by in quiet retirement from the fatigues of the last war, were employed for the conveyance of gas; and by a curious coincidence, various iron foundries desisted in a great measure from the manufacture of iron ordnance, and took up the peaceful employment of casting pipes for gas and water.

The breech-ends of the musket-barrels were broached and tapped, and the muzzles were screwed externally, to connect the two without detached sockets. From the rapid increase of gas-illumination, the old gun-barrels soon became scarce, and new tubes, with detached sockets, made by the old barrel-forgers, were first resorted to. This led to a series of valuable contrivances for the manufacture of the wrought-iron tubes, commencing with the Russell's patent in 1824, under which the tubes were first bent up by hand hammers and swages, to bring the edges near together; and were then welded between semi-circular swages, fixed respectively in the anvil, and the face of a small tilt hammer worked by machinery, by a series of blows along the tube either with or without a mandrel. The tube was completed on being passed between rollers with half-round grooves, which forced it over a conical or egg-shaped piece at the end of a long bar to perfect the interior surface.

Various steps of improvements have been since made; for instance, the skelps were bent at two squeezes, first to the semi-cylindrical, and then to the tubular form preparatory to welding, between a swage tool five feet long worked by machinery. The whole process was afterwards carried on by rollers, but abandoned on account of the unequal velocity at which the greatest and least diameters of the rollers travelled.

In the present method of manufacturing the patent welded tube, the end of the skelp is bent to the circular form, its entire length is raised to the welding heat in an appropriate furnace, and as it leaves the furnace almost at the point of fusion it is dragged by the chain of a draw-bench, after the manner of wire, through a pair of tongs with two bell-mouthed jaws, these are opened at the moment of introducing the end of the skelp, which is welded without the agency of a mandrel.

By this ingenious arrangement wrought-iron tubes may be made from the diameter of six inches internally, and about one-eighth to three-eighths of an inch thick, to as small as one quarter-inch diameter and one-tenth bore; and so admirably is the joining effected in those of the best description, that they will withstand the greatest pressures of gas, steam, or water to which they have been subjected, and they admit of being bent both in the heated and cold state, almost with impunity. Sometimes the tubes are made one upon the other when greater thickness is required, but these stout pipes and those larger than three inches are comparatively but little used.—(*Holtzapffel.*)

GASSING. In order to remove the hairy filaments from net-lace and other woven fabrics, they are passed over a large number of minute jets of gas, and between rollers.

GAS SINGEING MACHINE. See CALICO-PRINTING.

GAULT sometimes **GOLT,** a local term in some parts of England for clay, has been adopted into geological nomenclature to denote the argillaceous strata which separate the Upper and Lower Greensands. It is a dark blue or grey clay, used for making bricks and tiles; it affords a poor agricultural soil, which is generally converted into pasture.—H. W. B.

GAULTHERIA OIL, or *Wintergreen Oil.* A volatile oil obtained from the *Gaultheria procumbens,* the Wintergreen or Canada tea. It has an agreeable aromatic odour, and is used for scenting soaps.

GAULTHERINE. One of the hydrocarbons isomeric with oil of turpentine which exists in Wintergreen oil, and the oil obtained by distilling the *Betula lenta,* the sweet or cherry birch.

GAUZE. See CRAPE.

GAUZE WIRE CLOTH is a textile fabric, either plain or tweeled, made of brass, iron, or copper wire, of very various degrees of fineness and openness of textures. Its chief uses are for sieves and safety lamps.

GAY-LUSSITE is a white mineral of vitreous fracture, which crystallises in oblique rhomboidal prisms; specific gravity from 1·93 to 1·95; scratches gypsum, but is scratched by calcspar; affords water by calcination; it consists of carbonic acid, 28·66; soda, 20·44; lime, 17·70; water, 32·30; clay, 1·00. It is, in fact, by Dr. Ure's analysis, a hydrated soda-carbonate of lime in atomic proportions. This mineral occurs abundantly in insulated crystals, disseminated through the bed of clay which covers the *urao,* or native sesquicarbonate of soda, at Lagunilla in Columbia. It is known to the natives as *clavos,* or nails. Gay-Lussite is also found in Little Salt Lake, near Ragtown, Nevada.

GAZOLINE. A name given to one of the mineral oils. See NAPHTHA.

GEDGE'S ALLOY. A hard alloy of copper, zinc, and iron, said to be well adapted for sheathing ships. A good alloy contains about—copper 60, zinc 38·2, and iron 1·8 per cent.

GEHLENITE. A silicate of lime, alumina, and sesquioxide of iron; occurring in grey or brown crystals belonging to the pyramidal system. A product agreeing with gehlenite in both chemical composition and crystalline form occurs among blast-furnace slags.

GELATINE (Eng. and Fr.; *Gallerte, Leim,* Ger.), is an animal product which is never found in the humours, but it may be obtained by boiling with water the soft and solid parts, as the muscles, the skin, the cartilages, bones, ligaments, tendons, and membranes. Isinglass consists of from 86 to 93 per cent. of gelatine. This substance is very soluble in boiling water; the solution forming a tremulous mass of jelly when it cools. Cold water has little action upon gelatine. Alcohol and tannin precipitate gelatine from its solution; the former by abstracting the water, the latter by combining with the substance itself into an insoluble compound, of the nature of leather. No other acid, except the tannic, and no alkali, possesses the property of precipitating gelatine. But chlorine and certain salts render its solution more or less turbid; as the nitrate and bi-chloride of mercury, the proto-chloride of tin, and a few others. Sulphuric acid converts a solution of gelatine at a boiling heat into sugar. Gelatine consists of carbon, 47·88; hydrogen, 7·91; oxygen, 27·21.

Gelatine is produced by boiling the skin of animals in water, which in its crude but solid state is called *glue,* and when a tremulous semi-liquid, *size.* See those articles.

A fine gelatine for culinary uses is prepared and sold as Nelson's patent gelatine. It is thus prepared:—After washing the parings, &c., of skin, he scores their surfaces, and then digests them in a dilute caustic soda lye during ten days. They are next placed in an air-tight vat, lined with cement, kept at a temperature of 70° Fahr.; then washed in a revolving cylinder-apparatus with plenty of cold water, and afterwards exposed to the fumes of burning sulphur (sulphurous acid) in a wooden chamber. They are now squeezed to expel the moisture, and finally converted into soluble gelatine, by water in earthen vessels, enclosed in steam-cases. The fluid gelatine, is purified by straining it at a temperature of 100° or 120° Fahr.

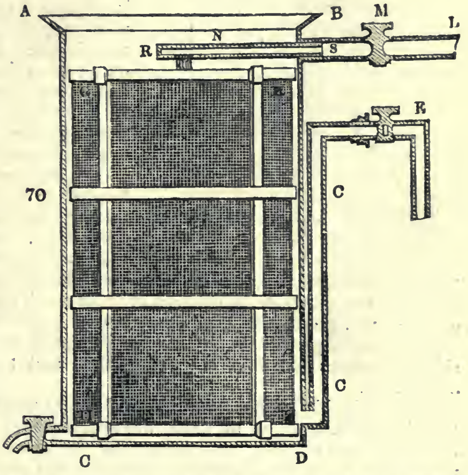
A sparkling gelatine has been prepared under a patent granted to Messrs. J. and G. Cox, of Edinburgh. By their process the substance is rendered perfectly pure, while it possesses a gelatinising force superior even to isinglass. It makes a splendid calves'-feet jelly and a milk-white blanc-mange. The patentees also prepare a semi-solid gelatine, resembling jujubes, which readily dissolves in warm water, as also in the mouth, and may be employed to make an extemporaneous jelly.

The gelatine of bones may be extracted best by the combined action of steam and a current of water trickling over their crushed fragments in a properly-constructed apparatus. When the gelatine is to be used as an alimentary article, the bones ought to be quite fresh, well preserved in brine, or to be dried strongly by a stove. Bones are best crushed by passing them between grooved iron rolls. Tha cast-iron cylinders in which they are to be steamed should be three times greater in length than in diameter. To obtain 1,000 rations of gelatinous soup daily, a charge of four cylinders is required; each being 3½ feet long, by 14 inches wide, capable of holding 70 lbs. of bones. These will yield each hour about 20 gallons of a strong jelly, and will require nearly 1 gallon of water in the form of steam, and 5 gallons of water to be passed through them in the liquid state. The 5 quarts of jelly produced hourly by each cylinder proceeds from the 1 quart of steam-water and 4 quarts of percolating water.

The boiler should furnish steam of about 223° Fahr., at a pressure of about 4 lbs. on the square inch.

In *fig.*1082 A, B, C, D, represent a vertical section of the cylinder; G, H, I, K, a section of the basket or cage, as filled with the bruised bones, inclosed in the cylinder; E, C, C, the pipe which conducts the steam down to the bottom of the cylinder; L, S, a pipe for introducing water into the interior; M, a stopcock for regulating the quantity of water (according to the force of the steam-pressure within the apparatus), which should be 3½ quarts per hour; N is a tube of tin plate fitting tightly into the part S of the pipe L; it is shut at R, and perforated below with a hole; it is inserted in its place, after the cage-full of bones has been introduced. *Fig.* 1083 is an elevation of the apparatus. A, B, C, D, represent the four cylinders, raised about 20 inches above the floor, and fixed in their seats by screws; *h h*, are the lids; *g g*, tubulures or valves in the lids; *i*, ring junction of the lid; *p*, a thermometer; *f f*, stopcocks for drawing off the jelly; *n n*, small gutters of tin-plate; *m*, the general gutter of discharge into the cistern *b*; *o*, a block and tackle for hoisting the cage-full of bones in and out.

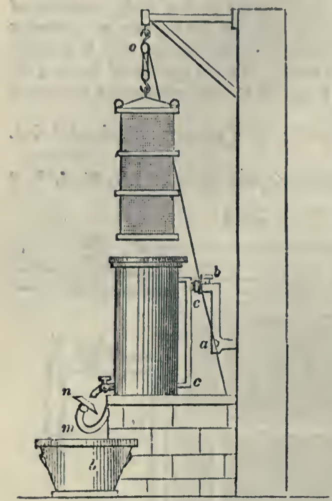
1082



1083

Fig. 1084 is an end view of the apparatus; *a*, the main steam-pipe; *a*, *b*, *c*, *c*, branches that conduct the steam to the bottom of the cylinder; *o*, the tackle for raising the cage; *s*, stopcock; *n*, small gutter; *m*, main conduit; *b*, cistern of reception.

1084



When a strong and pure jelly is wished for, the cylinder charged with the bones is to be wrapped in blanket-stuff; and whenever the grease ceases to drop, the stopcock which admits the cold water is to be shut, as also that at the bottom of the cylinder, which is to be opened only at the end of every hour, and so little as to let the gelatinous solution run out, without allowing any of the steam to escape with it.

Butchers' meat contains, on an average, in 100 pounds, 24 of dry flesh, 56 of water, and 20 of bones. These 20 pounds can furnish 6 pounds of alimentary substance in a dry state; whence it appears that, by the above means, one fourth more nutritious matter can be obtained than is usually got. A keen dispute has been carried on for some time in Paris, between the partisans and adversaries of gelatine as an article of food. It is probable that both parties have pushed their arguments too far. Calf's-foot jelly is still deemed a nutritious article by the medical men of this country, at least; though it is not to be trusted to alone, but should have a due admixture or interchange of fibrine, albumen, caseine, &c. See NUTRITION.

French Gelatine is sold in cakes, marked, like those of common glue, with the nets on which they have been dried. This gelatine is made at Paris, from the cuttings of skins used for making white kid gloves; it is coloured red, green, and blue, as well as sold colourless.

Swinbourne's patent refined Isinglass is a pure form of gelatine, procured from the skins of calves cut into very thin slices and treated simply with water at or about 200°.

D'Arcet, in his *Recherches sur les Substances nutritives que renferment les Os*, states that, in Paris, bones of all kinds are first digested with hydrochloric acid to extract the phosphate of lime, and then boiled in water under pressure. In this way a nutritious soup is prepared for the hospitals and other pauper establishments.

Dr. T. Richardson of Newcastle-on-Tyne treats bones first with muriatic or dilute sulphuric acid to dissolve out a portion of the mineral phosphates which they contain; the residue being then acted upon by sulphurous acid. The gelatine obtained after this process is treated with an alkaline sulphate or hyposulphate, or it may be treated with the phosphates of an alkali, or with the sulphurous-acid solution of the diphosphates of lime and magnesia. By any of these processes, it is said, the hardness and sizing-properties of gelatine from any source may be very considerably improved. See ISINGLASS.

GEMS are precious stones, which, by their colour, limpidity, lustre, brilliant polish, purity, and rarity, are sought after as objects of dress and decoration. Among these beautiful minerals, mankind have agreed in forming a select class to which the title of *gems* or *jewels* has been appropriated; while the term *precious stone* is more particularly given to substances which occur of a larger size and more commonly.

Diamonds, sapphires, emeralds, rubies, topazes, opals, hyacinths, and chrysoberyls, are reckoned the most valuable *gems*.

Crystalline quartz, pellucid, opalescent, or of various hues, amethyst, lapis-lazuli, malachite, jasper, agate, &c., are ranked in the much more numerous and inferior class of *precious stones*. These distinctions are not founded upon any strict philosophical principle, but are regulated by a conventional agreement, not very well defined; for it is impossible to subject these creatures of fashion and taste to the rigid subdivisions of science. We have only to consider the value currently attached to them, and take care not to confound two stones of the same colour, but which may be very differently prized by the *virtuoso*.

Since it usually happens that the true gems are in a cut and polished state, or even set in gold or silver, we are thereby unable to apply to them many of the criteria of mineralogical and chemical science. The cutting of the stone has removed or masked its crystalline character, and the phenomena of double or single refraction are often difficult to be observed; whilst the test by the blowpipe is inadmissible. Hence the only scientific resources that remain are the trial by electricity, which is often inconclusive; the degree of hardness, a criterion requiring great experience in the person who employs it; and lastly, the proof of specific gravity, unquestionably one of the surest means of distinguishing the really fine gems from ornamental stones of similar colour. This proof can be applied only to a stone that is not set.

The specific gravity may be determined by any person of common intelligence, with the aid of a small hydrostatic balance. If, for example, a stone of a fine crimson-red colour be offered for sale as an oriental ruby, the purchaser must ascertain if it be not a Siberian tourmaline, or a spinel ruby. Supposing its weight in air to be 100 grains, if he finds it reduced to 69 grains when weighed in water, he concludes that its bulk is equal to that of 31 grains of water, which is its loss of weight. Now, a real sapphire which weighs 100 grains in air, would have weighed 76·6 in water; a spinel ruby of 100 grains would have weighed 72·2 in water, and a Siberian tourmaline of 100 grains would have weighed only 69 grains in water. The quality of the stone in question is, therefore, determined beyond all dispute, and the purchaser may be thus protected from fraud. See DIAMOND, RUBY, &c. &c.

As the discrimination of one species of gem from another is often a matter of great practical importance, and sometimes of much delicacy, it may be useful to group together such easily-applied tests as will enable even an inexperienced observer to determine the true character of any given stone. In the following comparative tables the specific gravity (S.G.) is placed in the first column, as being in many cases the most valuable characteristic. This may be determined by means either of the hydrostatic balance or of Nicholson's hydrometer. For determining the loss of weight in water, a delicate chemical balance is generally needed; a common pair of grain scales is certainly of no use when operating on specimens weighing less than 10 grains. Distilled water should be employed; but, in its absence, rain-water may be used. With great experience, a rough notion of the specific gravity of a stone may be obtained by poising it in the palm of the hand. In the second column of the table the degree of hardness (H.) is specified. These relative degrees of hardness are expressed on Mohs's mineralogical scale. If the specimen under test be too small to be conveniently held in the fingers, it may be partially embedded in a stick of sealing-wax, and examined in this position. A glazier's diamond is sometimes useful, as it scratches every gem-stone, excepting the diamond; whilst a good steel file is serviceable in distinguishing true stones from pastes. The third column of the tables gives the character of the refraction, whether single (S.R.) or double (D.R.), which each gem exhibits. This character may be ascertained by placing the stone between two crossed plates of tourmaline; if the dark field becomes more or less illuminated, the mineral is doubly-refracting, whilst if it remains dark, it is probably singly-refracting. Other optical characters of cut stones may be examined by the dichroiscope. This instrument is of no service in dealing with singly-refracting minerals, but with doubly-refracting species it gives two images which often differ more or less decidedly in tint. The crystalline form and chemical composition are not noted in the following tables, because they are not available characters in examining cut gem-stones, but they are fully given in the articles which treat specially of each gem. As colour is the most obvious characteristic of a stone, it is used as the basis of arrangement in the following scheme. The colour of a cut stone is seen to greatest advantage when the specimen is held under water, at a depth of about half an inch from the surface.

In order to determine the true colour of a mounted stone, it should be removed from its setting; for the natural colour is often modified either by placing a foil behind the gem, or, occasionally, by painting the back of the stone itself.

Colourless Gems.

The colourless stones most likely to occur in commerce are the diamond, the topaz, and rock-crystal. These may be distinguished by the following characters:—

Diamond	S.G. 3·5	H. 10	S.R.
Topaz	„ 3·5	„ 8	D.R.
Rock-crystal	„ 2·5	„ 7	D.R.

The diamond is distinguished from all other stones by its excessive hardness; a glazier's diamond easily scratches topaz and rock-crystal, but does not touch, or scarcely touches, another diamond. The topaz is distinguished, in addition to the characters given above, by its perfect cleavage in one direction, so that a joint or flaw often runs across the stone; it also becomes electric when heated, or when a smooth face is excited by friction.

In addition to these gems, the following colourless stones, though comparatively rare, may sometimes occur in trade:—

White sapphire	S.G. 4·0	H. 9	D.R.
White spinel	„ 3·5	„ 8	S.R.
White zircon	„ 4·7	„ 7·5	D.R.
White beryl	„ 2·6	„ 7·5	D.R.
Phenakite	„ 3·0	„ 7·5	D.R.
Tourmaline	„ 3·0	„ 7	D.R.
Euclase	„ 3·0	„ 7·5	D.R.

Red Gems.

The following are the chief stones of this colour, to which may be added the red diamond, which occurs, however, but rarely:—

Ruby	S.G. 4	H. 9	D.R.
Spinel	„ 3·5	„ 8	S.R.
Garnet	„ 3·8	„ 7·5	S.R.
Topaz	„ 3·5	„ 8	D.R.
Rubellite	„ 3	„ 7·5	D.R.

Most of these stones present colours which are sufficiently distinct to be discriminated by the experienced eye. The ruby (true or oriental ruby) varies in tint from rose-red to carmine, the most esteemed stones presenting a deep rich red colour, called by jewellers pigeons' blood. The spinel (spinel ruby and balas ruby) is less brilliant in tint than the true ruby, and presents a variety of shades, some of which resemble the colours of certain garnets; the variety known as balas ruby is distinguished by a rose-pink colour, tending to blue. Garnets offer considerable variation in colour; the Bohemian garnet (pyrope) being of a dark fiery red, and the Oriental or Syrian garnet (almandine) varying in colour from deep crimson to violet. The topaz is never decidedly red, but sometimes presents a delicate pink tint, which is produced by the action of heat on stones which are normally of a yellow colour. Rubellite (red tourmaline) is characterized by becoming highly electric when heated or when exposed to friction.

By aid of the dichroiscope the red colour of the oriental ruby may be resolved either into a pale and a dark rose-red, or into a bluish and a yellowish red. The spinel and garnet, being singly-refracting species, do not admit of dichroiscopic examination.

Brown Gems.

Essonite	S.G. 3·6	H. 7·5	S.R.
Hyacinth	„ 4·7	„ 7·5	D.R.
Tourmaline	„ 3·0	„ 7·5	D.R.
Brown quartz	„ 2·6	„ 7	D.R.

Essonite (cinnamon stone or garnet) and hyacinth (zircon) present very similar colours—a fine reddish brown—but are readily distinguished by specific gravity. In the dichroiscope the colour of the zircon is resolved into a mixture of brown with greenish yellow and brown with red.

The brown tourmaline yields images of similar colours, and brown quartz gives a yellowish brown and a violet-brown image.

A few other stones of a brown colour are occasionally met with, namely:—brown diamond, chrysoberyl, axinite, idocrase, andalusite, and epidote.

Yellow Gems.

Topaz	S.G. 3·5	H. 8	D.R.
Chrysoberyl	„ 3·7	„ 8·5	D.R.
Yellow beryl	„ 2·7	„ 8	D.R.
Yellow quartz	„ 2·6	„ 7	D.R.
Zircon	„ 4·7	„ 7·5	D.R.
Oriental topaz	„ 4	„ 9	D.R.

The colour of the topaz is a straw-yellow or wine-yellow; that of the chrysoberyl a greenish yellow; and of the zircon a brownish yellow. The true topaz, false topaz (yellow quartz), and oriental topaz (yellow corundum) may be very similar in colour, but the three species are readily distinguished, as seen in the table, by differences in hardness and specific gravity. The colour of the topaz when examined in the dichroiscope is often different in three different directions, and may thus present a pale straw-yellow, a pale honey-yellow, and a reddish yellow.

Green Gems.

Emerald	S.G. 2·7	H. 8	D.R.
Chrysolite	„ 3·3	„ 6·5	D.R.
Tourmaline	„ 3·0	„ 7·5	D.R.
Oriental emerald	„ 4	„ 9	D.R.

The colour of the true emerald is a very bright green, the pale green and bluish green varieties being distinguished as beryl or aqua-marine: the emerald is rarely without flaws, which are so characteristic as to be imitated in mock stones. The chrysolite or peridot presents a very dull green colour, and is so soft as to be easily abraded when worn, and thus soon loses its brilliancy of surface and sharpness of edge. The dichroiscope resolves the colour of the emerald into a yellowish green and a bluish green; of the tourmaline into a pale green and a dark blackish green; and of the Oriental emerald (green corundum) into green and yellowish green. But the Oriental emerald rarely occurs in trade, and is said indeed to be the rarest of all stones.

Blue Gems.

Sapphire	S.G. 4	H. 9	D.R.
Blue topaz	„ 3·5	„ 8	D.R.
Blue beryl	„ 2·7	„ 8	D.R.
Blue tourmaline	„ 3	„ 7·5	D.R.

By means of the dichroiscope, the colour of sapphire is resolved into a pale and a dark blue; that of topaz into a whitish blue, and a greenish blue; of beryl into similar tints to those of topaz; and of tourmaline into a pale bluish green and a very dark bluish green. Cyanite is occasionally cut as a jeweller's stone.

Purple or Violet Gems.

Amethyst	S.G. 2·6	H. 7·5	D.R.
Oriental amethyst	„ 4	„ 9	D.R.
Iolite	„ 2·6	„ 7	D.R.

The common amethyst (purple quartz) and the Oriental amethyst (purple corundum) are very similar in colour, but are readily distinguished by specific gravity and hardness; it should, however, be remarked that jewellers are in the habit of calling any stone of fine colour 'Oriental amethyst,' though it may have no mineralogical claim to the name. Iolite (dichroite) is characterized by its strongly-marked dichroism, commonly exhibiting a blue colour in one direction and a brownish yellow in another; some varieties are pleochroic, or exhibit several distinct shades in different directions.

Imitation Gems.—In determining a doubtful specimen the observer should always bear in mind the possibility of its being merely a paste, or imitation in fine glass. The inferior hardness of glass, compared with that of any precious stone, renders the determination easy. Although the hardness of glass varies with its composition, it rarely exceeds 5·5; all glass may, therefore, be readily scratched with a steel file. The more brilliant the glass the softer it generally becomes; and, therefore, pastes when worn soon get blunt and jagged at their edges and corners, whilst the surfaces become dull and scratched: such imperfections, if not readily seen by the naked eye, are at once detected by aid of a lens. The specific gravity of paste is not an available test, for it varies from 2·5 to 4·5 according to its composition; the greater the proportion of lead present, the more brilliant, the denser, the softer, and the more fusible is the glass. Like all uncrystallized substances, glass is singly-refracting.

In examining a stone, it is also necessary to guard against *doublets* or *semi-stones*. These are made up of two pieces; the upper half being a real stone, and therefore presenting its proper degree of hardness, whilst the lower half is either an inferior stone or mere glass. When such stones are set, it is difficult to detect the fraud. The deception arising from the use of foil has already been noticed in this article.—F.W.R.

GEMS, ARTIFICIAL. These are glasses, the material of which they are composed being called Strass.

Strass, the paste or glass which generally forms the principal ingredient of imitation gems, is called after the name of a German jeweller by whom it was invented, at the commencement of the last century. It is composed of silica, potash, borax, the various oxides of lead, and sometimes of arsenic: chemically it may be regarded as a double silicate of potash and lead.

The silica may be furnished either by rock crystal, white sand, or flint; but, of these, the first is to be preferred, one of the principal considerations in these preparations being the extreme purity of the materials or ingredients employed. In this manufacture, which is of more importance, and attended with greater difficulty than most persons imagine, perfect success (independently of the choice of materials) depends upon the care taken, and the precautions to be observed. No crucibles should be used but those which have been proved, both as regards their composition, their power of withstanding the strongest heat, and their impenetrability to the action of metallic oxides.

All the substances to be melted should be first pulverised, and even ground with the greatest care. It should be remembered that the most perfect mixture can only be effected by numerous siftings, and that a separate sieve should be used for each ingredient, and never be made to serve for different substances. When mixed, the materials should be melted in a crucible, placed in the middle of a cylindrical furnace, terminated in a dome, the height of which should be 7 feet 6 inches, and its diameter 4 feet 3 inches. The fuel should consist as much as possible of thoroughly dry wood, chopped very small. The melting should be effected by means of a heat raised by degrees, and then steadily maintained, especially at the maximum temperature: then when once the melting has been thoroughly accomplished, which cannot o in less than from twenty to thirty hours, the crucible must be allowed to cool very slowly.

The art of imitating precious stones in paste has amazingly improved since the time of Strass, as was shown by the results of the great Paris Exposition of 1855. The imitations, especially as regards certain colours, leave little to be desired; but there is something still in that respect in which the imitation is far from being perfect.

Now that it is proved that the alkalis and vitrifiable earths are oxides of the metals, all that has to be done to obtain the finest effects is to combine them skilfully with other artificially-prepared metallic oxides, which have undergone the process of vitrification.

Experiments ought to be made with all oxidisable and vitrifiable substances, with the different salts, fluates, phosphates, phosphoric acid, &c.

The following are some of the mixtures generally known, but, it must be observed here that each artist has his own processes, ingredients, and proportions:—

Mixtures for Strass.

	1.	2.	3.	4.
	grains	grains	grains	grains
Rock crystal	3396·2	3007·8	2897·5	3007·8
Minium	5280·8	...	4231·25	
White lead (pure) . . .	...	5641·0	...	5641·0
Potash (pure)	1804·77	1044·0	1625·15	1044·0
Borax	232·1	305·0	181·28	301·5
Arsenic	10·18	10·18	5·09	

Common Strass.

Litharge, 77·16; white sand, 57·73; potash, 7·71.

Strass of Douhaut-Wieland.

Sifted rock crystal . .	2897·5	Deutoxide of arsenic . .	4·92
Boracic acid . . .	181·18	Potash (purest) . . .	1608·53
Minium (purest) . .	4451·37		

English Strass.

Calcined flints . . .	962·5	Calcined borax . . .	361·9
Pure potash . . .	481·25	Fine white lead . . .	120·89

Strass Bastenaire.

	1.	2.	3.	4.	5.
	grains	grains	grains	grains	grains
White sand, treated with hydrochloric acid	1543·23	1543·23	385·8	385·8	385·8
Minium, first quality. . .	6·16	2156·	771·61	925·8	848·65
White potash, well calcined .	370·32	493·76	108·2	61·72	154·32
Calcined borax	308·64	185·16	...	92·58	123·45
Crystallised nitrate of potash (nitre)	185·16	...	123·44	...	77·16
Peroxide of manganese . .	61·72	...	...	154·32	...
Deutoxide of arsenic . . .	...	9·26	...	23·15	...

Topaz: No. 1.

Whitest strass, 842·079; glass of antimony, 36·421; purple of Cassius, 0·738.

Another.

White lead of Clichy, 771·6; flints calcined and pulverised, 771·6.

Another.

White sand, well dressed	1543·23	Oxide of silver	77·16
Borax, calcined	138·88	Calcined potash	493·76
Minium	2237·64		

Sapphire: Whitest strass, 3858·086; pure oxide of cobalt, 57·708.

Ditto: another. Very fine strass, 481·25; purest oxide of cobalt, 1·697.

Emerald, No. 1. Strass, 3858·087; pure green oxide of copper, 35·643; oxide of chrome, 1·697.

Ditto: ordinary. Strass, 7716·174; acetate of copper, 61·11; oxide of iron, 12·731.

Ditto: another. Strass, 481·25; oxide of copper precipitated from the nitrate by potash, 334·45.

Emeralds (*Bastenaire*).

	1.	2.
	grains	grains
Well-washed sand	154·32	154·32
Minium	231·48	231·48
White potash, calcined	46·29	77·16
Borax, calcined	30·86	30·86
Yellow oxide of antimony	7·71	...
Pure oxide of cobalt	1·54	...
Green oxide of chrome	...	3·85

Amethyst (*Bastenaire*).

	Pale	Deep coloured
	grains	grains
Strass	7716·17	3858·08
Oxide of manganese	20·39	36·55
Oxide of cobalt	0·848	20·39
Purple of Cassius	...	0·848

Aquamarine.

Strass, 2913·53; Glass of antimony, 20,370; Oxide of cobalt, 1·265.

Syrian Garnet.

	1.	2.
	grains	grains
Strass	427·931	484·25
Glass of antimony	215·815	...
Purple of Cassius	1·697	2·150
Oxide of manganese	1·697	...

Observations. For topaz, No. 1, the clearest and most transparent glass of antimony should be used. Frequently this mixture only yields an opaque mass, translucent on the edges, and transmitting in thin fragments a red colour when held between the eye and the light: in that case rubies may be made of it.

To make them, a portion of the topaz material is taken, and mixed with eight parts of fine strass: these are melted in a Hessian crucible for thirty hours in a potter's furnace, and the result is a beautiful yellow glass-like strass, which, when cut, produces an imitation of the finest oriental rubies.

These may be made of another tint by using the following proportions:—

Strass, 2411·25; oxide of manganese, 61·310.

In the emerald, No. 1, by increasing the proportion of chrome or oxide of copper, and mixing with it oxide of iron, the green shade may be varied, and the periodot or the deep-tinted emerald may be imitated.

The manufacture of artificial gems has acquired an extreme development; immense factories are established at Septmoncal in the Jura, furnishing employment to more than 100 work people, who produce fabulous quantities.

Many ingenious persons in Paris vie with each other in bringing to perfection the most perfect processes, and produce truly surprising results. M. Savary especially, in his magnificent collections, and his perfect imitation of celebrated diamonds, has arrived at a degree of excellence which, apparently, can scarcely be surpassed.

We have alluded only to those imitations of gems in glass of which a large portion of the cheap jewellery is formed. Some very successful attempts have been made to manufacture true gems by an artificial process. M. Ebelmen has done much in this direction, and M. Henri Sainte-Claire Deville and M. Henri Caron communicated to the Academy of Sciences of Paris, in April 1858, a process which they had discovered for the production of a number of the gems which belong to the corundrum class, as the ruby, sapphire, &c. Essentially, the process consisted in exposing the fluoride of aluminium, mixed with a little charcoal and boracic acid, in a black-lead crucible, protected from the action of the air, to a white heat for about an hour. For details of the process, see *Comptes Rendus*, and *Annales de Chimie*.

GENAPPE. A worsted yarn used in the manufacture of fringes, braids, &c. From its smoothness it combines very readily with silk.

GENEVA. A grain-spirit flavoured with juniper-berries, manufactured extensively in Holland; hence it is frequently called HOLLANDS.

GENISTA. A genus of papilionaceous plants. *G. tinctoria* is the Dyer's Broom, which yields a yellow die, or, when mixed with woad, a green colour. A sprig of genista was the badge of Henry II.'s father, whence the family name Plantagenet (*Planta genista*).

GENTIAN. *Gentiana lutea.* The common or yellow gentian, which is said to owe its name to Gentius, king of Illyria, who introduced it as a medicine about 170 years before Christ.

The roots of the gentian are collected and dried by the peasants of Switzerland, the Tyrol, and in the Auvergne.

The bitter of the gentian is agreeable and aromatic; it is much used in medicine, and has on some occasions been employed instead of hops in beer.

GEOCRONITE. A native sulphantimonide of lead, from the silver mines of Sala, in Sweden. It appears to resemble KILBRICKENITE.

GEODE. A rounded nodule of stone, containing a cavity usually lined with crystals. Geodes frequently consist of agate, chalcedony, &c. See AGATE.

GEOGNOSY (γῆ, the *earth*, and γνῶσις, *knowledge*), means the science of the substances which compose the earth's crust. It originated with the German mineralogists.

GEOLOGY (γῆ, the *earth*, and λόγος, *a discourse*). The science which treats of the structure of the earth, and of the causes which have produced its present physical features.

GERANIUM, OIL OF. A name sometimes applied to the oil of ginger-grass, which is prepared in the East from certain species of *Andropogon.* This has of course, no relation whatever either to our wild geraniums (*crane's bills*) or to our garden geraniums (*Pelargoniums*).

GERHARDT'S ANHYDROUS ACETIC ACID. See ACETIC ACID, and Watts's 'Dictionary of Chemistry.'

GERMAN BLACK. See FRANKFORT BLACK.

GERMAN SILVER. M. Gersdorf, of Vienna, states that the proportion of the metals in this alloy should vary according to the uses for which it is destined. When intended as a substitute for silver, it should be composed of 25 parts of nickel, 25 of zinc, and 50 of copper. An alloy better adapted for rolling consists of 25 of nickel, 20 of zinc, and 60 of copper. Castings, such as candlesticks, bells, &c., may be made of an alloy, consisting of 20 of nickel, 20 of zinc, and 60 of copper; to which 3 of lead are added. The addition of 2 or 2½ of iron (in the shape of tin plate?) renders the alloys much whiter, but, at the same time, harder and more brittle.

Keferstein has given the following analysis of the genuine German silver, as made from the original ore found in Hildburghausen, near Suhl, in Henneberg:—

Copper	40·4
Nickel	31·6
Zinc	25·4
Iron	2·6
	100·0

Chinese *Pakfong*, a white alloy, according to the same authority, consists of 5 parts of copper, alloyed with 7 parts of nickel, and 7 parts of zinc.

The best alloy for making bearings, bushes, and steps for the steel or iron gudgeons, and pivots of machinery to run in, is said to consist of 90 parts of copper, 5 of zinc, and 5 of antimony. See ALLOY and COPPER.

GERMAN STEEL. A metal made of a white iron in forges where charcoal is employed, the ores used being either bog-iron ore or the sparry carbonate.

GERMAN TINDER. See AMADOU.

GERMAN YEAST. See YEAST.

GERMINATION. (Eng. and Fr.; *Das Keimen*, Ger.) The first indication of vital force in the embryo plant. The seed being placed in the soil, a proper temperature existing, and a due quantity of water being supplied, a chemical action is established, and heat is developed. In fact, a slow combustion takes place, during which oxygen is combined with carbon, and carbonic acid is liberated. The starch of the grain, by the process of germination, is converted into sugar by taking into combination one equivalent of the elements of water. While this operation is progressing, the embryo enlarges, sending down its root (radicle) into the soil, and forcing upwards, towards the light, the cotyledons or leaf lobes, and the plumule.

These phenomena of the commencement of vegetable life can be well studied in the process of malting, in which the barley, by the conversion of its starch into sugar, becomes malt. See MALTING.

The direct action of sunlight is injurious to the germinating seed, consequently it is a law of nature that a dark soil should be the bed in which this remarkable operation commences, and is continued, until the first leaves appear above the soil. In the process of malting, care is taken that the floors upon which the germination is established are but dimly illuminated.

It has been proved—the discovery having been first made by the editor of this Dictionary—that *Light* separated by means of absorbent media from the chemical power (*Actinism*) of the sunbeam entirely stops germination, whereas the dark chemical rays have the power of quickening germination, even when the seeds are placed at a considerable depth beneath the soil. As these experiments are rarely repeated, and as even in the most recent chemical publications (Watts's 'Dictionary of Chemistry,' amongst others), they are not alluded to, the old and in every way uncertain experiments of Saussure being adopted, it may be well to state the simple form of experiment by which the fact may be proved.

Take a piece of glass stained yellow with silver; ascertain that it is so, by exposing a little chloride of silver behind it, to sunshine. If the chloride of silver does not darken, the glass is of the right kind; all the chemical rays are cut off. Take another piece of glass of the deepest blue that can be obtained, the blue being the result of cobalt. In the first we have a glass through which the solar light passes freely, but it prevents the permeation of the chemical rays. In the second we have a medium which is traversed freely by the chemical rays (Actinism), but very little light is admitted. Place such pieces of glass over a box of earth, in which are planted an equal number of seeds, at the same depth; all the circumstances, as it regards moisture and temperature, being the same. The seeds under the blue glass will germinate with extraordinary rapidity, while the seeds under the yellow glass will not germinate at all. See 'Researches on Light,' and papers in the *Reports of the British Association* on 'The Influence of Light on the Growth of Plants, &c.,' by Robert Hunt. The following letter from Mr. Charles Lawson, of Edinburgh, September 8, 1853, has practically settled this important discovery:—

'My dear Sir,—I am favoured with yours of the 5th, relative to my practical experience in the effect of the chemical agency of coloured media on the germination of seeds and the growth of plants.

'I must first explain that it is our practice to test the germinating powers of all seeds which come into our warehouses before we send them out for sale; and of course it is an object to discover, with as little delay as possible, the extent that the vital principle is active, as the value comes to be depreciated in the ratio it is found to be dormant. For instance, if we sow 100 seeds of any sort, and the whole germinate, the seed will be of the highest current value; but if only 90 germinate, its value is 10 per cent. less; if 80, its value falls 20 per cent.

'I merely give this detail to show the practical value of this test, and the influence it exerts on the fluctuation of prices.

'Our usual plan formerly was to sow the seeds to be tested in a hotbed, or frame, and then watch the progress and note the results. It was usually from eight to fourteen days before we were in a condition to decide on the commercial value of the seeds under value.

'My attention was, however, directed to your excellent work, "On the Physical

Phenomena of Nature," about five years ago, and I resolved to put your theory to a practical test. I accordingly had a case made, the sides of which were formed of glass coloured blue or indigo, which case I attached to a small gas stove for engendering heat; in the case, shelves were fixed in the inside, on which were placed small pots wherein the seeds to be tested were sown.

'The results were all that could be looked for; the seeds freely germinating in from two to five days only, instead of from eight to fourteen days as before.

'I have not carried our experiments beyond the germination of seeds, so that I cannot afford practical information as to the effect of other rays on the after-culture of plants.

'I have, however, made some trials with the yellow ray in preventing the germination of seeds, which have been successful; and I have always found the violet ray prejudicial to the growth of the plant after germination.

'I remain, my dear Sir, very faithfully yours,

'To Robert Hunt, Esq.' 'Charles Lawson.'

Another application of the principles involved in the discovery—that the luminous rays checked germination and promoted the growth of ligneous fibre—has been made by the cultivators of early potatoes in the West of Cornwall. The seed potatoes are carefully placed on shelves in houses maintained at such a temperature that germination is set up. When they begin to shoot, an abundance of light is admitted to check the germinating process, and render the shoot woody and strong. In March—after the frosts—these potatoes are carefully placed in the soil, and so rapid is their growth and development that they are ready for the market in July. Upwards of 11,000 tons of potatoes, grown under these conditions, were sent from West Cornwall in July 1874.

GEROPIGA, or *Jerupiga.* A factitious liquor, imported, from Portugal, and used in this country for the adulteration of wines. It appears to be a compound of unfermented grape-juice, brandy, sugar, and colouring matter.

GERSDORFFITE. A sulpho-arsenide of nickel, containing, in typical varieties—arsenic, 45·5; sulphur, 19·4; nickel, 35·1. Found at Loos in Sweden, near Hartzgerode in the Hartz, and Craigmuir Mine, Scotland.

GEYSERITE. Siliceous sinter deposited from geysers or hot springs.

GHU-NALA-PAAT. *Corchorus olitorius* or *Hibiscus Manihot.* An Indian fibre much used by the natives. See Fibres.

GIBBSITE. A stalactitic hydrate of alumina, named after Colonel G. Gibbs, whose collection of minerals is now in Yale College.

GIBRALTAR STONE. Stalagmitic carbonate of lime resembling the Algerian onyx-marble, found in limestone-caverns at Gibraltar.

GIG MACHINES, are rotatory drums, mounted with thistles or wire teeth for teazling cloth. See Woollen Manufacture.

GILBERTITE. A micaceous mineral apparently related to kaolin, occurring with the china-stone of St. Austell in Cornwall.

GILDING (*Dorure*, Fr.; *Vergoldung*, Ger.). This art consists in covering bodies with a thin coat of gold, which may be done either by mechanical or chemical means. The mechanical mode is the application of gold-leaf or gold-powder to various surfaces, and their fixation by different means. Thus gold may be appiled to wood, plaster, pasteboard, leather; and to metals, such as silver, copper, iron, tin, and bronze; so that gilding, generally speaking, includes several arts, exercised by very different classes of tradesmen.

I. Mechanical Gilding.—Oil-gilding is the first method under this head, as oil is the fluid most generally used in the operation of this mechanical art. The following process has been much extolled at Paris:—

1. A coat of *impression* is to be given first of all, namely, a coat of white lead paint, made with drying linseed oil, containing very little oil of turpentine.

2. Calcined ceruse is to be ground very well with unboiled linseed oil, and tempered with essence of turpentine, in proportion as it is laid on. Three or four coats of this *hard tint* are to be applied evenly on the ornaments, and the parts which are to be most carefully gilded.

3. *The Gold colour* is then to be smoothly applied. This is merely the dregs of the colours, ground and tempered with oil, which remain in the little dish in which painters clean their brushes. This substance is extremely rich and gluey; after being ground up, and passed through fine linen cloth, it forms the ground for gold-leaf.

4. When the gold colour is dry enough to catch hold of the leaf gold, this is spread on the cushion, cut into pieces and carefully applied with the pallet knife, pressed down with cotton, and on the small ornaments with a fine brush.

5. If the gildings be for outside exposure, as balconies, gratings, statues, &c., they

must not be varnished, as simple oil-gilding stands better; for when it is varnished, a bright sunbeam acting after heavy rain, gives the gilding a jagged appearance. When the objects are inside ones, a coat of spirit-varnish may be passed over the gold-leaf, then a glow from the gilder's chafing dish may be given, and finally a coat of oil-varnish. The workman who causes the chafing dish to glide in front of the varnished surface must avoid stopping for an instant opposite any point, otherwise he would cause the varnish to boil and blister. This heat brings out the whole transparency of the varnish, and lustre of the gold.

Oil-Gilding is employed with varnish polish, upon equipages, mirror-frames, and other furniture. The following method is employed by eminent gilders at Paris :—

1. White lead, with half its weight of yellow ochre, and a little litharge, are separately ground very fine; and the whole is then tempered with linseed oil, thinned with essence of turpentine, and applied in an evenly coat, called *impression*.

2. When this coat is quite dry, several coats of the hard tint are given, even so many as 10 or 12, should the surface require it for smoothing and filling up the pores. These coats are given daily, leaving them to dry in the interval in a warm sunny exposure.

3. When the work is perfectly dry, it is first softened down with pumice stone and water, afterwards with worsted cloth and very finely powdered pumice, till the *hard tint* give no reflexion, and be as smooth as glass.

4. With a camel's-hair brush, there must be given lightly and with a gentle heat, from 4 to 5 coats at least, and even sometimes double that number, of fine lac-varnish.

5. When these are dry, the grounds of the pannels and the sculptures must be first polished with shave-grass (*de la prêle*); and next with putty of tin and tripoli, tempered with water, applied with woollen cloth; by which the varnish is polished till it shines like a mirror.

6. The work thus polished is carried into a hot place, free from dust, where it receives very lightly and smoothly, a thin coat of *gold colour*, much softened down. This coat is passed over it with a clean soft brush, and the thinner it is the better.

7. Whenever the gold colour is dry enough to take the gold, which is known by laying the back of the hand on a corner of the frame work, the gilding is begun and finished as usual.

8. The gold is smoothed off with a very soft brush, one of camel's hair, for example, of three fingers' breadth; after which it is left to dry for several days.

9. It is then varnished with a spirit-of-wine varnish; which is treated with the chafing dish as above described.

10. When this varnish is dry, two or three coats of copal, or oil of varnish, is applied, at intervals of two days.

11. Finally, the pannels are polished with a worsted cloth, imbued with tripoli and water, and lustre is given by friction with the palm of the hand, previously softened with a little olive oil, taking care not to rub off the gold.

In this country, *Burnished gilding* is practised by first giving a ground of size whiting, in several successive coats; next applying gilding size; and then the gold-leaf, which is burnished down with agate, or a dog's tooth.

Gilding in distemper of the French, is the same as our burnished gilding. Their process seems to be very elaborate, and the best consists of 17 operations; each of them is said to be essential.

1. *Encollage*, or the *Glue coat.* To a decoction of wormwood and garlic in water, strained through a cloth, a little common salt, and some vinegar are added. This composition, as being destructive of worms in wood, is mixed with as much good glue; and the mixture is spread in a hot state, with a brush of boar's hair. When plaster or marble is to be gilded, the salt must be left out of the above composition, as it is apt to attract humidity in damp places, and to come out as a white powder on the gilding. But the salt is indispensable for wood. The first glue coating is made thinner than the second.

2. *White preparation.* This consists in covering the above surface with 8, 10, or 12 coats of Spanish white, mixed up with strong size, each well worked on with the brush, and in some measure incorporated with the preceding coat, to prevent their peeling off in scales.

3. *Stopping up* the pores, with thick whiting and glue, and smoothing the surface with dog-skin.

4. Polishing the surface with pumice-stone and very cold water.

5. *Reparation*; in which a skilful artist retouches the whole.

6. *Cleansing*; with a damp linen rag, and then a soft sponge.

7. *Prêler.* This is rubbing with horse's tail (*shave-grass*) the parts to be yellowed, in order to make them softer.

8. *Yellowing.* With this view *yellow ochre* is carefully ground in water, and mixed with transparent colourless size. The thinner part of this mixture is applied hot over the white surface with a thin brush, which gives it a fine yellow hue.

9. *Ungraining*; consists in rubbing the whole work with shave-grass, to remove any granular appearance.

10. *Coat of assiette; trencher coat.* This is the composition on which the gold is to be laid. It is composed of Armenian bole, 1 pound; hematite, 2 ounces; and as much galena; each separately ground in water. The whole are then mixed together, and ground up with about a spoonful of olive oil. The *assiette* well made and applied gives beauty to the gilding. The *assiette* is tempered with a white sheepskin glue, very clear and well strained. This mixture is heated, and applied in three successive coats with a very fine long-haired brush.

11. *Rubbing*, with a piece of dry, linen cloth; except the parts which are be burnished, which are to receive other two coats of *assiette* tempered with glue.

12. *Gilding.* The surface being damped with cold water (iced in summer) has then the gold-leaf applied to it. The hollow grounds must always be gilded before the prominent parts. Water is dexterously applied by a soft brush, immediately behind the gold-leaf, before laying it down, which makes it lie smoother. Any excess of water is then removed with a dry brush.

13. *Burnishing*, with bloodstone.

14. *Deadening.* This consists in passing a thin coat of glue, slightly warmed, over the parts that are not to be burnished.

15. *Mending*; that is, moistening any broken points with a brush, and applying bits of gold-leaf to them.

16. The *vermeil coat.* Vermeil is a liquid which gives lustre and fire to the gold: and makes it resemble *or-moulu.* It is composed as follows: 2 ounces of annotto, 1 ounce of gamboge, 1 ounce of vermilion, half an ounce of dragon's blood, 2 ounces of salt of tartar, and 18 grains of saffron, are boiled in a litre (2 pints English) of water, over a slow fire, till the liquid be reduced to a fourth. The whole is then passed through a silk or muslin sieve. A little of this is made to glide lightly over the gold, with a very soft brush.

17. *Repassage*; is passing over the dead surfaces a second coat of deadening glue, which must be hotter than the first. This finishes the work, and gives it strength.

Leaf gilding, on paper or vellum, is done by giving them a coat of gum-water or fine size, applying the gold-leaf ere the surfaces be hard dry, and burnishing with agate.

Gold lettering, on bound books, is given without size, by laying the gold-leaf on the leather, and imprinting it with hot brass types.

The *edges of the leaves of books are gilded*, while they are in the press where they have been cut smooth, by applying a solution of isinglass in spirits, and laying on the gold when the edges are in a proper state of dryness. The French workmen employ a ground of Armenian bole, mixed with powdered sugar-candy, by means of white-of-egg. This ground is laid very thin upon the edges, after fine size or gum-water has been applied; and when the ground is dry it is rubbed smooth with a wet rag, which moistens it sufficiently to take the gold.

Japanners' gilding is done by sprinkling or daubing with wash-leather, some gold-powder over an oil sized surface, mixed with oil of turpentine. This gives the appearance of frosted gold. The gold-powder may be obtained, either by precipitating gold from its solution in *aqua regia* by a solution of pure sulphate of iron, or by evaporating away the mercury from some gold-amalgam.

II. Chemical Gilding, or the application of gold by chemical affinity to metallic surfaces.

A compound of copper with one-seventh of brass is the best metal for gilding on; copper by itself being too soft and dark coloured. Ordinary brass, however, answers very well. We shall describe the process of wash gilding, with M. D'Arcet's improvements, now generally adopted in Paris.

Wash gilding consists in applying evenly an amalgam of gold to the surface of a copper alloy, and dissipating the mercury with heat, so as to leave the gold film fixed. The surface is afterwards burnished or deadened at pleasure. The gold ought to be quite pure, and laminated to facilitate its combination with the mercury; which should also be pure.

Preparation of the amalgam.—After weighing the fine gold, the workman puts it in a crucible, and as soon as this becomes faintly red, he pours in the requisite quantity of mercury; which is about 8 to 1 of gold. He stirs up the mixture with an iron rod, bent hookwise at the end, leaving the crucible on the fire till he perceives that all the gold is dissolved. He then pours the amalgam into a small earthen dish containing water, washes it with care, and squeezes out of it with his fingers all the running mercury that he can. The amalgam that now remains on the sloping sides of the vessel is so pasty as to preserve the impression of the fingers. When this is squeezed in a chamois-leather bag, it gives up much mercury; and remains an amalgam, consisting of about 33 of mercury, and 57 of gold, in 100 parts. The mercury which passes through the bag, under the pressure of the fingers, holds a good deal of gold in solution; and is employed in making fresh amalgam.

Preparation of the mercurial solution.—The amalgam of gold is applied to brass, through the intervention of pure nitric acid, holding in solution a little mercury.

100 parts of mercury, and 110 parts by weight of pure nitric acid, specific gravity 1·33, are to be put into a glass matrass. On the application of a gentle heat the mercury dissolves with the disengagement of fumes of nitrous gas, which must be allowed to escape into the chimney. This solution is to be diluted with about 25 times its weight of pure water, and bottled up for use.

1. *Annealing.*—The workman anneals the piece of bronze after it has come out of the hands of the turner and engraver. He sets it among burning charcoal, or rather peats, which have a more equal and lively flame; covering it quite up, so that it may be oxidised as little as possible, and taking care that the thin parts of the piece do not become hotter than the thicker. This operation is done in a dark room, and when he sees the piece of a cherry-red colour, he removes the fuel from about it, lifts it out with long tongs, and sets it to cool slowly in the air.

2. The *decapage.*—The object of this process is to clear the surface from the coat of oxide which may have formed upon it. The piece is plunged into a bucket filled with extremely dilute sulphuric acid; it is left there long enough to allow the coat of oxide to be dissolved, or at least loosened; and it is then rubbed with a hard brush. When the piece becomes perfectly bright, it is washed and dried. Its surface may, however, be still a little variegated; and the piece is therefore dipped in nitric acid, specific gravity 1·33, and afterwards rubbed with a long-haired brush. The addition of a little common salt to the dilute sulphuric acid would probably save the use of nitric acid, which is so apt to produce a new coat of oxide. It is finally made quite dry (after washing in pure water), by being rubbed well with tanners' dry bark, sawdust, or bran. The surface should now appear somewhat depolished; for when it is very smooth, the gold does not adhere so well.

3. *Application of the amalgam.*—The gilder's *scratch-brush* or pencil, made with fine brass wire, is to be dipped into the solution of nitrate of mercury, and is then to be drawn over a lump of gold-amalgam, laid on the sloping side of an earthen vessel, after which it is to be applied to the surface of the brass. This process is to be repeated, dipping the brush into the solution, and drawing it over the amalgam, till the whole surface to be gilded is coated with its just proportion of gold. The piece is then washed in a body of water, dried, and put to the fire to volatilise the mercury. If one coat of gilding be insufficient, the piece is washed over anew with amalgam, and the operation recommenced till the work prove satisfactory.

4. *Volatilisation of the mercury.*—Whenever the piece is well coated with amalgam, the gilder exposes it to glowing charcoal, turning it about, and heating it by degrees to the proper point; he then withdraws it from the fire, lifts it with long pincers, and, seizing it in his left hand, protected by a stuffed glove, he turns it over in every direction, rubbing and striking it all the while with a long-haired brush, in order to equalise the amalgam. He now restores the piece to the fire, and treats it in the same way till the mercury be entirely volatilised, which he recognises by the hissing sound of a drop of water let fall on it. During this time he repairs the defective spots, taking care to volatilise the mercury very slowly. The piece, when thoroughly coated with gold, is washed, and scrubbed well with a brush in water acidulated with vinegar.

If the piece is to have some parts burnished, and others dead, the parts to be burnished are covered with a mixture of Spanish white, bruised sugar-candy, and gum dissolved in water. This operation is called in French *épargner* (*protecting*). When the gilder has *protected* the burnished points, he dries the piece, and carries the heat high enough to expel the little mercury which might still remain on it. He then plunges, it, while still a little hot, in water acidulated with sulphuric acid, washes it, dries it, and gives it the burnish.

5. The *burnish* is given by rubbing the piece with burnishers of hematite (bloodstone). The workman dips his burnisher in water sharpened with vinegar, and rubs the piece always in the same direction backwards and forwards, till it exhibits a fine polish, and a complete metallic lustre. He then washes it in cold water, dries it with fine linen cloth, and concludes the operation by drying it slowly on a grating placed above a chafing-dish of burning charcoal.

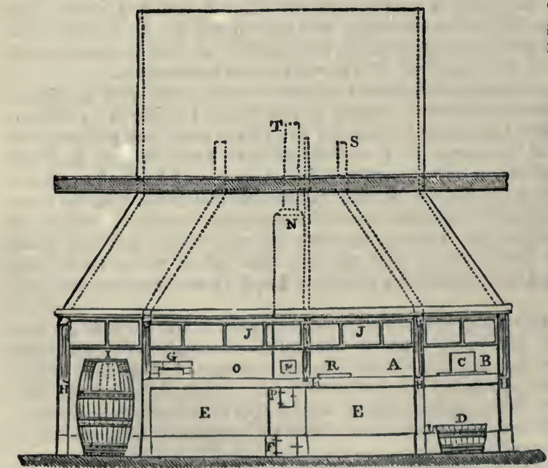
6. The *deadening* is given as follows:—The piece, covered with the *protection* on those parts that are to be burnished, is attached with an iron wire to the end of an iron rod, and is heated strongly so as to give a brown hue to the *épargne* by its partial carbonisation. The gilded piece assumes thus a fine tint of gold; and is next coated over with a mixture of sea salt, nitre, and alum fused in the water of crystallisation of the latter salt. The piece is now restored to the fire, and heated

till the saline crust which covers it becomes homogeneous, nearly transparent, and enters into true fusion. It is then taken from the fire and suddenly plunged into cold water, which separates the saline crust, carrying away even the coat of *épargne.* The piece is lastly passed through very weak nitric acid, washed in a great body of water, and dried by exposure either to the air, over a drying stove, or with clean linen cloths.

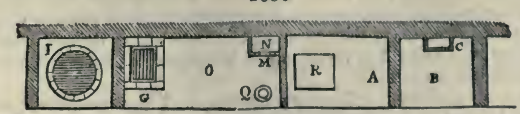
7. *Of or-moulu colour.*—When it is desired to put a piece of gilded bronze into *or-moulu* colour, it must be less scrubbed with the scratch-brush than usual, and made to *come back again* by heating it more strongly than if it were to be deadened, and allowing it then to cool a little. The *or-moulu* covering is a mixture of hematite, alum, and sea salt. This mixture is to be thinned with vinegar, and applied with a brush so as to cover the gilded brass, with reserve of the burnished parts. The piece is then put on glowing coals, urged a little by the bellows, and allowed to heat till the colour begins to blacken. The piece ought to be so hot that water sprinkled on it may cause a hissing noise. It is then taken from the fire, plunged into cold water, washed, and next rubbed with a brush dipped in vinegar, if the piece be smooth; but if it be chased, weak nitric acid must be used. In either case, it must be finally washed in a body of pure water, and dried over a gentle fire.

8. *Of red gold colour.*—To give this hue, the piece, after being coated with amalgam, and heated, is in this hot state to be suspended by an iron wire, and tempered with the composition known under the name of gilder's wax; made with yellow wax, red ochre, verdigris, and alum. In this state it is presented to the flame of a wood fire, is heated strongly, and the combustion of its coating is favoured by throwing some drops of the wax-mixture into the burning fuel. It is now turned round and round over the fire, so that the flame may act equally. When all the wax of the colouring is burned away, and when the flame is extinguished, the piece is to be plunged in water, washed, and scrubbed with the scratch-brush and pure vinegar. If the colour is not beautiful, and quite equal in shade, the piece is coated with verdigris dissolved in vinegar, dried over a gentle fire, plunged in water, and scrubbed with pure vinegar, or even with a little weak nitric acid if the piece exhibit too dark a hue. It is now washed, burnished, washed anew, wiped with linen cloths, and finally dried over a gentle fire.

1085



1086



The following is the outline of a complete gilding factory, as now fitted up at Paris:—

Figs. 1085, 1086, front elevation and plan of a complete gilding workshop.

P. Furnace of *appel*, or draught, serving at the same time to heat the deadening pan (*poêlon au mat*).

F. Ash-pit of this furnace.

N. Chimney of this furnace constructed of bricks, as far as the contraction of the great chimney, S, of the forge, and which is terminated by a summit pipe rising 2 or 3 yards above this contraction.

B. Forge for annealing the pieces of bronze; for drying the gilded pieces, &c.

C. Chimney of communication between the annealing forge B, and the space D below the forge. This chimney serves to carry the noxious fumes into the great vent of the factory.

U. Bucket for the brightening operation.

A. Forge for passing the amalgam over the piece.

R. Shelf for the brushing operations.

E E. Coal cellarets.

O. Forge for the deadening process.

G. Furnace for the same.

M. An opening into the furnace of *appel*, by which vapours may be let off from any operation by taking out the plug at M.

I. Cask in which the pieces of gilded brass are plunged for the deadening process. The vapours rising thence are carried up the general chimney.

J J. Casement with glass panes, which serves to contract the opening of the hearths, without obstructing the view. The casement may be rendered moveable to admit larger objects.

H H. Curtains of coarse cotton cloth, for closing at pleasure, in whole or part, one or several of the forges or hearths, and for quickening the current of air in the places where the curtains are not drawn.

Q. Opening above the draught furnace, which serves for the heating of the *poêlon au mat* (deadening pan).

Gilding on polished iron and steel.—If a nearly neutral solution of gold in muriatic acid be mixed with sulphuric ether, and agitated, the ether will take up the gold, and float above the denser acid. When this auriferous ether is applied by a hair-pencil to brightly-polished iron or steel, the ether flies off, and the gold adheres. It must be fixed by polishing with the burnisher. This gilding is not very rich or durable. In fact the affinity between gold and iron is feeble, compared with that between gold and copper and silver. But polished iron, steel, and copper, may be gilded with heat, by gold-leaf. They are first heated till the iron takes a bluish tint, and till the copper has attained to a like temperature; a first coat of gold-leaf is now applied, which is pressed gently down with a burnisher, and then exposed to a gentle heat. Several leaves either single or double are thus applied in succession, and the last is burnished down cold.

Mr. Elkington obtained a patent, in June 1836, for gilding copper, brass, &c., by means of potash or soda combined with carbonic acid, and with a solution of gold. Dissolve, says he, 5 oz. troy of fine gold in 52 oz. avoirdupois of nitro-muriatic acid of the following proportions: viz. 21 oz. of pure nitric acid, of spec. grav. 1·45, 17 oz. of pure muriatic acid, of spec. grav. 1·15, with 14 oz. of distilled water.

The gold being put into the mixture of acids and water, they are to be heated in a glass or other convenient vessel till the gold is dissolved; and it is usual to continue the application of heat after this is effected, until a reddish or yellowish vapour ceases to rise.

The clear liquid is to be carefully poured off from any sediment which generally appears, and results from a small portion of silver, which is generally found in alloy with gold. The clear liquid is to be placed in a suitable vessel of stone; pottery ware is preferred, Add to the solution of gold 4 gallons of distilled water, and 20 pounds of bicarbonate of potash of the best quality; let the whole boil moderately for 2 hours, the mixture will then be ready for use.

The articles to be gilded having been first perfectly cleaned from scale or grease, they are to be suspended on wires, conveniently for a workman to dip them in the liquid, which is kept boiling. The time required for gilding any particular article will depend on circumstances, partly on the quantity of gold remaining in the liquid, and partly on the size and weight of the article; but a little practice will readily give sufficient guidance to the workman.

Supposing the articles desired to be gilded be brass or copper buttons, or small articles for gilt toys, or ornaments of dress, such as earrings or bracelets, a considerable number of which may be strung on a hoop, or bended piece of copper or brass wire, and dipped into the vessel containing the boiling liquid above described, and moved therein, the requisite gilding will be generally obtained in from a few seconds to a minute; this is when the liquid is in the condition above described, and depending on the quality of the gilding desired; but if the liquid has been used some time, the quantity of gold will be lessened, which will vary the time of operating to produce a given effect, or the colour required, all of which will quickly be observed by the workman; and by noting the appearance of the articles from time to time, he will know when the desired object is obtained, though it is desirable to avoid as much as possible taking the articles out of the liquid.

When the operation is completed, the workman perfectly washes the articles so gilded with clean water; they may then be submitted to the usual process of colouring.

If the articles be cast figures of animals, or otherwise of considerable weight, compared with the articles above mentioned, the time required to perform the process will be greater.

In case it is desired to produce what is called a dead appearance, it may be performed by several processes: the one usually employed is to dead the articles in the process of cleaning, as practised by brass founders and other trades; it is produced by an acid, prepared for that purpose, sold by the makers under the term 'deading aquafortis,' which is well understood.

It may also be produced by a weak solution of nitrate of mercury, applied to the articles previous to the gilding process, as is practised in the process of gilding with mercury, previous to spreading the amalgam, but generally a much weaker solution; or the articles having been gilded may be dipped in a solution of nitrate of mercury, and submitted to heat to expel the same, as is practised in the usual process of gilding.

Cold gilding.—Sixty grains of fine gold and 12 of rose copper are to be dissolved in two ounces of aqua regia. When the solution is completed, it is to be dropped on clean linen rags, of such bulk as to absorb all the liquid. They are then dried, and burned into ashes. Those ashes contain the gold in powder.

When a piece is to be gilded, after subjecting it to the preliminary operations of softening or annealing and brightening, it is rubbed with a moistened cork, dipped in the above powder, till the surface seems to be sufficiently gilded. Large works are thereafter burnished with pieces of hematite, and small ones with steel burnishers, along with soap water.

In gilding small articles, as buttons, with amalgam, a portion of this is taken equivalent to the work to be done, and some nitrate-of-mercury solution is added to it in a wooden trough; the whole articles are now put in, and well worked about with a hard brush, till their surfaces are equably coated. They are then washed, dried, and put together into an iron frying-pan, and heated till the mercury begins to fly off, when they are turned out into a cap, in which they are tossed and well stirred about with a painter's brush. The operation must be repeated several times for a strong gilding. The surfaces are finally brightened by brushing them along with small beer or ale grounds.

For the processes of gilding by electro-chemical means, see ELECTRO-METALLURGY.

GIMP, or **GYMP**, a silk, woollen, or cotton twist, with often a metallic wire, but sometimes a coarse thread running through it; it is much used in coat-lace making.

GIN, or *Geneva*, from *Genièvre* (juniper), is an ardent spirit manufactured in London, and other places, in great quantities, and flavoured generally with juniper-berries. It is also made in Holland, and hence called Hollands gin in this country, to distinguish it from British gin. The materials employed in the distilleries of Schiedam are, two parts of unmalted rye from Riga, weighing about 54 lbs. per bushel, and one part of malted bigg, weighing about 37 lbs. per bushel. The mash-tun, which serves also as the fermenting tun, has a capacity of nearly 700 gallons, being about 5 feet in diameter at the mouth, rather narrower at the bottom, and 4½ feet deep; the stirring apparatus is an oblong rectangular iron grid made fast to the end of a wooden pole. About a barrel, = 36 gallons of water, at a temperature of from 162° to 168° (the former heat being best for the highly-dried rye), are put into the mash tun for every 1½ cwt. of meal, after which the malt is introduced and stirred, and lastly the rye is added. Powerful agitation is given to the magma till it becomes quite uniform; a process which a vigorous workman piques himself upon executing in the course of a few minutes. The mouth of the tun is immediately covered over with canvas, and further secured with a close wooden lid, to confine the heat; it is left in this state for two hours. The contents being then stirred up once more, the *transparent* spent wash of a preceding mashing is first added, and next as much cold water as will reduce the temperature of the whole to about 85° F. The best Flanders yeast, which had been brought, for the sake of carriage, to a doughy consistence by pressure, is now introduced to the amount of one pound to every 100 gallons of the mashed materials.

The gravity of the fresh wort is usually from 33 to 38 lbs. per Dicas' hydrometer; and the fermentation is carried on from 48 to 60 hours, at the end of which time the attenuation is from 7 to 4 lbs., that is, the specific gravity of the supernatant wash is from 1·007 to 1·004.

The distillers are induced, by the scarcity of beer-barm in Holland, to skim off a quantity of the yeast from the fermenting tuns, and to sell it to the bakers, whereby they obstruct materially the production of spirit, though they probably improve its quality, by preventing its impregnation with yeasty particles; an unpleasant result which seldom fails to take place in the whisky distilleries of the United Kingdom.

On the third day after the fermenting tun is set, the wash containing the grains is transferred to the still, and converted into low wines. To every 100 gallons of this liquor, two pounds of juniper-berries, from 3 to 5 years old, being added, along with about one quarter of a pound of salt, the whole are put into the low wine still, and the fine Hollands spirit is drawn off by a gentle and well-regulated heat, till the magma becomes exhausted; the first and the last products being mixed together; whereby a spirit, 2 to 3 per cent. above our hydrometer proof, is obtained, possessing the peculiar fine aroma of gin. The quantity of spirit varies from 18 to 21 gallons per quarter of grain; this large product being partly due to the employment of the spent wash of the preceding fermentation; an addition which contributes at the same time to improve the flavour.

London gin is, as we have stated, a corn spirit, which is, however, rendered sweet and cordial-like, by the use of several injurious substances. Plymouth gin, as manufactured by Coates and Co. of Plymouth, is a far purer spirit. The rectifiers employ a pure grain spirit, and flavour with the wash of the whisky distilleries. When wash is distilled, the fluid that comes over is called *singlings*, or *low wines*. It is concentrated or *doubled* by a second distillation, and becomes *raw corn spirit;* this is sold to the rectifier at 11 or 25 per cent. over proof.

Mr. Brande has given the following table of the quantities of alcohol (sp. gr. at 60° F.; 0·825) contained in different ardent spirits:—

Proportion of Alcohol in ardent Spirits.

	In 100 parts	
Brandy	55·39	by measure
Rum	53·68	,,
Gin	51·60	,,
Whisky, Scotch	54·32	,,
Do. Irish	53·20	,,

GINGER. *Zingiber officinale.* This species is herbaceous, with a creeping or tuberous rhizome. The flowers are irregular, and disposed in form of a dense spike or raceme. The *Zingiberaceæ* are natives of all parts of the intertropical zone: the common ginger is originally indigenous to the East Indies, but it is now cultivated in almost all warm parts of the globe. The rhizome or rootstock is the ginger of commerce. It is imported in large quantities from the East and West Indies and Africa.

Places	1868		1869		1870		1871		1872	
	Imports	Value	Imports	Value	Imports	Value	Imports	Value	Imports	Value
From	cwts.	£	cwts.	£	cwts.	£	cwts.	£	cwts.	£
West Coast of Africa	1,895	9,617								
Sierra Leone	9,970	13,386	9,556	11,380	6,855	8,999	3,948	5,540	..	..
British India:										
Bombay and Scinde	2,189	5,192	2,246	5,597	2,691	5,613	2,014	4,812	..	..
Madras	7,340	17,668	2,437	4,691	6,770	14,481	9,822	21,896	..	..
Bengal and Pegu	4,227	5,743	7,152	9,729	5,852	7,553	1,178	1,491	..	..
British West India Islands	24,813	53,618	11,594	25,341	8,211	16,585	8,542	23,547	..	..
Other parts	1,760	3,232	1,540	3,244	3,475	7,742	5,219	13,598	..	..
Total	52,194	101,456	34,535	59,982	33,854	60,973	32,723	70,884	31,904	71,681

GINGER BEER. A fermented drink containing an infusion of ginger. The following is a good and useful form for its manufacture:—

Barbadoes ginger root	12 ounces.
Tartaric acid	3 ounces.
White sugar	8 pounds.
Gum arabic	8 ounces.
Essence of lemon	2 drachms.
Water	9 gallons.

The ginger root, bruised, is to be boiled for an hour; then, the liquor being strained, the tartaric acid and sugar added, boiled and the same removed. The gum arabic dissolved in a separate portion of water, is added with the essence of lemons. When the whole has cooled to about 100° Fahr., some fresh yeast is to be added, and the beer carefully fermented. Then bottle for use.

Ginger-beer powders are thus prepared:—

White sugar	5 ounces.
Tartaric acid	1½ ounce.
Carbonate of soda	1½ ounce.
Powdered Jamaica ginger	2 drachms.
Essence of lemon	10 drops.

All the materials are to be carefully dried, and mixed while yet warm, in a warm mortar, and immediately bottled.

If the acid and the carbonate of soda are kept separate, these precautions are not necessary.

GINNING is the name of the operation by which the filaments of cotton are separated from the seeds. See COTTON MANUFACTURE.

GINSENG. The root of the *Panax Schinseng*, a plant belonging to the *Araliaceæ*, or ivy-order. This is highly esteemed as a medicine by the Chinese, who are said to value it at its weight in gold. The *American Ginseng* is the root of a closely-related plant *P. quinquefolium.*

GIRASOL. The name given by the French to fire-opal. See OPAL.

GLAIRE. The white-of-egg. This consists, according to Gmelin, of albumen 12·0, mucus 2·7, salts 0·3, water 85·0. Glaire or albumen (*ovalbumen*), is distinguished from the albumen of the serum of the blood (*seralbumen*), by its being coagulated by ether. Glaire is used by bookbinders in finishing the backs of books, and for a few other purposes in the arts. See ALBUMEN.

GLANCE. Any minerals exhibiting a brilliant lustre especially of a metallic character were so called, the term signifying *splendour.* Lead-glance, iron-glance, and the like are examples.

GLANCE-COAL, a name given to anthracite, of which there are two varieties, the *slaty* and the *conchoidal.* See ANTHRACITE and COAL.

GLANCE-COBALT. See COBALT.

GLANCE-COPPER. See COPPER.

GLASERITE. Native sulphate of potash, from Vesuvius.

GLASS (*Verre*, Fr.; *Glas*, Ger.) is a transparent solid formed by the fusion of siliceous and alkaline matter. It was known to the Phœnicians, and constituted for a long time an exclusive manufacture of that people, in consequence of its ingredients—natron, sand, and fuel—abounding upon their coasts. It is certain that the ancient Egyptians were acquainted with glass, for, although we find no mention of it in the writings of Moses, we discover glass ornaments in tombs which are as old as the days of Moses. According to Pliny and Strabo, the glass works of Sidon and Alexandria were famous in their times, and produced beautiful articles, which were cut, engraved, gilt, and stained of the most brilliant colours, in imitation of precious stones. The Romans employed glass for various purposes; and have left specimens in Herculaneum of window-glass, which must have been blown by methods analogous to the modern. The Phœnician processes seemed to have been learned by the Crusaders, and transferred to Venice in the 13th century, where they were long held secret, and formed a lucrative commercial monopoly. Soon after the middle of the seventeenth century Colbert enriched France with the blown mirror-glass manufacture.

Chance may have had a share in the invention of this curious fabrication, but there were circumstances in the most ancient arts likely to lead to it; such as the fusing and vitrifying heats required for the formation of pottery, and for the extraction of metals from their ores. Pliny ascribes the origin of glass to the following accident:—A merchant-ship laden with natron being driven upon the coast at the mouth of the river Belus, in tempestuous weather, the crew were compelled to cook their victuals ashore, and having placed lumps of the natron upon the sand, as supports to the kettles, found to their surprise masses of transparent stone among the cinders. The sand of this small stream of Galilee, which runs from the foot of Mount Carmel, was in consequence supposed to possess a peculiar virtue for making glass, and continued for ages to be sought after and exported to distant countries for this purpose. There exists good evidence that the manufacture of glass and of vitreous glazes is much older than the time ascribed by Pliny.

Agricola, the oldest author who has written technically upon glass, describes furnaces and processes closely resembling those employed at the present day. Neri, Kunckel, Henckel, Pott, Achard, and some other chemists, have since then composed treatises upon the subject; but Neri, Bosc, Antic, Loysel, and Allut, in the *Encyclopédie Méthodique*, are the best of the older authorities.

The Venetians were the first in modern times who attained to any degree of excellence in the art of working glass; but the French became eventually so zealous of rivalling them, particularly in the construction of mirrors, that a decree was issued by the court of France, declaring not only that the manufacture of glass should not derogate from the dignity of a nobleman, but that nobles alone should be masters of glass-works. Within the last fifty years, Great Britain has made rapid advances in this important art, and at the present day her pre-eminence in some departments hardly admits of dispute.

The window-glass manufacture was first begun in England in 1557, in Crutched Friars, London: and fine articles of flint-glass were soon afterwards made in the Savoy House, Strand. In 1635 the art received a great improvement from Sir Robert Mansell, by the use of coal-fuel instead of wood. The first sheets of blown glass for looking-glasses and coach-windows were made in 1673 at Lambeth, by Venetian artisans employed under the patronage of the Duke of Buckingham.

The casting of mirror-plates was commenced in France about the year 1688, by Abraham Thévart: an invention which gave rise soon afterwards to the establishment of the celebrated works of St. Gobain, which continued for nearly a century the sole place where this highly-prized object of luxury was well made. In cheapness, if not in excellence, the French mirror-plate has been for some time rivalled by the English.

The analyses of modern chemists, which will be detailed in the course of this article, and the light thrown upon the manufacture of glass in general by the accurate means now possessed of purifying its several ingredients, would have brought the art long since to the highest state of perfection in this country, but for the long-continued vexatious interference and obstructions of our Excise laws now happily at an end.

The researches of Berzelius having removed all doubts concerning the acid character of silica, the general composition of glass presents now no difficulty of conception. This substance consists of one or more salts, which are silicates with bases of potash, soda, lime, oxide of iron, alumina, or oxide of lead; in any of which compounds we can substitute one of these bases for another, provided that one alkaline base be left. Silica in its turn may be replaced by boracic acid, without causing the glass to lose its principal characters.

Under the title 'glass' are therefore comprehended various substances fusible at a high temperature, solid at ordinary temperatures, brilliant, generally more or less transparent, and always brittle. The following chemical distribution of glasses has been proposed:—

1. Soluble glass; a simple silicate of potash or soda; or of both these alkalis.
2. Crown-glass; silicate of potash and lime.
3. Bottle-glass; silicate of soda, lime, alumina, and iron.
4. Common window-glass; silicate of soda and lime; sometimes also of potash.
5. Plate-glass; silica, soda or potash, lime, and alumina.
6. Ordinary crystal-glass; silicate of potash and lead.
7. Flint-glass; silicate of potash and lead; richer in lead than the preceding.
8. Strass; silicate of potash and lead; still richer in lead.
9. Enamel; silicate and stannate or antimonate of potash or soda, and lead.

The following analyses of these varieties of glass will place their composition more completely before the reader:—

	Silica	Potash or soda	Lime	Oxide of lead	Alumina	Water
1. Soluble glass . .	62	26	0	0	0	12
2. Crown-glass . .	63	22	12	0	3	0
3. Bottle-glass . .	54	5	20	6 *ox. iron*	0	0
4. Window-glass. .	69	11 *soda*	13	0	7	0
5. Plate-glass . .	72	17 *soda*	6	2 *ox. iron*	2	0
6. Crystal . . .	61	6	0	33	0	0
7. Flint-glass . .	45	12	0	43	0	0
8. Strass . . .	38	8	0	53	1	0
9. Enamel . . .	31	8	0	50	10 *ox. tin*	0

	Silica	Potash	Lime	Alumina	Soda
Bohemian glass	76·0	15·0	8·0	1·0	0
,, opal-glass	80·9	17 6	·7	·8	0
,, mirror-glass	67·7	21·0	9·9	1·4	0
,, hard glass (as analysed by Mr. Rowney)	73·0	11·5	10·5	2·0	3

In the following table are also given the analyses of a certain number of Bohemian glasses, which will indicate their composition with precision, and show how uncertain their composition is :—

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.	No. 8.
Silica	71·6	71·7	69·4	62·8	75·9	78·85	70·	57·
Potash	11·0	12·7	11·8	22·1	...	5·5	20·	25·
Soda	...	2·3	...	...	17·5	12·05		
Lime	10·	10·3	9·2	12·5	3·8	5·6	4·	12·5
Magnesia	2·3							
Alumina	2·2	0·4	9·6	2·6	2·8	3·5	5·	3·
Oxide of iron	3·9	0·3	...	...	...	...	0·6	1·3
Oxide of manganese	0·2	0·2	...	...	...	...	0·4	0·4
	101·2	98·1	100·	100·	100·	100·5	100·	99·2

No. 1. Bohemian glass from Neufeld (M. Grus).

No. 2. A fine table glass from Neuwelt (M. Berthier); it is exceedingly beautiful, and is prepared, according to M. Perdonnet, with a mixture of 100 quartz, 50 caustic lime, 75 carbonate of potash, and a very small quantity of nitre, arsenious acid, and oxide of manganese.

No. 3. Old Bohemian glass (M. Dumas).

No. 4. Crown-glass of German manufacture (M. Dumas).

No. 5. Glass for mirrors (M. Dumas).

No. 6. Another glass for mirrors (M. Dumas).

No. 7. White table glass, from Siberberg near Gratzen.

No. 8. Mirror-glass from New-Hurkenthal, for the manufacture of cast mirrors.

Peligot gives the analysis of Venetian aventurine as follows :—

Silica	67·7	Oxide of Tin	2·3
Potash	5·5	Oxide of Lead	1·1
Lime	8·9	Metallic Copper	3·9
Soda	7·1	Oxide of Iron	3·5

See Aventurine.

The following analyses of different varieties of Continental glass are instructive :—

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.
Silica	71·7	69·2	62·8	60·4	53·55	42·5
Potash	12·7	15·8	22·1	3·2	5·48	11·7
Soda	2·5	3·0	...	S. pot.		
Lime	10·3	7·6	12·5	20·7	29·22	0·5
Alumina	0·4	1·2	2·6	10·4	6·01	1·8
Magnesia	...	2·0		0·6		
Oxide of iron	0·3	0·5		3·8	5·74	
,, manganese	0·2					
,, lead	...	...	...	...	...	43·5
Baryta	...	...	...	0·9		

No. 1. is a very beautiful white wine-glass of Neuwelt in Bohemia.

No. 2. Glass tubes, much more fusible than common wine-glasses.

No. 3. Crown-glass of Bohemia.

No. 4. Flask-glass of St. Etienne, for which some heavy spar is used.

No. 5. Glass of Sèvres.

No. 6. Guinand's flint-glass.

Some specimens of ancient glass, analysed by Richard Phillips, have the following composition:—

	Silica	Alumina	Oxide of iron	Manganese	Lime	Magnesia	Soda
Roman vase . .	70·58	1·80	0·53	0·48	8·00	trace	18·86
„ flatted glass .	71·95	trace	3·45	0·57	7·33	0·60	15·30
„ lachrymatory .	71·45	2·15	1·02	·17	8·14	trace	16·62

Thus we see that these ancient glasses were all soda-glasses.

Devitrification.—The glasses which contain several bases are liable to suffer different changes when they are melted or cooled slowly. The silica is divided among these bases, forming new compounds in definite proportions, which, by crystallising, separate from each other, so that the general mixture of the ingredients which constitute the glass is destroyed. It becomes then very hard, fibrous, opaque, much less fusible, a better conductor of electricity and of heat, forming what Réaumur styled *devitrified* glass; and what is called after him 'Réaumur's porcelain.'

This altered glass can always be produced in a more or less perfect state, by melting the glass and allowing it to cool very slowly; or merely by heating it to the softening pitch, and keeping it at that heat for some time. The process succeeds best with the most complex vitreous compounds, such as bottle-glass; next with ordinary window-glass; and, lastly, with glass of potash and lead.

This property ought to be kept constantly in view in manufacturing glass. It shows why in making bottles we should fashion them as quickly as possible with the aid of a mould, and re-heat them as seldom as may be absolutely necessary. If glass is often heated and cooled, it loses its ductility, becomes refractory, and exhibits a multitude of stony granulations throughout its substance. When coarse glass is worked at the enameller's lamp, it is apt to change its nature in the same way, if the workman be not quick and expert at his business.

Fusibility, Cooling, Annealing.—All glass is more or less fusible; when it is softened by the action of heat, it may be worked with the greatest ease, and may be drawn out into threads as fine as those of the cocoon of the silkworm. Glass, when it is submitted to rapid cooling, becomes very fragile, and presents several very remarkable phenomena, among which, as an example, Prince Rupert's drops may be instanced. Glass supports variations of temperature better in proportion as it has been more slowly cooled; thus, when it has been slightly annealed, or not at all, its fragility may be considerably diminished by annealing it in water, or better, in boiling oil.

Action of Atmospheric and Chemical Agents.—The harder and more infusible a glass is, the less it is alterable by the action of atmospheric and chemical agents, with the exception of hydrofluoric acid. Glass which is too alkaline attracts gradually the moisture of the air, and loses its lustre and polish. Many glasses are perceptibly attacked by a prolonged boiling with water, and *à fortiori* by acid and alkaline solutions; thus, the bottle-glass is frequently attacked by the tartar which is found in the wine. According to Guyton-Morveau, all glass which is attacked by prolonged boiling with concentrated solutions of alum, common salt, sulphuric acid, or potassa, is of bad quality.

From these facts we perceive the importance of making a careful choice of the glass intended to be worked in considerable masses, such as the large object-glasses of telescopes; as their annealing requires a very slow process of refrigeration, which is apt to cause devitrified specks and clouds. For such purposes, therefore, no other species of glass is well adapted, except that with bases of potash and lead; or that with bases of potash and lime. These two form the best flint-glass and crown-glass; and they should be exclusively employed for the construction of the object-glasses of achromatic telescopes.

Glass, it will be apparent from the analyses given (pp. 645, 646), may be defined, in technical phraseology, to be a transparent homogeneous compound formed by the fusion of silica with oxides of the alkaline, earthy, or common metals. It is usually colourless, and then resembles rock-crystal, but is occasionally stained by accident or design with coloured metallic oxides. At common temperatures it is hard and brittle, in thick pieces; in thin plates or threads, flexible and elastic; sonorous when struck; fracture conchoidal, and of that peculiar lustre called vitreous: at a red heat, becoming soft, ductile and plastic. Other bodies are capable of entering into vitreous fusion, as phosphoric acid, boracic acid, arsenic acid, as also certain metallic oxides, as of lead and antimony, and several chlorides; some of which are denominated glasses.

Silica, formerly styled the earth of flints, which constitutes the basis of all commercial glass, is infusible by itself in the strongest fire of our furnaces; but its vitreous fusion is easily effected by a competent addition of potash or soda, either alone or mixed with lime or litharge. The silica, which may be regarded as belonging to the class of acids, combines at the heat of fusion with these bases, to form saline compounds; and hence glass may be viewed as a silicate of certain oxides, in which the acid and the bases exist in equivalent proportions. Were these proportions, or the quantities of the bases which silica requires for its saturation at the melting point, exactly ascertained, we might readily determine beforehand the best proportions of materials for the glass-manufacture. But as this is far from being the case, and as it is, moreover, not improbable that the capacity of saturation of the silica varies with the temperature, and that the properties of glass also vary with the bases, we must in the present state of our knowledge, regulate the proportions rather by practice than by theory, though the latter may throw an indirect light upon the subject. For example, a good colourless glass has been found by analysis to consist of 72 parts of silica, 13 parts of potash, and 10 parts of lime, in 95 parts. If we reduce these numbers to the equivalent ratios, we shall have the following results, taking the atomic weights as given by Berzelius:—

1	atom	potash =	590	14·67	
1		lime	356	8·84	
3		silica	1,722	42·79	71·49
2		silica	1,155	28·79	
			3,823	95·00	

This glass would therefore have been properly better compounded with the just atomic proportions, to which it nearly approaches, viz. 71·49 silica, 14·67 potash, and 8·84 lime, instead of those given above as its actual constituents.

The proportions in which silica unites with the alkaline and other oxides are modified by the temperature as above stated; the lower the heat, the less silica will enter into the glass, and the more of the base will in general be required. If a glass which contains an excess of alkali be exposed to a much higher temperature than that of its formation, a portion of the base will be set free to act upon the materials of the earthen pot, or to be dissipated in fumes, until such a silicate remains as to constitute a permanent glass corresponding to that temperature. Hence the same mixture of vitrifiable materials will yield very different results, according to the heats in which it is fused and worked in the glass-house; and therefore the composition should always be referrible to 'the going' of the furnace. When a species of glass, which at a high temperature formed a transparent combination with a considerable quantity of lime, is kept for some time in fusion at a lower temperature, a portion of the lime unites with the silica into another combination of a semi-vitreous or even of a stony aspect, so as to spoil the transparency of the glass altogether. There is probably a supersilicate and a subsilicate formed in such cases; the latter being much the more fusible of the two compounds. The Réaumur's porcelain already mentioned, is an example of this species of vitreous change in which new affinities are exercised at a lower temperature. An excess of silica, caused by the volatilisation of alkaline matter with too strong firing, will bring on similar appearances.

The specific gravity of glass varies from 2·3 to 3·6. That of least specific gravity consists of merely silica and potash fused together; that with lime is somewhat denser, and with oxide of lead denser still. Plate-glass made from silica, soda, and lime, has a specific variety which varies from 2·3 to 3·6; crystal or flint-glass containing lead from 3·0 to 3·6.

The density of several glasses *without lead* is as follows:—

Old Bohemian glass (Dumas)	2·396
Bohemian bottle-glass	3·782
Do. window-glass	2·642
Fine glass, called Bohemian crystal	2·892
Mirror-glass of Cherbourg (Dumas)	2·506
Do. St. Gobain	2·488
Do. Newhaus, 1812 (Scholz)	2·551
Do. do. 1830	2·653

The power of glass to resist the action of water, alkalis, acids, air, and light is in general the greater the higher the temperature employed in its manufacture, the smaller the proportion of its fluxes, and the more exact the equivalent ratios of its constituents. When glass contains too much alkali, it is partially soluble in water. Most crystal-glass is affected by having water boiled in it for a considerable time; but crown-glass being poorer in alkali, and containing no lead, resists that action much longer, and is therefore better adapted to chemical operations. In general, also, potash-glass is more apt to become damp than soda-glass, agreeably to the respective hygrometric properties of these two alkalis, and also to the smaller proportion of soda than of potash requisite to form glass.

Air and light operate upon glass probably by their oxidising property. Bluish or greenish coloured glasses become by exposure colourless, in consequence undoubtedly of the peroxidation of the iron, to whose protoxide they owe their tint; other glasses become purple-red from the peroxidation of the manganese. The glasses which contain lead suffer another kind of change in the air, if sulphuretted hydrogen be present; the oxide of lead is converted into a sulphuret, with the effect of rendering the surface of the glass opaque and iridescent. The more lead is in the glass, the quicker does this iridescence supervene. By boiling concentrated sulphuric acid in a glass vessel, or upon glass, we can ascertain its power of resisting ordinary menstrua. Good glass will remain smooth and transparent; bad glass will become rough and dim. The conditions of decomposition, as it occurs in glass of great age, have not been satisfactorily explained; the glass of the Roman tombs decomposes from the surface, exfoliating in a remarkable manner, film after film, of a pearly and beautifully iridescent character, falling off one after the other. The same kind of change is seen on the windows of our ancient churches.

The brittleness of unannealed glass by change of temperature is sometimes very great. This defect may be corrected by slowly heating the vessel in salt-water or oil to the highest pitch consistent with the nature of these liquids, and letting it cool very slowly. Within the limits of that range of heat it will, in consequence of this treatment, bear alternations of temperature without cracking.

It has been said that glass made from silica and alkalis alone will not resist the action of water, but that the addition of a little lime is necessary for this effect. In general 100 parts of quartzose sand require 33 parts of dry carbonate of soda for their vitrification, and 45 parts of dry carbonate of potash. But to make unchangeable alkaline glass, especially with potash, a smaller quantity of this than the above should be used with a very violent heat. A small proportion of lime increases the density, hardness, and lustre of glass; and it aids in decomposing the alkaline sulphates and muriates always present in the pearlash of commerce. From 7 to 20 parts of dry-slaked lime have been added for 100 of silica, with advantage, it is said, in some German glass-manufactories, where the alkaline matter is soda; for potash does not assimilate well with the calcareous earth.

In many glass works on the Continent, sulphate of soda is the form under which alkaline matter is introduced into glass. This salt requires the addition of 8 per cent. of charcoal to decompose and dissipate its acid: a result which takes place at a high heat, without the addition of any lime. 88 lbs. of quartz-sand, 44 lbs. of dry Glauber salt, and 3 lbs. of charcoal, properly mixed and fused, afford a limpid, fluid, and workable glass; with the addition of 17 lbs. of lime, these materials fuse more readily into a plastic mass. If less carbon be added, the fusion becomes more tedious.

By a proper addition of galena (the native sulphide of lead) to Glauber salt and quartz-sand, without charcoal, it is said a tolerably good crystal-glass may be formed. The sulphuric acid of the salt is probably converted by the reaction of the sulphuret of lead into sulphurous-acid gas, which is disengaged.

One atom of sulphide of lead = 1495·67, is requisite to decompose 3 atoms of sulphate of soda = 2676. It is stated, on good authority, that a good colourless glass may be obtained by using Glauber salt without charcoal, as by the following formula:—

Quartz-sand . . .	100 lbs.	Lime	20 lbs.
Calcined Glauber salt. .	20 ,,	Cullet of soda-glass .	12 ,,

The melting-heat must be continued for 26½ hours. A small quantity of the sand is reserved to be thrown in towards the conclusion of the process, in order to facilitate the expulsion of air-bubbles. The above mixture will bear to be blanched by the addition of manganese and arsenic. The decomposition of the salt is in this case effected by the lime, with which the sulphuric acid first combines, which is then converted into sulphurous acid, and dissipated. Glass made in this way was found by analysis to consist of 79 parts of silica, 12 lime, and 9·6 soda, without any trace of gypsum or sulphuric acid.

Glauber salt is partially volatilised by the heat of the furnace, and acts upon the arch of the oven and the tops of the pots. This is best prevented by introducing at first into the pots the whole of the salt mixed with the charcoal, the lime, and one-fourth part of the sand; fusing this mixture at a moderate heat, and adding gradually afterwards the remainder of the sand, increasing the temperature at the same time. If we put in the whole ingredients together, as is done with potash-glass, the sand and lime soon fall to the bottom, while the salt rises to the surface, and the combination becomes difficult and unequal.

Sulphate of potash acts in the same way as sulphate of soda.

Chloride of sodium also, according to Kirn, may be used as a glass-flux with advantage. The most suitable proportions are 4 parts of potash, 2 of common salt, and 3 of lime, agreeably to the following compositions:—

	1.	2.
Quartz-sand	60·0	57·1
Calcined carbonate of potash . . .	17·8	19·1
Common salt	8·9	9·5
Lime	13·3	14·3

For No. 1, the melting heat must be 10 hours, which turns out a very pure, solid, good glass; for No. 2, 23 hours of the furnace are required. Instead of the potash, Glauber salt may be substituted; the proportions being then 19·1 Glauber salt, 9·5 chloride of sodium, 14·3 lime, 57·1 sand, and 1·3 charcoal.

.The oxide of lead is an essential constituent of the denser glasses, and may be regarded as replacing the lime, so as to form with the quartz-sand a silicate of lead. It assimilates best with purified pearlash, on account of the freedom of this alkali from iron, which is present in most sodas.

Its atomic constitution may be represented as follows:—

				Computation	Analysis
Silica	5 atoms	=	2877·0	59·19	59·20
Oxide of lead	1	=	1394·5	28·68	28·20
Potash	1	=	590·0	12·13	9·00
Oxides of iron and manganese .			...	...	1·40
			4861·5	100·00	97·80

The above analysis by Berthier relates to a specimen of the best English crystal-glass, perfectly colourless and free from air-bubbles. This kind of glass may, however, take several different proportions of potash and silica to the oxide of lead.

The composition of mirror-plate, as made on the Continent, is as follows:—

White quartz-sand	300 lbs.
Dry carbonate of soda	100 ,,
Lime slaked in the air	43 ,,
Cullet, or old glass	300 ,,

The manganese should not exceed one-half per cent. of the weight of soda.

Optical glass requires to be made with very peculiar care. It is of two different kinds: namely, *crown-glass* and *flint-glass*. The latter contains a considerable proportion of lead, in order to give it an increased dispersive power upon the rays of light, in proportion to its mean refractive power.

Optical crown-glass should be perfectly limpid, and have so little colour, that a pretty thick piece of it may give no appreciable tinge to the rays of light. It should be exempt from striæ or veins as well as air-bubbles, and have not the slightest degree of milkiness. It should, moreover, preserve these qualities when worked in considerable quantities. Potash is preferable to soda for making optical crown-glass, because the latter alkali is apt to make a glass which devitrifies and becomes opalescent, by long exposure to heat in the annealing process. A simple potash-silicate would be free from this defect, but it would be too attractive of moisture, and apt to decompose eventually by the humidity of the atmosphere. It should, therefore, contain a small quantity of lime, and as little potash as suffices for making a perfect glass at a pretty high temperature. It is probably owing to the high heats used in the English crown-glass works, and the moderate quantity of alkali (soda) which is employed, that our crown-glass has been found to answer so well for optical purposes.

The following recipe for crown-glass is excellent:—

	Parts
5 atoms of silica (2½ ?)	80
1 carbonate of soda	54
5 silica	80
1 carbonate of lime	50
1 atom of carbonate of baryta	98
5 atoms of silica	80

Silicates of lime and baryta *per se*, or even combined, are very refractory; but they vitrify well along with a third silicate, such as that of soda or potash.

The following are additional recipes for making different kinds of glass:—

1. *Bottle glass.*—11 lbs. of dry Glauber salt; 12 of soaper salts; a half bushel of waste soap ashes; 56 lbs. of sand; 22 of glass skimmings; 1 cwt. of green broken glass; 25 lbs. of basalt. This mixture affords a dark green glass.

2. Yellow or white sand, 100 parts; kelp, 30 to 40; lixiviated wood ashes, from 160 to 170; fresh wood ashes, 30 to 40; potter's clay, 80 to 100; cullet or broken glass, 100. If basalt be used, the proportion of kelp may be diminished.

In two bottle-glass houses in the neighbourhood of Valenciennes, an unknown ingredient, sold by a Belgian, was employed, which he called *spar*. This was discovered by chemical analysis to be sulphate of baryta. The glass-makers observed that the bottles which contained some of this substance were denser, more homogeneous, more fusible, and worked more kindly than those formed of the common materials. When one equivalent of the silicate of baryta = 123, is mixed with three of the silicate of soda = (3 × 77·6) 232·8, and exposed in a proper furnace, vitrification readily ensues, and the glass may be worked a little under a cherry-red heat, with as much ease as a glass of lead, and has nearly the same lustre.

3. *Green window-glass, or broad glass.*—11 lbs. of dry Glauber salt; 10 of soaper salts; half a bushel of lixiviated soap waste; 50 lbs. of sand; 22 of glass-pot skimmings; 1 cwt. of broken green glass.

4. *Crown-glass.*—300 parts of fine sand; 200 of good soda ash; 33 of lime; from 250 to 300 of broken glass; 60 of white sand; 30 of purified potash; 15 of saltpetre (1 of borax); ½ of arsenious acid.

5. *Nearly white table-glass.*—20 lbs. of potashes; 11 of dry Glauber salt; 16 of soaper salt; 55 of sand; 140 of cullet of the same kind.

Another.—100 lbs. of sand; 235 of kelp; 60 of wood ashes; 1⅓ of manganese; 100 of broken glass.

6. *White table-glass.*—40 lbs. of potashes; 11 of chalk; 76 of sand; ½ of manganese; 95 of white cullet.

Another.—50 lbs. of purified potashes; 100 of sand; 20 of chalk; 2 of saltpetre.

Bohemian table- or plate-glass is made with 63 parts of quartz; 26 of purified potashes; 11 of sifted slaked lime; and some cullet.

7. *Crystal glass.*—60 parts of purified potashes; 120 of sand; 24 of chalk; 2 of saltpetre; 2 of arsenious acid; $\frac{1}{16}$ of manganese.

Another.—70 parts of purified pearlashes; 120 of white sand; 10 of saltpetre; ½ of arsenious acid; ⅓ of manganese.

A third.—67 parts of sand; 23 of purified pearlashes; 10 of sifted slaked lime; ¼ of manganese; (5 to 8 of red lead).

A fourth.—120 parts of white sand; 50 of red lead; 40 of purified pearlashes; 20 of saltpetre; ⅓ of manganese.

A fifth.—120 parts of white sand; 40 of purified pearlashes; 35 of red lead; 13 of saltpetre; $\frac{1}{12}$ of manganese.

A sixth.—30 parts of the finest sand; 20 of red lead; 8 of purified pearlashes; 2 of saltpetre; a little arsenious acid and manganese.

A seventh.—100 parts of sand; 45 of red lead; 35 of purified pearlashes; ⅐ of manganese; ⅕ of arsenious acid.

8. *Plate-glass.*—300 parts of very white sand; 100 of dry purified soda; 43 of carbonate of lime; 1 of manganese; 300 of cullet.

Another.—720 parts of finest sand; 450 of purified soda; 80 of quicklime; 25 of saltpetre; 425 of cullet.

A little borax has also been prescribed; much of it communicates an exfoliating property to glass.

Practical Details of the Manufacture of Glass.

There are five different species of glass, each requiring a peculiar mode of fabrication and peculiar materials:—1. The coarsest and simplest form of this manufacture is *bottle-glass*. 2. Next to it in cheapness of material may be ranked *broad* or *spread window-glass*. An improved article of this kind is now made near Birmingham, under the name of British or German plate. 3. *Crown-glass* comes next, or window-glass, formed in large circular plates or discs. This glass is peculiar to Great Britain. 4. *Flint-glass*, *crystal-glass*, or glass of lead. 5. *Plate* or *fine mirror-glass*.

The Pots.—The materials of every kind of glass are vitrified in pots made of a pure refractory clay; the best kind of which is a species of shale or fire-clay dug out of the coal-measures near Stourbridge. It contains hardly any lime or iron, and consists of silica and alumina in nearly equal proportions. The masses are carefully picked, brushed, and ground under edge iron wheels of considerable weight, and sifted through sieves having 20 meshes in the square inch. This powder is moistened with water (best hot), and kneaded by the feet or a loam-mill into an uniform smooth paste. A large body of this dough should be made up at a time, and laid by in a damp cellar to ripen. Previously to working it into shapes, it should be mixed with about a fourth of its weight of cement of old pots, ground to powder. This mixture is sufficiently plastic, and being less contractile by heat, forms more solid and durable vessels. Glass-house pots have the figure of a truncated cone, with the narrow end undermost; those for bottle- and window-glass being open at top, about 30 inches diameter at bottom, 40 inches at the mouth, and 40 inches deep; but the flint-glass pots are covered in at top with a dome-cap, having a mouth at the side, by which the materials are introduced, and the glass is extracted. Bottle and crown-house pots are from 3 to 4 inches thick; those for flint-houses are an inch thinner, and of proportionally smaller capacity. See Clay.

The well-mixed and kneaded dough is first worked upon a board into a cake for the bottom; over this the sides are raised, by laying on its edges rolls of clay above each other with much manual labour, and careful condensation. The clay is made into lumps, is equalised, and slapped much in the same way as for making pottery. The pots thus fashioned must be dried very prudently, first in the atmospheric temperature, and finally in a stove floor, which usually borrows its heat directly from the glass-house. Before *setting the pots* in the furnace, they are annealed during 4 or 5 days, at a red heat in a small reverberatory vault made on purpose. When completely annealed, they are transferred with the utmost expedition into their seat in the fire, by means of powerful tongs supported on the axle of an iron-wheel carriage frame, and terminating in a long lever for raising them and swinging them round. The *pot-setting* is a desperate service, and when unskilfully conducted without due mechanical aids, is the forlorn hope of the glass-founder.

The glass-houses are usually built in the form of a cone from 60 to 100 feet high, and from 50 to 80 feet in diameter at the base. The furnace is constructed in the centre of the area, above an arched or groined gallery which extends across the whole space, and terminates without the walls, in large folding doors. This cavern must be sufficiently high to allow labourers to wheel out the cinders in their barrows. The middle of the vaulted top is left open in the building, and is covered over with the grate-bars of the furnace.

1. *Bottle-glass.*—The bottle-house and its furnace resembles nearly *fig.* 1092. The furnace is usually an oblong square chamber, built of large fire-bricks, and arched over with fire-stone, a siliceous grit of excellent quality extracted from the coal-measures of Newcastle. This furnace stands in the middle of the area; and has its base divided into three compartments. The central space is occupied with the grate-bars: and on either side is the platform or fire-brick *siége* (seat), raised about 12 inches above the level of the ribs upon which the pots rest. Each *siége* is about 3 feet broad.

In the sides of the furnace semi-circular holes of about a foot diameter are left, opposite to, and a little above the top of each pot, called working-holes, by which the workmen shovel in the materials, and take out the plastic gas. At each angle of the furnace there is likewise a hole of about the same size which communicates with the calcining furnace of a cylindrical form, dome-shaped at top. The flame that escapes from the founding or pot-furnace is thus economically brought to reverberate on the raw materials of the bottle-glass, so as to dissipate their carbonaceous or volatile impurities, and convert them into a frit. A bottle-house has generally eight other furnaces or fire arches; of which six are used for annealing the bottles after they are blown, and two for annealing the pots, before setting them in the furnace.

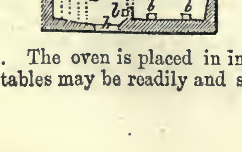
Generally, for common bottles, the common river-sand and soap-boilers' waste are used. About 3 parts of waste, consisting of the insoluble residuum of kelp mixed with lime, and a little saline substance, are employed for 1 part of sand. This waste is first of all calcined in two of the fire arches or reverberatories reserved for that purpose, called the coarse arches, where it is kept at a red heat, with occasional stirring; from 24 to 30 hours, being the period of a journey, or *journée*, in which the materials could be melted and worked into bottles. The roasted soap-waste is then withdrawn under the name of ashes, from its arch, coarsely ground, and mixed with its proper proportion of sand. This mixture is now put into the fire arch, and calcined during the working journey which extends to 10 or 12 hours. Whenever the pots are worked out, that frit is immediately transferred into them in its ignited state, and the founding process proceeds with such despatch that this first charge of materials is completely melted down in 6 hours, so that the pots might admit to be filled up again with the second charge of frit which is founded in 4 hours more. The heat is briskly continued, and in the course of from 12 to 8 hours, according to the size of the pots, the quality of the fuel, and the draught of the furnace, the vitrification is complete. Before blowing the bottles, however, the glass must be left to settle, and to cool down to the blowing consistency by shutting the *cave* doors and feeding holes, so as to exclude the air from the fire-grate and the bottom of the hearth. The glass or metal becomes more dense, and by its subsidence throws up the foreign lighter earthy and saline matters in the form of a scum on the surface, which is removed with skimming irons. The furnace is now charged with coal, to enable it to afford a working heat for 4 or 5 hours, at the end of which time more fuel is cautiously added to preserve adequate heat for finishing the *journey*.

It is hardly possible to convey in words alone a correct idea of the manipulations necessary to the formation of a wine-bottle. Six people are employed at this task; one, called a gatherer, dips the end of an iron tube, about five feet long, previously made red hot, into the pot of melted *metal*, turns the rod round so as to surround it with glass, lifts it out to cool a little, and then dips and turns it round again; and so in succession till a ball is formed on its end sufficient to make the required bottle. He then hands it to the blower, who rolls the plastic lump of glass on a smooth stone or cast-iron plate, till he brings it to the very end of the tube; he next introduces the pear-shaped ball into an open brass or cast-iron mould, shuts this together by pressing a pedal with his foot, and holding his tube vertically, blows through it, so as to expand the cooling glass into the form of the mould. Whenever he takes his foot from the pedal-lever, the mould simultaneously opens out into two halves and falls asunder by its bottom hinge. He then lifts the bottle up at the end of the rod and transfers it to the finisher, who, touching the glass-tube at the end of the pipe with a cold iron, cracks off the bottle smoothly at its mouth-ring. The finished bottles are immediately piled up in the hot annealing arch, where they are afterwards allowed to cool slowly for 24 hours at least.

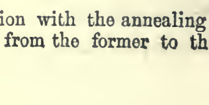
2. *Broad or spread window-glass.*—This kind of glass is called *inferior* window-glass in this country, because coarse in texture, of a wavy wrinkled surface, and very cheap; but on the Continent *spread* window-glass, being made with more care, is much better than ours, though still far inferior in transparency and polish to crown-glass, which has, therefore, nearly superseded it use among us. But Messrs. Chance and Co., of Birmingham, make *British sheet glass* upon the best principles, and turn out an article quite equal, if not superior, to anything of the kind made either in France or Belgium. Their materials are those used in the crown-glass manufacture. The vitrifying mixture is fritted for 20 or 30 hours in a reverberatory arch, with considerable stirring and puddling with long-handled shovels and rakes; and the frit is then transferred by shovels, while red hot, to the melting pots to be founded. When the glass is rightly vitrified, settled, and brought to a working heat, it is lifted out by iron tubes, blown into pears, which, being elongated into cylinders, are cracked up along one side parallel to the axis, by touching them with a cold iron dipped in water, and are then opened out into sheets. The glass cylinders are spread on a bed of smooth stone Paris-plaster, or laid on the bottom of a reverberatory arch; the cylinder being placed on its side horizontally, with the cracked line uppermost, gradually opens out, and flattens on the hearth. At one time, thick plates were thus prepared for subsequent polishing into mirrors; but the glass was never of very good quality; and this mode of making mirror-plate has accordingly been generally abandoned.

The spreading furnace or oven is that in which cylinders are expanded into tables or plates. It ought to be maintained at a brisk red heat, to facilitate the softening of the glass. The oven is placed in immediate connection with the annealing arch, so that the tables may be readily and safely transferred from the former to the latter.

1087



1088

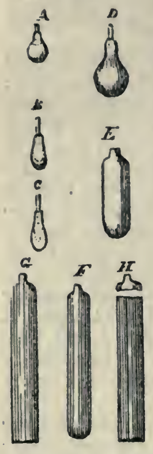


Sometimes the cylinders are spread in a large muffle-furnace, in order to protect them from being tarnished by sulphureous and carbonaceous fumes.

Fig. 1087 represents a ground plan of both the spreading and annealing furnace; *fig.* 1088 is an oblong section in the direction of the dotted-line *x x*, *fig.* 1087.

a is the fire-place; *b b*, the canals or flues through which the flame rises into both furnaces; *c*, the spreading furnace, upon whose sole is the spreading slab. *d*, is the cooling and annealing oven; *e e*, iron bars which extend obliquely across the annealing arch, and serve for resting the glass tables against during the cooling; *f f*, the channel along which the previously-cracked cylinders are slid, so as to be gradually warmed; *g*, the opening in the spreading furnace, for enabling the workmen to regulate the process; *h*, a door in the annealing arch, for introducing the tools requisite for raising up and removing the tables.

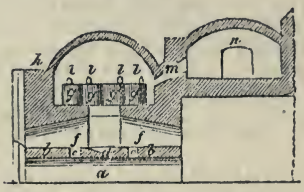
1089



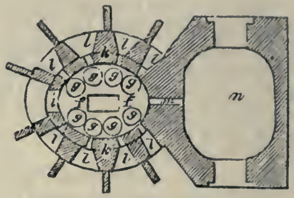
The series of transformations in sheet-glass, already described, is represented in *fig.* 1089, at A, B, C, D, E, F, G, H.

Figs. 1090 and 1091 represent a Bohemian furnace in which excellent white window-glass is founded. *Fig.* 1090 is a longitudinal section of the glass and annealing furnace. *Fig.* 1091 is the ground plan. *a* is the ash pit vaulted under the sole of the furnace; the fire-place itself is divided into three compartments, with a middle slab at *d*, which is hollowed in the centre, for collecting any split glass, and two hearth tiles or slabs *b b*. *c c* are the draught or air-holes; *e e* are arches upon which the bearing slabs *f f* partly rest. In the middle between these arches, the flame strikes upwards upon the pots *g g*, placed as closely together as possible for economy of room. *h* is the breast-wall of the furnace; *i*, *fig.* 1091, the opening through which the pots are introduced; it is bricked up as soon as they are set. *k k* is the base of the cone or dome of the furnace; *l l l*, the working orifices, which are made larger or smaller according to the size of the glass articles to be made. *m* is the flue which leads to the annealing stove *n*, with an arched door. Exterior to this there is usually a drying kiln, not shown in the figure; and there are adjoining stoves, called *arches*, for drying and annealing the new pots before they are set.

1090



1091



The cooling or annealing arch, or leer, is often built independent of the glass-house furnace; it is then heated by a separate fire-place, and constructed like a very long reverberatory furnace.

1092

The leer pans, or trays of sheet iron, are laid upon its bottom in an oblong series, and hooked to each other.

3. *Crown-glass.*—The crown-glass house with its furnace is represented in *fig.* 1092, where the *blowing* operation is shown on the one side of the figure, and the *flashing* on the other. The furnace is usually constructed to receive 4 or 6 pots, of such dimensions as to make about a ton of glass each at a time. There are, however, several subsidiary furnaces to a crown-house: 1, a reverberatory furnace or *calcar*, for calcining or fritting the materials; 2, a blowing furnace for blowing the pear-shaped balls made at the pot-holes, into large globes; 3, a flashing furnace, and bottoming hole for communicating a softening heat, in expanding the globe into a circular plate; 4, the annealing arch for the

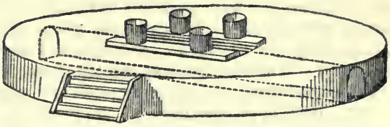
finished tables; 5, the reverberatory oven for annealing the pots prior to their being set upon the founding *siége*.

The materials of crown-glass used to be, fine sand, by measure 5 parts, or by weight 10; ground kelp, by measure 11 parts, or by weight 16½; but instead of kelp, soda-ash is now generally employed. From 6 to 8 cwts. of sand, lime, and soda-ash, mixed together in wooden boxes with a shovel are thrown on the sole of a large reverberatory. Here the mixture is well worked together with iron paddles, flat shovels, and rakes with long handles; the area of this furnace, being about 6 feet square, and the height 2 feet. The heat soon brings the materials to a pasty consistence, when they must be diligently turned over, to favour the dissipation of the carbon, sulphur, and other volatile matters of the kelp or soda-ash, and to incorporate the fixed ingredients uniformly with the sand. Towards the end of 3 hours, the fire is considerably raised, and when the fourth hour has expired, the fritting operation is finished. The mass is now shovelled or raked out into shallow cast-iron square cases, smoothed down, and divided before it hardens by cooling, into square lumps, by cross sections with the spade. These frit-bricks are afterwards piled up in a large apartment for use; and have been supposed to improve with age, by the efflorescence of their saline constituents into carbonate of soda on their surface.

The founding-pots are filled up with these blocks of frit, and the furnace is powerfully urged by opening all the subterranean passages to its grate, and closing all the doors and windows of the glass-house itself. After 8 or 10 hours the vitrification has made such progress, and the blocks first introduced are so far melted down, that another charge of frit can be thrown in, and thus the pot is fed with frit till the proper quantity is used. In about 16 hours the vitrification of the frit has taken place, and a considerable quantity, amounting often to the cwt. of liquid saline matter floats over the glass. This salt is carefully skimmed off into iron pots with long ladles. It is called Sandiver, or Glass-gall, and consists usually of chloride of sodium, with a little sulphate. The pot is now ready for receiving the *topping of cullet*, which is broken pieces of window-glass, to the amount of 3 or 4 cwts. This is shovelled in at short intervals; and as its pressure forces up the residuary saline matter, this is removed; for were it allowed to remain, the body of the glass would be materially deteriorated.

The heat is still continued for several hours till the glass is perfect, and the extrication of gas called the *boil*, which accompanies the fusion of crown-glass, has nearly terminated, when the fire is abated by shutting up the lower vault doors and every avenue to the grate, in order that the glass may settle fine. At the end of about 40 hours altogether, the fire being slightly raised by adding some coals, and opening the doors, the glass is carefully skimmed, and the working of the pots commences.

1093



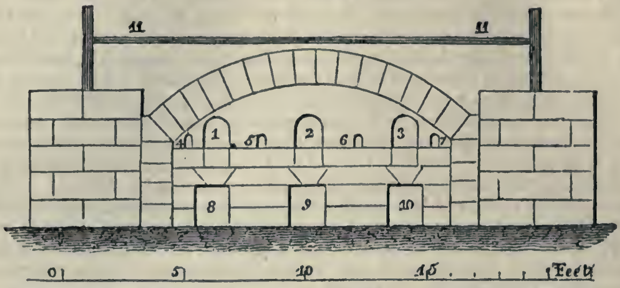
Before describing it, however, we may state that the marginal figure, 1093, shows the base of the crown-house cone, with the four open pots in two ranges, on opposite sides of the furnace, sitting on their raised *siéges* at each side of the grate. At one side of the base the door of the vault is shown, and its course is marked by the dotted lines.

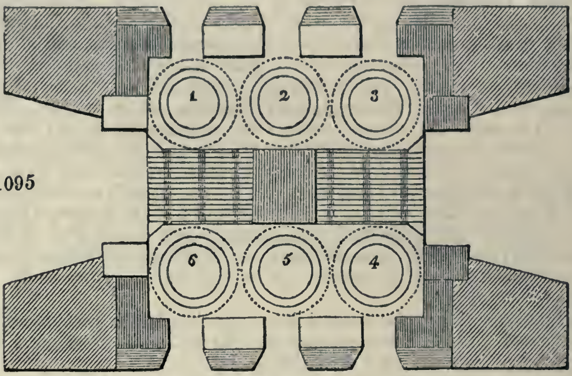
The crown-glass furnace, *figs.* 1094, 1095, is an oblong square, built in the centre of a brick cone, large enough to contain within it two or three pots at each side of the grate room, which is either divided as shown in the plan, or runs the whole length of the furnace, as the manufacturer chooses. *Fig.* 1095 is a ground plan, and *fig.* 1094 a front elevation of a six-pot furnace. 1, 2, 3, *fig.* 1094, are the working holes for the purposes of ventilation, of putting in the materials, and taking out the metal to be wrought. 4, 5, 6, 7, are pipe-holes for warming the pipes before beginning to work with them. 8, 9, 10, are foot holes for mending the pots and *siéges*. 11 is a bar of iron for binding the furnace, and keeping it from swelling.

The arch is of an elliptic form; though a barrel arch, that is, an arch shaped like the half of a barrel cut longwise through the centre, is sometimes used. But this soon gives way when used in the manufacture of crown-glass, although it does very well in the clay-furnace used for bottle-houses.

The best stone for building furnaces is fire-stone; it may be obtained in the neighbourhood of Newcastle from the coal-measures generally, and some of the sandstones of the eastern counties are found to answer the purpose admirably. The great danger in building furnaces is, lest the cement at the top should give way with the excessive heat, and by dropping into the pots, spoil the metal. The top should therefore be built with stones only, as loose as they can hold together after the centres are removed, and without any cement whatever. The stones expand and come quite close together when annealing: an operation which takes from eight to fourteen days at most. There is thus less risk of anything dropping from the roof of the furnace.

1094





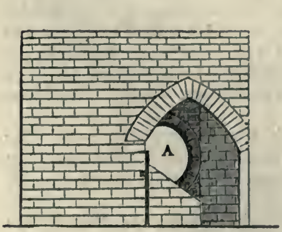
1095

The inside of the square of the furnace is built either of Stourbridge fire-clay annealed, or of fire-stone, to the thickness of sixteen inches. The outside is built of common brick, about nine inches in thickness.

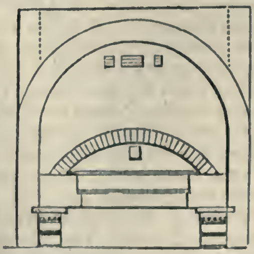
The furnace is thrown over an ash-pit, or cave as it is called, which admits the atmospheric air, and promotes the combustion in the furnace. This cave is built of stone until it comes beneath the grate room, when it is formed of fire-brick. The abutments are useful for binding and keeping the furnace together, and are built of masonry. The furnaces are stoutly clasped with iron all round, to keep them tight. In four-pot furnaces this is unnecessary, provided there be four good abutments.

Fig. 1096 is an elevation of the flashing furnace. The outside is built of common brick, the inside of fire-brick, and the mouth or nose of Stourbridge fire-clay.

1096



1097



1098

Fig. 1097 is the annealing kiln. It is built of common brick, except round the grate-room, where fire-brick is used.

Few tools are needed for blowing and flashing crown-glass. The requisite ball of plastic glass is gathered, in successive layers as for bottles, on the end of an iron tube, and rolled into a pear-shape, on a cast-iron plate; the workman taking care that the air blown into its cavity is surrounded with an equal body of glass, and if he perceives any side to be thicker than another, he corrects the inequality by rolling it on the sloping iron table called a marver (marbre). He now heats the bulb in the fire, and rolls it so as to form the glass upon the end of the tube, and by a dexterous swing or two he lengthens it, as shown in I, *fig.* 1098. To extend the neck of that pear, he next rolls it over a smooth iron rod, turned round in a horizontal direction, into the shape K, *fig.* 1098. By further expansion at the blowing furnace, he now brings it to the shape L, represented in *fig.* 1098.

This spheroid having become cool and somewhat stiff, is next carried to the bottoming hole (like *fig.* 1096), to be exposed to the action of flame. A slight wall erected before one half of this hole, screens the workman from the heat, but leaves room for the globe to pass between it and the posterior wall. The blowing-pipe is made to rest a little way from the neck of the globe, on a hook fixed in the front wall; and thus may be made easily to revolve on its axis, and by giving centrifugal force to the globe, while the bottom of it, or part opposite to the pipe, is softened by the heat, it soon assumes the form exhibited in M, *fig.* 1098.

In this state the flattened globe is removed from the fire, and its rod being rested on the *casher box* covered with coal cinders, another workman now applies the end of a solid iron rod tipped with melted glass, called a *punto*, to the nipple or prominence in the middle; and thus attaches it to the centre of the globe, while the first workman cracks off the globe by touching its tubular neck with an iron chisel dipped in cold water. The workman having thereby taken possession of the globe by its bottom or knobbled pole attached to its punty rod, he now carries it to another circular opening, where he exposes it to the action of moderate flame with regular rotation, and thus slowly heats the thick projecting remains of the former neck, and opens it slightly out, as shown at N, in *fig.* 1098. He next hands it to the *flasher*, who, resting the iron rod in a hook placed near the side of the orifice A, *fig.* 1096, wheels it rapidly round opposite to a powerful flame, till it assumes first the figure O, *fig.* 1098, and finally that of a flat circular table.

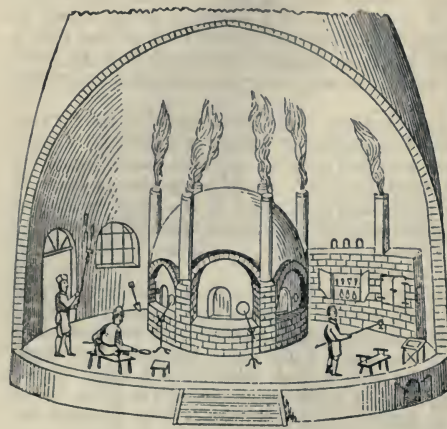
The flasher then walks off with the table, keeping up a slight rotation as he moves along, and when it is sufficiently cool, he turns down his rod into a vertical position, and lays the table flat on a dry block of fire-clay, or bed of sand, when an assistant nips it off from the *punto* with a pair of long iron shears, or cracks it off with a touch of cold iron. The loose table or plate is lastly lifted up horizontally on a double pronged iron fork, introduced into the annealing arch, *fig.* 1097, and raised on edge; an assistant with a long-kneed fork preventing it from falling too rapidly backwards. In this arch a great many tables of glass are piled up in iron frames, and slowly cooled from a heat of about 600° to 100° F., which takes about 24 hours; when they are removed. A circular plate or table of about 5 feet diameter weighs on an average 9 pounds.

4. *Flint-glass.*—This kind of glass is so called because originally made with calcined flints, as the siliceous ingredient. The materials at present employed in this country for the finest flint-glass are, first, sand, calcined, sifted, and washed; second, an oxide of lead, either red lead or litharge; and third, pearlash. Sand for flint-glass manufacture is obtained from the Isle of Wight, Aylesbury, the New Forest, and some other localities in this country. A very beautiful sand is brought from America, and some has been sent home from Australia. The pearl-ash of commerce must however be purified by digesting it in a very little hot water, which dissolves the carbonate of potash, and leaves the foreign salts, chiefly sulphate of potash, and chlorides of potassium and sodium. The solution of the carbonate being allowed to cool and become clear in lead pans, is then run off into a shallow iron boiler, and evaporated to dryness. Nitre is generally added as a fourth ingredient of the body of the glass; and it serves to correct any imperfections which might arise from accidental combustible particles, or from the lead being not duly oxidised. The above four substances constitute the main articles; to which we may add, arsenic and manganese, introduced in very small quantities, to purify the colour and clear up the transparency of the glass. The black oxide of manganese, when used in such quantity only as to peroxidise the iron of the sand, simply removes the green tinge caused by the protoxide of iron; but if more manganese be added than accomplishes that purpose, it will give a purple tinge to the glass. The arsenic is supposed to counteract the injury arising from excess of manganese, but is itself very apt on the other hand to communicate some degree of opalescence, or at least to impair the lustre of the glass.

The raw materials of flint-glass are always mixed with about a third or a fourth of their weight of broken glass of like quality; this mixture is thrown into the pot with a shovel; and more is added whenever the preceding portions by melting subside;

the object being to obtain a pot full of glass, to facilitate the skimming off the impurities and sandiver. The mouth of the pot is now shut, by applying clay-lute round the stopper, with the exception of a small orifice below, for the escape of the liquid saline matter. Flint-glass requires about 48 hours for its complete vitrification, though the materials are more fusible than those of crown-glass; in consequence of the contents of the pot being partially screened by its cover from the action of the fire, as also from the lower intensity of the heat.

1099



1100

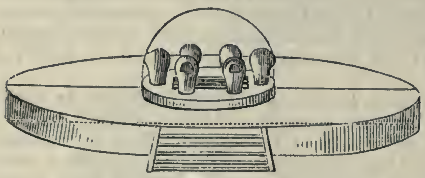


Fig. 1099 represents a flint-glass house for 6 pots with the arch or leer on one side for annealing the crystal ware. In *fig.* 1100, the base of the cone is seen, and the glass pots *in situ* on their platform ranged round the central fire-grate. The dotted line denotes the contour of the furnace, *fig.* 1099.

Whenever the glass appears fine, and is freed from its air-bubbles, which it usually is in about 36 hours, the heat is suffered to fall a little by closing the bottom valves, &c., that the pot may settle; but prior to working the metal, the heat is *somewhat raised* again.

It would be useless to describe the manual operations of fashioning the various articles of the flint-glass manufacture, because they are indefinitely varied to suit the conveniences and caprices of human society.

Every different flint-house has a peculiar proportion of glass materials. The following have been offered as good practical mixtures:—

1.	Fine white sand	300 parts.
	Red lead or litharge	200
	Refined pearl-ashes	80
	Nitre	20
	Arsenic and manganese, a minute quantity.	

2.	Fine sand	50·5
	Litharge	27·2
	Refined pearl-ashes (carbonate of potash, with 5 per cent. of water)	17·5
	Nitre	4·8
		100·0

To these quantities from 30 to 50 parts of broken glass, or cullet, are added, with about a two-thousandth part of manganese and a three-thousandth part of arsenic. But manganese varies so extremely in its purity, and contains often so much oxide of iron, that nothing can be predicated as to its quantity previously to trial.

M. Payen, an eminent manufacturing chemist in France, says that the composition of 'crystal' (the name given in France to their finest flint-glass) does not deviate much from the following proportions:—

	Wood fire.	Coal fire.
Siliceous sand	3	3
Minium	2	2¼
Carbonate of potash	1½	1⅔

The flint-glass *leer* for annealing glass is an arched gallery or large flue, about 36 feet long, 3 feet high, 4 wide; having its floor raised above 2 feet above the ground of the glass-house. The hot air and smoke of a fire-place at one end pass along this gallery, and are discharged by a chimney 8 or 10 feet short of the other end. On the floor of the vault, large iron trays are laid and hooked to each other in a series, which are drawn from the fire-end towards the other by a chain, wound about a cylinder by a winch-handle projecting through the side. The flint-glass articles are placed in their hot state into the tray next the fire, which is moved onwards to a cooler station whenever it is filled, and an empty tray is set in its place. Thus, in the course of about 20 hours, the glass advances to the cool end thoroughly annealed.

Besides colourless transparent glass, which forms the most important part of this manufacture, various coloured glasses are made to suit the taste of the public. The opaline crystal may be prepared by adding to the above composition (No. 2) phosphate of lime, or well-burnt bone-ash in fine powder, washed and dried. The article must be as uniform in thickness as possible, and speedily worked into shape, with a moderate heat. Oxide of tin, *putty-powder*, was formerly used for making opalescent glass, but the lustre of the body was always impaired by its means.

Crystal vessels are made of which the inner surface is colourless, and all the external facets coloured. Such works are easily executed. The end of the blowing-rod must be dipped first in the pot containing colourless glass, to form a bulb of a certain size, which being cooled a little is then dipped for an instant into the pot of coloured glass. The two layers are associated without intermixture; and when the article is finished in its form, it is white within and coloured without. Fluted lines somewhat deeply cut, pass through the coloured coat, and enter the colourless one; so that when they cross, their ends alone are coloured.

For some time past, likewise, various crystal articles have been exhibited in the market with coloured enamel figures on their surface, or with white incrustations of a silvery lustre in their interior. The former are prepared by placing the enamel object in the brass mould, at the place where it is sought to be attached. The bulb of glass being put into the mould, and blown while very hot, the small plate of enamel gets cemented to the surface. For making the white argentine incrustations, small figures are prepared with an impalpable powder of dry porcelain paste, cemented into a solid by means of a little gypsum plaster. When these pieces are thoroughly dried, they are laid on the glass while it is red hot, and a large patch of very liquid glass is placed above it, so as to encase it and form one body with the whole. In this way the incrustation is completely enclosed; and the polished surface of the crystal which scarcely touches it, gives a brilliant aspect, pleasing to the eye.

Optical Glass.—An uniform flint-glass, free from striæ, or *wreath*, is much in demand for the optician. It would appear that such an article was much more commonly made by the English manufacturers many years ago than at present; and that in improving the brilliancy of crystal-glass they have injured its fitness for constructing optical lenses, which depends, not so much on its whiteness and lustre, as on its homogeneous character. Even a potful of pretty uniform glass, when it stands sometime liquid, becomes eventually unequable by the subsidence of the denser portions; so that striæ and gelatinous appearances begin to manifest themselves, and the glass becomes of little value. Gas allowed to cool slowly in mass in the pot is particularly full of wreath, and if quickly refrigerated, that is, in two or three hours, it is apt to split into a multitude of minute splinters, of which no use can be made. For optical purposes, the glass must be taken out in its liquid state, being gathered on the end of the iron rod from the central portion of a recently-skimmed pot, after the upper layers have been worked off in general articles.

M. Guinand, of Brenets near Neufchâtel, a workman in the watch and clock trade, appears to have discovered processes that furnished almost certainly pieces of flint-glass capable of forming good lenses of remarkable dimensions, even of 11 inches diameter, of adequate density and transparency, and nearly free from striæ. Guinand's plan consisted mainly in thoroughly mixing the melted 'metal' with an iron rod. Guinand joined M. Frauenhofer, of Munich, and one of the largest of the lenses produced by them, the diameter of which is 9 inches, is now in the observatory at Dorpat.

M. Cauchoix, the eminent French optician, says, that out of ten object-glasses, 4 inches in diameter, made with M. Guinand's flint-glass, eight or nine turned out very good, while out of an equal number of object-glasses made of the flint-glass of the English and French manufactories, only one, or two at most, were found serviceable.

Guinand was long in communication with the Royal Astronomical Society of London; and he sent over some discs on flint-glass, of which Messrs. Dollond and Herschel made a favourable report. A commission was formed, consisting of Herschel, Dollond, Faraday, and Roget, but owing to the annoying interferences of the Excise officers, notwithstanding the Government had made some special exceptions in favour of these scientific experiments, the results were not practically of that high value which might have been expected. Many of the observations however, were of great value. Amongst other discoveries might be named the remarkable heavy glass, the *Silico-borate of lead*, with which the discovery of the 'so-called' magnetism of a ray of light was made. M. Guinand died, and one of his sons worked with M. Bontemps, while the widow and another son set up works in Switzerland. From their manufactory some examples of lenses were sent to the Great Exhibition of 1851. M. Bontemps was in 1848 prevailed upon to accept the invitation of Messrs. Chance Brothers and Co. to unite with them in attempts they were then making to improve the quality of glass. They succeeded in producing discs of extraordinary dimensions in flint of 29 inches diameter, weighing two cwts. and of crown-glass up to 20 inches. Messrs. Chance, at the recommendation of the Jury, were induced to submit their disc of flint-glass to the operation of grinding, finishing, and other processes necessary in order to ascertain the uniformity of its density throughout, and its superior quality was fully established.

M. Maës of Clichy, near Paris, proposes to manufacture optical glass, with the addition of baryta, magnesia, and oxide of zinc, in combination with boracic acid. The glass manufactured by M. Maës is exceedingly beautiful, but the boracic acid renders it very expensive.

An achromatic object-glass for telescopes and microscopes consists of at least two lenses; the one made with glass of lead, or flint-glass, and the other with crown-glass; the former possessing a power of dispersing the coloured rays relatively to its mean refractive power much greater than the latter; upon which principle, the achromatism of the image is produced, by re-uniting the different coloured rays into one focus. Three plans have been prescribed for obtaining homogeneous pieces of optical glass: 1, to lift a mass of it in large ladles, and let it cool in them; 2, to pour it out from the pots into moulds; 3, to allow it to cool in the pots, and afterwards to cut it off in horizontal strata. The last method seldom affords pieces of uniform density, unless peculiar precautions have been adopted to settle the flint-glass in uniform strata; because its materials are of such unequal density, the oxide of lead having a specific gravity of 8, and silica of 2·7, that they are apt to stand at irregular heights in the pots.

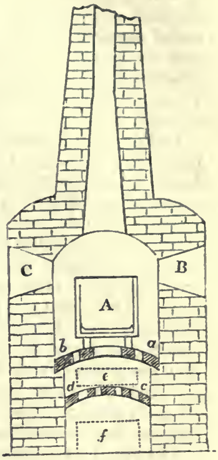
One main cause of these inequalities lies in the construction of the furnace, whereby the bottom of the pot is usually much less heated than the upper part. In a plate-glass furnace the temperature of the top of the pot has been found to be 130° Wedgw., while that of the bottom was only 110°, constituting a difference of no less than 2160° F. The necessary consequence is that the denser particles which subside to the bottom during the fusion of the materials, and after the first extrication of the gases, must remain there not, being duly agitated by the expansive force of heat, acting from below upwards.

The following suggestions, deduced from a consideration of principles, may probably lead to some improvements, if judiciously applied. The great object is to counteract the tendency of the glass of lead to distribute itself into strata of different densities; which may be effected either by mechanical agitation or by applying the greatest heat to the bottom of the pot. But however homogeneous the glass may be thereby made, its subsequent separation into strata of different densities must be prevented by rapid cooling and solidification. As the deeper the pots, the greater is the chance of unequal specific gravity in their contents, it would be advisable to make them wider and shallower than those in use for making ordinary glass. The intermixture may be effected either by lading the glass out of one pot into another in the furnace, and back again, with copper ladles, or by stirring it up with a rouser, and then allowing it to settle for a short time, till it becomes clear and free from air-bubbles. The pot may now be removed from the furnace, in order to solidify its contents in their homogeneous state; after which the glass may be broken in pieces, and be perfected by subjecting it to a second fusion; or what is easier and quicker, we may form suitable discs of glass without breaking down the potful, by lifting it out in flat copper ladles with iron shanks and transferring the lumps after a little while into the annealing leer.

To render a potful of glass homogeneous by agitation is a most difficult task as an iron rod would discolour it, and a copper rod would be apt to melt. An iron rod sheathed in laminated platinum would answer well, but for its expense. A stoneware tube supported within by a rod of iron might also be employed for the purpose in careful hands; the stirring being repeated several times, till at least the glass is suffered to stiffen a little by decrease of temperature. It must then be allowed to settle and cool, after which the pot, being of small dimensions, may be drawn out of the fire.

The second method of producing the desired uniformity of mixture, consists in applying a greater heat to the bottom than to the upper part of the melting pot. *Fig.* 1101 represents in section a furnace contrived to effect this object. It is cylindrical, and of a diameter no greater than to allow the flames to play round the pot, containing from three to four cwts. of vitreous materials. A is the pot resting upon the arched grid *b a*, built of fire-bricks, whose apertures are wide enough to let the flames rise freely, and strike the bottom and sides of the vessel. From 1½ to 2 feet under that arch, the fuel grate *c d* is placed. B C are the two working openings for introducing the materials and inspecting the progress of the fusion; they must be closed with fire-tiles and luted with fire-clay at the beginning of the process. At the back of the furnace, opposite the mouth of the fire-place, there is a doorway, which is bricked up, except upon occasion of putting in and taking out the pot. The draught is regulated by means of a slide-plate, upon the mouth of the ash-pit *f*. The pot being heated to the proper pitch, some purified pearl-ash, mixed with fully twice its weight of colourless quartz-sand, is to be thrown into it, and after the complete fusion of this mixture, the remaining part of the sand, along with the oxide of lead (fine litharge), is to be strewn upon the surface. These siliceous particles in their descent serve to extricate the air from the mass. Whenever the whole is fused, the heat must be strongly urged to insure a complete uniformity of combination by the internal motions of the particles. As soon as the gas has been found by making test phials to be perfectly fine, the fire must be withdrawn, the two working-holes must be opened, as well as the mouths of the fire-place and ash-pit to admit free ingress to cooling currents of air, so as to congeal the liquid mass as quickly as possible; a condition essential to the uniformity of the glass. It may be worth while to stir it a little with the pottery rod at the commencement of the cooling process. The solidified glass may be afterwards detached, by a hammer, in conchoidal discs, which after chipping off their edges, are to be placed in proper porcelain or stone-ware dishes, and exposed to a softening heat, in order to give them a lenticular shape. Great care must be taken that the heat thus applied by the muffle furnace be very equable, for otherwise wreathes might be very readily produced in the discs. A small oven upon the plan of a baker's is best fitted for this purpose, which being heated to dull redness, and then extinguished, is ready to soften and afterwards anneal the conchoidal pieces.

1101



Guinand's dense optical flint-glass of specific gravity 3·616, consists, by analysis, of oxide of lead, 43·05; silica, 44·3; and potash, 11·75; but requires for its formation the following ingredients:—100 pounds of ground quartz; 100 pounds of fine red lead; 35 pounds of purified potash; and from 2 to 4 pounds of saltpetre. As this species of glass is injured by an excess of potash, it should be compounded with rather a defect of it, and melted by a proportionably higher or longer heat. A good optical glass has been made in Germany with 7 parts of pure red lead, 3 parts of finely-ground quartz, and 2 parts of calcined borax.

5. *Plate-glass.*—This, like English crown-glass, has a soda flux, whereas flint-glass requires potash, and is never of good quality when made with soda. We shall distribute our account of this manufacture under two heads:

1. The different furnaces and principal machines, without whose knowledge it would be impossible to understand the several processes of a plate-glass factory.

2. The materials which enter into the composition of this kind of glass, and the series of operations which they undergo; devoting our chief attention to the changes and improvements which long experience, enlightened by modern chemistry, has introduced into the great manufactory of St. Gobain in France, under the direction of M. Tassaert. It may, however, be remarked that the English plate-glass manufacture derives peculiar advantages from the excellence of its grinding and polishing machinery.

The following description given by Dr. Ure refers almost entirely to the manufacture of plate-glass in France. It is retained in nearly its original form, and is, in all respects, applicable to the manufacture of plate-glass in this country.

The clay for making the bricks and pots should be free from lime and iron, and very refractory. It is mixed with the powder of old pots passed through a silk sieve. If the clay be very plastic it will bear its own weight of the powder, but if shorter in quality, it will take only three-fifths. But before mingling it with the cement of old pots, it must be dried, bruised, then picked, ground, and finally elutriated by agitation with water, decantation through a hair-sieve, and subsidence. The clay fluid after passing the sieve is called *slip* (*coulis*).

The furnace is built of dry bricks, cemented with slip, and has at each of its four angles a peculiar annealing arch, which communicates with the furnace interiorly, and thence derives sufficient heat to effect in part, if not wholly, the annealing of the pots, which are always deposited there a long time before they are used. Three of these arches, exclusively appropriated to this purpose, are called pot-arches. The fourth is called the *arch of the materials*, because it serves for drying them before they are founded. Each arch has, moreover, a principal opening called the throat, another called *bonnard*, by the French workmen, through which fire may be kindled in the arch itself, when it was thought to be necessary for the annealing of the pots; a practice now abandoned. The duration of a furnace is commonly a year, or at most 14 months; that of the arches is 30 years or upwards, as they are not exposed to so strong a heat.

In the manufacture of plate-glass, two sorts of crucibles are employed, called the pots and the basins (*cuvettes*). The first serve for containing the materials to be founded, and for keeping them a long time in the melted state. The *cuvettes* receive the melted glass, after it is refined, and decant it out on the table to be rolled into a plate. Three pots hold liquid glass for six small basins, or for three large ones, the latter being employed for making mirrors of great dimensions, that is, 100 inches long and upwards. Furnaces have been constructed with 6 pots and 12 *cuvettes*, 8 of which are small and 4 large; and *cuvettes* of three sizes are made, called *small*, *middling*, and *large*. The small are perfect cubes, the middling and the large ones are oblong parallelopipeds. Towards the middle of their height, a notch, or groove, two or three inches broad, and an inch deep, is left, called the girdle of the *cuvette*, by which part they are grasped with the tongs, or rather are clamped in the iron frame. This frame goes round the four sides of the small *cuvettes*, and may be placed indifferently upon all their sides; in the other *cuvettes*, the girdle extends only over the two large sides, because they cannot be turned up. See *m* T, *fig.* 1102.

The pot is an inverted truncated cone, like a crown-glass pot. It is about 30 inches high, and from 30 to 32 inches wide, including its thickness. There is only a few inches of difference between the diameter of the top and that of the bottom. The bottom is three inches thick, and the body turns gradually thinner till it is an inch at the mouth of the pot.

The large building or factory, of which the melting furnace occupies the middle space, is called the *halle* in French. At Ravenhead in Lancashire it is called the foundry, and is of magnificent dimensions; its length is 339 feet, and its breadth 155. The famous *halle* of St. Gobain is 174 feet by 120. Along the two side-walls of the *halle*, which are solidly constructed of hewn stone, there are openings like those of common ovens. These ovens, destined for the annealing of the newly cast plates, bear the name of *carquaises*. Their soles are raised two feet and a half above the level of the ground, in order to bring them into the same horizontal plane with the casting tables. Their length, amounting sometimes to 30 feet, and their breadth to 20, are required in order to accommodate 6, 8, or even 10 plates of glass alongside of each other. The front aperture is called the throat, and the back door the little throat (*gueulette*). The carquaise is heated by means of a fire-place of a square form, called a *tisar*, which extends along its side.

The founding or melting furnace is a square brick building laid on solid foundations, being from 8 to 10 feet in each of its fronts, and rising inside into a vault or crown about 10 feet high. At each angle of this square, a small oven or arch is constructed, likewise vaulted within, and communicating with the melting furnace by square flues, called *lunettes*, through which it receives a powerful heat, though much inferior to that round the pots. The arches are so distributed as that two of the exterior sides of the furnace stand wholly free, while the two other sides, on which the arches encroach. offer a free space of only 3 feet. In this interjacent space, two principal openings of the furnace, of equal size in each side, are left in the building. These are called tunnels. They are destined for the introduction of the pots and the fuel.

On looking through the tunnels into the side of the furnace, we perceive to the right hand and the left, along the two *free* sides, two low platforms or *siéges*, at least 30 inches in height and breadth. See *figs.* 1093, 1095.

These *siéges* (seats) being intended to support the pots and the cuvettes filled with heavy materials, are terminated by a slope, which ensures the solidity of the fire-clay mound. The slopes of the two *siéges* extend towards the middle of the furnace so near as to leave a space of only from 6 to 10 inches between them for the hearth. The end of this is perforated with a hole sufficiently large to give passage to the liquid glass of a broken pot, while the rest is preserved by lading it from the mouth into the adjoining cuvette.

In the two large parallel sides of the furnace, other apertures are left, much smaller than the tunnels, which are called *ouvreaux*, (peep-holes). The lower ones, or the *ouvreaux en bas*, called *cuvette*-openings, because, being allotted to the admission of these vessels, they are exactly on a level with the surface of the *siéges*, and with the floor of the *halle*. Plates of cast iron form the thresholds of these openings, and facilitate the ingress and egress of the *cuvettes*. The apertures are arched at the top, with hewn stone like the tunnels, and are 18 inches wide when the *cuvettes* are 16 inches broad.

The upper and smaller apertures, or the higher *ouvreaux*, called the *lading* holes, because they serve for transvasing the liquid glass, are three in number, and are placed 31 or 32 inches above the surface of the *siéges*. As the pots are only 30 inches high, it becomes easy to work through these openings either in the pots or the *cuvettes*. The pots stand opposite to the two pillars which separate the openings, so that a space is left between them for one or more *cuvettes* according to the size of the latter. It is obvious that if the tunnels and *ouvreaux* were left open, the furnace would not draw or take the requisite founding heat. Hence the openings are shut by means of fire-tiles. These are put in their places, and removed by means of two holes left in them in correspondence with the two prongs of a large iron fork supported by an axle and two iron wheels, and terminated by two handles which the workmen lay hold of when they wish to move the tile.

The closing of the tunnel is more complex. When it is shut or ready for the firing, the aperture appears built up with bricks and mortar from the top of the arch to the middle of the tunnel. The remainder of the doorway is closed,—1. on the two sides down to the bottom, by a small upright wall, likewise of bricks, and 8 inches broad, called walls of the *glaye*; 2, by an assemblage of pieces called pieces of the *glaye*, because the whole of the closure of the tunnel bears the name of *glaye*. The upper hole, 4 inches square, is called the *tisar*, through which the billets of wood are tossed into the fire. Fuel is also introduced into the posterior openings. The fire is always kept up on the hearth of the tunnel, which is, on this account, 4 inches higher than the furnace-hearth, in order that the glass which may accidentally fall down on it, and which does not flow off by the bottom-hole, may not impede the combustion. Should a body of glass, however, at any time obstruct the grate, it must be removed with rakes, by opening the tunnel and dismounting the fire-tile stoppers of the *glaye*.

Formerly wood-fuel alone was employed for heating the melting-furnaces of the mirror-plate manufactory of St. Gobain; but within these few years, the director of the works makes use with nearly equal advantage of pit-coal. In the same establishment, two melting-furnaces may be seen, one of which is fired with wood, and the other with coals, without any difference being perceptible in the quality of the glass furnished by either. It is not true, as has been stated, that the introduction of pit-coal has made it necessary to work with covered pots in order to avoid the discolouration of the materials, or that more alkali was required to compensate for the diminished heat in the covered pots. They are not now covered when pit-coal is used, and the same success is obtained as heretofore by leaving the materials two or three hours longer in the pots and the *cuvettes*. The construction of the furnaces in which coal is burned is the same as that with wood, with slight modifications. Instead of the close-bottomed hearth of the wood-furnace, there is an iron grate in the coal-hearth through which the air enters, and the waste ashes descend.

When billets of wood were used as fuel, they were well dried beforehand, by being placed a few days on a frame-work or wood called the wheel, placed two feet above the furnace and its arches, and supported on four pillars at some distance from the angles of the building.

The progress of chemistry, the discovery of a good process for the manufacture of soda from sea-salt, which furnishes a pure alkali of uniform power, and the certain methods of ascertaining its purity, have rendered this department of glass-making far more certain than formerly. At St. Gobain no alkali is employed, except artificial crystals of soda, prepared at the manufactory of Chauny, subsidiary to that establishment. The first crop of soda-crystals is reserved for the plate-glass manufacture; the other crystals and the mother-water salts are sold to the makers of inferior glass.

If glass contains much lead it has a yellow tint. If manganese is present it changes by the action of light to a pale rose. Iron imparts a dull greenish tint; therefore the proportions of all those materials should be adjusted with great care.

At the mirror-plate works of Ravenhead, near St. Helen's in Lancashire, soda-crystals, from the decomposition of the sulphate of soda by chalk and coal, have been also tried, but without equal success as at St. Gobain; the failure being unquestionably due to the impurity of the alkali. Hence, in the English establishment, the soda is obtained by treating sea-salt with pearlash, whence carbonate of soda and chloride of potassium result. The latter salt is crystallised out of the mingled solution, by evaporation at a moderate heat, for the carbonate of soda does not readily crystallise till the temperature of the solution falls below 60° Fahr. When the chloride of potassium is thus removed, the alkaline carbonate is evaporated to dryness.

Long experience at St. Gobain has proved that one part of dry carbonate of soda is adequate to vitrify perfectly three parts of fine siliceous sand, as that of the mound of Aumont near Senlis, of Alum Bay in the Isle of Wight, or of Lynn in Norfolk. It is also known that the degree of heat has a great influence upon the vitrification, and that increase of temperature will compensate for a certain deficiency of alkali; for it is certain that a very strong fire always dissipates a good deal of the soda, and yet the glass is not less beautiful. The most perfect mirror-plate has constantly afforded to M. Vauquelin, on analysis, a portion of soda inferior to what had been employed in its formation. Hence, it has become the practice to add, for every 100 parts of cullet, or broken plate, that is mixed with the glass-composition, one part of alkali, to make up for the loss that the old glass must have experienced.

To the above-mentioned proportions of sand and alkali, independently of the cullet which may be used, dry slaked lime carefully sifted is to be added to the amount of one seventh of the sand; or the proportion will be, sand, 7 cwts.; quicklime, 1 cwt.; dry carbonate of soda, 2 cwts. and 37 lbs.; besides cullet. The lime improves the quality of the glass, rendering it less brittle and less liable to change. The preceding quantities of materials, suitably blended, have been uniformly found to afford most advantageous results. The practice formerly was to dry that mixture, as soon as it was made, in the arch for the materials, but it has been ascertained that this step may be dispensed with, and the small portion of humidity present is dissipated almost instantly after they are thrown into the furnace. The coat of glaze previously applied to the inside of the pot prevents the moisture from doing them any harm. For this reason, when the demand for glass at St. Gobain is very great, the materials are neither fritted nor even dried, but shovelled directly into the pot; this is called founding *raw*. Six workmen are employed in shovelling in the materials either fritted or otherwise, for the sake of expedition, and to prevent the furnace getting cooled. One-third of the mixture is introduced at first; whenever this is melted, the second third is thrown in, and then the last. These three stages are called the first, second, and third fusion or founding.

According to the ancient practice, the founding and refining were both executed in the pots, and it was not till the glass was refined that it was laded into the *cuvettes*, where it remained only 3 hours, the time necessary for the disengagement of the air-bubbles introduced by the transvasion, and for giving the *metal* the proper consistence for casting. At present, the period requisite for founding and refining is equally divided between the pots and the *cuvettes*. The materials are left 16 hours in the pots, and as many in the *cuvettes*; so that in 32 hours the glass is ready to be cast. During the last two or three hours the fireman or *tiseur* ceases to add fuel; all the openings are shut, and the glass is allowed to assume the requisite fluidity; an operation called *stopping* the glass, or *performing the ceremony*.

The transfer of the glass into the *cuvettes* is called *lading* (*tréjetage*). Before this is done, the *cuvettes* are cleared out, that is, the glass remaining on their bottom is removed, and the ashes of the firing. They are lifted red hot out of the furnace by the method presently to be described, and placed on an iron plate, near a tub filled with water. The workmen, by means of iron paddles 6 feet long, flattened at one end and hammered to an edge, scoop out the fluid glass expeditiously, and throw it into water; the *cuvettes* are now returned to the furnace, and a few minutes afterwards the lading begins.

In this operation ladles of wrought iron are employed, furnished with long handles, which are plunged into the pots through the upper openings or lading holes, and immediately transfer their charge of glass into the buckets. Each workman dips his ladle only three times, and empties its contents into the *cuvette*. By these three immersions (whence the term *tréjeter* is derived) the large iron spoon is heated so much that when plunged into a tub full of water, it makes a noise like the roaring of a lion, which may be heard at a very great distance.

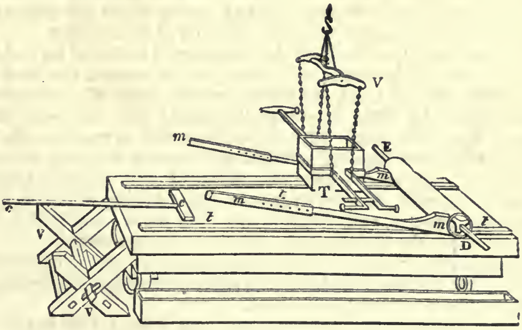
The founding, refining, and *ceremony* being finished, the workmen next try whether the glass be ready for casting. With this view the end of a rod is dipped into the bucket, which is called *drawing the glass*; the portion taken up being allowed to run off, naturally assumes a pear-shape, from the appearance of which they can judge if the consistence be proper, and if any air-bubbles remain. If all be right, the *cuvettes* are taken out of the furnace, and conveyed to the part of the *halle* where their contents are to be poured out. This process requires peculiar instruments and manipulations.

Casting.—While the glass is refining, that is, coming to its highest point of perfection, preparation is made for the most important process, the casting of the plate, whose success crowns all the preliminary labours and cares. The oven or *carquaise* destined to receive and anneal the plate is now heated by its small fire or *tisar* to such a pitch that its sole may have the same temperature as that of the plates, being nearly red hot at the moment of their being introduced. An unequal degree of heat in the *carquaise* would cause breakage of the glass. The casting-table is then rolled towards the front door or throat, by means of levers, and its surface is brought exactly to the level of the sole of the oven.

The table *t, t, t, fig.* 1102, is a mass of bronze, or now preferably cast iron, about 10 feet long, 5 feet broad, and from 6 to 7 inches thick, supported by a frame of carpentry, which rests on three cast-iron wheels. At the end of the table, opposite to that next to the front of the oven, is a very strong frame of timber-work, called the puppet or standard, upon which the bronze roller which spreads the glass is laid, before and after the casting. This is 5 feet long by 1 foot in diameter; it is thick in the metal, but hollow in the axis. The same roller can serve only for two plates at one casting, when another is put in its place, and the first is laid aside to cool; for otherwise the hot roller would, at a third casting, make the plate expand unequally, and cause it to crack. When the rollers are not in action they are laid aside in strong wooden trestles, like those employed by sawyers. On the two sides of the table, in the line of its length, are two parallel bars of bronze, *t, t,* destined to support the roller during its passage from end to end; the thickness of these bars determines that of the plate. The table being thus arranged, a crane is had recourse to for lifting the *cuvette*, and keeping it suspended, till it be emptied upon the table. This raising and suspension are effected by means of an iron gib, furnished with pulleys, held horizontally, and which turns with them.

The tongs, T, *fig.* 1102, are made of four iron bars, bent into a square frame in their middle, for embracing the bucket. Four chains, proceeding from the corners of the frame V, are united at their other ends into a ring, which fits into the hook of the crane. Things being thus arranged, all the workmen of the foundry co-operate in the manipulations of the casting. Two of them fetch, and place quickly in front of one of the lower openings, the small *cuvette*-carriage, which bears a forked bar of iron, having two prongs corresponding to the two holes left in the fire-tile door. This fork, mounted on the axle of two cast-iron wheels, extends at its other end into two branches terminated by handles, by which the workmen move the fork, lift out the tile stopper, and set it down against the outer wall of the furnace.

1102



The instant these men retire, two others push forward into the opening the extremity of the tongs-carriage, so as to seize the bucket by the girdle, or rather to clamp it. At the same time a third workman is busy with an iron pinch or long chisel, detaching the bucket from its seat, to which it often adheres by some spilt glass; whenever it is free, he withdraws it from the furnace. Two powerful branches of iron united by a bolt, like two scissor-blades, which open, come together, and join by a quadrant near the other end, form the tongs-carriage, which is mounted upon two wheels like a truck.

The same description will apply almost wholly to the iron-plate carriage, on which the bucket is laid the moment it is taken out of the furnace; the only difference in its construction is, that on the bent iron bars which form the tail or lower steps of this carriage (in place of the tongs) is permanently fastened an iron plate, on which the bucket is placed and carried for the casting.

Whenever the *cuvette* is set upon its carriage, it must be rapidly wheeled to its station near the crane. The tongs T, above described, are now applied to the girdle, and are then hooked upon the crane by the suspension-chains. In this position the bucket is skimmed by means of a copper tool called a sabre, because it has nearly the shape of that weapon. Every portion of the matter removed by the sabre is thrown into a copper ladle (*poche de gamin*), which is emptied from time to time into a cistern of water. After being skimmed, the bucket is lifted up, and brushed very clean on its sides and bottom; then, by the double handles of the suspension-tongs, it is swung round to the table, where it is seized by the workmen appointed to turn it over; the roller having been previously laid on its ruler-bars, near the end of the table which is in contact with the annealing oven. The *cuvette*-men begin to pour out towards the right extremity E of the roller, and terminate when it has arrived at the left extremity D. While preparing to do so, and at the instant of casting, two men place within the ruler-bar on each side, that is, between the bar and the liquid glass, two iron instruments called *hands*, *m m*, *m m*, which prevent the glass from spreading beyond the rulers, whilst another draws along the table the wiping bar *c c*, wrapped in linen, to remove dust, or any small objects which may interpose between the table and the liquid glass.

Whenever the melted glass is poured out, two men spread it over the table, guiding the roller slowly and steadily along, beyond the limits of the glass, and then run it smartly into the wooden standard prepared for its reception, in place of the trestles V V.

The empty bucket, while still red hot, is hung again upon the crane, set on its plate-iron carriage, freed from its tongs, and replaced in the furnace, to be speedily cleared out anew, and charged with fresh fluid from the pots. If, while the roller glides along, the two workmen who stand by with picking tools perceive *tears* in the matter in advance of the roller, and can dexterously snatch them out, they are suitably rewarded, according to the spot where the blemish lay, whether in the centre, where it would have proved most detrimental, or near the edge. These tears proceed usually from small portions of semi-vitrified matter which fall from the vault of the furnace, and from their density occupy the bottom of the *cuvettes*.

While the plate is still red hot and ductile, about 2 inches of its end opposite to the *carquaise* door is turned up with a tool; this portion is called the *head of the mirror*; against the outside of this head, the shovel, in the shape of a rake without teeth, is applied, with which the plate is eventually pushed into the oven, while two other workmen press upon the upper part of the head with a wooden pole, 8 feet long, to preserve the plate in its horizontal position, and prevent its being warped. The plate is now left for a few moments near the throat of the *carquaise*, to give it solidity; after which it is pushed further in, by means of a very long iron tool, whose extremity is forked like the letter y, and hence bears that name; and is thereby arranged in the most suitable spot for allowing other plates to be introduced.

However numerous the manipulations executed from the moment of withdrawing the *cuvette* from the furnace, till the cast plate is pushed into the annealing oven, they are all performed in less than five minutes.

When all the plates of the same casting have been placed in the *carquaise*, it is sealed up; that is to say, all its orifices are closed with sheets of iron, surrounded and made tight with plastic loam. With this precaution, the cooling goes on slowly and equably in every part, for no cooling current can have access to the interior of the oven.

After they are perfectly cooled, the plates are carefully withdrawn one after another, keeping them all the while in a horizontal position, till they are entirely out of the *carquaise*. As soon as each plate is taken out, one set of workmen lower quickly and steadily the edge which they hold, while another set raise the opposite edge, till the glass be placed upright on two cushions stuffed with straw, and covered with canvas. In this vertical position they pass through, beneath the lower edge of the plate, three girths or straps, each four feet long, thickened with leather in their middle, and ending in wooden handles; so that one embraces the middle of the plate, and the other two the ends. The workmen, six in number, now seize the handles of the straps, lift up the glass closely to their bodies, and convey it with a regular step to the warehouse. Here the head of the plate is first cut off with a diamond square, and then the whole is attentively examined, in reference to its defects and imperfections, to determine the sections which must be made of it, and the eventual size of the pieces. The parings and small cuttings detached are set aside, in order to be ground and mixed with the raw materials of another glass-pot.

The apartments in which the roughing-down and smoothing of the plates is performed, are furnished with a considerable number of stone tables, truly hewn and placed apart like billiard-tables, in a horizontal position, about 2 feet above the ground. They are rectangular, and of different sizes proportional to the dimensions of the plates, which they ought always to exceed a little. These tables are supported either on stone pillars or wooden frames, and are surrounded with a wooden board, whose upper edge stands somewhat below their level, and leaves in the space between it and the stone all round an interval of 3 or 4 inches, of which we shall presently see the use.

A cast plate, unless formed on a table quite new, has always one of its faces, the one next the table, rougher than the other; and with this facing the roughing-down begins. With this view, the smoother face is cemented on the stone table with Paris-plaster. But often instead of one plate, several are cemented alongside of each other, those of the same thickness being carefully selected. They then take one or more crude plates, of about one-third or one-fourth the surface of the plate fixed to the table, and fix it on them with liquid gypsum to the large base of a quadrangular truncated pyramid of stone, of a weight proportioned to its extent, or about a pound to the square inch. This pyramidal muller, if small sized, bears at each of its angles of the upper face a peg or ball, which the grinders lay hold of in working it; but when of greater dimension, there is adapted to it horizontally a wheel of slight construction, 8 or 10 feet in diameter, whose circumference is made of wood rounded so as to be seized with the hand. The upper plate is now rubbed over the lower ones, with moistened sand applied between.

This operation is, however, performed by machinery. The under plate being fixed or imbedded in stucco, on a solid table, the upper one likewise imbedded by the same cement in a cast-iron frame, has a motion of circumrotation given to it, closely resembling that communicated by the human hand and arm, moist sand being supplied between them. While an excentric mechanism imparts this double rotatory movement to the upper plate round its own centre, and of that centre round a point in the lower plate, this plate placed on a moveable platform changes its position by a slow horizontal motion, both in the direction of its length and its breadth. By this ingenious contrivance, which pervades the whole of the grinding and polishing machinery, a remarkable regularity of friction and truth of surface is produced. When the plates are sufficiently worked on one face, they are reversed in the frames, and worked together on the other. The Paris-plaster is usually coloured red, in order to show any defects in the glass.

The smoothing of the plates is effected on the same principles by the use of moist emery washed to successive degrees of fineness, for the successive stages of the operation; and the polishing process is performed by rubbers of hat-felt and a thin paste of colcothar and water. The *colcothar*, called also *crocus*, is red oxide of iron prepared by the ignition of copperas, with grinding and elutriation.

The last part, or the polishing process, is performed by hand. This is managed by females, who slide one plate over another, while a little moistened *putty of tin* finely levigated is thrown between.

Large mirror-plates are now the indispensable ornaments of every large and sumptuous apartment; they diffuse lustre and gaiety around them by reflecting the rays of light in a thousand lines, and by multiplying indefinitely the images of objects placed between opposite parallel planes.

The process of silvering plate-glass will be described under MIRRORS. For the production of the perfectly plane surface required to ensure true reflexion, a process of the most careful polishing is required. It will not differ from the process already described in any respect, beyond that of the extreme care which is required.

Not only is this great exactness of surface required for the production of mirrors of high class, but it is even more necessary in the plates of glass employed in the production of 'the Ghost,' as it is called, which a few years ago excited so much of the public attention at the Polytechnic Institution and elsewhere; this phenomenon being due to the total reflexion of highly-illuminated objects, from the plane surface of highly-polished glass, the objects themselves being hidden from the spectators.

The progress of the plate-glass manufacture is very instructive. Owing to the obstructions of Excise regulations, notwithstanding the reduction of the duty in 1819 to 60*s.* per cwt., the production in 1836 was but about 7,000 feet per week. In the latter year, however, the manufacture ceased to be confined to two houses; new establishments were formed, and in 1845 the production had more than tripled, at a great reduction of price. In 1845 the Excise duties on glass were abolished, and Sir R. Peel, in proposing their abolition, said, 'If you leave the manufacture altogether disburdened, as in France and Belgium, then, with your peculiar advantages of material, the command of alkali and coal, my belief is, you will supply almost the whole world.' And, thanks to the wisdom of that measure, freedom from fiscal regulation has opened the door to extraordinary advantages, by means of which the cost of production has been reduced to a point below that of any other country. In coal the savings effected by unrestricted action are no less than 80 per cent. in quantity alone, involving a corresponding decrease in the cost of furnaces, fire-clay, pots, tools, labour, and also in the erection of buildings that now suffice. The cost of coal, therefore, which, in London, in 1826 exceeded 1*s.* 10*d.* on each superficial foot of glass, is now about 2*d.* per foot. Sand also, which is its base, forming as it does nearly three-fifths of its composition, is obtained near London at 3*s.* 6*d.* and upwards per ton, of a quality superior to Lynn sand formerly used at 18*s.* per ton. The direct charge of labour in 1826 exceeded 1*s.* 6*d.* per foot; now the average rate of wages for skilled labour is higher by 20 per cent. than forty years ago. In 1819 two furnaces, each having a huge chimney-shaft, were required to produce 1,000 feet per week, while at the present time two furnaces, with only one chimney-shaft, suffice for the production of 12,000 feet, with the same, if not a less, consumption of fuel. Similarly, though in a less degree, grinding and polishing benches which then finished 200 feet each per week, now accomplish 500 feet to 700 feet, which, by judicious means, may be still further increased to 1,000 feet and upwards. By these means the whole cost has been reduced to nearly the price of common duty-paid window-glass thirty years ago; and whereas in 1819 the British make was 3,000 feet per week, sold at 20*s.* to 25*s.* per foot, it is now 140,000 feet, selling at 2*s.* and upwards according to quality. The former superior make of this country has, indeed, been greatly neglected, and this has led to a very large increase in the import of the finest fabrics of France and Belgium, so that these imports amounted in 1862 and 1863 to about 16,000 feet per week, and those countries have had a corresponding sale in foreign markets in the absence of such supplies from England; but still the exports of British plate-glass have increased about tenfold since 1849.

At home, glass is now extensively used in slabs for flooring and underground purposes, combining as it does greater strength than the York flag, with the additional advantage of conveying light; and slabs tested at Woolwich dockyard have been found to bear a pressure exceeding a ton weight. Many years ago, a supply of such slabs was required for the purpose of flooring a palace of one of the native princes of India, but the Excise restrictions then prevailing precluded its supply from England at less than 30*s.* per foot; it could now be afforded at 3*s.* to 4*s.* In fact, its true position has yet to be attained, when the resources of this country shall have stimulated that more full development of which it is susceptible, and Great Britain shall, as the author of the freedom of this industry predicted, 'supply almost the whole world.'

Bohemian Glass.—M. Péligot states that the hard glass of Bohemia is composed of 100 parts of silica, 12 parts of quicklime, and only 28 parts of carbonate of potash. These proportions give a glass quite unmanageable in ordinary furnaces; but the addition of a comparatively small quantity of boracic acid is capable of determining fusion, and the result is a glass having all the requisite limpidity at a high temperature, and possessing at the same time a great brilliancy and hardness.

The Bohemian glass is, within certain limits, perfectly elastic, and very sonorous; when well made, it is sufficiently hard to strike fire with steel, and is scratched with difficulty. The lead glasses, on the other hand, have but little hardness, and less in proportion as they contain more oxide of lead; besides which they rapidly lose their brilliancy by use.

The silica which is employed in Bohemia in the manufacture of glass is obtained by calcining crystalline quartz, and afterwards pounding it while dry. When the quartz has been heated to a cherry-red, it is withdrawn from the fire, and thrown immediately into cold water.

Almost all the Bohemian glass is a potash-glass, because soda and its salts give to glass a sensible yellowish tint. The limestone which is used is as white as Carrara marble. The clay employed for the crucibles is very white, and consists of silica, $45\frac{8}{10}$; alumina, $40\frac{4}{10}$; and water, $13\frac{8}{10}$.

The manufacture of glass in Bohemia is of very high antiquity, and the same peculiarities have always belonged to the true Bohemian manufacture.

In our modern times the Bohemian glass has been more especially celebrated for the beautiful varieties of colours which are produced. See Glass, Coloured.

Venetian Glass.—From an early date the city of Venice has been celebrated for its glass: the *reticulated glass*, the *crackle glass*, and the glass paper-weights, or *millefiore*, are all due to the Venetians.

The manufacture of *glass beads* at Murano, near Venice, has been carried on for an indefinite period, and Africa and Asia have been supplied from their glass-houses. The process is most ingeniously simple. Tubes of glass of every colour, are drawn out to great lengths in a gallery adjoining the glass-house pots, in the same way as the more moderate lengths of thermometer and barometer tubes are drawn in our glass-houses. These tubes are chopped into very small pieces of nearly uniform length on the upright edge of a fixed chisel. These elementary cylinders being then put in a heap into a mixture of fine sand and wood-ashes, are stirred about with an iron spatula till their cavities get filled. This curious mixture is now transferred to an iron pan suspended over a moderate fire, and continually stirred about as before, whereby the cylindrical bits assume a smooth rounded form; so that when removed from the fire and cleared out in the bore, they constitute beads, which are packed in casks, and exported in prodigious quantities to almost every country.

The manufacture of *reticulated glass*, for which Venice was equally celebrated, was long lost; it was at length revived by Pohl, and the crackle-glass was in like manner reproduced by the late Mr. Apsley Pellatt in 1851.

The reticulated glass is produced by a kind of network, consisting of small bubbles of air inclosed within the mass, and ranged in regular series crossing and interlacing each other. To produce this ornamental appearance, hollow glass cones or conical tube are kept prepared, containing already this network-arrangement of air-bubbles. These tubes are made by arranging a number of small glass rods round a centre so as to form a cylinder, and fixing them in this position by melted glass. The cylinder is then heated until the single rods stick together, when they are drawn out on the pipe to a long cone, and spirally twisted at the same time, the one half to the right and the other to the left, when one of these hollow cones is inserted into the other, and the two are heated until they fuse together; wherever the little rods cross each other a bubble of air will be inclosed, and this occurring in a very regular manner, the reticulated appearance is produced.

The Venetians were also celebrated for their *filigree*. This glass has of late years been re-introduced in France and in this country. The process of manufacture has been thus described by Mr. Apsley Pellatt, in his *Curiosities of Glass Manufacture*:—

'Before ornaments or vessels can be blown, small filigree-canes, with white or variously-coloured enamels must be drawn. These are first "whetted" off to the required lengths, and then put into a cylindrical mould with suitable internal recesses, and both cane and mould are thus submitted to a moderate heat. The selection of the colour of the canes depends upon the taste of the manufacturer; two to four white enamel-canes are chiefly used, alternately, with about half the number coloured. The blower then prepares a solid ball of transparent flint-glass, which being deposited in contact with the various canes, at a welding heat, occasions them to adhere. This solid ball is then taken from the mould, is re-heated, and "*marvered*" till the adhering projecting ornamental canes are rubbed into one uniform mass; the ball is next covered with a gathering of white glass, which must then be drawn to any size and length that may be required. Should a spiral cane be preferred, the "pucellas" holds the apex in a fixed position, while the ornamental mass, still adhering to the glass-maker's iron, is revolved during the process, till the requisite twist is given. Where vases are formed of alternately coloured and enamelled filigree-canes, the above process is repeated, and the usual mode of blowing is followed.'

The Venetian ball is a collection of waste pieces of filigree-glass conglomerated together without regular design: this is packed into a pocket of transparent glass, which is adhesively collapsed upon the interior mass by sucking up, producing outward pressure of the atmosphere.

Millefiore, or star-work of the Venetians, is similar to the last, only, the lozenges of glass are more regularly placed.

The *Vitro di Trino* of the Venetians is similar to the filigree in many respects; but by closing an outer on the inner case, each containing filigree-canes, a bubble of air is inclosed between each crossing of the canes.

The celebrated frosted glass of the Venetians was re-introduced by Mr. Apsley Pellatt in 1851, who thus describes the process of manufacture:—

'Frosted glass, like *Vitro de Trino*, is one of the few specimens of Venetian work not previously made by the Egyptians and the Romans; and not since executed by the Bohemian or French glass-makers. The process of making it, until recently practised at the Falcon Glass Works, was considered a lost art. Frosted glass has irregularly-varied marble-like projecting dislocations in its intervening fissures. Suddenly plunging hot glass into cold water produces crystalline convex fractures, with a polished exterior, like Derbyshire spar; but the concave intervening figures are caused, first by chilling, and then reheating at the furnace, and simultaneously expanding the reheated ball of glass by blowing; thus separating the crystals from each other, and leaving open figures between, which is done preparatory to forming vases or ornaments. Although frosted glass appears covered with fractures, it is perfectly sonorous.'

Glass, its physical condition and chemical constitution.—So far as may be inferred, from the analysis of ordinary commercial samples of window-glass, this substance has not only a very variable composition, but, worse than this, it is out of all keeping with anything like definite proportion. That it should be full of striæ, and, therefore, refract the rays of light unequally, as it does, so as to produce the most hideous appearances of distortion, is a mere natural consequence of its mechanical composition, which might, and must one day be corrected; but that whole nations should have come to view this defect as an unavoidable peculiarity, is precisely one of those surprising facts which demonstrate the influence of habit over the powers of the mind, and show how easily human reason can reconcile itself to the most gross inconsistencies. If window-glass had one uniform atomic composition, the tendency to form these striæ would nowhere exist in excess; and, therefore, their production would diminish as the skill of the workmen increased; but, with the present variable compound, the glass stretches unequally in different parts, by an equal application of force, and, in spite of human skill, presents a result alternately thick or thin, as accident determines. That these striæ have not the same composition as the parts surrounding them is very obvious, from the circumstance that, if striated glass be cut to an uniform thickness, and polished on both sides, the optical defects remain but little changed, and occasionally they are found to be increased. Again, it is known that the more complex the composition of any glass may be, the greater the liability to this striated structure—of which flint-glass offers an apposite illustration; for here, in addition to the ordinary components of glass, the silicate of lead is superadded. Now the specific gravity of silicate of lead is very high compared with that of silicate of soda, potash, or lime; hence unless employed in the exact quantity to form a chemical combination with the other silicates, a mere mechanical mixture is produced, of very different densities throughout; and the product, under the action of light, displays, permanently, that peculiar fugitive appearance seen when syrup and water, or alcohol and water, are mixed together; that is to say, a series of curved lines are formed by the unequal refraction of the two fluids, which entirely disappear, so soon as perfect admixture has taken place, but which remain in the case of flint-glass, from the utter impossibility of effecting the necessary union between its various parts. Although, however, this cannot be done mechanically, yet, in a chemical way, nature performs such operations with ease and unerring fidelity. The French chemist, Berthier, long ago proved that many neutral salts combine together by fusion in atomic proportions, and form new and definite compounds. Thus, carbonate of potash and carbonate of soda when mixed, atom for atom, unite and produce a compound more easy of fusion than the more fusible of the two; similarly, either of these carbonates will act with carbonate of baryta or strontia; and again, fluor-spar and sulphate of lime, two remarkably infusible substances, when mixed, melt readily, at a low red heat into a fluid as mobile and transparent as water. It is useless to multiply examples of this kind, for thousands exist; and the alkaline and earthy silicates form no exception to this almost universal rule. A mixture of silicate of potash and silicate of soda will, if in atomic ratios, fuse much more readily than either of them alone. But now, let us imagine an attempt to fuse these two bodies together, in any other proportion than that in which they are naturally disposed to combine;—say that the silicate of soda is in excess; then the silicate of potash would unite with exactly sufficient of the silicate of soda to produce the extremely fusible compound above spoken of; whilst the less easily fusible silicate of soda, added in excess, would form a kind of network throughout the mass. It may be said, that a higher heat would overcome this difficulty, by thoroughly liquefying the silicate of soda; and this is really the plan now used with that view; but, independent of the fact, that the mixed silicate of potash and soda would also undergo a corresponding liquefaction, and, therefore, favour the separation of the silicate of soda, yet, as chemical union is impossible, from the very conditions of the experiment, even the most perfect mechanical mixture, under the greatest advantages of fluidity, would never generate a homogeneous body. The striæ might, indeed, be diminished in size; but this would imply a corresponding increase in their number; and, if carried very far, complete opacity would result from such an endeavour to subvert the laws of nature. The power of the workmen to remedy this defect is therefore limited to the capability of modifying its more salient features; he can never remove nor destroy it. What we have here illustrated by the simplest of all assumptions, gathers and accumulates into a formidable evil when several silicates are fused together, having considerable differences of specific weight. Thus, in the case of flint-glass before alluded to, there are generally three, and sometimes five, of these silicates fused together, into, probably, one of the most antagonistic compounds that could be conceived, refracting and dispersing the ray of light in fifty directions, and demonstrating the unfriendly nature of its coerced union, by flying in pieces from the most trivial applications of heat or violence. Yet in flint-glass we are not surpassed, nor indeed equalled, by any other nation; and so thoroughly has this beautiful substance become associated with our industrial reputation, that the British name, flint-glass, has been adopted into several continental languages. Nevertheless, it cannot be doubted that a wide field of improvement is open in this quarter, and that some more solid foundation is needed by our manufacturers in this line, than the prestige of a name, or the force of capital.

In France, as in England, the ingredients are mixed with some care, and introduced into a crucible, heated by a powerful furnace. These ingredients are sand or silica, carbonate of soda, and carbonate of lime, with perhaps a little ground felspar in some cases. The carbonate of soda is first attacked by the silica, and its carbonic acid driven off, whilst the remaining silica and carbonate of lime become imbedded in the vitrifying mass. As the heat increases, a more perfect fusion takes place; and then the carbonic acid of the carbonate of lime makes its way through the fused materials by which they are mechanically mingled together during the effervescence, which is technically termed the 'boil;' and, provided no after-separation ensues from the process of 'settling,' the whole crucible or 'pot' of glass will have a uniform composition. But, as we have seen, this depends altogether upon the relative proportion of the materials towards each other, for an excess of either one or other of the bases will destroy the homogeneous character of the whole, and introduce a plexus of striæ. Now the plate-glass of St. Gobain is almost exactly an atomic compound, and consists of one atom of the trisilicate of soda and one atom of the trisilicate of lime, with a small percentage of alumina. Science must ever take the lead of prejudice and custom.

The examination of English plate-glass fully corroborates the general result deduced from the action of light. There is no approach to an atomic arrangement. The principal constituent is trisilicate of soda, but variable quantities of lime, alumina, and even magnesia, exist in it. Potash is sometimes present, and oxide of iron is invariably so; but in not one single instance, out of 17 samples examined with great care, could so much as a surmise of the doctrine of combining proportions be gathered from the result of the analyses. Similarly fruitless was a research instituted upon flint-glass, both British and foreign. Of 35 samples analysed, no satisfactory evidence could be adduced to favour the opinion that science had been a helpmate to industry, or was at all concerned in this branch of manufacture. There are, however, some points of vast interest associated with the practical working out of this matter. Potash is known to give a more brilliant and harder glass than soda, and alumina seems to tend in the same direction. The Bohemian glass, so celebrated throughout Europe, is a glass of this description, and contains silicate of alumina, silicate of lime, and silicate of potash, but not in chemical proportions. This glass is therefore striated, but it seems to permit of a more perfect decoration by metallic oxides that can be developed in glass of lime and soda. This very probably depends upon the alumina contained in it. From one singular oversight, the use of carbonate of baryta has not yet found its way into the composition of glass, though we can scarcely conceive a more hopeful material. This substance may be had in large quantity in the North of England, of great purity, and at a merely nominal cost as compared with its value for such a purpose as glass-making. That it would fuse readily with a due amount of soda, and give 'a boil' as well as chalk, there can be no doubt; whilst its great density will certainly improve the refractive power of the resulting product, and thus rival the brilliancy of lead- or flint-glass, without imparting that softness and liability to receive scratches which are so objectionable in the latter variety. One difficulty may perhaps reside in the want of information concerning the quantity to be employed. But this is easily adjusted; for it has been demonstrated that, during vitrification, the silicic acid unites to bases in the proportion of three atoms to one: consequently three atoms, or 138 parts, will always require one atom of each base. Therefore, this weight of good dry sand may be set against 54 of dry carbonate of soda, 70 of carbonate of potash, 50 of pure marble or chalk, 99 of carbonate of baryta, and 112 of oxide of lead or litharge. Suppose, then, that the object is to employ carbonate of baryta for the first time, here 6 atoms or 276 parts of sand, 1 atom or 54 parts of dry carbonate of soda, and 1 atom or 99 parts of carbonate of baryta, may be mixed and fused together with every prospect of obtaining a good result; or 9 atoms of silica, 1 of carbonate of potash, 1 of carbonate of soda, and 1 of carbonate of baryta, might be tried without fear of failure. Again, in the case of flint-glass, 112 of litharge, 54 of soda, and 276 of sand, would probably succeed, or an additional atom of trisilicate of potash might be used. For many years past, M. Dumas, now, perhaps, the first chemist in France, has been in the habit of demonstrating to his pupils that glass of all kinds, when properly made, must necessarily be an atomic compound; and yet we scarcely expect to find a single British glassmaker who will admit that his art is susceptible of such decisive and beautiful simplification.

To assist as far as we can in the attainment of this end, we shall proceed to describe a simple means for the analysis of glass, which will enable any person, possessed of even very trifling chemical skill, to determine the composition of any given sample of glass in a comparatively short time. From the nature of the material, it becomes necessary to divide the analysis into two distinct portions; one of which has for its object the estimation of its alkaline ingredients, the other that of the earthy, metallic, and siliceous matters. Having heated a sufficient quantity of the sample in question to dull redness, it must be suddenly thrown, whilst still hot, into a basin containing cold water. In this way it becomes cracked and flawed in all directions, so as to favour its reduction into powder. When dry it must, therefore, be carefully ground in an agate or steel mortar, until it has the appearance of fine flour. Nor is it a matter of indifference whether this takes place in contact with water or not; for glass in this extreme state of comminution readily gives up a part of its alkali to water; and hence, if ground in the presence of that fluid, the resulting analysis would prove incorrect. But we will suppose that a quantity of finely-powdered glass has been obtained as above indicated, and the amount of its alkali is desired; then weigh out 100 grains of the glass, and carefully mix with it 200 grains of pure fluor-spar in a similarly-powdered condition. Place the mixture in a platinum or leaden vessel, and pour over it 500 grains of strong sulphuric acid, stirring the whole well together with a silver spoon, but taking care not to remove any portion of the materials. Next, apply a heat of about 212° Fahr.; and as the process draws to a conclusion, this may be raised as high as 300°. When all evolution of gaseous fumes has ceased, water may be poured on the residuary mass to the extent of four or five ounces, and the mixture thrown on a filter. After the clear fluid has passed through, a little more water must be added to the filter, so as to wash out the whole of the soluble matter; these washings being joined to the original clear fluid, which consists of sulphate of soda or potash, or both, with a quantity of sulphate of lime, and perhaps also of magnesia and alumina. To this an excess of carbonate of ammonia must now be added, to admit of the separation of the earthy salts being effected by filtration. The clear solution is next boiled down to dryness, and the residue is heated red hot for a minute or two. This residue is the soda or potash, or both, formerly contained in 100 grains of the glass, but now united to sulphuric acid. Having ascertained its weight, the relative proportions of potash and soda may be found by testing its content of sulphuric acid with a barytic solution, and calculating the result by the well-known Archimedean equation; or, by dissolving the mixed salt in a small quantity of water, and after adding an excess of tartaric acid, leaving the whole for a few hours covered up in a cool place. Almost the whole of the potash will separate in this way as bitartrate of potash. The quantity of alkali may be determined from the atomic constitution of the alkaline salts. Thus, supposing the dry residue altogether composed of sulphate of soda, then as 72 grains of it indicate 32 of pure soda, the result may be obtained by the rule of proportion. The amount of alkali being known, another portion of the powdered glass must be employed for ascertaining the remainder of the ingredients. That is to say, 100 grains of the sample must be mixed with 200 grains of pure potash, and the whole fused together in a silver crucible, at a red heat, until perfect liquefaction ensues, when the crucible and its contents may be withdrawn from the fire, and, as soon as cool enough, boiled in half a pint of pure water, so as thoroughly to dissolve the fused mass from the crucible. An excess of nitric acid being poured into the solution, the mixture is then evaporated to dryness, by which means the silicic acid is rendered insoluble; consequently, on the application of water, this remains, and may be dried and weighed, whilst the lime, alumina, and lead of the glass may be separated from the soluble portion by the addition, first, of sulphuretted hydrogen, which separates the lead, then of ammonia, which throws down the alumina, and, next, by pouring in carbonate of ammonia, which precipitates the lime as a carbonate. Thus, therefore, the alkaline matters are found by one process, and the silica, earthy, and metallic constituents by another, both of which may be conducted at the same time. It has been recommended to employ carbonate of baryta in the analysis of glass; but the high temperature required with this substance dissipates a portion of the alkaline components, and thus leads to serious errors. Even mere fusion in a glass furnace expels soda from glass, and renders it more and more infusible; but this expulsion is much favoured by the presence of baryta. The above method of analysing glass is, therefore, to be preferred to the baryta plan, by individuals not habitually engaged in manipulative chemistry.—*Ure.*

Glass, for horticultural purposes.—An impression taken up loosely in the first instance from some experiments on the action of the chemical rays of light, when made to permeate coloured glass, has led the public frequently to conceive that glasses which admitted freely the chemical rays were the most adapted to accelerate the growth of plants. No more mistaken view was ever entertained. At different periods in the life of a plant different influences are necessary; at one time the chemical force is required, at another the luminous power, and at another the calorific agent. The solar rays, as we receive them direct from the sun, have those forces exactly adjusted to produce the best possible conditions; but under some of the artificial conditions in which we place plants, it is important to know the conditions of the solar rays best suited to produce a given effect. This we must attempt briefly to explain:—

1. Seeds germinating absorb oxygen, and convert their starch into sugar; this is a purely chemical process, and demands the full power of the *chemical rays* (*actinism*).

2. Wood-forming, from the decomposition of carbonic acid, is a function of the vital power of the plant, excited by *light* (*luminous force*).

3. Flowering and fruiting manifest compound actions, and appear to demand the combined power of *heat* (*calorific power*) and of the chemical rays.

Such are the three chief conditions in the phenomena of vegetable growth. Now *a*, a glass stained blue with cobalt admits the permeation of the chemical rays with great freedom, obstructing both light and heat; *b*, a glass stained yellow with silver, will powerfully obstruct the chemical rays, and allow the luminous rays to pass freely; *c*, deep copper or gold red glasses admit the maximum heat rays to pass freely, and in general allow of the permeation of a small quantity of the chemical rays.

When seed is placed in the soil to germinate, a blue glass placed above the soil will greatly accelerate the process; the first leaves will appear above the soil, in many instances, days before they are seen when the seed is under the ordinary conditions in the soil; but if a plant is allowed to grow under these circumstances, scarcely any wood is produced, but long succulent stalks are formed, with imperfect leaves.

After germination has taken place, if the plant is brought under the influence of the rays permeating yellow glass (*light* separated to a considerable extent from the *chemical power*), wood is formed abundantly, and very healthy plants with dark leaves are produced. For the production of perfect flowers and fruit, the red glass named is the most effective. Plants growing in conservatories which have been glazed with the colourless German sheet-glass, frequently suffer from scorching. To avoid this if possible, the editor of this volume was consulted on the glass which should be employed in glazing the great palm-house at Kew, the problem being to avoid the necessity of blinds, and to secure the plants from the injurious action of the scorching rays. By a long series of experiments it was determined that glass stained with a little of the oxide of copper, and from which there was an entire absence of manganese, entirely effected this end. The great palm-house in the Royal Botanic Gardens at Kew was glazed with glass made on this principle, by the Messrs. Chance Brothers and Co. of Birmingham, and it has now been tested by the sunshine of six-and-twenty summers (1874); and the plants, as every one may observe, grow most luxuriantly, and are entirely free from any indications of scorching on their leaves.

GLASS, COLOURED. Most of the metallic oxides impart a colour to glass, and some non-metallic, and even some substances derived from the organic kingdom have the power of imparting permanent colours to the vitreous combinations of flint and potash. There is much in this subject which still requires examination. M. Bontemps, at the meeting of the British Association at Birmingham, brought forward some very extraordinary facts in connection with the colouring powers of different bodies. Of his communication the following is an abstract:—

In the first place it was shown, that all the colours of the prismatic spectrum might be given to glass by the use of the oxide of iron in varying proportions, and by the agency of different degrees of heat: the conclusion of the author being, that all the colours are produced in their natural disposition in proportion as you increase the temperature. Similar phenomena were observed with the oxide of manganese. Manganese is employed to give a pink or purple tint to glass, and also to neutralise the slight green given by iron and carbon to glass in its manufacture. If the glass coloured by manganese remains too long in the melting-pot or the annealing-kiln, the *purple* tint turns first to a light *brownish-red*, then to *yellow*, and afterwards to *green*. White glass, in which a small proportion of manganese has been used, is liable to become light yellow by exposure to luminous power. This oxide is also, in certain window-glass, disposed to turn pink or purple under the action of the sun's rays. M. Bontemps has found that similar changes take place in the annealing oven. He has determined, by experiments made by him on polygonal lenses for M. Fresnel, that light is the agent producing the change mentioned: and the author expresses a doubt whether any change in the oxidation of the metal will explain the photogenic effect. A series of chromatic changes of a similar character were observed with the oxides of copper, the colours being in like manner regulated by the heat to which the glass was exposed. It was found that silver, although with less intensity, exhibited the same phenomena; and gold, although usually employed for the purpose of imparting varieties of red, was found by varying degrees of heating at a high temperature, and re-casting several times, to give a great many tints, varying from blue to pink, red, opaque yellow, and green. Charcoal in excess in a mixture of silica-alkaline glass gives a yellow colour, which is not so bright as the yellow from silver: and this yellow colour may be turned to a dark red by a second fire. The author is disposed to refer these chromatic changes to some modifications of the composing particles rather than to any chemical changes in the materials employed.

It is not possible in the present essay to enter into the minute details of this beautiful branch of glass-manufacture. In the following statement the materials ordinarily employed to colour glass alone are named.

YELLOW.—*Charcoal* or soot is used for producing the commoner varieties of yellow glass.

The glass of antimony, which is obtained by roasting sulphide of antimony until antimonious acid is formed, and melting it with about 5 per cent. of undecomposed sulphide of the same metal.

The antimonate of potash, a preparation similar to James's powder, is stated to answer the same purpose. Bohemian glass is coloured yellow with glass of antimony, minium, and oxide of iron.

Silver imparts a very beautiful yellow colour to glass; but it requires some caution in its mode of application. It is believed that the presence of alumina is necessary to the production of colour, since a fine yellow cannot be produced unless alumina be present. A mixture of powdered clay and chloride of silver is prepared, and spread upon the surface of the glass; the glass is then re-heated, and the silver penetrates to a certain depth into the glass, before the latter softens. The coating is then scraped off, and the fine yellow colour appears. If the silver yellow glass is held over the flame of burning wood, a peculiar opalescence is produced upon the surface, probably by the oxidation of the silver.

Uranium produces the beautiful canary-yellow, which is found in many articles of an ornamental kind. This glass possesses the very peculiar property of giving a green colour when it is looked *at*, although perfectly and purely yellow when looked *through*. This has been attributed to the presence of iron in the commercial oxide of uranium employed; but the purer the uranium is, the more beautifully will this phenomenon be brought out. It depends upon a very remarkable physical peculiarity belonging to uranium and some other bodies. See FLUORESCENCE.

RED.—A common brownish-red colour is produced in glass by *oxide of iron*, added as ochre, or in the state of pure peroxide. Muller found ancient glass to contain silicic acid, alkalis, lime, magnesia, alumina, protoxide of iron, and suboxide of copper.

Copper is more generally employed in colouring glass red. The use of this metal for such a purpose dates from very high antiquity, and all through the middle ages it was employed to produce the reds which we see in the fine old windows left by our ancestors for our admiration. The ancient *Hæmatinone* was a copper-red glass. Suboxide of copper is used, either in the state of commercial copper-scale, or it is prepared by heating copper-turnings to redness. If, during the fusion of the glass in the pot, the suboxide unites with an additional quantity of oxygen, green and not red is the result. This is avoided by combining some reducing agent with the melted substance. Glass thus coloured does not exhibit its red colour on leaving the crucible; it is nearly colourless, or with a tinge of green even when cold; but if it is then heated a second time it assumes the red colour. H. Rose supposes that a colourless neutral or acid silicate of the suboxide of copper is formed at a high temperature, and that the subsequent softening of the glass at a lower temperature causes the decomposition of this compound and a separation of a portion of the suboxide. We believe that no such chemical change takes place, and that the alteration is due merely to a change in the molecular arrangement of the particles. The suboxide of copper possesses an intense colouring power, so great indeed that glass coloured with even a very small quantity is almost impermeable to light; hence it is usual merely to *flash* colourless glass with this coloured glass, that is, to spread a very thin film of it over the colourless surface. A process for colouring glass red, after its manufacture, with sulphide of copper has been introduced by Bedford.

Gold can, according to circumstances, be made to impart a ruby, carmine, or pink tint to glass. The purple of Cassius was employed; but Dr. Fuss first showed that a mere solution of gold without the presence of tin, as in the salt named, is capable of producing rose and carmine coloured glass.

Similar changes to those already described with copper occur with the salts of gold. Perhaps the glass is colourless in the pot, and it then remains colourless when cold; but when re-heated, the glass quickly assumes a light red colour, which rapidly spreads from the heated point over the whole glass, and increases in intensity until it becomes nearly a black-red. This coloured glass can be again rendered colourless by fusion and slow cooling; its colour is again produced by a repetition of the heating process. If, however, it is suddenly cooled it cannot again be made to resume its ruby colour. This is also an example confirmatory in the highest degree of the view, that no chemical change takes place; but that all the phenomena are due to alterations in molecular structure. The practice of *flashing* colourless glass with the ruby glass from gold is commonly adopted. The beautiful examples of the Bohemian glass manufacture, in which we have a mixture of rich ruby and the purest crystal, are produced in this way. A globe of hot colourless glass is taken from the pot, and a cake of ruby glass, prepared with a composition called *Schmelze,* is warmed and brought into contact with the melted globe; this ruby glass rapidly diffuses itself over the surface, and the required article is blown or moulded with a coating of glass, coloured ruby by gold, of any required thickness.

Schmelze is prepared with 500 parts of silica, 800 of minium, 100 of nitre, and the same quantity of potash. A very small portion of a solution of gold in *aqua regia* is intimately mixed with 500 parts of Schmelze, 43 parts of prismatic borax, 3 or 4 of oxide of tin, and a similar quantity of oxide of antimony. This mixture is heated for twelve hours in an open crucible placed in a flat furnace, and then cooled slowly in an annealing oven. A *Bohemian ruby,* especially so called, is prepared by melting together fulminating gold rubbed in with oil of turpentine, quartz powdered, and fritted minium, sulphide of antimony, peroxide of manganese, and potash. Böhme has given an analysis of a Venetian ruby glass, in which $\frac{1}{20}$th of a grain of gold is combined with about 150 of the ordinary ingredients of glass, with some tin and iron.

Manganese is sometimes employed to give a fine amethystine colour to glass; care is however required to prevent the reduction of the peroxide of manganese in the process.

GREEN.—Green colours may be obtained by a variety of metallic oxides. *Protoxide of iron* imparts a dull green; an emerald-green colour is given by *oxide of copper.* Either copper-scales or verdigris dried and powdered are employed, the colour being much finer with a lead glass, than with one containing no lead. Translucent or *dull glass* is converted into a deep blue or turquoise colour by oxide of copper and not into a green. An emerald green is also produced by the *oxide of chromium.* Two kinds of Bohemian green glass, known respectively as the ancient and modern emerald greens, are prepared from mixtures of the oxides of nickel and of uranium.

BLUE.—The only fine blue is produced by cobalt. The manufacture of *smalt* or *zaffre* is so important that it will be treated of in a separate article. See SMALT and COBALT.

BROWN.—Peroxide of manganese with zaffre yields a fine garnet-like brown.

PINK or FLESH-COLOUR.—Oxide of iron and alumina, obtained by heating a mixture of alum and green vitriol.

ORANGE.—Peroxide of iron with chloride of silver.

JASPER.—A Bohemian glass, generally black, but of fine lustre, prepared by adding forge scales, charcoal, and bone ashes to the ordinary materials for glass.

Amongst the different varieties of glass, artificial gems may be enumerated. For a description of their manufacture, see GEMS, ARTIFICIAL.

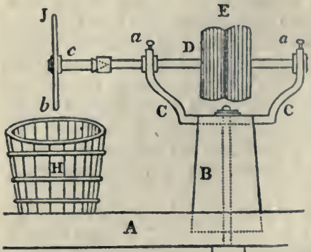
GLASS, STAINED. See GLASS, COLOURED.

GLASS CUTTING AND GRINDING, for common and optical purposes. By this mechanical process the surface of glass may be modified into almost any ornamental or useful form.

1. *The grinding of crystal ware.* This kind of glass is best adapted to receive polished facets, both on account of its relative softness, and its higher refractive power, which gives lustre to its surface. The cutting-shop should be a spacious long apartment, furnished with numerous skylights, having the grinding and polishing lathes arranged right under them, which are set in motion by a steam-engine or water-wheel at one end of the building. A shaft is fixed as usual in gallewses along the ceiling; and from the pulleys of the shaft, bands descend to turn the different lathes, by passing round the driving pulleys near their ends.

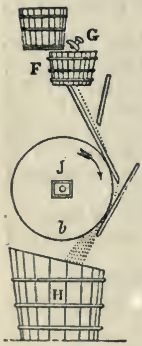
The turning lathe is of the simplest construction. *Fig.* 1103, D, is an iron spindle with two well-turned prolongations, running in the iron puppets *a a,* between two concave boshes of tin or type-metal, which may be pressed more or less together by the thumb-screws shown in the figure. These two puppets are made fast to the wooden support B, which is attached by a strong screw and bolt to the longitudinal beam of the workshop A. E is the fast and loose pulley for putting the lathe into and out of gear with the driving shaft. The projecting end of the spindle is furnished with a hollow head-piece, into which the rod *c* is pushed tight. This rod carries the cutting or grinding disc plate. For heavy work, this rod is fixed into the head by a screw. When a conical fit is preferred, the cone is covered with lead to increase the friction.

1103



Upon projecting rods or spindles of that kind the different discs for cutting the glass are made fast. Some of these are made of fine sandstone or polishing slate, from 8 to 10 inches in diameter, and from ¾ to ½ inch thick. They must be carefully turned and polished at the lathe, not only upon their rounded but upon their flat face, in order to grind and polish in their turn the flat and carved surfaces of glass vessels. Other discs of the same diameter, but only ¾ of an inch thick, are made of cast tin truly turned, and serve for polishing the vessels previously ground; a third set consists of sheet iron from ⅙ to ½ an inch thick, and 12 inches in diameter, and are destined to cut grooves in glass by the aid of sand and water. Small discs of well-hammered copper from ½ to 3 inches in diameter, whose circumference is sometimes flat, and sometimes concave or convex, serve to make all sorts of delineations upon glass by means of emery and oil. Lastly, there are rods of copper or brass furnished with small hemispheres from $\frac{1}{24}$ to ¼ of an inch in diameter, to excavate round hollows in glass. Wooden discs are also employed for polishing, made of white wood cut across the grain, as also of cork.

1104



The cutting of deep indentations, and of grooves, is usually performed by the iron disc, with sand and water, which are allowed constantly to trickle down from a wooden hopper placed right over it, and furnished with a wooden stopple or plug at the apex, to regulate by its greater or less looseness the flow of the grinding materials. The same effect may be produced by using buckets, as shown in *fig.* 1104. The sand which is contained in the bucket F, above the lathe, has a spigot and faucet inserted near its bottom, and is supplied with a stream of water from the stopcock in the vessel G, which, together, running down the inclined board, are conducted to the periphery of the disc as shown in the figure, to whose lowest point the glass vessel is applied with pressure by the hand. The sand and water are afterwards collected in the tub H. Finer markings which are to remain without lustre, are made with the small copper discs, emery, and oil. The polishing is effected by the edge of the tin disc, which is from time to time moistened with putty (white oxide of tin) and water. The wooden disc is also employed for this purpose with putty, colcothar, or washed tripoli. For fine delineations, the glass is first traced over with some coloured varnish, to guide the hand of the cutter.

In grinding and facetting crystal glass, the deep grooves are first cut, for example, the cross lines, with the iron disc and rounded edge, by means of sand and water. That disc is one-sixth of an inch thick and 12 inches in diameter. With another iron disc about half an inch thick, and more or less in diameter, according to the curvature of the surface, the grooves may be widened. These roughly cut parts must be next smoothed down with the sandstone disc and water, and then polished with the wooden disc about half an inch thick, to whose edge the workman applies, from time to time, a bag of fine linen containing some ground pumice moistened with water. When the cork or wooden disc edged with hat-felt is used for polishing, putty or colcothar is applied to it. The above several processes in a large manufactory are usually committed to several workmen on the principle of the division of labour, so that each may become expert in his department.

2. *The grinding of optical glasses.*—The glasses intended for optical purposes being spherically ground, are called lenses; and are used either as simple magnifiers and spectacles, or for telescopes and microscopes. The curvature is always a portion of a sphere, and either convex or concave. This form insures the convergence or divergence of the rays of light that pass through them, as the polishing does the brightness of the image.

The grinding of the lenses is performed in brass moulds, either concave or convex, formed to the same curvature as that desired in the lenses; and may be worked either by hand or by machinery. A gauge is first cut out of brass or copper plate to suit the curvature of the lens, the circular arc being traced by a pair of compasses. In this way both a convex and concave circular gauge are obtained. To these gauges the brass moulds are turned. Sometimes, also, lead moulds are used. After the two moulds are made, they are ground face to face with fine emery.

The piece of glass is now roughed into a circular form by a pair of pincers, leaving it a little larger than the finished lens ought to be, and then smoothed round upon the stone disc, or in an old mould with emery and water, and is next made fast to a holdfast. This consists of a round brass plate, having a screw in its back; and is somewhat smaller in diameter than the lens, and two-thirds as thick. This is turned concave upon the lathe, and then attached to the piece of glass by drops of pitch applied to several points of its surface, taking care, while the pitch is warm, that the centre of the glass coincides with the centre of the brass plate. This serves not merely as a holdfast, by enabling a person to seize its edge with the fingers, but it prevents the glass from bending by the necessary pressure in grinding.

The glass must now be ground with coarse emery upon its appropriate mould, whether convex or concave, the emery being all the time kept moist with water. To prevent the heat of the hand from affecting the glass, a rod for holding the brass plate is screwed to its back. For every six turns of circular motion, it must receive two or three rubs across the diameter in different directions, and so on alternately. The middle point of the glass must never pass beyond the edge of the mould; nor should strong pressure be at any time applied. Whenever the glass has assumed the shape of the mould, and touches it in every point, the coarse emery must be washed away, finer be substituted in its place, and the grinding be continued as before, till all the scratches disappear, and a uniform dead surface be produced. A commencement of polishing is now to be given with pumice-stone powder. During all this time the convex mould should be occasionally worked in the concave, in order that both may preserve their correspondence of shape between them. After the one surface has been thus finished, the glass must be turned over, and treated in the same way upon the other side.

Both surfaces are now to be polished. With this view equal parts of pitch and resin must be melted together, and strained through a cloth to separate all impurities. The concave mould is next to be heated, and covered with that mixture in a fluid state to the thickness uniformly of one quarter of an inch. The cold convex mould is now to be pressed down into the yielding pitch, its surface being quite clean and dry, in order to give the pitch the exact form of the ground lens; and both are to be plunged into cold water till they be chilled. This pitch impression is now the mould upon which the glass is to be polished, according to the methods above described, with finely-washed colcothar and water, till the surface become perfectly clear and brilliant. To prevent the pitch from changing its figure by the friction, cross lines must be cut in it about half an inch asunder, and one-twelfth of an inch broad and deep. These grooves remove all the superfluous parts of the polishing powder, and tend to preserve the polishing surface of the pitch clean and unaltered. No additional colcothar after the first is required in this part of the process, but only a drop of water from time to time. The pitch gets warm as the polishing advances, and renders the friction more laborious from the adhesion between the surfaces. No interruption must now be suffered in the work, nor must either water or colcothar be added; but should the pitch become too adhesive, it must be merely breathed upon till the polish be complete. The nearer the lens is brought to a true and fine surface in the first grinding, the better and more easy does the polishing become. It should never be submitted to this process with any scratches perceptible in it, even when examined by a magnifier.

As to small lenses and spectacle eyes, several are ground and polished together. The pieces of glass are affixed by means of a resinous cement to the mould, close to each other, and are then all treated as if they formed but one large lens. Plane glasses are ground upon a surface of pitch rendered plane by the pressure of a piece of plate glass upon it in its softened state.

Lenses are also ground and polished by means of machinery, into the details of which the limits of this work will not allow us to enter. See LENSES.

(For the *Importations* of glass see Table at top of next page.)

GLASS PAPER and **CLOTH.** Paper and cloth being covered with glue, sand, varying in its degree of fineness, is dusted over it, and of course adheres. These are used for polishing, or removing the rough surfaces of woods and metals.

GLASS, WATER. The term 'water-glass' is applied to those alkaline silicates which, by containing an excess of alkali, are soluble in water. A potash water-glass may be prepared by melting together 45 parts of silica, 30 of potash, and 3 of carbon, in the form of pulverised wood-charcoal. Soda water-glass may be obtained by fusing a mixture of 45 parts of silica, 23 of calcined soda, and 3 of charcoal. Water-glass is used for rendering wood and textile fabrics uninflammable; it is employed in the preparation of Ransome's artificial stone, and was introduced by Von Fuchs in his stereochromatic wall-painting. See STEREOCHROMY; STONE, ARTIFICIAL.

Our *Importations* of glass have been as follow in the years given:—

	1871		1872	
	Quantities	Value	Quantities	Value
Window-glass (not being plate-glass) and German sheet-glass, including shades and cylinders:	cwts.	£	cwts.	£
From Belgium	413,792	296,041	415,769	309,921
„ France	3,225	13,721	10,616	58,027
„ other countries	3,277	4,420	753	924
Total	420,294	314,182	427,129	368,872
Flint-glass:				
From Germany.	24,798	164,180	26,559	194,832
„ Belgium	29,963	45,039	30,107	53,222
„ France	10,725	36,604	4,713	19,371
„ other countries	499	2,338	616	3,071
Total	65,985	248,161	61,995	270,496
Plate, silvered or not:				
From Holland	1,285	4,226	192	586
„ Belgium	28,035	73,046	31,898	82,336
„ France	8,452	34,480	9,212	32,176
„ other countries	128	1,001	900	3,077
Total	37,900	112,753	42,202	118,175
Manufactures unenumerated:				
From Germany	20,215	123,830	22,027	115,915
„ Holland	4,418	18,071	9,802	18,341
„ Belgium	38,787	124,380	68,416	196,051
„ France	39,293	41,477	53,747	107,055
„ Italy	1,252	9,745	986	9,173
„ other countries	1,328	2,289	1,852	2,590
Total	105,293	319,792	156,830	449,125

GLAUBER'S SALTS (the *Sal cartharticus Glauberi*, or *Sal mirabile Glauberi*). Sulphate of soda was discovered by Glauber in 1658. Its composition is: soda, 19·24; sulphuric acid, 24·76; water, 56·00; total, 100·00.

GLAUCONITE. A mineral occurring generally in the form of dark green grains, which give a colour to certain rocks, especially to the Cretaceous Greensands. The grains are said to be, in many cases, casts of Foraminifera. Glauconite is a hydrous silicate of iron, alumina, potash, &c.

GLAZES. See Pottery.

GLAZIER, is the workman who cuts plates or panes of glass with the diamond, and fastens them by means of putty in frames or window casements. See Diamond, for an explanation of its glass-cutting property.

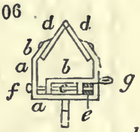
GLAZING. The process of giving a hard polished surface to bodies. Paper is glazed by the use of resins, gelatine, &c. See Paper. Pottery is glazed by the use of certain fusible materials. See Pottery and Porcelain. Some metals are said to be 'glazed' when, by means of polishing-wheels, the highest finish is put upon their surfaces.

GLIMMER. Many talcose and micaceous minerals were so called by the old miners. Werner applied the term to several varieties of mica; and Haidinger gave it to the species known as *Muscovite.* The terms Glimmer and Glidder are still applied by Cornish miners to the pearly shining surfaces of several minerals and to clays.

GLOVE MANUFACTURE. In February 1822, Mr. James Winter of Stoke-under-Hambdon, in the county of Somerset, obtained a patent for an improvement upon a former patent machine of his for sewing and pointing leather gloves. *Fig.* 1105 represents a pedestal, upon which the instrument called the jaws is to be placed.

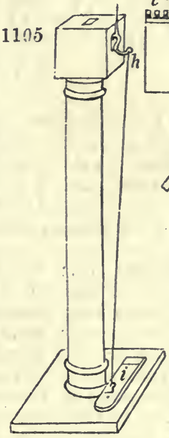
Fig. 1106 shows the jaws, which, instead of opening and closing by a circular movement upon a joint, as described in the former specification, are now made to open and shut by a parallel horizontal movement, effected by a slide and screw; *a a* is the fixed jaw, made of one piece, on the under side of which is a tenon, to be inserted into the top of the pedestal. By means of this tenon the jaws may be readily removed, and another similar pair of jaws placed in their stead, which affords the advantage of expediting the operation by enabling one person to prepare the work while another is sewing; *b b* is the moveable jaw, made of one piece. The two jaws being placed together in the manner shown at *fig.* 1107, the moveable jaw traverses backwards and forwards upon two guide-bars, *c*, which are made to pass through holes exactly fitted to them, in the lower parts of the jaws. At the upper parts of the jaws are what are called the indexes, *d d*, which are pressed tightly together by a spring shown at *fig.* 1108, and intended to be introduced between the perpendicular ribs of the jaws at *e*. At *f* is a thumb-screw, passing through the ribs for the purpose of tightening the jaws, and holding the leather fast between the indexes while being sewn; this screw, however, will seldom, if ever, be necessary if the spring is sufficiently strong; *g* is an eye or ring fixed to the moveable jaw, through which the end of a lever, *h* in *fig.* 1105, passes; this lever is connected by a spring to a treadle *i*, at the base of the pedestal, and by the pressure of the right foot upon this treadle the moveable jaw is withdrawn; so that the person employed in sewing may shift the leather, and place another part of the glove between the jaws. The pieces called indexes are connected to the upper part of the jaws by screws passing through elongated holes which render them capable of adjustment.

1106



1110

1105



1111

1108

1109

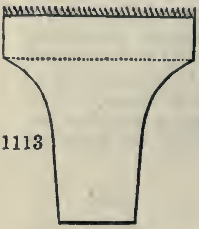
1107

The patentee states that, in addition to the index described in his former patent, which is applicable to what is called round-seam sewing only, and which permits the leather to expand but in one direction, when the needle is passed through it, namely, upwards, he now makes two indexes of different construction, one of which he calls the receding index, and the other the longitudinally-grooved index. *Fig.* 1108 represents an end view, and *fig.* 1109 a top view of the receding index, which is particularly adapted for what are called 'drawn sewing,' and 'prick-seam sewing.' This index, instead of biting to the top, is so rounded off in the inside from the bottom of the cross grooves, as to permit the needles, by being passed backwards and forwards, to carry the silk thread on each side of the leather without passing over it. *Fig.* 1110 represents an end view of the longitudinally-grooved index, partly open, to show the section of the grooves more distinctly; and *fig.* 1111 represents an inside view of one side of the same index, in which the longitudinal groove is shown, passing from *k* to *l*. This index is more particularly adapted to round-seam sewing, and permits the leather to expand in every direction when the needle is passed through it, by which the leather is less strained, and the sewing consequently rendered much stronger.

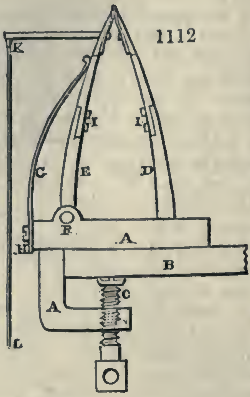
GLOVE-SEWING. The following simple and ingenious apparatus, invented by an Englishman, has been employed extensively in Paris. The instrument is shown in profile ready for action in *fig.* 1112. It resembles an iron vice, having the upper portion of each jaw made of brass, and tipped with a kind of comb of the same metal. The teeth of this comb, only one-twelfth of an inch long, are perfectly regular and equal. Change combs are provided for different styles of work. The vice A A is made fast to the edge of the bench or table B, of the proper height, by a thumb-screw C, armed with a cramp which lays hold of the wood. Of the two jaws composing the machine, the one D is made fast to the foot A A, but the other, E, is moveable upon the solid base of the machine by means of a hinge at the point F. At I I is shown how the upper brass portion is adjusted to the lower part made of iron; the two being secured to each other by two stout screws. The comb, seen separately in *fig.* 1114, is made fast to the upper end of each jaw, by the three screws *n*, *n*, *n*. *Fig.* 1113 is a front view of the jaw mounted with its comb, to illustrate its construction.

The lever K corresponds, by the stout iron wire L, with a pedal pressed by the needlewoman's foot, whenever she wishes to separate the two jaws, in order to insert between them the parallel edges of leather to be sewed. The instant she lifts her foot, the two jaws join by the force of the spring G, which pushes the moveable jaw E against the stationary one D. The spring is made fast to the frame of the vice by the screw H.

1113



1112



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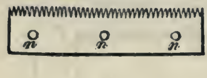


After putting the double edge to be sewed in its place, the woman passes her needle successively through all the teeth of the comb, and is sure of making a regular seam in every direction, provided she is careful to make the needle graze along the bottom of the notches. As soon as this piece is sewed, she presses down the pedal with her toes, whereby the jaws start asunder, allowing her to introduce a new seam; and so on in quick succession.

The comb may have any desired shape, straight or curved; and the teeth may be either larger or smaller, according to the kind of work to be done. With this view, the combs might be changed as occasion requires; but it is more economical to have sets of vices ready mounted with combs of every requisite size and form.

It is estimated that the value of the gloves manufactured in France is between 1,600,000*l.* and 2,000,000*l.*, and is still rapidly increasing. The kid and lamb skins used for glazed gloves are dressed at Paris, Grenoble, Annonay, Romans, and Charlemont. The Paris manufacturers whose gloves are most esteemed employ workmen from Vendôme.

GLUCINA (*Glucine*, Fr.; *Beryllerde*, Ger.) is one of the primitive earths, originally discovered by Vauquelin in 1797 in the emerald of Limoges; he called it glucina from the sweet taste possessed by its salts. Its existence in several other minerals has since been proved: viz., in cymophane or chrysoberyl, phenacite, euclase, gadolinite, leucophane, &c. Its properties have been comparatively little studied, owing to the tedious and expensive processes required for its preparation.

GLUCINUM, the metal of Glucina, has been obtained by M. H. Debray (*Ann. Chem. et Phys.* xliv. 5) by the following process:—Into a wide glass tube are introduced two vessels, one containing chloride of glucinum, and the other sodium, deprived of the greatest part of the adhering naphtha by compression between two sheets of blotting-paper. The glass tube is placed in a combustion-furnace. It is then traversed by a current of hydrogen, passing from the chloride of glucinum to the sodium. The sodium is not placed in the tube until all the air has been expelled by the hydrogen. The tube is then heated just where the sodium is placed, which by this means is deprived of the last particle of naphtha, and fuses. The chloride of glucinum is then heated. The vapour of chloride driven forwards by the hydrogen arrives over the fused sodium. It then swells up, and the heat generated by chemical action is sufficient to raise the contents of the vessel to redness which often breaks the vessel if made of porcelain. The operation is ended when the chloride of glucinum sublimes beyond the sodium vessel. When the tube is cool the vessel is withdrawn, and in the place of the sodium a large quantity of a blackish substance is found, composed of common salt and the metal glucinum in brilliant spangles, and sometimes even in globules. This match is quickly detached and fused in a small crucible, with the addition of some dried common salt, which acts as a flux, and facilitates the union of the globules of metal.

It is a white metal, whose density is 2·1. It may be forged and rolled into sheets like gold. Its melting-point is inferior to that of silver. It may be melted in the outer blowpipe flame, without exhibiting the phenomenon of ignition presented by zinc and iron under the same circumstances. It cannot be set on fire in an atmosphere of pure oxygen, but in both cases is covered with a film of oxide, which seems to protect it from further action. It is not acted on by sulphur, but readily combines with chlorine and iodine by the aid of heat. See Watts's 'Dictionary of Chemistry.'

GLUCOSE. The name given to grape- and starch-sugar by M. Dumas.

GLUE (*Colle forte*, Fr.; *Leim*, *Tischlerleim*, Ger.) is the chemical substance gelatine in a dry state. The preparation and preservation of the skin and other animal matters employed in the manufacture of glue, constitute a peculiar branch of industry. Those who exercise it should study to prevent the fermentation of the substances, and to diminish the cost of carriage by depriving them of as much water as can conveniently be done. They may then be put in preparation by macerating them in milk of lime, renewed three or four times in the course of a fortnight or three weeks. This process is performed in large tanks of masonry. They are next taken out with all the adhering lime, and laid in a layer, 2 or 3 inches thick, to drain and dry, upon a sloping pavement, where they are turned over by prongs two or three times a day. The action of the lime dissolves the blood and certain soft parts, attacks the epidermis, and disposes the gelatinous matter to dissolve more readily. When the cleansed matters are dried, they may be packed in sacks or hogsheads, and transported to the glue-manufactory at any distance. The principal substances of which glue is made are the parings of ox and other thick hides, which form the strongest article, the refuse of the leather-dresser; both afford from 45 to 55 per cent. of glue. The tendons, and many other offals of slaughter-houses, also afford materials, though of an inferior quality, for the purpose. The refuse of tanneries, such as the ears of oxen, calves, sheep, &c., are better articles; but parings of parchment, old gloves, and, in fact, animal skin in every form, uncombined with tannin, may be made into glue.

The manufacturer who receives these materials is generally careful to ensure their purification by subjecting them to a weak lime steep, and rinsing them by exposure in baskets to a stream of water. They are lastly drained upon a sloping surface and well turned over till the quicklime gets mild by absorption of carbonic acid; for, in its caustic state, it would damage the glue at the heat of boiling water. It is not necessary, however, to dry them before they are put into the boiler, because they dissolve faster in their soft and tumefied state.

The boiler is made of copper, rather shallow in proportion to its area, with a uniform flat bottom, equably exposed all over to the flame of the fire. Above the true bottom there is a false one of copper or iron, pierced with holes, and standing upon feet 3 or 4 inches high; which serves to sustain the animal matters, and prevent them from being injured by the fire. The copper being filled to two-thirds of its height with soft water, is then heaped up with the bulky animal substances, so high as to surmount its brim. But soon after the ebullition begins they sink down, and, in a few hours get entirely immersed in the liquid. They should be stirred about from time to time, and well pressed down towards the false bottom, while a steady but gentle boil is maintained.

The solution must be drawn off in successive portions; a method which fractions the products, or subdivides them into articles of various value, gradually decreasing from the first portion drawn off to the last. It has been ascertained by careful experiments that gelatine gets altered over the fire very soon after it is dissolved, if the heat of 212° is maintained, and it ought therefore to be drawn off whenever it is sufficiently fluid and strong for forming a clear gelatinous mass on cooling, capable of being cut into moderately firm slices by the wire. The point is commonly determined by filling half an egg-shell with the liquor, and exposing it to the air to cool. The jelly ought to get very consistent in the course of a few minutes; if not so, the boiling must be persisted in a little longer. When this term is attained, the fire is smothered up, and the contents of the boiler are left to settle for a quarter of an hour. The stopcock being partially turned, all the thin gelatinous liquor is run off into a deep boiler, immersed in a warm water bath, so that it may continue hot and fluid for several hours. At the end of this time the supernatant clear liquid is to be drawn off into congealing boxes, as will be presently explained.

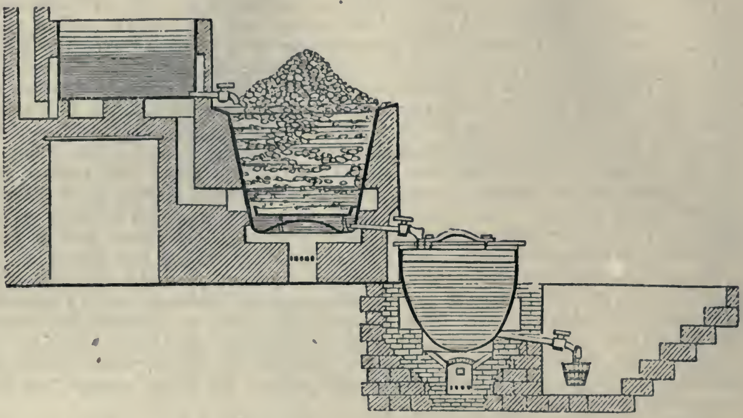
The residue, or undissolved matter in the boiler, is to be again supplied with a quantity of boiling water from an adjoining copper, and are to be once more subjected to the action of the fire, till the contents assume the appearance of dissolved jelly, and afford a fresh quantity of strong glue liquor, by the stopcock. The 'grounds' should be subjected a third time to this operation, after which they may be put into a bag, and squeezed in a press to leave nothing unextracted. The latter solutions are usually too weak to form glue directly, but they may be strengthened by boiling with a portion of fresh skin-parings.

Fig. 1115 represents a convenient apparatus for the boiling of skins into glue, in which there are three coppers upon three different levels: the uppermost being acted upon by the waste heat of the chimney, provides warm water in the most economical way; the second contains the crude materials, with water for dissolving them; and the third receives the solution to be settled. The last vessel is double, with water contained between the outer and inner one; and discharges its contents by a stopcock into buckets for filling the gelatinising wooden boxes. The last-made solution has about one-five-hundredth part of alum in powder usually added to it, with proper agitation, after which it is left to settle for several hours.

The three successive boils furnish three different qualities of glue.

Flanders or Dutch glue, long much esteemed on the Continent, was made in the manner above described, but at two boils, from animal offals well washed and soaked, so as to need less boiling. The liquor being drawn off thinner, was therefore less coloured, and being made into thinner plates was very transparent. The above two boils gave two qualities of glue.

1115



By the English practice, the whole of the animal matter is brought into solution at once, and the liquor being drawn off, hot water is poured on the residuum, and made to boil on it for some time, when the liquor thus obtained is merely used instead of water upon a fresh quantity of glue-materials. The first drawn off liquor is kept hot in a settling copper for five hours, and then the clear solution is drawn off into the boxes.

The boxes are made of deal, of a square form, but a little narrower at bottom than at top. When very regular cakes of glue are wished for, cross grooves of the desired square form are cut in the bottom of the box. The liquid glue is poured into the boxes placed very level, through funnels furnished with filter cloths, till it stands at the brim of each. The apartment in which this is done ought to be as cool and dry as possible, to favour the solidification of the glue, and should be floored with stone flags kept very clean, so that if any glue run through the seams, it may be recovered. At the end of 12 or 18 hours, or usually in the morning if the boxes have been filled over-night, the glue is sufficiently firm for the nets, and they are at this time removed to an upper story, mounted with ventilating windows to admit the air from all quarters. Here the boxes are inverted upon a moistened table, so that the gelatinous cake thus turned out will not adhere to its surface; usually the moist blade of a long knife is insinuated round the sides of the boxes beforehand to loosen the glue. The mass is first divided into horizontal layers by a brass wire stretched in a frame, like that of a bow-saw, and guided by rulers which are placed at distances corresponding to the desired thickness of the cake of glue. The lines formed by the grooves in the bottom of the box define the superficial area of each cake, where it is to be cut with a moist knife. The gelatinous layers thus formed, must be dexterously lifted, and immediately laid upon nets stretched in wooden frames, till each frame be filled. These frames are set over each other at distances of about three inches, being supported by small wooden pegs, stuck into mortise holes in an upright, fixed round the room; so that the air may have perfectly free access on every side. The cakes must moreover be turned upside down upon the nets twice or thrice every day, which is readily managed, as each frame may be slid out like a drawer, upon the pegs at its two sides.

The drying of the glue is the most precarious part of the manufacture. The least disturbance of the weather may injure the glue during the two or three first days of its exposure; should the temperature of the air rise considerably, the gelatine may turn so soft as to become unshapely, and even run through the meshes upon the pieces below, or it may get attached to the strings and surround them, so as not to be separable without plunging the net into boiling water. If frost supervene, the water may freeze and form numerous cracks in the cakes. Such pieces must be immediately re-melted and re-formed. A slight fog even produces upon glue newly exposed a serious deterioration; the damp condensed upon its surface occasioning a general mouldiness. A thunderstorm sometimes destroys the coagulating power in the whole laminæ at once; or causes the glue to *turn* on the nets, in the language of the manufacturer. A wind too dry or too hot may cause it to dry so quickly, as to prevent it from contracting to its proper size without numerous cracks and fissures. In this predicament, the closing of all the flaps of the windows is the only means of abating the mischief. On these accounts it is of importance to select the most temperate season of the year, such as spring and autumn, for the glue-manufacture.

After the glue is dried upon the nets it may still preserve too much flexibility, or softness at least, to be saleable; in which case it must be dried in a stove by artificial heat. This aid is peculiarly requisite in a humid climate, like that of Great Britain.

When sufficiently dry it next receives a gloss, by being dipped, cake by cake, in hot water, and then rubbed with a brush, also moistened in hot water; after which the glue is arranged upon a hurdle, and transferred to the stove-room, if the weather be not sufficiently hot. One day of proper drought will make it ready for being packed up in casks.

The pale-coloured, hard, and solid article, possessing a brilliant fracture, which is made from the parings of ox-hides by the first process, is the best and most cohesive, and is most suitable for joiners, cabinet-makers, painters, &c. But many workmen are influenced by such ignorant prejudices, that they still prefer a dark-coloured article, with somewhat of a fetid odour, indicative of its impurity and bad preparation, the result of bad materials and too long exposure to the boiling heat.

There is a good deal of glue made in France from bones freed from the phosphate of lime by muriatic acid. This is a poor article, possessing little cohesive force. It dissolves almost entirely in cold water, which is the best criterion of its imperfection. Glue should merely soften in cold water, and the more considerably it swells, the better, generally speaking, it is.

Some manufacturers prefer a brass to a copper pan for boiling glue, and insist much on skimming it as it boils; but the apparatus represented renders skimming of little consequence. For use, glue should be broken into small pieces, put along with some water in a vessel, allowed to soak for some hours, and subjected to the heat of a boiling-water bath, but not boiled itself. The surrounding hot water keeps it long in a fit state for joiners, cabinet-makers, &c.

Water containing only one-hundredth part of good glue, forms a tremulous solid. When the solution, however, is heated and cooled several times, it loses the property of gelatinising, even though it be enclosed in a vessel hermetically sealed. Isinglass or fish-glue undergoes the same change. Common glue is not soluble in alcohol, but is precipitated in a white, coherent, elastic mass, when its watery solution is treated with that fluid. By transmitting chlorine gas through a warm solution of glue, a combination is very readily effected, and a viscid mass is obtained like that thrown down by alcohol. A little chlorine suffices to precipitate the whole of the glue. Concentrated sulphuric acid makes glue undergo remarkable changes; during which are produced sugar of gelatine, leucine, an animal matter, &c. Nitric acid, with the aid of heat, converts glue into malic acid, oxalic acid, a fat analogous to suet, and into tannin; so that, in this way, one piece of skin may be made to tan another. When the mixture of glue and nitric acid is much evaporated, a detonation at last takes place. Strong acetic acid renders glue first soft and transparent, and then dissolves it. Though the solution does not gelatinise, it preserves the property of glueing surfaces together when it dries. Liquid glue dissolves a considerable quantity of lime, and also of the phosphate of lime recently precipitated. Accordingly glue is sometimes contaminated with that salt. Tannin, both natural and artificial, combines with glue; and with such effect, that one part of glue dissolved in 5,000 parts of water affords a sensible precipitate with the infusion of nutgalls. Tannin unites with glue in several proportions, which are to each other as the numbers 1, 1½, and 2: one compound consists of 100 glue and 89 tannin; another of 100 glue and 60 tannin; and a third of 100 glue and 120 tannin. These two substances cannot be afterwards separated from each other by any known chemical process.

Glue may be freed from the foreign animal matters generally present in it, by softening it in cold water, washing it with the same several times till it no longer gives out any colour, then bruising it with the hand, and suspending it in a linen bag beneath the surface of a large quantity of water at 60° F. In this case, the water loaded with the soluble impurities of the glue gradually sinks to the bottom of the vessel, while the pure glue remains in the bag surrounded with water. If this softened glue be heated to 92° without adding water, it will liquefy; and if we heat it to 122°, and filter it, some albuminous and other impurities will remain on the filter, while a colourless solution of glue will pass through.

Experiments have not yet explained how gelatine is formed from skin by ebullition. It is a change somewhat analogous to that of starch into gum and sugar, and takes place without any appreciable disengagement of gas, and even in close vessels. Gelatine, says Berzelius, does not exist in the living body, but several animal tissues, such as skin, cartilages, hartshorn, tendons, the serous membranes, and bones, are susceptible of being converted into it. See GELATINE.

GLUTEN (*Colle vegetale* and *Gluten*, Fr.; *Kleber*, Ger.) was first extracted by Beccaria from wheat-flour, and was long regarded as a proximate principle of plants, till Einhoff, Taddei, and Berzelius succeeded in showing that it may be resolved by means of alcohol into three different substances: one of which resembles closely animal albumen, and has been called *Zymome*, or vegetable albumen; another has been called *Gliadine;* and a third, *Mucine.*

Gluten, when dried in the air or a stove, diminishes greatly in size, becomes hard, brittle, glistening, and of a deep yellow colour. It is insoluble in ether, fat and essential oils, and nearly so in water. Alcohol and acetic acid cause gluten to swell and make a sort of milky solution. Dilute acids and alkaline lyes dissolve gluten. Its constituents are not precisely determined, but nitrogen is one of them, and accordingly when moist gluten is left to ferment, it exhales the smell of old cheese.

Some years since, M. E. M. Martin, of Vervins, proposed to extract the starch without injuring the gluten, which then becomes available for alimentary purposes. His process is a mechanical one (resembling that long practised in laboratories for procuring gluten), and consists in washing wheat-flour, made into a paste, with water, either by the hand or machinery.

The gluten thus obtained is susceptible of numerous useful applications for alimentary purposes. Mixed with wheat-flour, in the proportions of 30 parts of flour, 10 of fresh gluten, and 7 of water, it has been employed to produce a superior sort of macaroni, vermicelli, and other kinds of Italian pastes; and MM. Véron Frères, of Paris, have made with it a new sort of paste, which they have termed *granulated gluten* (*gluten granulé*).

GLYCERINE is a sweet substance extracted from fatty substances. It may be prepared in the utmost purity by the following process:—'If we take equal parts of olive-oil and finely-ground litharge, put them into a basin with a little water, set this on a sand-bath moderately heated, and stir the mixture constantly, with the occasional addition of hot water to replace what is lost by evaporation, we shall obtain, in a short time, a soap or plaster of lead. If, after having added more water to this, we remove the vessel from the fire, decant the liquor, filter it, pass sulphuretted hydrogen through it to separate the lead, then filter afresh, and concentrate the liquor as much as possible without burning, upon the sand-bath, we obtain glycerine; but what remains must be finally evaporated within the receiver of the air-pump. Glycerine thus prepared is a transparent liquid, without colour or smell, and of a syrupy consistence. It has a very sweet taste. It specific gravity is 1·27 at the temperature of 60°. When thrown upon burning coals, it takes fire and burns like an oil. Water combines with it in almost all proportions; alcohol dissolves it readily; nitric acid converts it into oxalic acid; and, according to Vogel, sulphuric acid transforms it into sugar, in the same way as it does starch. By yeast it becomes acid by the formation of formic and metacetic acids.'

Its constituents are, carbon 40, hydrogen 9, oxygen 51, in 100.

Glycerine is one of the products of the saponification of fat-oils. It is produced in large quantities in the soap-manufactories in a very impure state, being contaminated with saline and empyreumatic matters, and having a very strong disagreeable odour. In order to obtain glycerine from this source, the residuary liquors are evaporated and treated with alcohol, which dissolves out the glycerine. The alcohol having been separated by evaporation, the glycerine is diluted with water, and boiled with animal charcoal. This process must be repeated several times, or until the result is sufficiently free from smell. It is, however, difficult to obtain pure glycerine from this source, on account of the nature and condition of the ingredients usually employed in making soap, which it is almost impossible to deprive of rancid odour.

The compounds of glycerine with the fatty acids constitute the various kind of fats and oils, but the base does not appear to have the same composition in all. A certain quantity of water appears to separate, and the equivalent of glycerine to be in some fats, but half what it is in others.

Glycerine is now obtained in great quantities from palm-oil, in the process of purification for candles. It is employed with much advantage to preserve soft-bodied animals. It is manufactured into soap, is administered internally, and is supposed to possess highly nutritive properties. It has been employed in cases of deafness, and in diseases of the throat. By some it is used to preserve collodion plates in a state of sensitiveness for many days.

Glycerine has many important uses in the arts. The use of it as a soap, *glycerine soap*, is now familiar to all. It may be used for preserving articles of food, especially such as require to be kept moist, as fruits and the like, in tin cases. Meat is said to keep well in glycerine, and preserve its flavour. It is recommended to modellers for keeping their clay moist. In the *Technologist*, January 1858, a process of madder-dyeing with the aid of glycerine is described. It has been much used in printing processes, especially, for printing receipt and postage stamps. Vasseurs and Houbigant patented an application of glycerine. They dilute it with four or five times its weight of water; with this, paper is moistened, and it retains its moist condition for any length of time. It may be introduced into the paper pulp, or it may be mixed with the ink. In either case copies can be readily taken by pressure. Glycerine never freezes; it is therefore recommended as a lubricant for delicate machinery, and it has been used for floating ships' compasses, as it will not solidify in cold climates, or evaporate in hot ones.

Amongst other purposes to which glycerine has been applied, it has been substituted for lard, as a basis for ointments, by forming a 'plasma' of glycerine and starch. Fifty grains of the *Tous-les-mois* starch are to be rubbed with one ounce of glycerine, and the mixture heated to 240° for a few minutes, or till it becomes translucent. See Watts's 'Dictionary of Chemistry.'

Klever has estimated the solubilities of a number of substances in glycerine. The following are his results:—At the ordinary temperature 100 parts of glycerine dissolve

98 parts of	Carbonate of soda.
60 ,,	Borate of soda.
50 ,,	Arseniate of potash.
50 ,,	Arseniate of soda.
50 ,,	Chloride of zinc.
50 ,,	Tannin.
50 ,,	Urea.
40 ,,	Alum.
40 ,,	Iodide of potassium.
40 ,,	Iodide of zinc.
35 ,,	Sulphate of zinc.
33 ,,	Sulphate of atropine.
33 ,,	Cyanide of potassium.
30 ,,	Sulphate of copper.
27 ,,	Cyanide of mercury.
25 ,,	Bromide of potassium.
25 ,,	Protosulphate of iron.
22·5 ,,	Sulphate of strychnine.
20 ,,	Acetate of morphine.
20 ,,	Acetate of lead.
20 ,,	Arsenious acid.
20 ,,	Carbonate of ammonia.
20 ,,	Chlorate of soda.
20 ,,	Hydrochlorate of ammonia.
20 ,,	Hydrochlorate of morphia.
16 parts of	Lactate of protoxide of iron.
15 ,,	Oxalic acid.
10 ,,	Acetate of copper.
10 ,,	Benzoic acid.
10 ,,	Boracic acid.
10 ,,	Chloride of barium.
8 ,,	Bicarbonate of soda.
8 ,,	Tartrate of iron.
7·5 ,,	Bichloride of mercury.
6·7 ,,	Sulphate of cinchonine.
5·5 ,,	Tartar emetic.
5 ,,	Polysulphuret of calcium.
4 ,,	Nitrate of strychnine.
3·5 ,,	Chlorate of potash.
3 ,,	Atropine.
2·25 ,,	Brucine.
1·90 ,,	Iodine.
1 ,,	Veratrine.
0·50 ,,	Cinchonine.
0·50 ,,	Quinine.
0·45 ,,	Morphine.
0·25 ,,	Tannate of quinine.
0·25 ,,	Strychnine.
0·20 ,,	Phosphorus.
0·10 ,,	Sulphur.

GLYCERINE, NITRO. See Nitro-Glycerine.

GLYOXILINE. See Explosive Agents.

GLYPHOGRAPHY. A process introduced some years since to cheapen wood-engraving. A metal plate was covered with a thick etching-ground, and an etching made through to the metal in the usual manner. Several coats of ink were then applied by means of a small composition roller. This adheres only to the varnish. When the hollows are deep enough, the plate is placed in connection with a voltaic battery, and copper is deposited in the usual way; the result being a plate with the drawing in relief. See Electro-Metallurgy.

GNEISS may be called stratified, or, by those who object to that term, foliated granite, being formed of the same materials as granite, namely, felspar, quartz, and mica.—*Lyell.*

Gneiss might indeed, in its purest and most typical form, be termed schistose granite, consisting, like granite, of felspar, quartz, and mica; but having those minerals arranged in layers or plates, rather than in a confused aggregation of crystals.—*Jukes.*

In whatever state of aggregation the particles of gneiss may have been originally deposited, we know now that it is a hard, tough, crystalline rock, exhibiting curved and twisted lines of stratification, and composed in the main of quartz, felspar, mica, and hornblende. Mineralogically speaking, it differs from the granite rocks with which it is associated chiefly in this, that while the crystals of quartz, felspar, &c., are distinct and entire in granite, in gneiss they are broken, water-worn, and confusedly aggregated. Hence the general belief is, that gneiss or gneissose rocks are but the particles of granite weathered and worn, carried down by streams and rivers, and deposited in the seas of that early period.—*Page.*

GOAF. The waste space left by working a seam of coal, often filled in with refuse sometimes called GOB.

GOBBIN or **GOAFFIN.** The refuse left behind in working coal, and thrown into the goaf.

GOBELIN MANUFACTORY. This establishment, which has long been celebrated for its tapestry, took its name from the brothers Gobelin. Giles Gobelin, a dyer at Paris, in the time of Francis I., had found out an improvement in the then usual scarlet dye; and as he had remarked that the water of the rivulet Bièvre, in the suburbs of St. Marceau, was excellent for his art, he erected on it a large dye-house, which, out of ridicule, was called *Folie-Gobelins* (*Rabelais.*) About this period a Flemish painter, whom same name Peter Koek, and others Kloek, and who had travelled a long time in the East, established, and continued to his death in 1550, a manufactory for dyeing scarlet cloth by an improved process. Through the means of Colbert, minister of Louis XIV., one of the Gobelins learned the process used for preparing the German scarlet dye from one Gluck, whom some consider to be Gulich (who was said to have learned to dye scarlet from one Kuffelar, a dyer at Leyden), and others as Kloek; and the Parisian scarlet dye soon rose into so great repute that the populace imagined that Gobelin had acquired the art from the devil. It is known that Louis XIV., by the advice of Colbert, purchased Gobelin's building from his successors in 1667, and transformed it into a palace, to which he gave the name of *Hôtel Royal des Gobelins,* and which he assigned for the use of first-rate artists, particularly painters, jewellers, weavers of tapestry, and others.—*Beckmann.*

The national manufactory is now alone remarkable for its production in textile manufacture of some of the finest works of art; and not only does it excel in the high character of its designs, but also in the brilliancy and permanence of its *colours.*

GOITRE-STICKS. The stems of the *Sargassum bacciferum,* supposed by some to be useful in curing goître, by virtue of the iodine which they contain.

GOLD. (Eng. and Ger.; *Or,* Fr.) This metal is distinguished by its splendid yellow colour; its great density = 19·3, compared to water 1·0; its pre-eminent ductility and malleability, whence it can be beaten into leaves only 1-282,000th of an inch thick; and its insolubility in any acid menstruum, except the mixture of muriatic and nitric acids, called *aqua regia*—because gold was deemed by the alchemists to be the king of minerals—or in solutions of chlorine.

Gold is almost always found in the metallic state, frequently crystallised in the cube, and its derivative forms.

Mr. J. Arthur Phillips, in his work on 'The Mining and Metallurgy of Gold and Silver,' gives the following modes of occurrence of gold:—

'*Native gold.*—An alloy of gold and silver, associated with small quantities of copper, iron, and other metals.

'*Palladium gold.*—Gold and palladium; porpezite.

'*Rhodium gold.*—Gold and rhodium.

'*Gold-amalgam.*—A native amalgam of gold and mercury.

'*Sylvanite,* or Graphic Tellurium.—An ore, being a telluride of gold and silver.

'*Nagyagite.*—An ore; telluride of lead, containing gold, silver, and copper.'

In addition to these, gold is found associated with copper and iron pyrites; whether in chemical combination, or simply existing in mechanical mixture, does not appear to have been satisfactorily determined.

Native gold is almost always associated with silver. A few examples will show how this native alloy varies.

The *Electrum* of Pliny was not probably found native, although it is often stated to have been so. It seems to have been an alloy, containing at least 20 per cent. of silver.

	Gold	Silver
Transylvanian gold:		
Vöröspatak	60·49	38·74
South American gold:		
Antioquia	64·93	35·07
Marmato	73·45	26·48
British Columbian gold:		
Stephen's Creek	79·50	19·70

	Gold	Silver
Welsh gold:		
Welsh Gold-mining Co.	76·40	22·70
Scotch gold:		
Sutherland	79·22	20·78
Wanlock Head	86·60	12·39
Californian gold:		
Mariposa	81·00	18·70
Russian gold:		
Boruschkoi	83·85	16·15
Australian gold:		
South Australia	87·78	6·07
African gold:		
Ashantee	90·055	9·940

Gold occurs in threads of various sizes, twisted and interlaced into a chain of minute octahedral crystals; as also in spangled or rounded grains, which, when of a certain magnitude, are called *pepitas.* The small grains are not fragments broken from a greater mass; but they show by their flattened ovoid shape, and their rounded outline, that this is their original state. Humboldt states that the largest *pepita* known was one found in Peru weighing about 12 kilogrammes (26½ lbs. avoird.); but masses have been quoted in the province of Quito which weighed nearly four times as much. Some of the 'nuggets' from Australia have greatly exceeded this. The specific gravity of native gold varies from 13·3 to 17·7.

The mineral formations in which this metal occurs are the crystalline primitive rocks, the compact transition rocks, the trachytic and trap rocks, and alluvial grounds. Sir Roderick Murchison says, in a chapter *On the Original Formation of Gold,* in his 'Siluria':—

'We may first proceed to consider the nature and limits of the rich gold-bearing rocks, and then offer proofs that the chief auriferous wealth, as derived from them, occurs in superficial detritus. Appealing to the structure of the different mountains, which at former periods have afforded, or still afford, any notable amount of gold, we find in all a general agreement. Whether, referring to past history, we cast our eyes to the countries watered by the sources of the Golden Tagus, to the Phrygia and Thrace of the Greeks and Romans, to the Bohemia of the Middle Ages, to tracts in Britain which were worked in old times, and are now either abandoned, or very slightly productive, or to those chains in America and Australia, which, previously unsearched, have in our times proved so rich, we invariably find the same constants in nature. In all these lands, gold has been imparted abundantly to the ancient rocks only, whose order and succession we have traced, or their associated eruptive rocks. Sometimes, however, it is also shown to be diffused through the body of such rocks, whether of igneous or of aqueous origin. The stratified rocks of the highest antiquity, such as the oldest gneiss and quartz rocks (like those, for example, of Scandinavia and the Northern Highlands of Scotland), have very seldom borne gold; but the sedimentary accumulations which followed, or the Silurian, Devonian, and Carboniferous (particularly the first of these three) have been the deposits which, in the tracts where they have undergone a metamorphosis or change of structure by the influence of igneous agency, or other causes, have been the *chief* sources whence gold has been derived.'

Gold is usually either disseminated through the rocks, often in extreme minuteness, or spread out in thin plates or grains on their surface, or, lastly, implanted in their cavities, under the shape of filaments or aborescent crystallisation. The minerals composing gold-bearing veins are either quartz, calcspar, or sulphate of baryta. The ores that accompany the gold in these veins are chiefly iron pyrites, copper pyrites, galena, blende, and mispickel (arsenical pyrites).

In the ores called auriferous pyrites, this metal occurs generally in an invisible form; but though invisible in the fresh pyrites, the gold becomes visible by its decomposition; as the hydrated oxide of iron allows the native gold particles to shine forth on their reddish-brown ground, even when the precious metal may constitute only the five-millionth part of its weight, as at the Rammelsberg in the Hartz. In that state it has been extracted with profit; most frequently by amalgamation with mercury, proving that the gold was in the native state, and not in that of a sulphuret. The iron pyrites of Wicklow and of some of our English mines, contain gold. After the sulphur of the ore has been separated in the process of manufacturing sulphuric acid, the residuary mass, called 'sulphur-cake,' is roasted with common salt. This is thrown into hot water, the copper which is present is dissolved as chloride of copper. The silver present has been converted by the roasting process into a chloride; this is dissolved out with a strong brine, from which the silver is precipitated by zinc. The silver cake obtained in this way is sold from prices varying from 6*s.* to 10*s.* the ounce, the additional sum, above 5*s.* 6*d.* the ounce for pure silver, being given for the gold it contains. See PYRITES.

Principal Gold Mines.

Gold exists in the primitive strata, disseminated in small grains, spangles, and crystals. Brazil affords a remarkable example of this species of gold mine. Beds of granular quartz, or micaceous specular iron, in the Sierra of Cocäes, 12 leagues beyond Villa Rica, which form a portion of a mica-slate district, include a great quantity of native gold in spangles, which in this ferruginous rock replace mica.

The auriferous ores of Hungary and Transylvania, composed of tellurium, silver pyrites, or sulphide of silver, and native gold, lie in masses or veins in a rock of trachyte, or in a decomposed felspar subordinate to it. Such is the locality of the gold ore of Königsberg, of Telkebanya, between Eperies and Tokay in Hungary, and probably that of the gold ores of Kapnick, Felsöbanya, &c., in Transylvania; an arrangement nearly the same with what occurs in Equatorial America. The auriferous veins of Guanaxuato, of Real del Monte, of Villalpando, are similar to those of Schemnitz in Hungary, as to magnitude, relative position, the nature of the ores they include, and of the rocks they traverse. Breislak and Hacquet have described the gold mines of Transylvania as situated in the crater of an ancient volcano. The trachytes which, in some districts, form the principal portions of the rocks including gold, are regarded as of igneous or volcanic origin.

It would seem, however, that the primary source of the gold is not in these rocks, but rather in the syenites and greenstone-porphyries, which in Hungary and Transylvania are rich in great auriferous deposits; for gold has never been found in the trachyte of the Euganean mountains, of the mountains of the Vicentin, or those of the Auvergne; all of which are superposed upon granite rocks.

If it be true that the ancients worked mines of gold in the island of Ischia, it would be another example, and a very remarkable one, of the presence of this metal in trachytes of an origin evidently volcanic.

Gold, from whatever rocks derived, is common in the alluvial deposits near the primitive rocks just described. It is found disseminated in the siliceous, argillaceous, and ferruginous sands of certain plains and rivers, especially in their re-entering angles, at the season of low water, and after storms and temporary floods. It has been supposed that the gold found in the beds of rivers has been torn out by the waters from the veins and primitive rocks, which they traverse. This opinion, suggested at first by Delius, and supported by Deborn, Guettard, Robitant, Balbo, &c., appears to be founded upon just observations: 1. The soil of these plains contains frequently, at a certain depth, and in several spots, spangles of gold, separable by washing. 2. The beds of the auriferous rivers and streamlets contain more gold after storms of rain upon the plains than in any other circumstances. 3. It happens almost always that gold is found among the sands of rivers only in a very circumscribed space. Thus it is known that the Orco contains no gold, except from Pont to its junction with the Po. The Ticino affords gold only below the Lago Maggiore, and consequently far from the primitive mountains, after traversing a lake, where its course is slackened, and into which whatsoever is carried down from these mountains must have been deposited. The Rhine gives more gold near Strasburg than near Basle, though the latter be much closer to the mountains. The sands of the Danube do not contain a grain of gold, while this river runs in a mountainous region; that is, from the frontiers of the bishopric of Passau to Efferding; but its sands become auriferous in the plains below. The same thing is true of the Ems; the sands of the upper portion of this river, as it flows among the mountains of Styria, include no gold; but from its entrance into the plain at Steyer, till its embouchure in the Danube, its sands become auriferous, and are even rich enough to be washed with profit.

The greater part of the auriferous sands in Europe, Asia, Africa, and America, are black or red, and consequently ferruginous; a remarkable circumstance in the geological position of alluvial gold. M. Napione supposes that the gold of these ferruginous grounds is due to the decomposition of auriferous pyrites. The auriferous sand occurring in Hungary almost always in the neighbourhood of the beds of *lignite*, and the petrified wood covered with gold grains, found buried at a depth of 55 yards in clay, in the mine of Vöröspatak near Abrabanya in Transylvania, might lead us to presume that the epoch of the formation of the auriferous alluvia is not remote from that of the lignites. The same association of gold ore and fossil wood occurs in South America, at Moco. Near the village of Lloro have been discovered, at a depth of 20 feet, large trunks of petrified trees, surrounded with fragments of trap rocks interspersed with spangles of gold and platinum. But the alluvial soil affords likewise all the characters of the basaltic rocks; thus in France, the Cèze and the Gardon, auriferous rivers, where they afford most gold, flow over ground apparently derived from the destruction of the trap rocks, which occur *in situ* higher up the country. This fact had struck Réaumur, and this celebrated observer had remarked that the sand which more immediately accompanies the gold spangles in most rivers, and particularly in the Rhone and the Rhine, is composed, like that of Ceylon and Expailly, of black protoxide of iron and small grains of rubies, corundum, hyacinth, &c. Titanium has been observed more recently. It has, lastly, been remarked that the gold of alluvial formations is purer than that extracted from rocks.

Spain anciently possessed mines of gold in regular veins, especially in the province of Asturias; but the richness of the Mexican mines caused them to be neglected. Julius Cæsar is said to have paid his enormous debts, and have added largely to the Roman treasury, from the wealth which he derived from the Spanish mines. The Tagus, and some other streams of that country, were said to roll over golden sands. France contains no workable gold mines; but it presents in several of its rivers auriferous sands. There are some gold mines in Piedmont; particularly the veins of auriferous pyrites of Macugnagna, at the foot of Monte Rosa, lying in a mountain of gneiss; and although they do not contain 10 or 11 grains of gold in a hundred-weight, they have long defrayed the expense of working them. On the southern slope of the Pennine Alps, from the Simplon and Monte Rosa to the valley of Aoste, several auriferous districts and rivers occur. Such are the torrent Evenson, which has afforded much gold by washing; the Orco, in its passage from the Pont to the Po: the reddish grounds over which this little river runs for several miles, and the hills in the neighbourhood of Chivasso, contain gold spangles in considerable quantity.

In the county of Wicklow, in Ireland, in the year 1796, some fine specimens of gold were found,—one mass weighing twenty-two ounces. The gold is found in the *débris* of the valley at the base of Croghan-Kinshela; and it would appear to be derived from the granite of that mountain, or the hornblendic greenstones by which it is traversed. Messrs. Weaver and Mills, however, prosecuted extensive mine-workings in search of the source of the gold without any success. As we have already stated, the pyrites of Wicklow contains gold, but no auriferous veins have been discovered. In Cornwall gold has been found in the tin-streams of Carnon vale, in the Pentuan stream works at Menaccan, and some few other spots; and some of the quartz veins traversing the slate have been found to contain gold. Many of the gossans of the copper lodes are known to have gold in them; but it is only in a few rare instances that the precious metal has been separated.

In Devonshire, near North Molton,—at the Britannia and at the Poltsmore mine,—gold has been found in small quantities, associated with the minerals of the district; but it has never paid the cost of obtaining it. In Scotland also gold has been found. Pennant says: 'In the reigns of James IV. and V. vast wealth was procured in the Lead Hills, from the gold washed from the mountains; in the reign of the latter not less than the value of 300,000*l.* sterling.' We are told that in another locality a piece of gold weighing thirty ounces was found; but we cannot find any good authority for this statement. The gold-bearing districts of Scotland are described at p. 698.

The Gold Mines of North Wales having acquired a large share of attention, it has been thought desirable to insert the following notice from the pen of a gentleman who has most industriously investigated the quartz lodes of Merionethshire.

In North Wales, the older slaty rocks are auriferous. Professor Ramsay has examined and described the district, and especially the mineral and quartz veins of Cwm-eisen-isaf and Dol-y-frwynog, which contain gold. At Gogofau, not far from Llandovery, the Romans worked for gold, the remains of their workings being still to be discovered. Gogofau has been described by Mr. W. Warington Smyth in the 'Memoirs of the Geological Survey.'

The existence of gold in the British Isles was known at a very remote period of history, and it is certain that many adventurers, in crazy craft, came to this country in search of metallic wealth. Julius Cæsar, probably, invaded these islands more for the acquisition of supposed riches than the conquest of a rude and barbarous people. This opinion is strengthened, if not confirmed, by the expression of Galgacus, whilst attacking the Caledonians, 'Britain produces gold, silver, and other metals, the booty of victory.'[1]

A celebrated 'Triad' makes three Welsh chieftains the enviable possessors of *golden cars*, and Meyrick reasonably infers from this, that gold mines were worked by the Welsh (*Cymri*), at a very early period.[2]

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[1] 'Fert Britannia aurum et argentum et alia metalla, pretium victoriæ; gignit et oceanus margarita sed subfusca et liventia.'—Tacitus, *Vita Agricolæ*, cap. xii.

[2] 'History and Antiquities of the County of Cardiganshire.' 1810.

The style of the golden weapons, torques, bracelets, &c., that have been found at various times is very simple, and quite unlike the style of ornamentation of the early Christian period; it is therefore naturally inferred that they belonged to a time long anterior to that.

It is, however, certain that the Romans actually discovered gold in Wales, and wrought it too: for independently of the statement of Tacitus, just quoted, there are evidences, plenty, of Roman mine-works where gold must have been the principal, if not the sole object of exploration. One of the most remarkable is Gogofau, in Caermarthenshire.[1] This gold-mine is situate on the banks of the Cothy, and forms part of the grounds of Dolau-Cothy. Here a quartz-lode has been 'worked open to the day,' and levels driven 170 feet through the slate. The officers of the Geological Survey discovered gold here, and a *metallurgical workshop.* Amongst other things a beautiful gold necklace was found, which is now in the possession of Mrs. Johnnes, the wife of the gentleman to whom the property belongs. Other instances might be cited, in proof of the former existence of gold in tolerably large quantities in many parts of these islands.[2]

Strabo coincides with Tacitus, as to the precious metals: but Cæsar makes no mention of gold and silver. Cicero (B.C. 106) says: 'In Britannia nihil esse audio neque auri neque argenti,'[3] and, in another Epistle (ad Attic.) he says, 'it was well known that not a single grain of silver could be found in the island.'[4] The statements of Cicero do not, however, tally with subsequent history, and are contradicted by Camden and other modern authorities. Probably there is not, and never was, gold and silver enough discovered in Britain to be, as Tacitus thought, 'the price of victory;' yet the comparative scarcity of precious stones at the time would tend to pre-induce a desire to possess in quantity the next best representatives of value, the precious and the baser metals.

Cimboline, prince of the Trinobantes, had a coinage of gold. This was supposed to be made of British gold, obtained in Essex, but the Essex gold mine is exceedingly problematical.

An idea appears constantly to have prevailed that the gold of this country was by no means of insignificant quantity or value. The 'avarice of kings' and the exigencies of State, as soon as possible, and as a matter of course, laid claim not only to all the gold and silver found, but to all the baser metals as well. These pretensions were, however, subsequently abandoned, and the Crown was divested of all rights in minerals, except gold and silver; these precious metals being retained, as it was said, 'for the purposes of coinage, and to support the dignity of the Crown.'[5] That great legal authority, Sir Edward Coke, laid down the law, 'that *veyns* of gold and silver in the grounds of subjects belong to the king by his prerogative, for they are *Royall* mines,'[6] and the Justices and Barons in the 'Great Case of Mines' (1568) unanimously agreed,[7] 'That by the law, all mines of gold and silver within the realm, whether in the lands of the queen or her subjects, belong to the queen by prerogative, with liberty to dig and carry it away.' And so firmly was the prerogative of the Crown thus established, that it was agreed that a royal mine could not be severed from the Crown; but the judges overruled this. The only doubt existing in the time of Elizabeth was whether, if gold and silver were found intermixed with the baser metals, the whole became a royal mine.

Some contended that any quantity of gold or silver so found was sufficient, whilst others held the opinion that the gold and silver must exceed in value the other metals; but the judges decided that even where the gold or silver in a mine of base metals in the land of a subject was of less value than the base metal, the mere circumstance of its existence makes it a royal mine. The uncertainty of the law, on this decision, caused general distrust, and destroyed to a great extent this kind of enterprise; therefore, in the first year of William and Mary an act was passed (cap. 30.) wherein it was declared that no mine of copper, tin, iron, or lead, shall hereafter be adjudged a royal mine, although gold or silver might be extracted out of the same. This provision, also, was soon considered insufficient, and in the fifth year of William and Mary, an act was passed (cap. 6.) entitled 'An Act to prevent Disputes and Controversies concerning Royal Mines,' wherein it was enacted, that all persons, being subjects of the crown of England, owners of mines within the kingdom of England, dominion of

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[1] 'Note on the Gogofau or Ogofau Mine, near Pumpsant in Caermarthenshire.' By W. W. Smyth, M.A., 'Memoirs of the Geological Survey of the United Kingdom.'

[2] See 'Lectures on Gold,' delivered in the Museum of Practical Geology.

[3] *Epist. ad Famil.*

[4] Sir John Pettus, *Fodinæ Regales.*

[5] Plowden, 338. Black. 'Com.,' Stephens's edit. 1858, vol. ii. p. 556.

[6] 'Inst.' 132; 2 'Inst.' 576, 1861.

[7] See 'The Law relating to Mines, Minerals and Quarries in Great Britain and Ireland.' By Arundel Rogers, Esq.

Wales, or Berwick-upon-Tweed, wherein there is copper, tin, iron, or lead, may enjoy &c. the same, notwithstanding said mines may be pretended, or claimed to be, royal mines. But by the 2nd statute, the Crown, or any other person claiming royal mines under the Crown, has the option of purchasing said ores before removal, other than tin ore, in the counties of Cornwall and Devon, upon payment of a price fixed by the said act, viz. copper 13*l.*; tin, 2*l.*; iron, 2*l.*; and lead, 9*l.* per ton. By the 35 Geo. III. c. 134, the right of preemption which is given to the Crown, and those claiming under the Crown, so far as relates to lead, can only be claimed upon payment of 25*l.* per ton instead of 9*l.* as previously fixed.

From this it would appear—1. That the right of preemption given to the Crown is limited to copper, iron, and lead, wheresoever found, and to tin to be found in England, other than in Cornwall and Devon, if such ores contain gold or silver. 2. That the rights of the Crown to all mines where gold and silver exist intermixed with any substance whatever other than copper, iron, lead, or tin, remain unaffected by either of the statutes of William and Mary. 3. That the rights of the subject to all mines of copper, lead, and tin, even if gold or silver is found therewith, is confirmed by the said statutes, subject only to the right of preemption just stated.[1] But, if any other auriferous ones be discovered, it will be difficult to determine the respective rights of the Crown and the subject to such a mine, unless the 'Great Case of Mines' should be adopted in favour of the Crown. Under any circumstances there is no provision made for such a discovery. Independently of this, the law is not settled, that pure gold and silver, *wherever found*, are the absolute property of the Crown. It is, however, not a little remarkable, that the Crown has *no right of entry* upon private lands to search for its own; nor has it ever exercised its right of preemption as regards lead ore containing silver. But, since the gold discoveries in Wales in 1854, the practice of the office of Woods and Forests has been nearly as follows, viz.:—

1. Where the gold is found in combination with other metals, the *whole* of which, with the necessary easements for working, *are* vested in the Crown, the Crown deals with the case *in the same manner as an ordinary licence to search for minerals*; viz., 30*l.* per annum minimum rent, and one-twelfth royalty on the gold.

2. Where the gold is found in combination with the minerals specified in the acts of William and Mary, and which are *not* vested in the Crown; the Crown *proposes to accept a royalty in lieu of the right of preemption.*

3. Where the gold is found in a virgin state, or secreted in rocks, and not in combination with the ores and minerals specified in those acts, or land where the minerals are *not* vested in the Crown—the Crown requires the parties *to take a licence on payment of a nominal annual rent, and a royalty upon the gold raised.*

The Clogau (Welsh gold) mines are at present working under a royalty to the Crown. There is no mine working under the second. The Castell Carn Dochan mine, on the property of Sir Watkin W. Wynn, Bart. is not working. It is obvious, as a general rule, that the terms exacted by the Crown are far too burdensome to encourage persons in this kind of adventure. It is thought that if the Crown would consent to impose a small annual rental, and, say, a royalty of five per cent. on the net *profits*, it would be paid readily, explorations would be made to a larger extent by private individuals, and the Crown would be a gainer from lands, upon which it has no right of entry to realise its own.

In *England*, gold has been said on very doubtful evidence to exist in quantities of commercial value in the following counties: viz., Cornwall, Devon, Somerset, Gloucester, Worcester, Salop, Bedford, Derby, Chester, Lancaster, Westmoreland, Cumberland, Northumberland, Durham, and York. The tin-streams of Cornwall have yielded a little, and very small quantities of gold have been found in North Devon, especially near North Molton.

In *Scotland*, it has been found in the following counties: viz., Sutherland, Aberdeen, Fife, Perth, Stirling, Linlithgow, Lanark, Dumfries, Ayr, Selkirk, and Kirkcudbright. Lanarkshire is said by Pennant to have yielded 130,000 ounces.

In *Ireland*, the gold-bearing countries are Londonderry, Antrim, Wicklow,[2] Wexford, and Kildare. A nugget weighing 22 ounces was found in Wicklow, and said to be the largest ever found in Europe.[3]

In *Wales*, the known gold-producing counties are Carnarvon, Flint, Cardigan, Caermarthen, Pembroke, and Merioneth. Until recently Cardiganshire, probably, has rendered more service to the State, and profit to the explorers by the production

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[1] Rogers *v.* Brenton, 10 Q. B. 49.

[2] See Smyth, 'On the Mines of Wicklow.' 'Memoirs, Geol. Survey of Great Britain.'

[3] British Gold, with especial reference to the Gold Mines of Merionethshire.' By R. Hunt, F.R.S. 'Quarterly Journal of Science,' 1865.

of gold than any other Welsh county, although Sir H. Middleton, while ostensibly working for *silver* in the time of Charles I. and his 'most loyal chemist and mineralogist Thomas Bushell,' did not leave on record all their knowledge respecting Welsh *gold* and its associated minerals.[1] But within the last few years, Merionethshire has taken golden honours, sufficient, at least, to make them noteworthy. Hence an especial reference to the gold-mines of that county.

There are several claimants for the honour of having been the earliest of the Welsh gold-finders of later times. Mr. O'Niell, in 1836, is said to have found it at Cae Mawr, and Mr. James Harvey, afterwards, at Berthllwyd. Captain Roberts says he discovered it before either. But, undoubtedly, Mr. Arthur Dean must be allowed to take the lead. In 1843, Mr. Dean discovered some rich gold ores at Cwmheisian, and boldly stated, in the face of national disbelief, that 'a complete system of auriferous veins existed throughout the whole of the Snowdonian or Lower Silurian formations of North Wales.'[2]

Mr. Dean, and after him Mr. Clement, worked about 500 tons of the Cwmheisian minerals, and obtained at the rate of more than half an ounce of gold to the ton. The proprietor Mr. Bruin was unable to carry on the works, and then the gold question slumbered until ten years afterwards, when at the Clogau mine, a pile of 'poor copper ore' was found. This grass-grown refuse was carefully examined by Mr. J. C. Goodman of Dolgelley, who discovered that it really contained less of copper than of gold. Some of the stones, weighing several pounds, had gold disseminated throughout. In one beautiful specimen, now in the possession of Mr. Readwin, there is the mark of a boring-iron, which has passed through the solid gold. Some of this 'poor copper-ore' was put to the test, and Mr. Goodman obtained 14½ ozs. of gold from 100 lbs. weight. A stone weighing 3 cwts. was taken from the lode, stamped and sold for *5s.* per pound weight.[3]

Such novel and interesting facts as these naturally gave rise to the most extravagant expectations as to the ultimate value of the discovery. The quartz-lodes of the district were indiscriminately attacked by the hammers of ardent gold-seekers. The Crown got a small harvest by granting gold-licences, and a good deal of rash speculation and loss was the necessary consequence.

Much weight was attached to Sir Roderick Murchison's Australian prophecy, and that recorded opinion of his, in the *Siluria*, that 'the most usual position of gold is in quartzose vein-stones that traverse altered palæozoic states, frequently near their junction with eruptive rocks, whether of igneous or of aqueous origin.' And it was a remarkable coincidence, that the gold at Clogau was found at the junction of the Cambrian sandstones, and the Lingula flags of the Lower Silurian rocks near an eruptive bar of porphyritic greenstone.

About this time, a valuable paper appeared in the *Transactions* of the Geological Society of London, in which the geology of this problematical district is described at great length by Professor Ramsay, Director-General of the Geological Survey of Great Britain.[4]

Of course, this became an era of joint-stock speculation, and companies were formed for working Clogau, Cwmheisian, and other mines, containing, or supposed to contain, auriferous minerals.

Eventually, the rich Clogau mine became the subject of two Chancery suits, and the other mines, one after another, collapsed, after ineffectual attempts to extract gold by various means of amalgamation.

The vexed question again lay dormant until 1857 and 1858, when the Vigra and Clogau mines were sold by order of the Court of Chancery, and bought by Messrs. Readwin and Williams, who, with a few other enterprising persons, set them to work for copper and gold, with Captain John Parry as mine agent. The Dolfrwynog, the Prince of Wales, and the Cambrian mines were also started to work for gold.

About this time Professor Ramsay, referring to the discoveries of gold at these mines, wrote, 'In the Ural Mountains, South Australia, Canada, and other parts of the world, gold occurs in rocks of the same general age, and apparently under the same circumstances.'[5] There was, however, nothing of importance discovered until the end of 1852, when several bunches of gold were found in the forebreast of a shallow level, on the south side of the gold-lode at Clogau, and early in the following year, the gold appeared associated with yellow copper-ore and telluric bismuth,

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[1] 'The Gold Discoveries of Merioneth.' By T. A. Readwin, F.G.S. 1860.

[2] 'Notice respecting the discovery of Gold Ores in Merionethshire, North Wales.' By Arthur Dean, C.E. 'British Association Reports,' 1844.

[3] On the Occurrence of Gold in Merionethshire.' By T. A. Readwin, F.G.S. 'British Association Reports,' 1861.

[4] 'On the Geology of the Gold-bearing District of Merionethshire.' By Professor A. C. Ramsay.

[5] Monograph in the 'Geologist,' February 1858. By Professor Ramsay, F.R.S., &c.

generally diffused throughout the lode, and visible from the top of the level to the bottom.

This discovery was the signal for the resuscitation of several dormant gold mines, and the creation of a host of new schemes, all of which have suspended operations, with the exception of Clogau, which has recently been resumed (1874), not so much on account of the paucity of gold, as of the difficulty of extracting it by the means at command.

The neighbourhoods of Dolgelly and Bala at present appear to comprise all the known Merioneth gold mines, and the following particulars thereof are chiefly compiled from papers on this subject in the *British Association Reports*, by Mr. Readwin, who treats of them as being in the Dolgelley and Bala districts.[1] According to this writer, the Dolgelley district is bounded by the river Mawddach, the Great Llawllech or Merioneth anticlinal range, and the river Camlan, to which may be added a continuation of three or four miles further NE., following the junction of the Cambrian sandstones, and the Lower Silurian Lingula-flags of the Geological Survey, and included in the Survey-maps, 75 S.E., and the upper part of 59 N.E.

The geological features of the district are now too well known to require more than a repetition of the general statement, that the rocks are of the Cambrian and Lower Silurian series, forming a junction in a very sinuous course, and frequently cut through by narrow bands of porphyritic greenstone. The district is full of faults, and the metalliferous veins have a general bearing N.E. and S.W., with an underlie to the N.

There is a continuation of rocks of precisely the same character for a distance of six or seven miles, running in a N.E. direction to Castell Carn Dochan in the Bala district.[2]

It may be here noted, that during the various explorations, gold has been found associated with iron-pyrites, blende, galena, heavy spar, copper-pyrites, clay-slate, Silurian shale, quartz, telluric bismuth or tetradymite, carbonate of lime, talcose-schist, iron oxide, grey copper-ore, phosphate and arsenate of lead, and orpiment. It has also been found in *pepitas*, and nearly pure in quartz, or alloyed with from 10 to 20 per cent of silver,[3] and a little copper and platinum.

A number of specimens were exhibited at the International Exhibition 1862, by the Vigra and Clogau Company, and by Mr. T. A. Readwin.

For convenience, the Dolgelley district is divided into the following sections: viz., Cwmheisian, Maesgwm, Berthllwydd, Cambrian, Clogau and Vigra, situate severally in the parishes of Llanfachreth, Trawsfynydd, Llanddwye, Llaneltyd, and Llanaber.

Cwmheisian Section. At the Cwmheisian mine, there is a junction of fourteen lodes nearly forty feet wide, and the whole mass of lode itself is said to contain gold in small quantities. Blende is occasionally found very rich in gold. Mr. Dean extracted 148 ounces from 157½ tons, and Mr. Clement 170 ounces from 300 tons. Some specimens have been found by Mr. Readwin, containing as much as 87 ounces to the ton. Almost all the known methods of gold-extraction have been tried at this mine; but owing to the great preponderance of sulphides in the mineral, none of them succeeded. This is a fact to be regretted, since immense quantities of the lode itself could be actually quarried, and there is plenty of water-power to dress it inexpensively.

Gwynfynydd mine is opposite Cwmheisian. Galena from this mine, though poor in silver, assayed 8 ounces of gold to the ton. But some blende in quartz associated with arsenate and phosphate of lead and orpiment, produced gold at the rate of 156 ounces to the ton. Half-a-ton of mineral from the '*Doubt-me-not-lode*,' gave by amalgamation 9 oz. 13 dwts. of gold. There were a large number of lodes opened on, varying in width from 1 to 66 feet, and gold could be seen in the lodes at the surface in different places. This mine is at an elevation of 300 to 400 feet, and has belonging to it the beautiful waterfalls Pistil-y-Cain and the Rhiadwr Mawddach, one with a fall of 123 feet, the other 87; so that, commanding the water of the two rivers, the Cain and the Mawddach, with an unlimited quantity of mineral procurable by means of adits, large operations, at comparatively little cost, might be carried on here, with the prospect of making a small quantity of gold pay a profit.

From about five tons of lode stuff, 15¾ ounces of gold were extracted in 1862.

Gold has also been found in small quantities at the Hafod-y-Bach, Penmaur, Buarthrae, Doledd, and Penbryn. *Tyddynglwadis* mine is situate exactly at the junc-

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[1] See 'British Association Reports,' 1861, 1862, 1863, 1864, and 1865. Papers by T. A. Readwin, F.G.S.

[2] See Maps, Geological Survey,' 74 S.W. and 75 S.E.

[3] List of gold ores from Merionethshire, exhibited by Mr. Readwin, International Exhibition, 1862.

tion of the Cambrian and Lower Silurian rocks, which is distinctly observable at the top of Pistil-y-Cain. This mining sett is full of faults. The galena averages 50 to 60 ounces of silver to the ton, and from 6 to 11 dwts. of gold. A small string of silver-ore was found in the deep level in 1865, containing 2,200 ounces of silver to the ton. Some moss pulled from the river side had specks of gold attached to its roots. It was at this mine that Mr. Readwin first discovered a fragment of the trilobite *Paradoxides*, many more fragments of which were found afterwards by Mr. E. Williamson and Mr. Plant. At *Cefndwddwr*, adjoining Tyddynglwadis, visible gold is found apparently dispersed throughout a fine quartz lode, and has yielded eight ounces of gold from five tons of lode-stuff.

At the old *Dolfrwynog* mine, specimens of decomposed quartz contained over 400 ounces of gold to the ton. One stone weighing fifteen ounces gave twelve ounces of gold.

The *North Dolfrwynog* lode-stuff has assayed 30 dwts. to the ton. About 100 tons of alluvium from the east bank of the Mawddach, on this mine, was washed with the object of ascertaining whether the particles of gold found therein increased in size from the surface to the bed-rock. This was found to be the case. Several ounces of gold were obtained, and it is probable that the whole side of this mountain contains gold, which might be profitably worked on the erection of machinery to economise labour.

West Dolfrwynog adjoins, and is marked on the Ordnance Map 'Turf Copper mine,' from the fact that a few years ago, about 10,000*l*. worth of copper was sold from the ashes of peat, there burnt for the purpose. Quartz and yellow and grey copper-ore from this place have assayed six ounces of gold to the ton, and along the east bank of the Mawddach the alluvium resembles that of North Dolfrwynog.

The *Maesgwm Section* is on the western side of the Trawsfynydd road, nearly opposite Tyddynglwadis, and includes Maesgwm, Ganllwydd, and Coed-cy-fair. At *Ganllwydd* in 1863, several masses of quartz were found to contain visible gold.

The *Berthllwydd Section* includes Berthllwydd (Cefn coch), Goitref, Caegwernog, Caemawr, Benrhos, Tynybenrhos, and Glasdir. *Berthllwydd mine* is on the summit of the lofty ridge behind Tynygroes, on the Trawsfynydd road from Dolgelley. Here is the 'grand champion lode' of the district, which runs N.N.E. and S.S.W. for about a mile. Auriferous blende and galena are the chief products, and some very rich specimens have been found, as well as pepitas and fine gold-dust in the alluvium. The Welsh Gold Company, to whom this and Goitref and Caegwernog mines belong, obtained, in 1866, 666 ounces of gold from 1,982 tons of lode-stuff. At *Caemawr* adjoining, the first visible gold of the district is said to have been discovered. The lode-stuff assays 9 to 11 dwts. of gold to the ton, and the alluvium also contains gold. At *Benrhos* and *Tynybenrhos*, the alluvium contains specks of gold. At *Glasdir*, above 15,000*l*. worth of copper-ore has been quarried, and extraordinarily rich specimens of auriferous copper- and iron-pyrites have been found. At the *Garn* mine rich gold-quartz has been found by Captain John Parry.

The *Cambrian Section* includes the Cambrian mine, the Princess Alice, Moel Ispri, and Cwmabseifian mines, which extend along the road from Dolgelley to Barmouth. The *Cambrian* mine produced some very rich blende; containing at the rate of 350 ounces to the ton. Specimens of Silurian shale have been found with the appearance of having been electro-gilt. This mine has been thoroughly explored, but without producing gold sufficient to pay for working. At Cwmabseifian, Moel Ispri, and the Princess Alice mines, gold has been found in the quartzose lode-stuff, associated with blende and iron-pyrites. At the *Prince of Wales* mine, a few large blocks of blende have been broken, containing at the rate of 456 ounces of gold to the ton. From 5 cwts. of lode-stuff, 17 oz. of gold were obtained. The preponderance of sulphides here renders amalgamation at present wholly inoperative.

The Mawddach river has been examined from Cwmheisian to Llaneltyd Bridge by Mr. Readwin, who found grain-gold with platin-iridium in small quantities. Gold was also previously found by the Hon. F. Walpole and Sir Augustus Webster. Professor Ramsay suggests, with much reason, the possibility of gold being found in the 'marine drift.'

The *Clogau Section* includes Clogau, Garthgell, Hendreforian, West Clogau, Maesclawdd, and Tynycornel.

'The Clogau, St. David, No. 1 mine is certainly the richest gold mine ever worked in the British Islands, and may compare favourably with the quartz-reefs of Australia. Taking this lode as a type of the neighbourhood, it will be well to describe it.

'The lode has an average bearing 15° N.E., and is intersected by a very powerful cross-course bearing 30° N.W. and dipping slightly S.W. The lode traverses beds of indurated Silurian clay-slate, which are interstratified with thick beds of greenstone. There is also a large greenstone dyke, which is traversed by a portion of the lode for a length of about 60 fathoms, until they are intersected by a great cross-course. Behind this cross-course the lode is extremely rich in gold. It should be stated that the lode is composed almost entirely of quartz, with here and there some carbonate of lime. Throughout the quartz, yellow copper-ore is in small quantities, disseminated, as well as gold. Where the gold is most abundant, telluric bismuth in fine silvery-white grains is generally present, and an opinion prevails that whenever that mineral is met with, gold is near at hand. It was commonly supposed that gold is only to be found near the surface. Mr. Dean has favoured us with some notes on this point, which are exceedingly important if all the conditions have been correctly observed. Without comment Mr. Dean's own words are given:—

'The opaque white quartz floors, which are comparatively poor in gold, alternate with others of a greenish white colour, very dense, and of a shining conchoidal fracture; the latter are the rich gold-bearing floors: we have, therefore, alternate rich and poor floors. From the dip of the floors the deposits of gold appear individually to dip eastward, but, as the bands of clay-slate forming the walls of the lode below the greenstone dip westward down to the cross-course, the succession of bunches of gold in the alternate floors of greenish quartz follow the dip of the clay-slate. This is an important point in the relation to the recurrence of rich deposits of gold in depth below the present bottom. This quotation sufficiently indicates the hypothesis that, with a recurrence of the same conditions in depth, rich, or perhaps richer, deposits of gold may be met with. There is a very close analogy between gold and tin. It was an opinion, held with much obstinacy for a long period, that tin would never be found deep in the earth. Experience has now proved the fallacy of this, for the most abundant deposits of tin are now worked at depths of between 200 and 300 fathoms.'[1]

The most remarkable item in Welsh gold statistics is the fact of 9,363 ounces of gold having been obtained from less than 40 tons of quartz. It was here that the 'poor copper-ore' referred to was found, from which some 20 tons had been picked, sampled, and sold as 'copper-ore,' and probably several thousand ounces of gold were contained in it. The St. Helen smelters made no report, but offered an advance of 5*s.* a ton for as much more of it as could be raised. A discovery of rich gold in another lode has been made of a similar character to the St. David's lode.

The gold obtained from this mine to May 30, 1866, was 11,663 ounces from 5,063 tons of quartz, averaging about 42 dwts. to the ton. At *Garthgell* the St. David's lode having been thrown, could not be re-traced; at *Tynycornel* this lode has not been opened on; and at *Hendreforian* and *Maesclawdd*, the lode-stuff is auriferous, but few explorations were made. At *West Clogau* (Llachfraith), 1 ton of lode-stuff gave 17 dwts. of gold. Some profitless work has been done here. Mr. Readwin found visible gold here at nearly 150 fathoms lower than the upper level at St. David's lode.

The *Vigra Section* includes Vigra, Tyddyndu, North Vigra, Nantcoch, Wellington, Fachynys, and Llanaber mines. At all these mines the lode-stuff is auriferous, but it has not been found of commercial value.

Bala district. The gold discovery here was chiefly confined to Castell Carn Dochan mine, near the beautiful lake of Bala (Llyn Tegid) on land belonging to Sir Watkin W. Wynn, Bart.

This mine is situated about five miles from Bala, on the N.W. side of the turnpike-road leading to Dolgelley, and about two miles from the village of Llanuwchllyn. There is one auriferous lode very remarkable. It runs nearly N.E. and S.W. and has a dip to the S. This lode is exposed to view for about twelve fathoms, showing specks of gold nearly the whole distance. The lode-stuff is generally free from sulphides. The quartz, unlike Merioneth quartz, resembles that at Clunes, in Australia, and some boulders have been broken up and found to contain specks of visible gold throughout. The upper portion of the lode appears to have slipped over the lower, and down the face of the hill, leaving behind it a record of where it had been, in characters of gold. Large loose masses of greenstone have been found, having incrustations of quartz spangled with gold. The *débris* yielded gold of equal value with the lode-stuff. This mine has been properly opened, improved reduction machinery erected, and has made regular monthly returns of gold. The

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[1] 'British Gold, with especial reference to the Gold Mines of Merionethshire,' By Robert Hunt, F.R.S. 'Quarterly Journal of Science,' 1865.

quantity of lode-stuff reduced was 3,500 tons, and the gold produced 1,606 ounces (Dec. 1866).

A brief reference to the various modes of gold-extraction used in Merionethshire will be interesting.

In the earlier stages of gold-mining (1843) at Cwmheisian, the ore was finely stamped and concentrated by washing apparatus, and afterwards amalgamated by *arrastras*, or smelted. After this the gold-mines lay dormant until the Californian discoveries in 1853, when rich gold-quartz was at the same time found at Clogau. The amalgamating machines of Britten and Berdan were then introduced; but it was soon found impossible to work auriferous sulphides indiscriminately by trituration in quicksilver. A good deal, however, of the rich ore at Clogau was treated in this way with very profitable results; but in some cases rich ore yielded only a small portion of its contained gold, and generally much gold was found in the 'tailings.' Washing apparatus was erected at the Cambrian mine, on the Marmata plan, but with no satisfactory results. This method was improved by Mr. Belt at the Prince of Wales mine by the addition of shaking tables, and troughs of quicksilver; but the process only partly succeeded, there being very little gold in the stuff, and that little associated constantly with heavy sulphides. Barrel amalgamation had been previously tried here, at a great cost, but failed for the same reason.

A mode of triturating the ores in quicksilver, having all the vices of Berdan, and none of its virtues, was introduced at the old Dolfrwynog mine, together with an old plan of forcing the ground ore through a body of quicksilver. It is not publicly known whether this proceeding was a total failure or not. No gold appears to have been accounted for, although some of the richest ore in Wales was found at this mine at the time. The sluice-box principle was adopted at North Dolfrwynog on the alluvium, with the object referred to; but it was discovered that much more gold was lost than gained by the pursuit, and it was discontinued.

Mitchell's amalgamators were next introduced at Cwmheisian, which were vessels of quicksilver, through which the ground mineral was intended to be forced by means of a succession of screws, in order that the particles of gold might be presented to the greatest possible surface of quicksilver, and for a long period of time. This plan was found utterly useless with minerals containing sulphides in excess.

Sloper's plan of separating the metals by specific gravity was also tried on the alluvium by the patentee, at North Dolfrwynog, and failed.

In 1862, Mr. Mosheimer introduced his machinery at Garthgell, Clogau, Cwmheisian, and Castell Carn Dochan. After stamping the minerals in the usual way, Mr. Mosheimer at that time proposed to grind them in his horizontal pans with heated quicksilver, adding chemicals, occasionally, for the purpose of liberating the gold from the sulphides. At Cwmheisian this plan was useless because of the sulphides. The quicksilver constantly became 'sick,' dragged in strings after the mullers, and lost apparently all its natural affinity for gold. Only a very small portion of the contained gold was extracted, and the rest left in the tailings.

At Clogau and Castell Carn Dochan, however, the results were very different. The quartz-lodes at these mines are comparatively free from sulphides, there is a little bismuth sulphide found at Clogau, and a little iron sulphide at Castell Carn Dochan—but at both mines, without heating the quicksilver, or introducing chemicals, the gold was practically all extracted; from the richer minerals by Britten's and from the bulk by Mosheimer's machines.

In 1866 the gold reduction works at Castell Carn Dochan were the most complete. There, the ore-stuff as it comes from the mine was taken direct to the stamps, reduced very fine, the metalliferous particles concentrated on blankets, the blanket sand further concentrated, and then amalgamated in the 'Mosheimers' and 'Brittens;' all the waste water, &c. passed into shaking boxes containing quicksilver, and thence through a series of Hungarian pans, such as are used at Schemnitz. The gold here being all free, scarcely a trace of gold was ever found in the tailings. The same plan, with some modifications, was successfully used at Clogau.

A long experience has now elicited that sulphides of lead, arsenic, antimony, zinc, bismuth. &c. will frequently so envelope small particles of gold with a film or tarnish, that quicksilver cannot touch it. The trituration of such sulphides in quicksilver generally destroys its fluidity and amalgamating power, or reduces it to minute globules, which, owing to the tarnish they also have by some means acquired, refuse to re-unite, and are consequently washed away with the tailings. Hence a great loss of both quicksilver and gold, because generally these minute globules, so washed away, are really gold-amalgam. Again, the quicksilver of commerce is very seldom in a fit state for complete amalgamation, even of free gold, and it is well known also that the slightest quantity of greasy matter will tarnish and render useless, until re-distillation, a large quantity of quicksilver.

In 1865, Mr. W. Crookes, F.R.S. the discoverer of thallium, proposed to remedy the evils attendant on the trituration of sulphides and arsenides in quicksilver by the introduction of sodium.

In laboratory-experiments the effects of Mr. Crookes' discovery were very conspicuous:—

1. A small quantity of sodium-amalgam added to ordinary quicksilver greatly increased its brightness and affinity for gold.

2. A bar of gold completely covered with tallow dipped into quicksilver containing sodium was instantly amalgamated.

3. Greasy ('sickened') quicksilver was instantly made bright and clear by the addition of the sodium-amalgam.

4. 'Floured' quicksilver immediately collected on the introduction of a small quantity of the sodium-amalgam.

These novel facts induced Mr. Readwin to put the invention to a crucial test, at the Gwynfynydd mine. He thus writes: 'I have made a series of experimental trials, which have given me some confidence in the utility of Mr. Crookes' invention. I selected for trial such auriferous minerals from Cwmheisian, Tyddynglwadis, North Dolfrwynog, Gwynfynydd, Glasdir, and other places, that have always heretofore either sickened the quicksilver, or refused to give up, by amalgamation, the gold known to be contained in them by analysis. In no one instance, during these experiments (some of which were of 48 hours' duration), did I derange the quicksilver in operation, and in every instance I obtained gold from it, on distillation. The quantities of gold, of course, varied with the samples of minerals treated, and did not in any way affect the value of the experiments, the object of which was chiefly to prove whether heterogeneous minerals could be treated by this method, when they would not submit to other tried methods. The most remarkable, and in my opinion the most important, effect of the sodium, was seen in an experiment on 56 lbs. of mixed minerals from one of the Gwynfynydd lodes. The gold in this lode is often visible and associated with sulphides of lead, zinc, and arsenic. Quicksilver in its ordinary state was first used in this experiment, which shortly became completely 'sickened' by yellow sulphide of arsenic (orpiment), and completely coated the 'Britten' machine with *arsenic-amalgam.* Whilst in this state, sodium-amalgam of about 3 per cent. strength was introduced; the quicksilver soon recovered its fluidity, became quite bright and clear, and on distillation yielded nearly two ounces of gold. I made many other experiments, and in practice I found that, although I was always able to obtain gold by the use of sodium when I could not obtain it otherwise, I discovered that an excess of sodium predisposed the quicksilver to take up other metals, to the partial exclusion of the one most particularly desired; but in all cases the quicksilver was kept quite bright and clear, and on washing out the machines, the subdivided particles were most rapidly re-united, a circumstance of itself of the greatest importance.[1]

Mr. Readwin believes that native lead exists to a considerable extent in some of the minerals, and he shows that the prevalence of galena, &c., is the greatest hindrance in amalgamation. If this be so, and the lead can be taken out of the concentrated ores before amalgamation without losing the gold and silver, the plan may possibly render amalgamation of the residue practicable. Mr. Peter Spence, of Manchester, proposed to calcine the sulphides containing galena till completely oxidised; a portion of the galena is thus converted into sulphate of lead, and a portion into oxide of lead. This oxide and sulphate of lead is then washed in a solution of carbonate of soda, and the sulphate is converted into a carbonate. The calcined ore is then put into a solution of caustic alkali, the mixture is stirred for a short time, the solution taken off, and more solution added whilst the oxide of lead remains; the various solutions added together are allowed to settle, and, when perfectly clear, drawn off into a vessel into which carbonic acid can be thrown into the solution and absorbed by it; as the carbonic acid becomes absorbed by the solution, the soda becomes carbonated, and *white lead* is deposited.

Mr. Spence undoubtedly can convert the sulphide into carbonate of lead, as he proposes, but the process has not in any way affected the value of auriferous and argentiferous minerals. Mr. Spence asserts positively that by his process the lead in any ores can be converted into white lead, leaving the residual and accidental products for after-treatment, according to their nature and value, and this in a rapid and inexpensive manner.

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[1] Since the above experiments were tried Mr. Crookes has improved his process, and thus avoids the ill effects of an excess of sodium; the improvements met the approval of Dr. W. Allen Miller and other high authorities.

As to the profitable working of auriferous minerals in Wales, Mr. Readwin writes:—

'After several years of experimental effort to work the gold-minerals to a profit, I am more fixed in my opinion than ever, notwithstanding the equivocal position the subject holds as a commercial pursuit, that gold-mining can and will be made remunerative, if certain essential and natural conditions prevail at the respective mines: first, there must be a large and continuous quantity of the auriferous mineral cheaply obtainable by means of adits and tramways; secondly, there must be efficient water-power available on the spot; thirdly, there must be no more cats about the premises than will catch mice. Under such circumstances, provided forty or fifty tons can be raised per diem, a quarter of an ounce of gold to the ton ought to pay all costs of reduction, and I think it would. Many of the difficulties of amalgamation can now be overcome, by the use of sodium or potassium, in some such way as patented by Mr. Crookes.'[1]

It remains to be proved whether, after Mr. Spence's process, the minerals can be further utilised. It seems reasonable to suppose this possible. If the ores containing sulphur are found in quantity, and concentrated so as to lessen the cost of transit, then calcined, the lead-sulphide converted into carbonate, the sulphur collected, the zinc-oxide (if any) made into spelter; the residual products thus obtained at an inconsiderable cost may contain the precious metals in quantity sufficiently valuable to amalgamate either with or without the use of sodium, as proposed by Mr. Crookes. At all events, another step appears to have been gained towards the solution of the problem, 'Can British gold be worked to a profit?'

The following returns of gold raised in Merionethshire were approximately correct up to the end of 1864:—

tons	cwts.	qrs.				oz.	dwts.	grs.
1	4	0	of gold-quartz from	River Mawddach	gave of gold	2	0	0
100	0	0	„	Alluvium	„	5	0	0
5	0	0	„	Cefndwddwr	„	8	0	0
5	1	3	„	Gwynfynydd	„	15	15	12
50	0	0	„	Cambrian	„	30	0	0
20	0	0	„	Prince of Wales	„	63	0	0
312	1	2	„	Dolfrwynog	„	167	5	5
50	0	0	„	Clogau (prior to 1860)	„	200	0	0
487	0	0	„	Cwmheisian	„	334	0	0
1,982	8	1	„	Cefn Coch (Welsh Gold Co.)		666	6	2
3,500	0	0	„	Castell Carn Dochan (June 30)		1,606	0	0
5,140	0	0	„	Clogau (since 1860)	„	11,850	0	0
11,652	14	6				14,947	6	19

The actual returns from these mines from 1861 to the end of 1870 have been as follow:—

Year	Weight			Value		
	ozs.	dwts.	grs.	£	*s.*	*d.*
1861	2,784	0	0	10,816	17	0
1862	5,299	1	12	20,390	15	5
1863	552	12	19	1,747	0	0
1864	2,887	0	0	9,991	0	0
1865	1,664	11	0	Value not given		
1866	742	16	10	„		
1867	1,520	6	21	„		
1868	435	14	28	„		
1869	Nil					
1870	191	0	0	„		

In 1874 explorations at Vigra and Clogau were again commenced.

The Gold-mines of Scotland.—The following remarks on the gold and gold-fields of Scotland are by Dr. W. Lauder Lindsay:—

'Before making general observations on the Scottish gold-fields, or comparing them, as regards their richness or extent, with those of other auriferous countries, which are

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[1] 'On the Recent Discovery of Gold at Gwyfynydd.' By T. A. Readwin, F.G.S. 'British Association Reports,' 1865.

better known, I propose giving briefly the principal results of my observations and inquiries at and concerning what I may safely denominate the Crawford or *Leadhills gold-field*, the whole of that moorland and hill-region of the southern highlands—Upper Clydesdale—the southern extremity of Lanarkshire, variously known as Crawford, or Crawford Moor, or Crawford-Lindsay, which includes the district now known as the Leadhills, and forms the watershed of the four great southern rivers (the Clyde, Nith, Tweed, and Annan), has repeatedly, and in various ways, proved to be more or less auriferous. Long prior to the modern system of "prospecting," some of the Leadhills valleys were the scene of the far-famed alluvial washings, under Sir Bevis Bulmer in 1578–92, and it was from the produce of such washings that the Scottish regalia were fashioned in 1542, and Kings James IV. and V.'s celebrated bonnet-pieces coined. Bulmer's chief washings are said to have been in the valley of the Elvan, and he is also represented as having washed the whole bed of the Glengonner water. But vestiges of ancient "diggins" are to be met with in many parts of the Leadhills district. For instance, I found the haugh or "flat" on the banks of the Glengonner water above Abington, and immediately below Glencaple Burn, covered with a series of quartz-like mounds, exactly resembling those with which I was familiar in the famous Gabriel's gully at Tuafoka in Otago, and which are said really to mark the site, or one of the sites, of Bulmer's celebrated workings. It was the gold-prospecting in this district, it is said, that led to the discovery of the lead, which has proved so much more permanent a source of prosperity to the district, to which it has, morever, given its distinctive modern name of late years; and at present gold is systematically collected by the Leadhill miners chiefly in certain localities, viz. in the Windgate or Windygate burn, in Langcleuch burn, in Bellgall burn, in the whole course of the Elvan and Glengonner, from the Clyde to their source. The gold occurs chiefly in the gravelly clay, locally known as "till," as this coats the flanks of all the Leadhills valleys; but it is also to be found in the shingle, gravels, or clays of the stream-beds. This gold is invariably what is known as "drift" or "alluvial" gold. There is no present local evidence of the existence of auriferous quartzites. But in 1803 the late Professor Traill of Edinburgh found gold in a vein of quartz *in situ* at Wanlock-Head. All the gold belonging to this district which I have seen is of a granular or nuggety character, and quite comparable with the usual produce of Otago, or other auriferous countries. Some of the "nuggets" found in former times, and preserved in the cabinets of local proprietors, are of very considerable size and value. The cabinet of the late Lord Hopetoun contains two: one of them weighing 2 lbs. 3 oz. = 27 oz. or 12,960 grs., which at the current price of gold in Australia, 4*l.* per ounce, is worth 108*l.*; collected, it is said, about 1502, prior to the systematic workings of Bulmer. The other, weighing 1 oz. 10 dwts., or 720 grs. The first would appear to be by far the largest mass of gold ever found in Scotland. Since, however, systematic gold-workings on a large scale were discontinued, the size of the Leadhills nuggets has been greatly smaller, the largest seldom now exceeding 2 or 3 grs., though they are frequently found of that size. Just previous to my visit, in the autumn of 1863, a nugget of 30 grs. had been found, and another single nugget, whose weight I failed to ascertain, sold for 25*s.* at Abington. More generally the gold occurs here as rough granules, coarser and larger than those constituting what could properly be called "dust," and of this considerable quantities are frequently collected in limited periods for special purposes, such as marriage-gifts, or jewellery, to or for the local proprietors. Thus, in a fortnight, in 1862, 975 grs. were collected for the Countess of Hopetoun; and on another occasion, 600 grs. in six weeks by thirty men at spare hours, fifteen working in the forenoon, and the other half in the afternoon. About Abington, in 1851, similar quantities were collected under similar circumstances to furnish marriage jewellery for Lady Colebrooke. Between May and October 1863, three miners, in the intervals of leisure from their usual work, collected for me 33 grs., which they found in the "till," about forty yards above the bed of the stream, half-way down the Langcleugh burn, between Leadhills and Elvanfoot: their charge was 20*s.*, that is, at the rate of about 15*l.* per ounce, or 7½*d.* per grain. During the last five years the price of crude gold in Australia and New Zealand has averaged from 3*l.* 17*s.* 6*d.* to 4*l.* per ounce, so that the Scottish diggers obtained for their produce nearly four times as much as the New Zealand or Australian diggers got for theirs. The price appears at first sight to be extremely and disproportionally high; but the cases are by no means parallel, for in the case of the Leadhills gold, the collection is made to meet the demands for cabinet specimens, or for jewellery materials under circumstances quite exceptional. The Leadhills miners collect their gold mostly to order; it is thus at once disposed of, and hence gold is seldom to be found there for sale, or only in very small quantity. On one occasion I was offered a sample of 140 to 160 grs. for 5*l.*; that is, at the rate at which I purchased my smaller sample, but the miners have rarely so much in their possession unsold. In the summer of 1862, by way of holiday work, the miners frequently collected quantities of 14 to 54 grs. The able-bodied Leadhills miner never, however, gives up his usual labour, at which he earns 15*s.* per week, for the more precarious gains to be derived from gold-finding. To gold-seeking he devotes only his spare hours, his holiday time, or his periods of sickness or debility. The price he generally more or less readily obtains for his gold varies necessarily with the demand and supply. Sometimes it rises to 7½*d.* per grain, or 15*l.* per ounce, sometimes it falls to 5*d.*, but the more common or average price is 6*d.* per grain, or 12*l.* per ounce, while the average market-price may be quoted at present at 4*l.* per ounce, or 2*d.* per grain. The director of the mines at Leadhills estimates gold-washing at these prices as only capable of yielding, at present wages, 3*d.* per day, while lead-mining gives upwards of 2*s.*, or more than eight times as much, with the great additional advantage of a certain or regular occupation.

'The Scottish gold-fields may be divided geographically or topographically into three: the Northern, Central, and Southern.

'1. The *Northern* comprises the greater part of the counties of Sutherland, Ross, Inverness, and Argyle, north of the Caledonian Canal. It occupies the longitudinal axis of the northern peninsula of Scotland, is second in size only to the Central area, and has yet almost entirely to be explored.

'2. The *Central* lies between the Caledonian Canal and the valley of the Tay; includes a great part of the shires of Inverness (southern half), Aberdeen, Banff. Kincardine, Perth, Forfar, Argyle, Stirling, and Dumbarton. It is by far the largest of the three areas, Like the Southern gold-field, it forms a transverse belt across Scotland, and much of it remains to be explored.

'3. The *Southern* comprises great part of Dumfries, Kirkcudbright, Wigtown, Ayr, Selkirk, Peebles, and Lanarkshire, and includes, more particularly, parts of the districts of Nithsdale, Annandale, Eskdale, Ettrickdale, Tweeddale, and Clydesdale, and the Lammermuirs (in Haddington and Berwick). It is the smallest of the three areas, but is the best known, and, so far as ascertained, the richest.

'At many localities throughout the area which I have assigned to the Scottish gold-fields, actual finds of gold have been made in recent or former times, and this is one of the strongest arguments for their thorough exploration. Of such gold-finds, the following will suffice as illustrations:—

'I. *Northern Gold-Field.* 1. *Sutherlandshire.*—Helmsdale water. A nugget found here in former times weighed 10 dwts., or 240 grs.

'II. *Central Gold-Field.* 1. *Perthshire.*—(A.) *Breadalbane,* area of Loch Tay, and head-waters of the Tay. A nugget found in former times weighed 2 oz., or 960 grs. Sir James Simpson tells me that he was shown a specimen of gold, with its matrix (quartz), by the late Marquis of Breadalbane, from Tyndrum. In 1861 Professor Tennent of London found gold in quartz, associated with iron-pyrites at Taymouth.

'(B.) *Upper Strathearn,* area of Loch Earn, and the head-waters of the Earn. Glen Lednoch (Ritchie); streams falling from the north into Loch Earn (Ritchie); Ardvoirlich (south side of Loch Earn.

'(C.) *Glenalmond* (Mercer); Glenquoich, and other valleys of the Grampians.

'2. *Forfarshire.*—Clova district, areas of Angus, Edzell, and Glenesk.

'3. *Aberdeenshire,* area of the Dee, Braemar, Invercauld, coast about Aberdeen, and in the sea-sand.

'In New Zealand, and other auriferous countries, gold is very commonly associated with *magnetic iron sand,* containing or not titanium, and other minerals, or with iron sulphides. It is of interest to know that the sands of the Dee, which consist, mainly, of the *débris* of granite and gneiss, contain considerable quantities of magnetic iron-sand and iserine, with which are associated smaller amounts of titanium, uranium, and arsenic. The gneiss of Braemar often contains *much* magnetite in place of mica (Nicol), while iron, or oxides, or sulphides, are common in all the schists and granite of Aberdeenshire (Nicol).

'4. *Argyleshire,* Dunoon.

'III. *Southern Gold-Field.* 1. Head-waters of the *Clyde,* including the Ech, Crawford Moor, or Leadhills district; Elvan water, Glengonner, Glencaple, Winloch, Short Cleuch, Lammington burn.

'2. Head-waters of the *Tweed*; Manor water, which flows north to the Tweed; Meggat water, which flows south to St. Mary's loch; other feeders of the Yarrow and Glengaber.

'There are traces of prospecting and digging in former days in Meggatt water valley, similar to those which occur in Leadhills. In the British Museum I saw two specimens of Tweeddale gold: the one nuggety, and in quartz, a very rich sample;

the other granular, rather than nuggety. Griffin prospected St. Mary's loch district, and found gold in dust or granules everywhere.

'3. Head-waters of the *Annan*, Moffatdale; streams falling into Moffat water; Hartfell range, about Dobbs Linn; several small finds of gold were made in the summer of 1863, and one small nugget, weighing about 6 grs., was exhibited in Moffat.'

Sutherland Diggings from 1867 *to* 1869. In 1867 it was noised abroad that gold was abundant in Sutherland, and for a period a considerable number of adventurers were found working, for gold, on the estates of the Duke of Sutherland.

The following are the only returns which have been obtained, as the result of the workings in this district:—

	ozs	dwt	grs		£	*s.*	*d.*
1868. Helmsdale: *Sutherland* . .	577	0	0	valued at	2,000	0	0
1869. Kildonan ,, . .	17	17	8½	,,	61	3	9

The monthly returns of gold from the diggers at Kildonan were declared as follow:—

1869.	ozs.	dwt.	grs.
April	5	8	2
May	3	11	17½
June	2	16	18
July	2	0	3
August	1	8	10
September	1	6	19
October	0	15	12
November	0	8	6
December	0	1	17
	17	17	8½

It is tolerably certain that some gold was obtained, which was not declared by the diggers; but the fact of all the works being abandoned proved that the gold found was insufficient to pay for the labour bestowed upon it. On April 20, 1869, Mr. J. F. Campbell, of Islay, wrote thus in his 'Something from "the Diggins" in Sutherland':—'The Sutherland "diggins" are now established and likely to be worked for some time to come. More than 280 men are paying a pound a month for leave to camp out and work like navvies in claims of 40 feet square; so that they must be earning wages or going crazy. If many men go away, more diggers arise daily, and gold is almost daily found at new spots. It is estimated that 6,000*l.* has been washed from the shingle of two small burns already.'

At Helmsdale, near the mouth of the river, and in the jaws of the glen, are more heaps of stuff like Brora moraines, and the Helmsdale leads back to Beinn Ormen and Clibric again. Gold has been found in burns, which come in from both sides of the Helmsdale strath, in burns which come from the south, and in those which come from the Caithness range on the north. The source of the gold has not yet been found in Helmsdale. The gold is in stuff sorted by modern burns, and it is now worked in watercourses which come down from the Caithness side of the Helmsdale glen. These are branch-burns, which arise amongst bare granite and Silurian rocks, and flow down the side of the main groove towards the main river. These branch-burns have done a good deal of digging and carving on their own account; they have done more than the main river; so they have worked longer. The Kildonan Burn has carved a trench in crystalline Silurian rock from the place where the chief diggings are now carried on down to the farmhouse. It is about 20 feet below the road; it is about 80 feet deep behind the new township, which has been christened Baile'-n-oir, or Golden Town. In this it is like other burns, and marks a gradual rise of land at this spot. Where the fall is rapid, this rock-groove is now washed clean, or left with a few large stones on the bottom. Above this bit of river-cutting is a 'flat,' in which a lot of rolled drift settled probably long before the rock-cut was deepened by the stream below the flat. The water in this 'flat' or 'creek' now meanders through rolled drift, washing it, carrying off the lighter parts and leaving big stones, heavy iron-sand, garnets, and gold. Little gold has been got out of the actual watercourse, but some was found there at first, and that find started the diggings. For about a mile, the whole of this water-worn drift is being turned over and washed in various contrivances, and every-one of these engines is worked on the same principle as the natural engine which washed and sorted this drift.

[1] Òr-méin=gold mine.

The simplest engine is the tin basin. A spadeful of stuff is turned in, and then the pan is dipped into water; the washer shakes the pan, and tosses up the mass; the stuff, being free to move, falls; and the heaviest stuff falls fastest. First, the mud floats away, and lastly, at the bottom of the pan, a small heavy stratum remains, in which a lucky man may find a speck or scale of yellow gold, or a nugget as big as the half of a split pea. The cradle acts on the same principle; so does Long Tom. Each is a contrivance for rocking or raking drift in flowing water with a still pool for the heavy ore to settle in. The long sluice, however, is the best imitation of the burn itself, and the long sluice does most work. It consists of a long wooden trough with a smooth bottom, ending in a bit of crossed grating like the floor of a boat. Beyond this is a longer trough to carry the water down to the burn. A small lead is made, and a small fall comes in at the head of this wooden model of a Highland strath.

Fig. 1116 represents the section of a 'claim' in the Kildonan Burn, drawn by J. F. Campbell, Esq., of Islay. Water-worn drift arranged by running water in a groove carved in the edges of disturbed metamorphosed bent beds of Silurian rocks. Most of the gold is found near the rock amongst the biggest stones, and in chinks of the rock.

1116

Gold in Europe.—There are auriferous sands in some rivers of Switzerland, as the Reuss and the Aar. In Germany no mine of gold is worked, except in the territory of Salzburg, amid the chain of mountains which separates the Tyrol and Carinthia.

The mines of Hungary and Transylvania are the only gold mines of any great importance in Europe; they are remarkable for their position, the peculiar metals that accompany them, and their product, estimated at about 1,430 pounds avoird. annually. The principal ones are in Hungary: 1, those of the Königsberg; the native gold is disseminated in ores of sulphuret of silver, which occur in small masses and in veins in a decomposing felspar rock, amid a conglomerate of pumice, constituting a portion of the trachytic formation; 2, those of Borson, Schemnitz; and 3, of Felsöbanya: ores also of auriferous sulphuret of silver occur in veins of syenite and greenstone-porphyry; 4, those of Telkebanya, to the south of Kaschau, are in a deposit of auriferous pyrites, amid trap rocks of the most recent formation.

In Transylvania the gold occurs in veins, often of great magnitude. These veins have no side plates or wall stones, but abut, without intermediate gangues, on the primitive rock. They consist of decomposing quartz, ferriferous limestone, heavy spar, fluor-spar, and sulphuret of silver. The name of Kapnik deserves notice, where the gold is associated with orpiment, and that of Vöröspatak in granite rocks; those of Offenbanya, Zalatna, and Nagy-Ag, where it is associated with tellurium. The last is in syenitic rock on the limits of the trachyte.

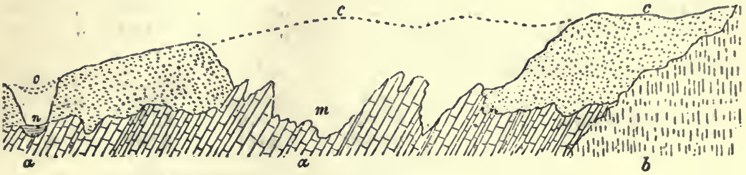
In Italy the only gold mines of importance are in the north of Piedmont. The principal mines are those of Vallanzasca, Val-Toppa, and Pestarena. In 1866 these mines produced 5,952 ounces of gold.

In Sweden, the mine of Edelfors in Småland may be mentioned, where the gold occurs native and in auriferous pyrites; the veins are a brown quartz, in a mountain of foliated hornstone.

In Siberia, native gold occurs in a hornstone at Schlangeberg or Zmeof, and at Zmeino-garsk in the Altai Mountains, accompanied with many other ores.

The gold mine of Beresow in the Ural Mountains has been long known, consisting of *partially-decomposed auriferous pyrites*, disseminated in a vein of greasy quartz. This is, according to Murchison, 'the only work at which subterranean mining in the solid rock is still practised; there the shaft traverses a mass of apparently metamorphosed and crystalline matrix, called "*beresite*," resembling a decomposed granite with veins of quartz, in which some gold is disseminated.' About 1820, a very rich deposit of native gold was discovered on the eastern side of the Ural Mountains, disseminated at some yards deep in an argillaceous loam, and accompanied with the *débris* of rocks which usually compose the auriferous alluvial soils, as greenstone, serpentine, peroxide of iron, corundum, &c. The rivers of this district possess auriferous sands.

1117



At the Soimanofsk mines, south of Miask, great piles of ancient drift or gravel having been removed for the extraction of gold, the eroded edges of highly-inclined crystalline limestones have been exposed, which, from being much nearer the centre of the chain than the above, are probably of Silurian or Devonian age (*fig.* 1117). It is from the adjacent eruptive serpentinous masses and slaty rocks *b*, that the gold shingle *c*, (usually most auriferous near the surface of the abraded rock *a*) has been derived. The tops of the highly-inclined beds *a* are in fact rounded off, and the interstices between them worn into holes and cavities, as if by very powerful action of water. Now here, as at Berezovsk, mammoth-remains have been found. They were lodged in the lowest part of the excavation, at the spot marked *m*, and at about fifty feet beneath the original surface of overlying coarse gravel *c*, before it was removed by the workmen from the vacant space under the dotted line. The feeble influence of the streams *n*, which now flow, in excavating even the loose shingle is seen at the spot marked *o*, the bed of the rivulet having been lowered by *human* labour from its natural level *o*, to that marked *n*, for the convenience of the diggers.—*Murchison.*

It was from the infillings of one of the gravelly depressions between the elevations, south of Miask, that the largest lump of solid gold was found, of which at that time (1824) there was any record. The 'pepita' weighs ninety-six pounds troy, and is still exhibited in the museum of the Imperial School of Mines at St. Petersburg.

The quantity of gold raised in Russia during five years was as follows:—

1847	1700 poods.
1848	1660 „
1849	1530 „
1850	1490 „
1851	1266 „
	7646

Equal to about 296,932 lbs. troy in five years.—*Lectures on Gold, R. Hunt.*

The total production of gold in Russia has of late years been as follows:—

(*Ural, Eastern and Western Siberia*).

	Government Mines. oz.	Private Mines. oz.	Total oz.
1860	111,984	665,986	767,870
1861	105,959	643,159	749,118
1862	102,857	640,885	752,742

	oz.
1847 (the year of maximum production)	961,616
1852 (the year of minimum production)	720,320

The largest single production in 1860 was from the Aurora Steam Works on the

Ojne river, in the Jenesei district, belonging to Messrs. Rjasonow & Co., namely, 54,020 ounces, $\frac{880}{1000}$ to $\frac{890}{1000}$ fine; or at 3*l.* 15*s.* 6*d.* per ounce, value 203,925*l.* 10*s.*

	dwts.	grs.	
In 1823 the sands washed in the Beresow district yielded .	2	5·6	per ton.
1861 ,, ,, ,, ,, .	0	8·1	,,
1828 ,, Bogalousk (N. Ural) .	1	4·7	,,
1830 ,, ,, ,, ,, .	5	18·4	,,
1860 ,, ,, ,, ,, .	0	20·8	,,
1861 (first half year) ,, Mijask ,, ,, .	0	12·3	,,

The force employed was in 1860:—

	Men	Women.	Horses and Mules.	Steam-Engines.
W. and E. Siberia . . .	31,796	919	8,751	—
Ural	20,352	2,181	8,339	4
Total . . .	52,148	3,100	17,090	4

The average payments for royalties in the private mines is 7 per cent.

In Erman's 'Archives' we find that in the year 1851, the gold of the Uralian washing and amalgamation-works produced 332 poods; the Nertschinsk works, 67 poods; the remaining West and East Siberian washings, 1,107 poods; the produce of the Altai Mountains and of Nertschinsk Siberian works, 39 poods; making 1,546 poods.

Gold in Asia.—In Asia, and especially in its southern districts, there are many mines, streams, rivers, and wastes which contain this metal. The Pactolus, a small river of Lydia, rolled over such golden sands, that it was supposed to constitute the origin of the wealth of Crœsus. But these deposits are now poor and forgotten. Japan, Formosa, Ceylon, Java, Sumatra, Borneo, the Philippines, and some other islands of the Indian Archipelago, are rich in gold streams. Those of Borneo are worked by the Chinese in an alluvial soil, on the western coast, at the foot of a chain of volcanic mountains.

Little or no gold comes into Europe from Asia, because its servile inhabitants place their fortune in treasure, and love to hoard up that precious metal.

Numerous gold mines occur on the two slopes of the chain of the Cailas mountains in the Oundès, a province of Little Thibet. The gold lies in quartz veins, which traverse a very crumbling reddish granite. Gold is said to have been found in tolerable abundance in the sands of some of the tributaries to the Amour river.

Gold in Africa.—Africa was, with Spain, the source of the greater portion of the gold possessed by the ancients. The gold which Africa still brings into the market is always in dust, showing that the metal is obtained by washing the alluvial soils. None of it is collected in the north of that continent; three or four districts only are remarkable for the quantity of gold they produce.

The first mines are those of Kordofan, between Darfour and Abyssinia. The negroes transport the gold in quills of the ostrich or vulture. These mines seem to have been known to the ancients, who considered Ethiopia to abound in gold. Herodotus relates that the king of that country exhibited to the ambassadors of Cambyses all their prisoners bound with golden chains.

The second and chief exploitation of gold-dust is to the south of the great desert of Zaara, in the western part of Africa, from the mouth of the Senegal to the Cape of Palms. The gold occurs in spangles, chiefly near the surface of the earth, in the beds of rivulets, and always in a ferruginous earth. In some places the negroes dig pits in the soil to a depth of about 40 feet, unsupported by any props: they do not follow any vein, nor do they construct a gallery; but by repeated washings they separate the gold from the earthy matters.

The same district furnishes also the greater part of what is carried to Morocco, Fez, and Algiers, by the caravans which go from Timbuctoo on the Niger, across the great desert of Zaara. The gold which arrives by Sennaar at Cairo and Alexandria comes from the same quarter. From Mungo Park's description, it appears that the gold spangles are found usually in a ferruginous small gravel, buried under rolled pebbles.

The third spot in Africa where gold is collected is on the south-east coast, between the twenty-fifth and the twenty-second degree of south latitude, opposite to Madagascar, in the county of Sofala. Some persons think that this was the kingdom of Ophir, whence Solomon obtained his gold.

The following account of the Transvaal gold-fields is abstracted from a communication to the 'Times,' dated December 28, 1873:—

'It may be well to explain the origin of the word "Transvaal," which, simple as it is, may not at first be apparent. The "Vaal," which in Boer lingo means, as I understand, "grey," is a magnificent river, taking its rise hundreds of miles away in the Drakensberg mountains, and falling into the still larger and longer Orange river. Some dissatisfied Boers, seceded from the Cape Colony and elsewhere, resolved to form a "South African Republic," took possession of the country on the other side of the Vaal, and christened it the "Transvaal." The river in winter is fordable at frequent intervals; but when in summer it rises, or, as the Boers say, "comes down," it forms a rapid broad stream, very dangerous to cross.

'Before this letter can reach England you will have published some accounts of the finds of gold, so that I shall not now go much into detail. The latest news is that 13¼ lbs. were found in one hour in a single claim, the largest nugget weighing 4 lbs. This gold was brought down to Kimberley diamond-fields on Christmas-day, and has excited much admiration. I know, as facts, of the following finds:—In one week a party dug out 15 oz.; next week, 34 oz.; another party 100 oz. in four weeks, and so on. The present number of diggers is about 500, but fully 800 are now on their road from Kimberley. I have private letters from "Pilgrim's Rest"—the latest rush—also of a highly satisfactory character.

'Now, what does all this portend? The clearest way, perhaps, will be to summarize the situation, as follows:—

'The whole of South Africa is at this moment in a highly prosperous condition; money is plentiful, and, generally speaking, everyone is well off. Our banks, our steamship-companies are flourishing; and although this may not prove to be a second Australia or California, there is a pretty firm conviction that South Africa is likely to be a very important appendage to Her Majesty's empire. Every one is in good spirits, because it is felt that, at length, South Africa will be better appreciated and understood at home.

'The present diggings at Leydenburg are situated in about lat. 25° S., long. 31° E.; Cape Town is in lat. 34° S., long. 18° E.; Algoa Bay, lat. 34° S., long. 26° E.; Natal, lat. 30° S., long. 31° E. So that the approximate distances from the three ports are: Cape Town, 1,200 miles; Algoa Bay, 800 miles; Natal, 400 miles. Delagoa Bay must for the present be left out of the question, until the French arbitration is settled, and until a railway is run through the unhealthy belt.'

It is well known that gold is also found in Western Africa, along the 'Gold Coast,' and some fine examples of nuggets of this gold were brought to this country at the conclusion of the late war (1874). The nuggets were, in most cases, associated with a ferruginous earth, giving a ruddy colour to the gold. An analysis of this Ashantee gold, by Professor Church, is given on p. 687.

Gold in South America.—During the last, and the commencement of the present century, the richest gold mines were found in South America. It occurs there principally in spangles among the alluvial earths, and in the beds of rivers; more rarely in veins.

The gold of Mexico is in a great measure contained in the argentiferous veins, so numerous in that country, whose principal localities are mentioned under the article SILVER. The silver of the argentiferous ores of Guanaxuato contains one 360th of its weight of gold; the annual product of the mines being valued at from 2,640 to 3,300 pounds avoirdupois.

Oaxaco contains the only auriferous veins explored as gold mines in Mexico; they traverse the rocks of gneiss and mica slate.

All the rivers of the province of Caracas, to ten degrees north of the line, flow over golden sands.

Peru is not rich in gold ores. In the provinces of Huailas and Pataz, this metal is mined in veins of greasy quartz, variegated with red ferruginous spots, which traverse primitive rocks. The mines called *pacos de oro*, consist of ores of iron and copper oxides, containing a great quantity of gold.

Most of the gold furnished by New Grenada (New Columbia) is the product of washings established in alluvial grounds. The gold exists in spangles and in grains, disseminated among fragments of greenstone and porphyry. At Choco, along with the gold and platinum, hyacinths, zircons, and titanium occur. There has been found, as already stated, in the auriferous localities, large trunks of petrified trees. The gold of Antioquia is 20 carats fine, that of Choco 21, and the largest lump or *pepita* of gold weighed about 27½ pounds avoirdupois. The gold of Chili also occurs in alluvial formations.

Brazil does not contain many gold mines, properly so called; for the veins containing the metal are seldom worked. Dr. Walsh says gold was first known to exist in the Brazils in 1543. The Indians made their fishing-hooks of it, and from them it was discovered that it was found in the beds of streams, brought down from the mountains.

But the first ore found by a white man in that country was in the year 1693; this discovery led to the colonisation of the Minas Geräes, and to all those evils resulting from 'the cursed lust of gold,' with details of which the history of South America abounds.

It was in the sands of the Mandi, a branch of the Rio Dolce, at Catapreta, that the auriferous ferruginous sands were first discovered in 1682. Since then they have been found almost everywhere at the foot of the immense chain of mountains, which runs nearly parallel with the coast, from the 5th degree south to the 30th. It is particularly near Villa Rica, in the environs of the village Cocäes, that the numerous washings for gold are established. The *pepitas* occur in different forms, often adhering to micaceous specular iron. But in the province of Minas Geräes, the gold occurs also in veins, in beds, and in grains, disseminated among the alluvial loams. It has been estimated in annual product, by several authors, at about 2,800 lbs. avoirdupois of fine metal.

Almost all the gold formerly brought into the market was from alluvial lands, and had been extracted by washing; but now numerous veins of auriferous quartz and deposits of auriferous pyrites are worked. The Morro Velho mine, belonging to the St. John del Rey Company, is perhaps the most important Brazilian gold mine.

Gold in North America.—Californian Gold Mines. The accident which first revealed the golden treasures of the soil of California is thus related by a writer in the 'Quarterly Review' for September 1852:—

Captain Suter, the first white man who had established himself in the district where the Americanos joins the Sacramento, having erected a saw-mill on the former river, whose tail-race turned out to be too narrow, took out the wheel, and let the water run freely off. A great body of earth having been carried away by the torrent, laid bare many shining yellow spangles, and on examination Mr. Marshall, his surveyor, picked up several little lumps of gold. He and Captain Suter then commenced a search together, and gathered an ounce of the ore from the sand without any difficulty; and with his knife the captain picked out a lump of an ounce and a half from the rock. A Kentuckian workman employed at the mill had espied their supposed secret discovery, and when, after a short absence, the gentlemen returned, he showed them a handful of the glittering dust. The captain hired a gang of fifty Indians, and set them to work. The news spread, but the announcement of the discovery was received with incredulity beyond the immediate neighbourhood. But presently, when large and continuous imports of gold from San Francisco placed the matter beyond doubt, there ensued such a stir in the States, as even in that go-ahead region is wholly without parallel: numbers of every age, and of every variety of occupation, pushed for the land of promise. Many were accompanied by their families, and most under the excitement of the hour overlooked their physical unfitness, and their inability to procure necessaries. The waters of the Humboldt, from their head to their 'sink,' a space of nearly 300 miles, are in the dry season strongly impregnated with alkali, and it was here that they first began to faint. Some died from thirst, others from ague, others fell beneath the burdens they attempted to carry when their last animal dropped into the putrid marsh, which grew thicker at every step. Beyond the 'sink' the diminished bands had to encounter sixty or seventy miles of desert, where not a blade of herbage grew, and not a drop of pure water could be procured; and those who pushed safely through this ordeal had still to ascend the icy slopes of Sierra Nevada, where the rigours of winter were added to all other difficulties. At different points, one being almost in sight of the golden land, overwearied groups had formed encampments, in case perhaps some help might reach them. It is to the credit of the settlers that, on hearing this, they strained their resources to the utmost to afford relief. Yet, when all was done, a sick, destitute, most wretched horde of stragglers was all that remained of the multitude who, full of hope and spirits, had commenced the prairie journey.

The development of the gold-fields of California has been so remarkable, that it appears necessary to devote some space to a consideration of the conditions under which the auriferous treasures are discovered. This cannot be better done than by quoting Professor Blake's remarks on the 'Geognosy of the Gold-Drift of California.'

With the exception of the diluvial strata, the whole geological formation of the Sierra range consists of igneous and metamorphic rocks; the former are mostly porphyritic in the lower hills, whilst higher up trachytic rocks are more frequently met with. The metamorphic rocks consist of micaceous schists, slates both talcose and micaceous, metamorphic sandstones and limestones, with occasional beds of conglomerate. The stratified rocks have been much displaced: it is rare to find them with a dip of less than 70°, and they are generally very nearly perpendicular. The strike of the beds in that section to which Professor Blake's observations have been confined (between the Stanislaus and Yuba rivers) is extremely uniform, being from 5° to 10°

W. of N. and E. of S. The extent of the diluvial deposits is commensurate, or nearly so, with that of the gold-bearing region, in that part of the country which he has examined. They are found in a belt of land from thirty to sixty miles broad, and running parallel with the axis of the range; and, from facts that he has ascertained from others, he states that he has no doubt but that they exist throughout all the gold-bearing region, both north and south. These diluvial deposits are met with as we advance towards the lower hills of the Sierra, extending frequently some miles into the plain. On ascending from the lower hills towards the mountains, the diluvial beds no longer occupy the same relative position: occasionally deposits of rounded stones can be found in the valleys and on the sides of the hills, but when this is the case, their origin can always be traced to deposits existing on the tops of the surrounding hills, from which they have been brought down by the action of the causes now at work. As we ascend towards the axis of the chain, these deposits become more extensive, and at a distance of twenty or thirty miles from the lower hills, they are found occupying the crests of almost all the highest ridges in the country; but besides being found on the crests of the ridges, where their extent frequently does not exceed a few yards in breadth, they are also met with covering the extensive elevated flats which exist on the benches between the different watercourses, forming continuous beds of some miles in extent, which are rarely interrupted by the protrusion of any of the older rocks. Where found in elevated positions, the lower hills and valleys are entirely free from them; frequently a large section of the country will be enclosed with two high ridges capped by deposits, and diverging from a common point; in the intervening space will be seen many secondary ridges, sometimes fifteen or eighteen hundred feet high, formed entirely of the older rocks, no traces of deposits being found on their surface, nor in the ravines that lead from them.

The depth of these deposits is extremely variable. Sometimes nothing more than a trace of them in the presence of a few round pebbles lying on the top of a ridge is found; the valleys and ravines in the neighbourhood containing their disintegrated elements in considerable quantities. In other instances, particularly where spread out over the elevated flats, they are of a moderate and pretty uniform thickness for a considerable distance, varying from two to three feet to a few inches, and this, too, in positions where the surface could not have been exposed to any great amount of denudation. They are again found many hundred feet in thickness, composed of superimposed strata of different mineralogical constitution, generally horizontal and conformable with each other.

The localities where the deposits are met with most extensively disclosed, and that have been worked, are at Nevada and at Mokelumne hill. At the former place they form the crest of a high mountain, called the Sugar-loaf, full 2,000 feet above the level of Deer Creek, the upper 600 feet being formed entirely of diluvial strata. At Mokelumne hill they are also 200 feet deep, forming here also the summit of a high and isolated mountain. The elements of which they are composed differ considerably in different localities, although there are through the whole series many points of resemblance. In the lower valleys and flats between the ranges of the lower hills, they appear to consist of beds of gravel, containing occasional boulders of quartz and the harder rocks. On the elevated flats higher up in the mountains, the surface of these deposits is generally covered by a reddish loam, mixed with small gravel; whilst reposing on the bed-rock, and a few inches above it, is found a stratum containing large boulders and gravel, the boulders being principally quartz. On the tops of the hills and the crests of the ridges, where they generally attain their greatest thickness, we find them composed of many distinct strata lying nearly horizontal and conformable with each other, and generally also with the surface of the underlying rocks. In these situations the most superficial stratum is composed of a mass of extremely hard conglomerate, containing principally trachytic rocks, imbedded in a hard argillaceous cement. It is this hard stratum that has undoubtedly preserved the underlying beds from the destructive influence which has so powerfully acted on the surrounding rocks.

At other points the whole series consists of conglomerates and soft friable sandstone. In the lower strata quartzose conglomerates, with an argillaceous cement, or loose quartzose gravel, always prevail, with large boulders of quartz, weighing frequently two or three tons, having their surface worn smooth and the angles rounded. The deposits of the heavier rocks have been formed on spots which were evidently lower than the level of the surrounding rocks; whilst on those parts which were higher at the time the deposits were formed, the higher trachytic rocks are found. As far as Professor Blake's researches have extended, the more quartzose conglomerates have been invariably found on the erupted rocks, whilst the stratified rocks which they had upheaved were only covered by the trachytic conglomerates. The pebbles of which these conglomerates are composed present specimens of all the harder rocks: metamorphic sandstones, clinkstone, trap, porphyries, and quartz, make up the larger part of the mass. They are all perfectly rounded, but in the lower deposits are so soft that, with the exception of the trap and quartz, they generally fall to pieces on exposure to the air. The strata, as before observed, are nearly horizontal and conformable; if they have any dip, it appears to have been owing to the slope of the surface of the rock on which they were deposited; in fact, no displacement seems to have taken place in this country since the time of their formation. They lie perfectly horizontal over the almost vertical edges of the upheaved slate-rocks.

As regards the mineral riches of these deposits, it would appear that gold is found wherever they exist. The ravines coming from the ridges on which they are found are generally extremely rich, and always contain gold, even in places where the deposits themselves have been worked without success. In some places where they have been worked as much as thirty thousand dollars have been taken from a claim of fifteen feet square; and there are many instances where ten and fifteen thousand dollars have been taken from claims of the same size. But few of these rich spots have, up to the present time, been opened, yet there can be no doubt but that many still remain to be discovered. Where the deposits are found extending over a large surface on the elevated flats, gold is always met with, generally diffused through the gravel immediately above the rock on which they rest.

A recent Blue-book gives some important information on the subject of Californian mines. It states that the short supply of water during the past year has interfered materially with mining operations, both in Canada and Nevada. Many of the quartz-mills in this State have been idle for many months, and hydraulic mining has had to be suspended altogether in many localities, both from want of water for hydraulic use and from the accumulation of the 'tailings.' Every year new capital is brought to bear on mining enterprise; and it is no longer difficult to find the requisite means to work a mine, if the prospects are at all encouraging.

During the past year, notwithstanding the limited supply of water, there have been more enterprises started or increased in magnitude than in any previous year. Hydraulic mining is the most attractive, and as the course of the old river-channels are more surely traced, this interest will be enormously extended. The State geologist has had, during the past two years, some of his staff employed in tracing the course of these rivers, and the result of these scientific researches will be to facilitate the action of the mines materially. In a semi-official report he says:—

'In the prosecution of this work a large amount of valuable information has already been collected, both of a geographical and geological character. It is confidently expected that the working-up of all materials collected, with the accompanying maps and sections, will exhibit the phenomenon of gravel deposits—in regard to which there has been so much discussion and such a multiplicity of opinions—in a new light, and that many difficulties which have hitherto perplexed the miners will be solved. He desired the work to be continuously prosecuted until a full and detailed map and report on the whole region have been prepared, which he thought would be accomplished the next session if the pecuniary means are forthcoming.'

Hydraulic mining is becoming more general through the mining districts. It was for some years mainly confined to the counties of Yuba, Nevada, Placer, El Dorado, and Butte, but it is spreading to Mariposa in the south, and Trinitio, Klamath, and Liskyon counties, in the north. Yuba and Nevada, always the leading counties in hydraulic mining, still maintain the ascendency. From one small district in the former county nearly 100,000*l*. were received, and the yield from the completion of tunnels will be much greater this year. Tuolumne has added to the counties known to possess old river-channels. A large ditch is nearly completed to bring water from the Tuolumne river to a very extensive gravel-deposit near La Grange, which is said to be unusually rich and free from cement. The great hindrance to the working of these mines has generally been the want of drainage-capacity, which has compelled the construction of long and expensive tunnels, a work of great labour and time.

The large ditches now furnishing water for hydraulic purposes supply hydraulic power from nozzles of 7 inches in diameter, and the force is tremendous. Two or three years ago a 3-inch nozzle was the largest in use. A great many very fine quartz-mills have been built, with all the improvements that science and practical experience have taught; and though labour has not depreciated sensibly in value, quartz of a much lower grade can be profitably worked than heretofore.

The two leading quartz-mines of California—the Amador, in Amador county, and the Eureka, in Nevada county—have paid in dividends respectively 172,000*l*. (since it has been an incorporated company) and 354,800*l*. The total yield of the California gold mines is estimated at 3,000,000*l*. Extraordinary developments have been made in the great 'Comstock lead' of Nevada, and the yield has reached 2,200,000*l*., fully one-third more than the product of 1870. The more recent discoveries have been in the 'Crown Point' and 'Belcher' mines, which have proved so flattering as to send the value of their stock far above what it has ever before reached. The latter has heretofore paid in dividends but little over the assessment, but it recommenced paying dividends in January 1871, by one payment of 10 dollars per cent. per share, equal to 28,000*l.* The following are the dividends paid by four of the leading mines of this lode:—Chollar Potosi, 330,400*l.*; Crown Point, 168,000*l*; Hale and Norcross, 32,000*l.*; Yellow Jacket, 88,800*l.*

The coinage of gold at the San Francisco mint was as follows:—

1867.	1868.	1869.	1870.
Dols.	Dols.	Dols.	Dols.
17,370,535	17,365,000	14,365,550	20,355,000

Gold produced in the States and Territories west of the Missouri river during 1871: from Raymond's 'Mining Statistics West of the Rocky Mountains.' Gold bullion, amalgam, or dust:—

	Dols.
Arizona	163,739,93
British Columbia	1,349,580,83
Colorado	2,605,681,50
California	16,167,484,05
Idaho	1,471,067,21
Montana	4,031,502,00
Oregon	1,693,602,15
Utah	221,262,14
Washington	320,107,09
Total	28,024,026,90

Professor Raymond gives his estimate of the gold and silver productions in the United States for the year 1871 as follows, as compared with former years:—

	1869	1870	1871
	dollars	dollars	dollars
Arizona	1,000,000	800,000	800,000
California	22,500,000	25,000,000	20,000,000
Colorado	4,000,000[1]	3,675,000	4,663,000
Idaho	7,000,000	6,000,000	5,000,000
Montana	9,000,000	9,100,000	8,050,000
Nevada	14,000,000	16,000,000	22,500,000
New Mexico	500,000	500,000	500,000
Oregon and Washington	3,000,000	3,000,000	2,500,000
Wyoming	...	100,000	100,000
Utah	...	1,300,000	2,300,000
Other sources	500,000[2]	525,000	250,000
Total	61,500,000	66,000,000	66,663,000

[1] Including Wyoming. [2] Including Utah.

The estimated production of gold and silver for the five years ending 1871 in the United States, based upon the coinage of the mints and the foreign exports, according to the commerce and navigation reports, was as follows:—

Years	Gold	Silver	Total production
	£	£	£
1867	7,700,000	3,800,000	11,500,000
1868	7,000,000	3,000,000	10,000,000
1869	6,500,000	2,800,000	9,300,000
1870	6,000,000	3,200,000	9,200,000
1871	5,600,000	4,400,000	10,000,000

Statement of Deposits and Coinage at the Mint of the United States and Branches during the year ended December 31, 1871.

	Gold deposits	Silver deposits	Total deposits
	dollars	dollars	dollars
United States Mint, Philadelphia	2,884,645,61	2,124,924,26	5,009,569,87
Branch Mint, San Francisco	24,960,122,61	1,247,567,05	26,207,689,66
„ Carson City	2,515,132,79	2,994,456,17	5,459,597,96
„ Denver	1,020,223,37	2,937,67	1,023,161,04
Assay office, Charlotte	16,122,37	164,52	16,286,89
Total	31,396,246,75	6,320,058,67	37,716,305,42

About one-third of the value of the silver-production is also gold, which should be deducted from the second column and added to the first, to show the exact proportion of each metal produced. The above statement does not embrace the gold and silver exported in the form of ore.

Gold in Canada.—In the Progress Report, Mr. Henry G. Vennor of the Geological Survey of Canada, after referring to notices of gold in former reports, says:—

The portion of the townships of Madoc and Marmora, in which the only mines now (1872) being worked for gold are situated, is that immediately surrounding the granite area known as the Huckleberry Rocks. These rocks occupy a very large part of the south-western quarter of Madoc and the south-eastern quarter of Marmora, extending north-westward on the boundary line between these townships as far as the middle of the eighteenth lot, with a breadth of about four miles, the river Moira, in Marmora, forming their western limit.

In the talcoid slates are found large bedded quartz-veins, holding sulphurets of iron and copper, and native gold. A uniform relation between the gold- and iron-bearing zone is shown as probable. The gold in Madoc and Marmora occurs:—

1. In bedded metalliferous lodes.
2. In slate bands, impregnated with sulphurets.
3. In nests, or bunches, with quartz and sulphurets in dolomite.
4. In cross or fissure veins (of minor importance).

Seven mines were worked for gold in 1871, in the province of Ontario; the gold produced in 1871, being 500 ounces from Cook Mine. Mr. Charles Robb of the Canadian Geological Survey says:—'Within the last three years most important discoveries of auriferous veins have been made, and operations commenced for developing them on an extensive scale and with good prospects of success.'

In the *Province of Quebec* the following quantities of gold were obtained:—

1869	1050½ ounces,	value	18,909$
1870	581 „	„	10,467
1871	115 „	„	2,070

Gold exported from Canada.

	1866[1]	1867[1]	1868[1 2]	1869[1 2]	1870[1 2]	1871
Coin and Bullion,	499,498*l.*	607,507*l.*	1,013,785*l.*	878,793*l.*	1,647,608*l.*	1,372,292*l.*

The Gold-Fields of British Columbia.—That the auriferous deposits of this region are spread over a considerable scope of country is apparent from the fact that paying diggings have already been found on the Fraser river, extending from Fort Hope almost to Fort Alexander, a continuous distance of nearly 400 miles. Among the tributaries of this stream, Thompson and Bridge rivers are known to be auriferous. Extensive works are established, and large quantities of gold are produced, but returns of quantities cannot be obtained.

The return of gold mining generally throughout the Province is:—

1869	value	1,824,871$
1870	„	1,333,745
1871	„	1,349,581

Gold Mines of Nova Scotia.—The production of gold in Nova Scotia has been as follows:—

---

[1] Years ending June 30.

[2] Exclusive of exports to other Provinces of the Dominion.

1862–72.						
Annual yield	Declared quantities			Estimated quantities stolen and not reported		
	Native	From quartz	Total	Native	From quartz	Total
	ozs.	ozs.	ozs.	ozs.	ozs.	ozs.
1862	311·000	6,964·000	7,275·000	39·000	686·000	725·000
1863	28·000	13,937·735	13,965·735	22·000	1,376·265	1,398·265
1864	86·631	19,936·296	20,022·927	13·369	1,963·704	1,977·073
1865	112·830	25,341·387	25,454·217	37·170	2,508·613	2,545·783
1866	49·089	25,155·565	25,204·654	50·911	2,544·435	2,595·346
1867	84·931	27,229·642	27,314·573	15·069	2,670·358	2,685·427
1868	22·983	20,518·338	20,541·321	27·017	2,031·662	2,058·679
1869	177·923	17,690·117	17,868·040	22·077	1,809·883	1,831·960
1870	176·831	19,689·429	19,866·260	23·169	2,110·571	2,133·740
1871	9·115	19,218·243	19,227·358	90·885	1,781·757	1,872·642
1872	73·563	13,021·300	13,094·363	26·437	1,278·700	1,305·137
1862–73	1,132·896	208,702·052	209,834·948	367·104	20,761·948	21,129·052
District yield						
Sherbrooke .	38·000	57,496·379	57,984·379	2·000	5,763·621	5,765·621
Waverley . .		44,523·033	44,523·033		4,451·967	4,451·967
Renfrew . .		26,749·396	26,749·396		2,675·004	2,675·004
Wine Harbour .		20,491·317	20,491·317		2,048·683	2,048·683
Montagu . .		13,423·744	13,423·744		1,341·856	1,341·856
Oldham . .		13,106·642	13,106·642		1,313·358	1,313·358
Tangier . .	208·350	10,241·002	10,449·352	21,650	1,023·998	1,045·648
Otormont . .	18·000	10,204·783	10,222·783	2·000	1,020·217	1,022·217
Uniacke . .		7,978·937	7,978·937		796·063	796·063
Caribou . .		2,329·150	2,329·150		230·850	230·850
Ovens . .	311·000	131·412	442·412	189·000	18·588	207·588
Unclassified .	556·771	1,135·001	1,691·772	143·229	28·999	172·228
Lawrencetown .	·775	441·256	441·031	9·225	48·744	57·969
Total . .	1,132·896	208,702·052	209,834·948	367·104	20,761·948	21,129·052 209,834·948
Grand total .	...	...	...	...	...	231,065·000

The Gold Produce of Nova Scotia for 1873.

	ozs.	dwts.	grs.
January	1,014	13	0
February	1,068	19	16
March	1,100	10	9
April	1,167	16	12
May	1,263	2	2
June	966	1	18
July	1,031	1	12
August	911	4	20
September	1,053	2	7
October	965	14	17
November	704	14	5
December	605	6	21
Total for 1873 .	11,852	7	19

Australian Gold-Mines.—The discovery of the great gold-field in Australia to the westward of Bathurst, about 150 miles from Sydney, was officially made known in Great Britain, by a despatch from Sir C. A. Fitzroy to Earl Grey, on the 18th September 1851, many persons with a tin dish having obtained from one to two ounces per day. On May 25th, he writes that lumps have been obtained, varying in weight from one ounce to four pounds. On May 29th, he writes that gold has been found in abundance, that people of every class are proceeding to the locality, that the field is rich, and, from the geological formation of the country, of immense area. By assay the gold is found to consist of 91·1 of that metal, and about 8·333 of silver, with a little base metal; or of 22 carats in fineness. July 17th, a mass of gold weighing 106 lbs. was found imbedded in the quartz-matrix, about 53 miles from Bathurst; and much more, justifying the anticipations formed of the vast richness and extent of the gold-field in this colony. This magnificent treasure, the property of Dr. Kerr, surpassed the largest mass found in California, which was 28 lbs.; and that in Russia, which was 70 lbs., now in the Museum at St. Petersburg. One party of six persons got at the same time 400*l.* in ten days, by means of a quicksilver machine; and a party of three, who were unsuccessful for seven days, obtained in five days more than 200 ounces.

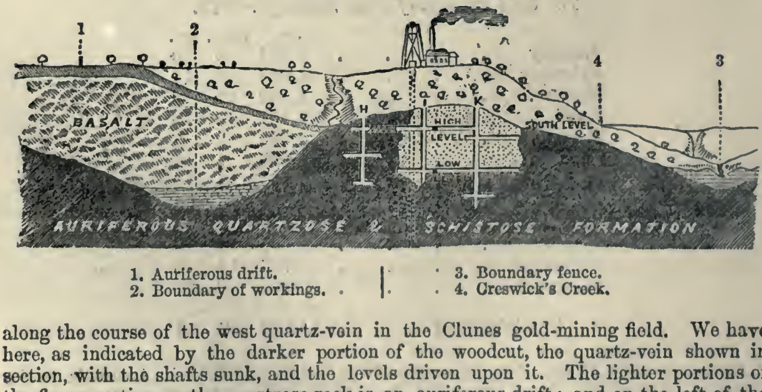
Numerous claims have been made by persons who have thought that they had given the first indications of gold in Australia. To the late Sir Roderick Murchison is, however, due the merit of pointing out that gold might probably be found in Australia, long before it was known in Europe that gold existed in that important colony. Sir Roderick Murchison thus gives us the facts :—

'Having in the year 1844 recently returned from the auriferous Ural mountains, I had the advantage of examining the numerous specimens collected by my friend Count Strzelecki along the eastern chain of Australia. Seeing the great similarity of the rocks of those two distant countries, I could have little difficulty in drawing a parallel between them; in doing which I was naturally struck by the circumstance that no gold had *yet* been found in the Australian range, which I termed in anticipation the 'Cordillera,' impressed with the conviction that gold would, sooner or later, be found in the great British colony. I learnt in 1846 with satisfaction that a specimen of the ore had been discovered. I thereupon encouraged the unemployed miners of Cornwall to emigrate, and dig for gold as they dug for tin in the gravel of their own district. These notices were, as far as I know, the first printed documents relating to Australian gold.'

August 25th, 1851, Lieutenant-Governor C. J. Latrobe announced to Earl Grey from Melbourne, the discovery of large deposits of gold in that district of the colony. In a second Parliamentary blue-book, issued February 3rd, 1852, it is stated that 79,340 ounces of gold, worth 257,855*l.* 7*s.*, had been previously forwarded to England; and that the gold-fields of the colony of Victoria rival, if they do not exceed in value, the first-discovered gold-fields of New South Wales; the total value being then 300,000*l.*; and but a little time afterwards about half a million sterling. Mr. E. Hargreaves, Commissioner for Crown lands, announced from Bathurst, that no part of California which he had seen had produced gold so generally and to such an extent as Summerhill Creek, the Turon River, and its tributaries.

For the purpose of conveying a correct idea of the conditions under which the greatest quantity of the Australian gold occurs, three plans have been selected from different districts. The first of these (*fig.* 1118) represents a longitudinal section along the course of the west quartz-vein in the Clunes gold-mining field. We have here, as indicated by the darker portion of the woodcut, the quartz-vein shown in section, with the shafts sunk, and the levels driven upon it. The lighter portions of the figure resting on the quartzose rock is an auriferous drift; and on the left of the section the great basaltic formation is shown.

1118

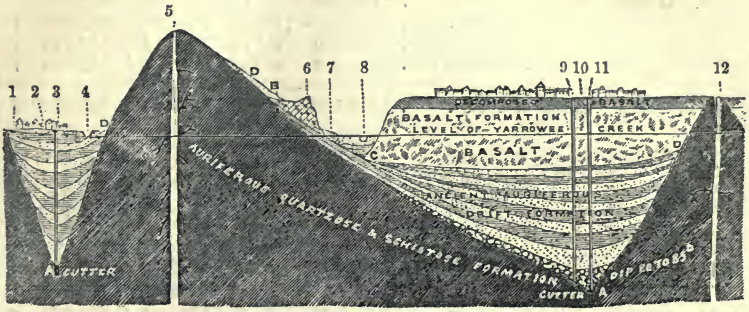


1. Auriferous drift.
2. Boundary of workings.
3. Boundary fence.
4. Creswick's Creek.

Fig. 1119 is a section of a portion of the Ballarat gold-field. It is an east and west section from the Red Streak-lead across Post-Office Hill, White Flat, the township of Ballarat West, and the quartz-reef west of the township; and it shows the auriferous drift, schist, quartz, and basalt formations of the district.

In those two sections we have, therefore, all the conditions shown of the processes of mining on the quartz-lodes and in the alluvial deposits.

1119



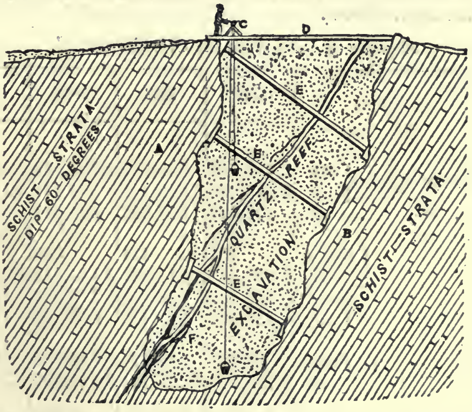
1. The town of Ballarat East.
2. The main road.
3. The Red-Streak lead.
4. The creek.
5. Old Post-office hill, with quartz-reef.
6. Basalt escarpment south of Golden Point.
7. White flat recent auriferous alluvial deposit.
8. Yarrowee Creek.
10. The Gravel-Pits lead.

9 and 11 are two shafts sunk into the ancient auriferous alluvial deposit.
12. Quartz-reef beyond the town of Ballarat West, shown in the drawing.
B is the remains of a lava stream, interrupted by the schist and clay-slate hills.
D·D is the gravel strata which invariably rest on the side of the schist hills which surround the Ballarat basin.

Fig. 1120 is a section from the Boroondara and Bulleen gold mines, a few miles from the capital of Victoria. It is the east and west section of the Carlton Estate quartz-reef, and is mainly given to illustrate the unskilful and dangerous condition of many of the workings undertaken by men who have no experience in subterranean operations. The shaft, if such it can be called, is about 40 feet deep; and the reef dips with the solid strata at an angle of about 60 degrees to the horizon.

The wall of the shaft at A is not supported on the footwall by props and proper timbering, which it should be, as indicated by E E E. The windlass at C, and the framework at D, are both exceedingly insecure. This is the mode of proceeding in a very important working, where almost every piece of quartz broken out contains gold, and also antimony and iron. At the point F the quartz-reef was exceedingly rich, and there it branches off into small strings, yielding 22 ounces of gold to the ton.

1120



It is not necessary here to trace the progress of gold-mining in this colony. The quantity of gold discovered and exported has been enormous. Some exceedingly large 'nuggets' have been found; one in Forest Creek, weighing 27 lbs. 6 oz. 15 dwts., and the Welcome Nugget, weighing 2,217 oz. 16 dwts.

The following are the returns made by the inspector to the government of *Victoria* in the years given:—

	Alluvial		Quartz		Total	
	ozs.	dwts.	ozs.	dwts.	ozs.	dwts.
1871. Quarter ending March 31 .	173,200	2	139,934	15	313,134	17
,, June 30 . .	180,744	13	174,686	14	355,431	7
,, September 30 .	165,909	6	181,788	18	347,678	4
,, December 31 .	178,336	0	174,362	0	352,698	1
Total of 1871 . .	698,190	1	670,770	7	1,368,960	8
1872. Quarter ending March 31 .	171,851	10	164,670	8	336,521	18
,, June 30 . .	157,484	5	161,777	15	319,262	0
,, September 30 .	164,572	3	172,700	10	337,272	13
,, December 31 .	194,321	2	173,242	5	367,563	7
Total of 1872 . .	688,229	0	672,390	18	1,360,619	18
1873. Quarter ending March 31 .	129,046	2	168,665	5	297,711	7
,, June 30 . .	123,643	6	159,604	17	283,248	3
,, September 30 .	132,354	5	173,405	15	305,760	0
,, December 31 .	145,271	2	168,321	0	313,592	2
Total of 1873 . .	630,314	15	669,996	17	1,300,310	12

Mr. R. Brough Smyth, the Secretary for Mines, remarks in his report that it is impossible to state what quantity of gold is raised in any year; but the following figures afford data on which estimates may be founded:—

	1871			1872			1873		
	ozs.	dwts.	grs.	ozs.	dwts.	grs.	ozs.	dwts.	grs.
Exported according to returns furnished by the Hon. the Commissioners of Trade and Customs	1,355,477	3	0	1,160,554	19	0	1,115,987	14	0
Received at the Melbourne Branch of the Royal Mint	..		..	121,965	17	0	104,891	6	0
Raised according to the estimates made by the Mining Registrars . . .	1,368,942	9	4	1,331,377	18	0	1,170,397	12	0
Purchased by the several banks, from returns made by the managers . .	1,290,844	18	1	1,218,094	9	0	1,162,492	14	0

From the first discovery of gold in the colony of Victoria to December 31st, 1872, the quantity of gold exported and minted was 42,037,326 oz. 5 dwts., at 4*l.* per ounce: this gave the value 168,149,305*l.*

Exports of Gold from the Colonies named.

		1867	1868	1869	1870	1871
VICTORIA:						
Gold, exclusive of specie	ozs.	1,433,687	1,960,713	1,700,973	1,529,821	1,647,389
	£	5,738,993	7,843,197	6,804,179	6,119,782	6,590,962
Specie gold . . .	£	671,936	507,662	684,819	577,840	347,513
NEW SOUTH WALES:						
Gold Coin . .	boxes	453	414	500	296	401
	£	2,041,383	1,771,005	2,184,612	1,206,569	1,724,088
Dust and bar. .	ozs.	136,348	98,669	149,094	178,513	156,382
	£	544,661	382,616	578,260	672,254	601,250
NEW ZEALAND:						
Gold, exclusive of specie	ozs.	686,753	637,474	614,282	544,857	730,023
	£	2,724,276	2,492,721	2,341,592	2,163,910	2,788,368
QUEENSLAND:						
Gold-dust . .	ozs.	49,092	165,801	138,221	136,773	125,295
	£	189,248	593,516	523,045	489,539	449,170

The imports of Australian gold into the United Kingdom in 1873 exhibited a large increase as compared with 1872, having amounted to 9,471,601*l.* as compared with 6,014,621*l.* in 1872, and 6,919,480*l.* in 1871.

Gold in New Zealand.—Dr. Hector in the 'Geological Survey Progress Report' gives the following account:—'Gold had been long known to exist at Coromandel, a little north of the Shortland District, in 1852, and it had been regularly worked there since 1862. Rumours had also long existed that gold was plentiful in the Thames Valley, and several Maoris and Europeans had brought specimens to Auckland at various times from 1865. In July 1867, a native chief, named Taipari, stimulated by the offer of the Provincial Government of a reward of 5,000*l.* for any one who should discover a payable gold-field, employed several men, both Europeans and Natives to prospect his land; and gold was obtained by sluicing in the Karaka and Hope Creeks. This was taken to Auckland and shown to the Deputy Superintendent and the Native Commissioner, and at the same time Taipari offered to throw open his lands as a gold-field. Satisfactory arrangements having been made with him, the result was that a block of land from the Hope to the Pukehinan Creeks, known as the Karaka block, was proclaimed a gold-field on August 1, 1867, and a town was laid out at the mouth of the Kawaeranga, and named Shortland. Parties at once set to work sluicing on the Karaka, Waiotahi, and Moauataiari, but with indifferent results; when on August 17, four men discovered the gold *in situ* in the Kuranni on the face of a waterfall, on the spot now so well known as Hunt's Reef. This led to further exploration for quartz veins, and in a month gold had been found in about a dozen places. Further discoveries quickly followed. Sluicing was abandoned, and quartz-mining recognised as the true industry of the field. So satisfactorily did this turn out that, at the end of December 1868, or seventeen months after the first proclamation of the field, not only had two other distinct districts, Tapu and Puriri, been started, but about 1,200 claims had been taken up near Shortland, between 800 and 850 of which were then actually working, and probably 600 of the number had seen gold in greater or less quantities. Twenty-seven crushing machines were on the ground, and thirteen others were going up. The yield of gold had exceeded 83,000 ounces, valued at more than 200,000*l.*; and the population numbered about 18,000 souls.

'Gold is now being worked at Puriri—in the district between Shortland and Tararu, and at Tapu. It has also been found in one or two places between Tararu and Tapu; and as the same geological structure extends over the whole district, there is every probability of its existing much more extensively than has yet been discovered.

'The quality of the gold differs considerably in different parts of the field, and even from the same claim, it often varies a good deal. Out of twenty-eight assays from various parts of the Shortland District, furnished by the assayer of the Union Bank of Australia the highest gave 19·5, and the lowest 9·625 carats fine, both being from the Waiotahi Creek; while, from the Lord Derby claim, also on the Waiotahi, some stone yielded nearly pure silver, being only 2·75 carats fine, and worth only 9*s.* 8*d.* an ounce. The average of the 28 assays is 15 carats fine.

'The following table gives the result of these assays separated into districts; and although they are much too few to give any decided results, they show an unmistakeable tendency towards a poorer gold, that is, one containing more silver, as they go northward:—

Locality	Highest carats	Lowest carats	Average carats	Number of assays
Karaka	16·094	16·062	16·078	2
Waiotahi	19·500	9·625	16·094	4
Moauataiari	17·594	14·687	15·937	8
Kuranni	16·594	13·937	15·000	8
Ponga Flat	16·656	12·000	14·328	2
Head of Madman's Gully . .	14·031	13·656	13·781	3
Tararu	...	...	13·968	1

'The gold is very widely distributed through the district, although certain parts appear at present to contain it in more considerable quantities than others; but the mines have not yet been long enough worked to pronounce with much certainty on this point. The fact before mentioned, that probably 600 out of 1,200 claims had seen gold, shows well how widely it is distributed through the country, for it must be borne in mind that, unlike most quartz-mining districts, the reefs here are not continuous for far, and that the greater part are but thin irregular veins; so that the country was not taken up along lines of leads only, but *en masse*, nearly the whole of the country between the Hope and Tararu being pegged off. It follows from this, that nearly one-half of the surface of the country contains more or less gold *in situ*. Major Heaphy informs me that he has had thirty-one assays made of quartz from the same number of veins from various localities in the Opitomoko and Tararu

Creeks, all of which gave more or less indications of gold. Two only showed a trace: while the three highest were 3 oz. 6 dwts.; and 3 oz. 10 dwts.; and 3 oz. 18 dwts. to the ton respectively, the average of the whole being 1 oz. 15 dwts. 8 grs. In none of them could gold be seen with the naked eye. Out of 1,200 claims that have been taken up in the Shortland District I estimate that about 150, or 12 per cent., have found gold in sufficient quantity to justify the expectation that they will turn out permanently payable mines, and I have no doubt but that, as time goes on, many more will be added to the number. As nearly the whole of the Shortland District has been taken up, and more or less proved it follows that about an eighth of its surface, which is about 2,000 acres, contains payable auriferous quartz-veins.'

The Report gave the following return of the yield of gold from the Thames district up to March 31, 1869, taken from the Customs' Returns:—

Quarter ending March 31, 1869 . . .	41,674 ozs.,	value 131,273*l.*
The yield previous to March 31, 1868 . .	81,035 „	„ 250,405*l.*
Making a total yield for Thames and Coromandel district to March 31, 1869 . . .	122,709 „	„ 381,678*l.*

The total yield of gold from all parts of New Zealand up to the same date was 4,549,952 ozs., value 17,674,532*l.*

The total value of gold exported from New Zealand in 1871 was 2,787,520*l.*, produced from the several gold-fields to the following amounts. The total value of the gold exported in 1870 being 2,157,585*l.*, showing an increase of 629,935*l.*:—

	1870	1871
The produce of gold-field in Provinces of *Auckland* .	£319,146	£1,188,708
„ „ *Marlborough* .	7,408	7,468
„ „ *Nelson* . .	591,510	439,936
„ „ *Wellington* .	120	...
„ County of *Westland* . .	578,707	531,648
„ Province of *Otago*, including *Southland* . . .	660,694	619,760

The total value of gold exported from New Zealand from April 1, 1857, to December 31, 1871, was 6,272,878 ounces; the total value being 24,352,999*l.*

The statistics of New Zealand, 1871, give the exports of *gold-dust* as follow:—

	ozs.	£
To United Kingdom	185,026	705,257
New South Wales	294,695	748,649
Victoria	332,150	1,301,839
China	4,833	18,737
Germany.	1	83
United States of America. . .	3,317	13,883
	730,023	2,788,368

Value of Total Imports of Bullion and Specie from the British Colonial Possessions.

	1867	1868	1869	1870	1871
	£	£	£	£	£
India, to March 31 . . .	13,236,904	11,775,373	15,155,953	13,954,806	5,444,822
Straits Settlements . . .	1,005,011	680,968	761,590	285,377	1,081,482
Ceylon	892,040	999,189	1,227,929	540,690	855,141
Mauritius	127,967	200,028	224,863	134,164	236,865
Labuan	9,582	14,882	..	12,522	6,917
New South Wales . . .	1,815,953	1,766,988	849,711	989,885	2,300,423
Victoria	1,083,451	2,159,479	1,708,226	1,994,778	2,508,870
South Australia. . . .	93,392	64,508	91,500	16,000	90,000
Western Australia . . .	1,745	..	..	5,020	25
Tasmania	..	13,500	36,500	3,000	..
New Zealand	30,000	347,040	139,150	112,690	202,983
Queensland	125,802	6,011	6,570	6,586	34,780
Cape of Good Hope . . .	10,000	40,452	15,100	150,000	522,435
St. Helena	..	..	..	500	..
Sierra Leone	..	..	..	..	20,265
Ontario and Quebec, to June 30	1,935,690	1,019,822	884,798	851,077	555,125
Nova Scotia	..	..	41	52,158	14,271
British Columbia . . } Vancouver's Island . . }	27	16,497	..	56	..
West India Islands (Bahamas).	833	..	..	..	..
Jamaica	..	51	..	..	..
Trinidad	68,390	36,522	106,623	156,073	163,360

Value of the registered Imports of Gold into the United Kingdom from various Countries.

Countries from which imported	Computed Value							Declared Value	
	1864	1865	1866	1867	1868	1869	1870	1871	1872
	£	£	£	£	£	£	£	£	£
Russia	50,530	19,512	138,004	61,406	...	3,285	120,840	415,463	38,300
Hanse Towns	208,090	14,981	503,030	54,679	42,268	25,481	29,921	922,381	453,583
Holland	2,252	4,767	70,482	14,470	918	257	278,180	15,757	13,406
Belgium	10,282	110,335	196,278	13,585	4,092	1,937	156,046	813,833	305,386
France	573,913	307,765	2,843,356	387,319	280,170	695,851	315,767	3,708,203	2,116,557
Portugal, Azores, and Madeira	94,147	746,571	550,846	285,615	402,891	4,429	300	...	1,500
Spain and Canaries	11,548	25,388	28,896	25,234	19,159	7,537	6,765	8,464	14,218
Gibraltar	27,345	37,685	32,156	36,289	48,391	53,137	48,079	49,266	52,641
Malta	12,712	2,807	33,104	44,420	70,712	172,093	184,693	144,713	95,018
Turkey	2,129	1,468	98,631	732	...	3,294	243,547	30,845	700
Egypt	65,831	316,149	128,183	101,026	5,794	27,343	748,954	45,529	6,986
West Coast of Africa	96,078	111,907	120,333	146,182	118,875	100,214	116,142	137,328	108,869
British Possessions in South Africa	3,524	49,305	6,375	15,167	8,480	2,022	536	200	290
British India	58,002	462,095	1,167,425	205,285	302,178	37,380	723,172	247,464	99,435
Australia	2,656,971	5,051,170	6,839,674	5,801,207	6,989,594	7,892,757	6,478,616	6,898,826	5,983,232
British Columbia	11,946	...	...	2,335	...	...	...	...	...
British North American Provinces	110,447	126,276	153,372	136,345	169,518	76,000	213,820	370,224	35,400
Mexico, South America (except Brazil), and West Indies	5,239,899	2,444,181	1,841,384	2,808,367	1,252,816	1,960,683	1,635,360	993,930	704,065
Brazil	180,996	339,549	327,957	615,318	437,492	868,907	288,503	178,431	116,783
United States of America	7,479,790	4,304,495	8,412,286	5,026,185	6,976,455	1,828,694	6,994,051	6,287,595	8,287,109
Other countries	4,519	9,164	17,869	18,985	6,374	9,511	232,436	145,422	35,964
Total	16,900,951	14,485,570	23,509,641	15,800,159	17,136,177	13,770,812	18,806,728	21,618,924	18,469,422

The Importations of Gold into the United Kingdom, in other forms, are given as follow:—

	1871		1872	
	Quantities	Value	Quantities	Value
Leaves	No.	£	No.	£
From Belgium	19,858,000	26,543	18,647,400	32,458
,, France	1,776,400	4,030	3,016,000	5,985
,, other countries . . .	651,988	945	490,600	1,035
Total . . .	22,286,388	31,518	22,154,000	39,478
Ore of Gold, or ore of which the greater part in value is Gold	tons	£	tons	£
From Chili	111	24,290	...	...
,, Dutch West India Islands	...	...	265	6,730
,, other countries . . .	20	1,338	55	1,084
Total . . .	131	25,628	320	7,814

Gold, Metallurgic Treatment of.—The gold found in the sands of rivers, or in auriferous soils, need not be subjected to any metallurgic process, properly speaking. The gold seekers separate it from the sands, by washing them first upon inclined tables, sometimes covered with a cloth, and then by hand in wooden bowels of a particular form. The methods of working vary in different localities. The people called Bohemians, Cigans, or Tchinganes, who wash the auriferous sands in Hungary, employ a plank with 24 transverse grooves cut in its surface. They hold this plank in an inclined position, and put the sand to be washed in the first groove; they then throw water on it, when the gold, mixed with a little sand, collects usually towards the lowest furrow. They remove this mixture into a flat wooden basin, and by a peculiar sleight of hand separate the gold entirely from the sand. The richest of the auriferous ores consist of the native gold quite visible, disseminated in a gangue, but the veins are seldom continuous for any length. The other ores of this district are auriferous metallic sulphides, such as sulphides of copper, silver, arsenic, &c., and particularly iron.

The stony ores are first ground in the stamping mill, and then washed in hand-basins, or on wooden tables.

The auriferous sulphides are much more common, but much poorer than the former ores; some contain only one 200,000th part of gold, and yet they may be worked with advantage, when treated with skill and economy.

The gold of these ores is separated by two different processes; namely, by fusion and amalgamation.

The auriferous metallic sulphides are first roasted; then melted into *mattes*, which are roasted anew; next fused with lead, whence an auriferous lead is obtained, which may be refined by the process of cupellation.

When the gold ores are very rich, they are melted directly with lead, without preliminary calcination or fusion. These processes are however little practised, because they are less economical and certain than amalgamation, especially when the gold-ores are very poor.

If these ores consist of copper pyrites, and if their treatment has been pushed to the point of obtaining auriferous rose-copper, or even black copper including gold, the precious metal cannot be separated by the process of liquation, because the gold having more affinity for copper than for lead, can be but partially run off by the latter metal. For these reasons the process of amalgamation is far preferable. This process being the same for silver, we reserve its full description for that metal. See SILVER.

The rich ores in which the native gold is apparent, and merely disseminated in a stony gangue, are directly triturated with quicksilver, without any preparatory operation. As to the poor ores, in which the gold seems lost amid a great mass of iron, sulphide of copper, &c., they are subjected to a roasting process before being amalgamated. This process seems requisite to lay bare the gold enveloped in the sulphurets. The quicksilver with which the ore is now ground seizes the whole of its gold, in however small quantity this metal may be present.

The gold produced by the refining process with lead is free from copper and lead, but it may contain iron, tin, or silver. It cannot be separated from iron and tin without great difficulty and expense, if the proportion of gold be too small to admit of the employment of muriatic acid.

By cupellation with lead, gold may be deprived of any antimony united with it.

Tin gives gold a remarkable hardness and brittleness; a piece of gold, exposed for some time over a bath of red-hot tin, becomes brittle. The same thing happens more readily over antimony, from the volatility of this metal. A two-thousandth part of antimony, bismuth, or lead destroys the ductility of gold. The tin may be got rid of by throwing some corrosive sublimate or nitre into a crucible, containing the melted alloy. By the first agent, perchloride of tin is volatilised; by the second, stannate of potash forms, which is carried off in the resulting alkaline scoriæ.

Gold treated by the process of amalgamation contains commonly nothing but a little silver. The silver is dissolved out by nitric acid, which leaves the gold untouched; but to make this *parting* with success and economy on the great scale, several precautions must be observed.

If the gold do not contain fully two-thirds of its weight of silver, this metal, being thoroughly enveloped by the gold, is partially screened from the action of the acid. Whenever, therefore, it is known by a trial on a small scale, that the silver is much below this proportion, we must bring the alloy of gold and silver to that standard by adding the requisite quantity of the latter metal. This process is called quartation.

This alloy is then granulated or laminated; and from twice to thrice its weight of sulphuric or nitric acid is to be boiled upon it; and when it is judged that the solution has been pushed as far as possible by this first acid, it is decanted, and new acid is poured on. Lastly, after having washed the gold, some sulphuric acid is to be boiled over it, which carries off a two or three thousandth part of silver, which nitric acid alone could not dissolve. Thus perfectly pure gold is obtained.

The silver held in solution by the sulphuric or nitric acid is precipitated in the metallic state by copper, or in the state of chloride by sea-salt. See SILVER.

Gold has less affinity for oxygen than any metal. When alone, it cannot be oxidised at any degree of heat with contact of air, although in combination with other oxidised bodies, it may pass into a state of an oxide, and be even vitrified. The purple smoke into which gold-leaf is converted by an electric discharge is not an oxide, for it is equally formed when the discharge is made through it in hydrogen gas. There are two oxides of gold; the first or protoxide is a green powder, which may be obtained by pouring, in the cold, a solution of potash into a solution of the metallic chloride. It is not durable, but soon changes in the menstruum into metallic gold and peroxide. Its constituents are 96·13 metal and 3·87 oxygen. The peroxide is best prepared by adding magnesia to a solution of the metallic chloride; washing the precipitate with water till this no longer takes a yellow tint from muriatic acid; then digesting strong nitric acid upon the residuum, which removes the magnesia, and leaves the peroxide in the form of a black or dark brown powder, which seems to partake more of the properties of a metallic acid than a base. It contains 10·77 per cent. of oxygen. For the curious combination of gold and tin, called the purple precipitate of Cassius, see PURPLE OF CASSIUS; COLOURS.

GOLD AND SILVER REFINING. Since the object of this book is to treat more especially of the application of scientific processes to commercial undertakings, it will not be out of place to give some account of the processes by which gold and silver are refined, or rendered free from other metals. In the laboratory, where chemical manipulation has reached a great way to perfection, the precious metals are separated by nitric acid and other agents, but the processes are far too expensive and tedious to admit of being used upon a large scale.

For the purposes of rendering gold containing foreign metals sufficiently pure for the operations of coining, the late Mr. Warrington described a process by which fused gold is treated with black oxide of copper, with a view to oxidising those metals which render gold too brittle for manufacture into coin. Mr. Warrington proposed to add to fused gold, which is found to be alloyed with tin, antimony, and arsenic, 10 per cent. of its weight of the black oxide of copper, which, not being fusible, is capable of being stirred up with the fused mass of gold, just as sand may be stirred up with mercury, but with this great advantage, that the oxide of copper contains oxygen, with which it parts readily to oxidise any metal having a greater affinity for oxygen than itself. The metals, once oxidised, become lighter than the fused metal, and mixing mechanically, or combining chemically with the black oxide of copper, float to the surface and are removed. In the execution of Mr. Warrington's proposition, it is imperative to use crucibles free from reducing agents, such as carbon, and it is found that half an hour is sufficient time to allow the contact of the oxide of copper with the fused gold.

It has been generally stated by those supposed to be acquainted with the subject, that gold containing tin, antimony, and arsenic is so brittle as to render it wholly unfit for coining. This requires modification, for although these metals, as well as lead, render gold so brittle that it will readily break between the fingers, yet it is not true to say that it renders gold so brittle as to be incapable of being coined. In June and July 1859, some brittle gold, to the extent of about 64,000 ounces, passed through the Mint. The bars were so brittle that they broke with the slightest blow from a hammer, but by special treatment the gold was coined into the toughest coins ever produced. It may now be stated that if the system of manufacture be changed to suit the requirements of the case, gold cannot be found too brittle for the purpose of coining. This is simply a matter of fact, but the expense of coining brittle gold is undoubtedly very great; it is therefore wise that Mr. Warrington's plan should be adopted for all gold containing the volatile metals or tin. Osmium-iridium does not render gold brittle. Dr. Percy and Mr. Smith have demonstrated that all metallic substances found in commerce contain traces of gold, which can be separated by carefully-conducted chemical processes, and it is found that silver is peculiarly liable to be in alloy with gold, and gold with silver; hence a process of refining which shall effect the separation of as little as one five-hundredth part of gold from its mass of silver, is a matter of the utmost commercial importance.

It is with regret that it is stated that the refineries of London are conducted with such secrecy as to render a full description of any one of them impossible, while the ignorance which will induce the proprietors of these establishments to attempt such quietude is much to be pitied, for, except so far as regards details of interior arrangement, their processes are as well known and understood as it is possible for any manufacture to be.

In Paris (the London refiners are known to use the 'French process'), the plan adopted is founded on the fact, that at a high temperature sulphuric acid parts with one equivalent of its oxygen to oxidise an atom of a metal, while the atom of oxide so formed at once combines with another atom of sulphuric acid to form a sulphate. The atom of sulphuric acid which has parted with its atom of oxygen passes off as gaseous sulphurous acid.

If mercury be boiled with sulphuric acid (commonly called oil of vitriol), it is found that it entirely loses its metallic existence, and assumes the form of a dense white salt. This change takes place at the expense of the sulphuric acid, and is shown by the following equation. For explanation sake, call mercury Hg, and sulphuric acid SO^3; if now it is assumed that one part or atom of Hg be boiled with two parts or atoms of SO^3, we have $Hg + SO^3 + SO^3$, and for elucidation we may write SO^3 as equal to $SO^2 + O$; then we have $Hg + O + SO^3 + SO^2$, which, under the influence of heat, become $\underbrace{HgOSO^3}_{\text{a white salt.}} + \underbrace{SO^2}_{\text{gas.}}$

If now the mind substitutes silver for mercury, and so writes Ag instead of Hg, the whole matter will be understood. The silver is dissolved in sulphuric acid just as sugar would be in water, and in this fact we have a valuable means of separating it from gold. If for a moment one imagines a mass of silver alloyed with gold to be represented by a piece of sponge filled with water and frozen, it is well known that if the mass be warmed the ice is melted, and in the form of water filters from the sponge; just so, if a mass of the alloy of the precious metals be boiled in sulphuric acid, the silver is dissolved or washed away, leaving the gold in the form of a sponge, which, as it becomes exposed to the bubbling of the acid, is detached and falls to the bottom of the vessel in which it is boiled.

If by assay the silver to be refined is found to be very rich in gold, it is better to fuse the mass with more silver, so as to produce a mass containing at least 3 of silver to 1 of gold, and this alloy, in its fluid state, should be poured into cold water, by which the falling stream is suddenly chilled, and the particles become what is technically called 'granulated.' The stream should fall some distance (not less than 2 feet) through the air before it reaches the water, that the copper (if any be present) may be as much as possible oxidised, with a view to saving sulphuric acid.

In all cases the alloyed metals should be granulated, because the extended surface of metal presented to the hot acid saves much time.

Silver containing less than $\frac{1}{500}$ part of its weight of gold is found not to pay for separation, but any which contains this amount or more is treated as follows:—

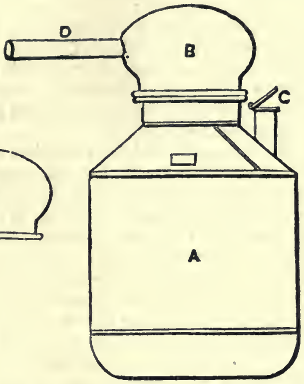
Vessels of platinum were formerly used and were deemed indispensable, but experiment has proved that these may be safely replaced by cast-iron vessels; in both cases the boilers or retorts are provided with tubes passing from the top into chambers which receive the acid gases and vapours.

The platinum vessels used by Mr. Mathison and subsequently by Messrs. Rothschild for many years are now out of use; but as sketches of the vessels actually used cannot be obtained, it is deemed wise to give a sketch of the platinum vessels, which weigh 323·40 troy ounces, and contain, if filled to the neck, 8 gallons of water. A, the retort or boiler; B, the head, provided with a tube of platinum, D, to which is joined at the time of use a long tube of lead. C is a tube terminating on the shoulder of the boiler, and provided with a lid, and is of service to allow of the occasional stirring of the silver during solution, and of the addition of the small quantity of acid at the termination of the chemical action. The vessels became much coated with gold, which was removed with difficulty and at great risk of attacking the platinum.

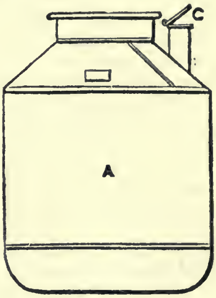
The sketches (*figs.* 1121, 1122, and 1123) are on a scale of 1 inch to a foot.

According to convenience and requirements, the retort or boilers may be multiplied as to number, but about 5 or 6 would seem to be a convenient set for operations. Independently of the smaller prime cost of cast-iron retorts or boilers (now used in place of platinum), there is the advantage of being able to use acid which is not free from impurities, because the cost of the retorts is practically not worth consideration, if taken in relation to the extra price which must be paid for pure acid. Besides these facts, it is found that owing to some influence (is it chemical or catalytic ?) which the iron exerts, less acid is required to be used in proportion to the precious metals than was used when platinum vessels were believed to be necessary.

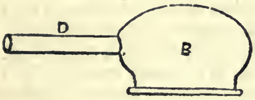
1121



1122



1123



A charge for one boiler varies from 1,130 to 1,300 troy ounces of the granulated mixed precious metals, and is heated with about twice or twice and a half times its weight of sulphuric acid of sp. gr. 1·7047. The heat is gradually raised until effervescence takes place, and it is then regulated with care, while at last, the temperature is raised nearly to the boiling point. As in the case of mercury so in the case of silver, it is better not to rise quite to the boiling point, else sulphuric acid distils off with the escaping sulphurous acid. According to the care with which the granulating has been effected, each charge is heated from 3 to 4 hours. When the elimination of sulphurous acid ceases, the operation is known to be terminated, and chemical examination shows that exactly equivalent quantities of sulphate of silver and sulphate of copper are formed to account for the sulphuric acid. In practice the sulphurous acid is frequently lost, although in all refineries it should be used for the re-composition of sulphuric acid.

Leading from the top of the boiler or retort is a horizontal leaden tube from 8 to 10 yards long, terminating in a leaden chamber, in which sulphuric and sulphurous acids accumulate with some sulphate of silver, mechanically carried over by the violence of the chemical action. It is found that the acid which accumulates in this leaden chamber has a sp. gr. of from 1·3804 to 1·4493. The reduced strength of the acid from 1·7047 to this point is readily understood if the fact be remembered that sulphuric acid is really a compound of anhydrous sulphuric acid and water, and that only the anhydrous sulphuric acid is concerned, although the water performs the friendly part of leading it into action on the silver; the action having commenced, the water is done with, and passes off with the sulphurous acid as it is eliminated; but independently of this cause, it is found that sulphuric acid, by boiling, parts with water, and concentrates itself, until by and by the anhydrous acid itself distils off, and when this is seen, it is at once known that the operation is carried rather too far. When the action has quite terminated, it is customary to add to each boiler or retort from 60 to 80 troy ounces of sulphuric acid of sp. gr. 1·6656, procured from the liquor which has deposited sulphate of copper (presently described); then to pour the whole into a leaden boiler, and boil it for a few minutes; afterwards withdraw the fire, and allow to stand for half an hour, during which time the gold is precipitated. The object in adding this amount of sulphuric acid is to form a clear solution, that the gold may be enabled to settle to the bottom; water could not be added, because it would probably cause an explosion by the heat evolved in its combination, and because sulphate of silver is not very soluble in water, while it is soluble to a very large extent in hot sulphuric acid. At the end of half an hour the clear liquor, containing in solution the silver and copper as sulphates, is decanted and mixed with so much water as shall reduce it to a sp. gr. of from 1·2080 to 1·2605, and well stirred. Copper plates are then introduced, while the solution is kept hot or boiling by a jet of steam.

The silver salt is decomposed by the copper plates, and the copper passes into solution as sulphate of copper, so that at the end of the precipitation the solution contains the copper of the original alloy, as well as the copper which has been used to precipitate the silver. The silver precipitates or falls to the bottom in a finely divided or spongy form, and it is commonly thought that the whole of the silver is thrown down when a portion of the solution is not rendered turbid by a solution of chloride of sodium; but in the presence of a strongly acid solution this test is not to be relied on for minute quantities; therefore, in some refineries, the solution is allowed to rest for days together in leaden cisterns in which copper plates are placed, so that by these means the last traces of silver are obtained.

If the amount of gold be very minute, the original solution is well stirred and then allowed to settle for some time; when finely-divided gold, mechanically mixed with crystals of sulphate of silver and crystals of sulphate of copper, is found at the bottom. This deposit is boiled with water, and is then transferred to a vessel in which it is kept hot, and is brought into contact with suspended copper plates, by which the silver is rendered metallic, and falling to the bottom of the vessel, mixes with the gold. The mixed precipitate of silver and gold is then dried, melted, and granulated, and treated with sulphuric acid, as in the process already described. By this extra process the gold becomes concentrated by the removal of the silver, and is then thrown down in larger and more easily collected particles. When the gold is finely divided and precipitates slowly, the following plan is sometimes adopted:—The whole precipitate, containing finely-divided gold mixed with sulphate of silver, is washed well with warm water, and left to rest. The sulphate of silver is dissolved, whilst the gold settles to the bottom of the vessel, but it is still mixed with a minute quantity of sulphate of silver. It is drained and placed in the retort or boiler of cast iron, and boiled with sulphuric acid; this boiling is twice repeated, and at last a very diluted solution of sulphate of silver is obtained; but by the boiling the gold has assumed a form which enables it to precipitate rapidly; in fact, the flocculent sponge becomes a mass of dense particles, which fall readily to the bottom, are collected and well washed, to free them from silver, and are then dried ready for melting.

The solution of sulphate of silver is evaporated in leaden vessels by the agency of steam, until it becomes saturated, and is then allowed to stand for an hour that all the gold may separate, and is afterwards drawn off either by a tap placed about half an inch from the bottom of the vessel, or by a siphon, and is then treated with copper plates, as already detailed.

In all cases the precipitated spongy silver is carefully washed to free it from sulphate of copper, and dried by heat or by hydraulic pressure; but if dried by pressure the masses obtained are found to contain from 8 to 10 per cent. of water, and are therefore dried by a gentle heat to avoid the breaking-up of the masses, from the sudden formation of steam, as well as to save the chance of destroying the pot of Picardy clay in which the silver is melted when it has been dried.

After melting, the silver is found to retain traces of gold, which are so minute as to be overlooked, since the cost of recovery would exceed the value of the gold to be recovered; but the silver is found to be alloyed with from 5 to 6 thousandths of its weight of copper, which appears to be left in the form of sulphate, notwithstanding the washings to which the silver has been subjected. It is practically impossible to wash away the last traces of sulphate of copper. This small amount of copper is of little importance, since it amounts to but 5 parts of copper alloyed with 995 parts of silver, yet this may be removed by fusion and treatment with nitrate of potassa.

During the whole process, even if copper be not present in the original mass of metal to be refined, it is to be observed that copper plates are used for precipitating the silver; therefore sulphate of copper is formed in considerable quantities, and as this salt has a high commercial value as giving the base for many colours used in painting and paper-hangings, as well as for agricultural purposes, it becomes desirable to obtain this salt in a saleable form. The solution is therefore evaporated to a sp. gr. of 1·3804, and allowed to cool, when crystals deposit; but since sulphate of copper deposited from strongly acid solutions is mixed with the anhydrous salt, the whole mass of crystals is re-dissolved in warm water, and allowed to stand in leaden vessels about

6 ft. long, 3 ft. deep, and 3 ft. wide, that the crystals may deposit slowly, as slow formation produces large crystals, which are more easily collected. The sulphate of copper is represented by $CuO,SO^3,5HO$ ($\mathbf{CuSO^4,5H^2O}$). The mother-liquors are evaporated and returned to the works, being in fact free sulphuric acid, with a small amount of sulphate of copper in solution. The parts of the hydraulic presses which come in contact with the silver at the time of pressing are coated with a compound of tin and lead, hardened by mixture with antimony. Cast iron is very little attacked by concentrated sulphuric acid, but it is necessary to avoid wrought iron in any shape, and copper vessels would of course be rapidly destroyed.

The floors should be covered with lead of tolerable thickness. The melting-pots used in France are made of Picardy clay, and hold from 2,200 to 2,600 troy ounces of silver. The pots cost from 4*d.* to 6*d.* each, and if dried and used with care, very seldom crack or break.

The total cost of refining silver in Paris, inclusive of the loss by melting, is stated to be 15 centimes for 32 troy ounces; but it must be understood that the loss of silver by melting is absolutely very minute, because the flues are swept, and the sweepings so obtained are made to yield the silver which has been volatilised, while the pots, &c., are ground and made to yield their absorbed silver.

In the event of the mass containing much copper and little silver, it is usual to granulate the mass and roast the granulated particles to oxidise the copper; the oxide of copper is then dissolved out by diluted sulphuric acid, and the remaining mass of silver, with a smaller amount of copper, is treated in the ordinary way.

If the gold contains platinum, it is found that it is apt to retain from 4 to 5 per cent. of silver, which must be separated by mixing the precipitated gold with about a fourth of its weight of anhydrous sulphate of soda (which is preferred to sulphate of potassa, on account of its greater solubility in water), and to moisten this mass with concentrated sulphuric acid, using about 6 or 7 parts of acid to every 10 parts of sulphate of soda. The moistened mass is then heated till sulphuric acid ceases to distil off, and the heat is then raised till the whole mass melts; and by extracting the sulphate of silver and sulphate of soda the gold will be found to contain 99·40 per cent. of gold; but if the process be repeated, the gold is obtained of a purity of 99·90.

When the silver has been removed, the gold is fused with nitre, which oxidises and removes the platinum; but the potash salt formed is found to contain gold, so that the gold and platinum are obtained from the potash salt mixed with fused nitre by the process of cupellation, for which see SILVER.—G.F.A.

A simple process of refining gold by means of chlorine gas was introduced a few years ago by Mr. F. B. Miller, of the Sydney branch of the Royal Mint. It consists in passing chlorine through the melted gold, by thrusting into the molten metal a small clay tube connected with the stoneware vessel in which the chlorine is generated. The evolved chlorine combines with the silver in the alloy, and the chloride of silver thus formed floats on the surface of the purified gold. Miller's processs is now extensively used, and may always be advantageously applied when the proportion of silver in the gold does not much exceed ten per cent.

The following remarks on the 'Hall-Marking of Gold' is from the pen of Mr. Wm. Chaffers, the author of 'Hall-Marks on Plate.'

The guarantee of the quality of gold and silver as stamped by the Government Assay Offices is a matter of such great importance to the public that any doubt thrown upon it ought immediately to be thoroughly investigated.

The standard of the precious metals has been insisted on by the laws of the land for more than 600 years, and the assaying of them was a privilege conferred, as early as the year 1300, by Edward I., upon the Goldsmiths' Company, who stamped them with the Leopard's Head, as a sign to the public that a piece of gold or silver was actually of the quality thereby signified. It was ordained in 1327 that in all cities and towns in England where goldsmiths reside, one or two of the craft for the rest of the trade should come to London and have the stamp of a puncheon of a Leopard's Head marked upon their work, as of ancient time it has been ordained, and at that early date it was enjoined that three stamps should be put upon the plate: 1. The goldsmith's mark who made it. 2. The mark of the assayer (a letter of the alphabet denoting the year). 3. The mark of the Goldsmiths' Hall (a Leopard's Head crowned). Another mark of a lion passant, denoting that the piece was standard, was added about 1545. . . . In 1423 other towns were privileged to mark plate; but as many had discontinued, another act was passed in 1700, by which York, Exeter, Bristol, Chester, and Norwich were formally appointed. In 1702 Newcastle was added to the list, and in 1773 Birmingham and Sheffield were also privileged to assay and stamp silver plate, each town placing a stamp of their arms for the purpose of identification.

These two standards of plate—gold of 22 carats, and silver of 11 oz. 2 dwts.—or sterling have remained unchanged, except for a short period of 25 years, when a purer quality of gold was introduced called the new standard, but it was found too soft for general use.

In 1798 a lower standard of gold, consisting of 18 carats pure gold out of the 24, was allowed by the Act, indicated by the stamp of a crown and 18 instead of the lion passant. In 1854 inferior qualities of gold were legalised to be stamped in figures setting forth the fineness—viz. 15, 12 and 9 carats pure gold out of the 24.

It may be well to state for the information of the public, and to put people on their guard in purchasing gold—that whether of the best or worst quality, it is still termed so and sold as warranted gold, although the value ranges from 85*s.* to 30*s.* per oz.—that 24-carat, or pure gold, is worth 4*l.* 4*s.* 11½*d.* per oz.; 22-carat, or standard, is worth 3*l.* 17*s.* 10½*d.* per oz.; 20-carat (Ireland only) is worth 3*l.* 10*s.* 9½*d.* per oz.; 18-carat is worth 3*l.* 3*s.* 8½*d.* per oz.; 15-carat is worth 2*l.* 13*s.* 1*d.* per oz.; 12-carat is worth 2*l.* 2*s.* 5¾*d.* per oz.; 9-carat is worth 1*l.* 11*s.* 10½*d.* per oz.

Hence any purchaser may tell by the stamp the intrinsic value of the article offered for sale, to which must necessarily be added the cost of manufacturing. The marks thus affixed to the article by the Government Assay Offices afford the surest guarantees, and have never before been questioned. It is true a slight variation of a few grains may be detected in assaying a finished piece such as a watch-case, but this arises from the solder employed in putting the object together.

GOLD ASSAYING.—This may be conveniently divided into: 1. The assaying of gold ores; 2. The assaying of gold alloys.

1. *The Assaying of Gold Ores.—a. Quartz and Earthy Substances containing Gold.*—The ore is reduced to fine powder and passed through a sieve of 80 holes to the linear inch, and any residual gold is carefully collected, rolled up in a convenient quantity of lead, cupelled (for a description of the process of cupellation and the furnace employed, see SILVER), and the resulting button of metal treated in the same manner as those subsequently obtained from the assay of the sifted portion. The total weight of the sample is ascertained in order that the proportion of gold and silver obtained from the residual metal may be calculated. The sifted portion is well mixed and submitted to assay as follows:—From 500 to 1,000 grs. of the ore are weighed out and mixed with from 600 to 1,200 grs. of dried carbonate of soda, 500 grs. of litharge or red lead, and 20 grs. of charcoal-powder. The mixture is placed in a Cornish or earthen crucible, and then submitted to a gradually increasing heat in an air-furnace, heated with coke or other suitable fuel, until fusion is completed in from 20 to 30 minutes. Considerable effervescence will occur at the first part of the operation, from the escape of carbonic acid gas; when tranquil the crucible is removed from the furnace and its contents poured into an iron ingot-mould (*fig.* 534, Art. COPPER), and when cold the slag is detached from the button of lead. The lead is cupelled (see SILVER), and the button of gold and silver weighed in a balance, turning with $\frac{1}{1000}$th of a grain. After weighing, the button is rolled up along with 2½ times its weight or less of silver, in from 10 to 50 grains of lead, re-cupelled, and the alloy obtained flattened out under a hammer, parted, and the gold weighed. After correction for the silver contained in the litharge or red lead used for the assay, the amount of silver present is ascertained by deducting the weight of the gold from the weight of the silver and gold previously found. For fusion, part of the carbonate of soda may be replaced by calcined borax; the boro-silicates produced being more fusible than silicates.

b. Auriferous Pyrites with or without Vein-Stuff and Earthy Matters.—1,000 grs. of the finely-powdered ore are to be taken, and calcined in a *roasting-dish* in a muffle, or in an earthen crucible, in an open air-furnace. The heat is carefully regulated at first to prevent softening of the particles or clotting, and the calcination continued, with frequent stirring, until the smell of sulphurous acid ceases. When cold, the calcined ore is mixed with about 500 grs. of dried carbonate of soda, from 300 to 400 grs. of calcined borax, 500 grs. of litharge or red lead, and from 30 to 60 grs. of charcoal-powder, according to the proportion of oxide of iron present. Fusion is conducted in an earthen crucible, and the assay completed as previously described (*a*). Sand may be used in place of borax, and is cheaper. When arsenic is present, it is only partly expelled by calcination. A piece of iron is therefore added during fusion, and the *speiss* obtained detached from the button of lead before cupellation. When copper pyrites is present the addition of more litharge or red lead is required for fusion to remove the copper during cupellation. In England and Australia the gold and silver results obtained from the assay are reported to ounces, pennyweights, and grains troy upon the statute ton of 2,240 lbs.

c. Assay in the 'Washing-bowl,' Tin-dish, or other Vessel.—This method is often resorted to in prospecting at the diggings, and under other circumstances, to ascertain the approximate quantity of gold (native gold) present in a sample of quartz or other ore. The ore is finely powdered, and from 1,000 to 7,000 grs. (= 1 lb. avoid.) are thrown upon the washing vessel, and thoroughly wetted with water. The muddy portion is first removed, and the washing repeated with successive portions of water, and with a shaking motion, which can only be acquired by practice, so as to finally collect the gold in the lower part of the vessel. When the earthy matters have been removed, the gold is carefully dried, collected, and weighed, or in some cases mercury is added to collect the gold, and the amalgam afterwards heated to drive off the mercury, and the residual gold weighed. When pyrites is present, it remains for the most part with the gold. To separate it, the residue is roasted or calcined, and the resulting oxides of iron and copper removed by submitting it to a washing process, with or without the addition of mercury.

2. *The Assaying of Gold Alloys.*—*a. Gold-parting.*—Bar-gold, and alloys used for monetary and other purposes, are assayed by this method. 10 grs., or other convenient quantity, of the sample is weighed out on a balance turning with $\frac{1}{1000}$th of a grain. To the weighed metal is added 2½ times its weight. or less of silver, and both are rolled up in 60 grs. or more of lead-foil, according to the quantity of copper present, and cupelled, in order to alloy the gold with the silver, and remove the copper or other metallic impurities. When cold the resulting button is removed from the cupel, cleansed, and flattened out under the hammer, or rolled out into a riband or fillet of from 2½ to 3 inches in length. The fillet is annealed by heating it to dull redness, and then rolled up into a loose coil. The coil is transferred to a parting flask, and boiled for 15 minutes in nitric acid, of specific gravity 1·2 (about 1 part by measure of acid to 2 of water). The acid is carefully poured off, the cornet washed with warm distilled water, and then boiled for 20 minutes in nitric acid, of specific gravity 1·3 (about 1 part by measure of acid to 1 of water), a fire-clay pea, or a small piece of well-burnt charcoal, being placed in the flask to prevent the ebullition taking place irregularly and with sudden bursts, which would be liable to break the *cornet*, or eject a portion of the liquid from the flask. The acid is poured off, the cornet washed with water, and the clay pea removed. The cornet is transferred to a small clay crucible, by dexterously inverting the flask previously filled with water. The water is drained off from the crucible, and the cornet dried, annealed, or heated to dull redness, and weighed. A very small portion of silver is retained by the gold. In order to ascertain the amount of error due to the surcharge or the *correction* for this silver when several assays are made, a number of *proofs* or *checks* are passed through the process along with the alloys. These proofs consist of weighed portions of pure gold, to which is added a proportion of copper equal to that estimated to exist in the alloy to be assayed. The excess of weight finally obtained in these proofs gives the amount to be deducted. It generally varies from 0·1 to 0·5 in 1,000. The amount of *correction* will depend on the weight of alloy submitted to assay, the proportion of silver added, the care in *firing*, the strength of the nitric acid used, and the time employed in the first and second boilings. The cornets are sometimes boiled a third time in nitric acid. In accurate assaying of gold bullion and other alloys of gold, it is absolutely necessary that the acids should be pure, and that the silver used is most carefully freed from the traces of gold which it usually contains.

The last traces of silver may be removed from the cornet by treating it before the final annealing with fusing bisulphate of potash in a porcelain crucible. When sufficiently cool, the whole is heated with hot water containing a little sulphuric acid, and the cornet dried and ignited. By this means gold may be obtained of almost absolute purity, or $\frac{1000}{1000}$, as it is termed. The following results obtained by the late Mr. T. H. Henry will serve for illustration:—Ten grains of pure gold, alloyed with three times its weight of silver, cupelled, and boiled with acid at 22° B., and 32° B., once, weighed 10·016. Ten grains of a half-sovereign, with silver, &c., and acid at 22°, and twice at 32° B., gave 915·4; again, 915·6. With acid, as before, and bisulphate of potash, 915·2; again, 915·2.

Pure gold alloyed with copper, to bring it to standard, cupelled with silver and lead, and treated with acids and bisulphate, gave in one case precisely the same as was taken originally, or $\frac{1000}{1000}$, and in another 999·98.

The assays are reported on 1,000 parts to ⅓rd of a thousandth. The assays are also returned on the 24 parts or *carats*; pure gold is said to be *fine*. Thus—if 18 parts by weight of gold are obtained from 24 parts of the alloy submitted to assay, it is said to be 18-carats fine. For jewellers and others the assays are also reported in relation to British Standard. Standard gold contains 22 parts of gold in 24. If the assay result of gold is less than this amount it is said to be *worse*, or if more is said to be *better*. than standard. For example, 23 parts in 24 would be reported 1 carat better, or 21 parts would be reported 1 carat worse than standard.

Where a number of assays have to be made, a series of flasks are heated simultaneously over a number of gas-burners arranged in rows. In order to save time and to diminish the amount of manipulation. several methods have more recently been devised. At the Sydney Mint each fillet coil is impressed with a number, and 16 of them are boiled with acid in one flask. The plan which is now being generally adopted, consists in placing the fillet coils in a series of platinum cups or thimbles, each cup being provided with several fine slits. These cups are then arranged in rows in a perforated platinum tray, and the whole placed in a vessel of platinum or other material containing nitric acid. After boiling in acid for a given time, the tray is lifted out, dipped in water, and then transferred to a vessel containing a stronger acid; after boiling, the tray containing the gold cornets is then removed, washed in water, dried, and carefully heated in a muffle. The cornets are then removed and weighed.

The platinum cups are made of various sizes, according to the quantity of alloy operated on, and the platinum trays constructed to receive from 16 or more of the cups as may be desired. A tray to hold 49 cups is about 4 inches square, and each cup ⅝ths of an inch in depth and ½ inch in diameter at the top. The use of platinum cups is a modification of the plan first introduced by Mr. T. H. Henry and Mr. C. Tookey in 1854. They constructed glass tubes, provided at the lower part with perforated discs of platinum, and having a rim near the upper end. In the assay process a fillet coil was placed in each tube. A number of these tubes were supported by a porcelain plate having circular holes, the holes and tubes being numbered. Thus arranged, a number of them could be boiled at one time in a vessel containing nitric acid, and readily removed for subsequent treatment. The platinum cups and parting apparatus were first manufactured and introduced by Messrs. Johnson and Matthey.

At the Mint Conference held at Vienna in 1857 the following process was agreed upon:—Add to 1 part of gold supposed to be present 2½ parts of silver, wrap up in paper, and introduce into a cupel in which the requisite amount of lead is just fusing. After cupellation, the button of gold and silver is flattened out by hammering or rolling, then ignited, and rolled into a coil. The coils are then treated, first, with nitric acid of 1·2 sp. gravity, afterwards with nitric acid of 1·3 sp. gravity, and lastly it is washed with water, ignited and weighed.

The process recommended in the old French official report is as follows:—Twelve grains of the gold intended to be assayed must be mixed with thirty grains of fine silver, and cupelled with 108 grains of lead. The cupellation must be carefully attended to, and all the imperfect buttons rejected. When the cupellation is ended, the button must be reduced, by lamination, into a plate of 1½ inch, or rather more, in length, and four or five lines in breadth. This must be rolled up upon a quill, and placed in a matrass capable of holding about three ounces of liquid, when filled up to its narrow part. Two ounces and a half of very pure aquafortis, of the strength of 20 degrees of Baumé's aerometer, must then be poured upon it; and the matrass being placed upon hot ashes, or sand, the acid must be kept gently boiling for a quarter of an hour: the acid must then be cautiously decanted, and an additional quantity of 1½ ounce must be poured upon the metal, and slightly boiled for twelve minutes. This being likewise carefully decanted, the small spiral pieces of metal must be washed with filtered river-water, or distilled water, by filling the matrass with this fluid. The vessel is then to be reversed, by applying the extremity of its neck against the bottom of a crucible of fine earth, the internal surface of which is very smooth. The annealing must now be made, after having separated the portion of water which had fallen into the crucible; and lastly, the annealed gold must be weighed. For the certainty of this operation, two assays must be made in the same manner, together with a third assay upon gold of twenty-four carats, or upon gold the fineness of which is perfectly and generally known.

No conclusion must be drawn from this assay, unless the latter gold should prove to be of the fineness of twenty-four carats exactly, or of its known degree of fineness; for, if there be either loss or surplus, it may be inferred that the other two assays, having undergone the same operation, must be subject to the same error. The operation being made according to this process by several assayers, all the assayers must have obtained an uniform result without communication with each other.

M. Vauquelin recommends to boil 60 parts of nitric acid at 22° Baumé, on the spiral slip, or cornet of gold and silver alloy, for twenty-five minutes, and replace the liquid afterwards by acid of 32°, which must be boiled on it for eight minutes. This process is free from uncertainty, when the assay is performed upon an alloy containing a considerable quantity of copper. But this is not the case in assaying finer gold; for then a little silver always remains in the gold. The surcharge which occurs here is 2 or 3 thousandths. M. Claudet recommends the following process:—He takes 0·500 of the fine gold to be assayed; cupels it with 1·500 of silver and 1·000 of lead; forms, with the button from the cupel, a riband or strip three inches long, which he rolls into a cornet. He puts this into a matrass with acid at 22° B., which he boils for 3 or 4 minutes. He replaces this by acid of 32° B., and boils for ten minutes; then decants off, and boils again with acid of 32°, which must be finally boiled for 8 or 10 minutes. He washes the cornet, and puts it entire into a small crucible permeable to water; heats the crucible to dull redness in the muffle, when the gold assumes the metallic lustre and the cornet becomes solid. It is now taken out of the crucible and weighed.

When the alloy contains platinum, the assay presents greater difficulties. In general, to separate with accuracy the platinum from the gold, we must avail ourselves of a peculiar property of platinum; when alloyed with silver, it becomes soluble in nitric acid. Therefore, by a proper quartation of the alloy by cupellation, and boiling the button with nitric acid, we may get a residuum of pure gold. If we were to treat the button with sulphuric acid, however, we should dissolve nothing but the silver. The copper is easily removed by cupellation.

The examination may also be employed for assay purposes to indicate the quantity of silver necessary for quartation or parting.

b. Silver Parting.—This method is employed for estimating gold in certain varieties of silver. When an alloy of silver and gold contains about 65 per cent. or more of silver, the silver may be completely removed by the action of nitric acid. 20 grs. of the silver are to be weighed out, transferred direct to the parting flask, and boiled in the first and second nitric acids for about the same time and in the same manner as for *gold parting*. The residual gold, which is generally left in the state of fine powder, is very carefully washed with water, transferred to a crucible, dried, ignited and weighed. If the silver under examination contains lead, antimony, and other impurities, it is first cupelled with lead and the button afterwards cleaned, and flattened out, before submitting it to the parting process.

c. Assay by the Touchstone or the Touch.—This method is used by jewellers and others to ascertain the approximate fineness or quality of gold trinkets, &c., and to prevent fraud. It depends on comparing the colour and other properties of a minute portion of the metal tested, with those of small bars of alloys, the composition of which is known. For this purpose we require a *Touchstone* of a black colour, consisting of Lydian stone, pottery, or other substance; and a series of *needles* or alloys of gold and copper, gold and silver, or gold silver and copper, &c. Thus the set of gold and copper needles may consist of pure gold; 23½ carats of gold with ½ carat of silver; 23 carats of gold with 1 carat of silver; 22½ carats of gold with 1½ carat of silver; and so on, till the silver amounts to four carats; after which the addition may proceed by whole carats. A *Test acid*, consisting of nitric acid, or of nitric acid with about 2 per cent. of hydrochloric acid, is used. The examination may be made as follows:—First remove the superficial coating of gold, by rubbing or otherwise. Then compare the streak produced by rubbing the article upon the touchstone with those produced from the alloys. When the one is found which most closely corresponds in colour, both streaks are tested with the acid, and a judgment formed therefrom.

The attentive assayer compares not only the colour of the stroke made upon the touchstone by the metal under examination with that produced by the needle, but will likewise attend to the sensation of roughness, dryness, smoothness, or greasiness, which the texture of the rubbed metal excites when abraded by the stone. When two strokes perfectly alike in colour are made upon the stone, the test acid will affect them very differently if they are not of similar compositions. The stone itself may also be made red-hot by the fire, or by the blowpipe, if thin black pottery be used; in which case the phenomena of oxidation will differ according to the nature and quantity of the alloy.

GOLD, ALLOYS OF. See ALLOY.

GOLD-AMALGAM. See AMALGAM.

GOLD-BEATERS' SKIN. This skin is prepared from the external or peritoneal coat of the cæcum or blind gut of neat cattle. The workman separates and turns over the portion which encircles the junction of this pouch with the rest of the intestines, and draws it off inverted from the other coats to the length of 25 or 30 inches. It is then immersed a short time in a weak solution of potash, and is cleaned by straying upon a board with a knife. When thus well cleaned, and by soaking in water, the piece is stretched upon a kind of frame from 40 to 50 inches in length and 11 inches wide, and made up of two uprights held together by two cross-pieces having longitudinal grooves two and a half lines in width. The surface of the membrane, which was outside in the animal, is placed in contact with the upper part of the frame; it is stretched in every direction, and is glued to its rim. Another membrane is then stretched above the first, with its external surface placed upwards, and is attached to it by glueing around the edges. When dry, the membranes are separated by running a sharp knife along the grooves. Each strip is then glued upon a frame similar to the first one, but without a groove, and is washed over with a solution composed of alum, 1 ounce; water, 2 quarts.

When the surface is dried, a sponge dipped in a concentrated solution of fish-glue in white wine, rendered aromatic by cloves, nutmegs, or camphor, is passed over it. When this coating is dried, it is covered with a coat of white of eggs, and the strip is cut in pieces 5½ inches square, which are then smoothed out under a press, and made up into leaves.

A body is given to the pieces of gut; that is, they are moistened with an infusion of cinnamon, nutmeg, and other warm and aromatic ingredients, in order to preserve them: an operation repeated after they have been dried in the air. When the leaves of skin are dry, they are put in a press, and are ready for use. After the parchment, vellum, and gut-membrane have been a good deal hammered, they become unfit for work, till they are restored to proper flexibility, by being placed, leaf by leaf, between leaves of white paper, moistened sometimes with vinegar, at others with white wine. They are left in this condition for three or four hours, under compression of a plank loaded with weights. When they have imbibed the proper humidity, they are put between leaves of parchment 12 inches square, and beat in that situation for a whole day. They are then rubbed over with fine calcined gypsum, as the vellum was originally. The gut-skin is apt to contract damp in standing, and is therefore dried before being used.

GOLD-BEATING. This is the art of reducing gold to extremely thin leaves, by beating with a hammer. The processes employed for this purpose may be applied to other metals, as silver, platinum, and copper. The Romans used to gild the ceilings and walls of their apartments; and Pliny tells us, that from an ounce of gold forming a plate of 4 fingers square, about 600 leaves of the same area were hammered. At the present day, a piece of gold is extended so as to cover a space of 651,590 times greater than its primary surface when cast.

The gold employed in this art ought to be of the finest standard. Alloy hardens gold and renders it less malleable; so that the fraudulent tradesman who should attempt to debase the gold would expose himself to much greater loss in the operations than he could derive of profit from the alloy.

The average thickness of common gold-leaf is $\frac{1}{282000}$ of an inch.

Four principal operations constitute the art of gold-beating:—1. The casting of the gold ingots. 3. The lamination. 2. The hammering. 4. The beating.

1. *The casting.*—The gold is melted in a crucible along with a little borax. When it has become liquid enough, it is poured out into an ingot-mould previously heated, and greased on the inside. The ingot is taken out and annealed in hot ashes, which both soften it and free it from grease, The moulds are made of cast iron, with a somewhat concave internal surface, to compensate for the greater contraction of the central parts of the metal in cooling than the edges. The ingots weigh about 2 ounces each, and are ¾ of an inch broad.

2. *The forging.*—When the ingot is cold, the French gold-beaters hammer it out on a mass of steel 4 inches long, and 3 broad. The hammer for this purpose is called the forging hammer. It weighs about 3 pounds, with a head at one end and a wedge at the other, the head presenting a square face of 1½ inch. Its handle is 6 inches long. The workman reduces the ingot to the thickness of ⅛th of an inch at most; and during this operation he anneals it whenever its substance becomes hard and apt to crack. The English gold-beaters omit this process of hammering.

3. *The lamination.*—The rollers employed for this purpose should be of a most perfectly cylindrical figure, a polished surface, and so powerful as not to bend or yield in the operation. The ultimate excellence of the gold-leaf depends very much on the precision with which the riband is extended in the rolling press. The gold-beater desires to have a riband of such thinness that a square inch of it will weigh 6½ grains. Frequent annealings are requisite during the lamination.

4. *Beating.*—The riband of gold being thus prepared uniform, the gold-beater cuts it with shears into small squares of an inch each, having previously divided it with compasses, so that the pieces may be of as equal weight as possible. The squares are piled over each other in parcels of 150, with a piece of fine calf-skin vellum interspersed between each, and about twenty extra vellums at the top and bottom. These vellum leaves are about 4 inches square, on whose centre lie the gold laminæ, each of an inch square. This packet is kept together by being thrust into a case of strong parchment open at the ends, so as to form a belt or band, whose open sides are covered in by a second case drawn over the packet at right angles to the first. Thus the packet becomes sufficiently compact to bear beating with a hammer of 15 or 16 pounds weight, having a circular face nearly four inches in diameter, and somewhat convex, whereby it strikes the centre of the packet most forcibly, and thus squeezes out the plates laterally.

The beating is performed on a very strong bench or stool, framed to receive a heavy block of marble, about 9 inches square on the surface, enclosed upon every side by wood-work, except the front, where a leather apron is attached which the workman lays before him to preserve any fragments of gold that may fall out of the packet. The hammer is short-handled, and is managed by the workman with one hand; who strikes fairly on the middle of the packet, frequently turning it over to beat both sides alike;

a feat dextrously done in the interval of two strokes, so as not to lose a blow. The packet is occasionally bent or rolled between the hands to loosen the leaves and secure the ready extension of the gold; or it is taken to pieces to finish the gold, and to shift the central leaves to the outside, and *vice versâ*, that everything may be equalised. Whenever the gold plates have extended under this treatment to nearly the size of the vellum, they are removed from the packet, and cut into four equal squares by a knife. They are thus reduced to nearly the same size as at first, and are again made up into packets, and enclosed as before, with this difference, that skins prepared from ox-gut are now interposed between each gold-leaf, instead of vellum. The second course of beating is performed with a smaller hammer, about 10 pounds in weight, and is continued till the leaves are extended to the size of the skins. During this period, the packet must be often folded, to render the gold as loose as possible between the membranes; otherwise the leaves are easily chafed and broken. They are once more spread on a cushion, and subdivided into four square pieces by means of two pieces of cane cut to very sharp edges, and fixed down transversely on a board. This rectangular cross being applied on each leaf, with slight pressure, divides it into four equal portions. These are next made up into a third packet of convenient thickness, and finally hammered out to the area of fine gold-leaf, whose average size is from 3 to 3½ inches square. The leaves will now have obtained an area 192 times greater than the plates before the hammering began. As these were originally an inch square, and 75 of them weighed an ounce (= 6½ × 75 = 487½), the surface of the finished leaves will be 192 × 75 = 14,400 square inches, or 100 square feet per ounce troy. This is by no means the ultimate degree of attenuation, for an ounce may be hammered so as to cover 160 square feet; but the waste incident in this case, from the number of broken leaves, and the increase and nicety of the labour, make this an unprofitable refinement; while the gilder finds such thin leaves make less durable and satisfactory work.

The finished leaves of gold are put up in small books made of single leaves of soft paper, rubbed over with red chalk to prevent adhesion between them. Before putting the leaves in these books, however, they are lifted one by one with a delicate pair of pincers out of the finishing packet, and spread out on a leather cushion by blowing them flat down. They are then cut to one size by a sharp-edged square moulding of cane, glued on a flat board. When this square-framed edge is pressed upon the gold, it cuts it to the desired size and shape. Each book commonly contains 25 gold-leaves.

We must now describe some peculiarities of the French practice of gold-beating. The workman cuts the laminated ribands of an inch broad into portions an inch and a half long. These are called *quartiers*. He takes 24 of them, which he places exactly over each other, so as to form a thickness of about an inch, the riband being ½ of a line, or $\frac{1}{24}$th of an inch thick; and he beats them together on a steel slab with the round face (*panne*) of the hammer, so as to stretch them truly out into the square form. He begins by extending the substance towards the edges, thereafter advancing towards the middle; he then does as much on the other side, and finally hammers the centre. By repeating this mode of beating as often as necessary, he reduces at once all the *quartiers* (squares) of the same packet, till none of them is thicker than a leaf of grey paper, and of the size of a square of 2 inches each side.

When the *quartiers* are brought to this state, the workman takes 56 of them, which he piles over each other, and with which he forms the first packet (*caucher*) in the manner already described; only two leaves of vellum are interposed between each gold-leaf. The empty leaves of vellum at the top and bottom of the packet are called *emplures*. They are 4 inches square, as well as the parchment pieces.

The packet thus prepared forms a rectangular parallelopiped; it is inclosed in two sheaths, composed each of several leaves of parchment applied to each, and glued at the two sides, forming a bag open at either end.

The block of black marble is a foot square at top, and 18 inches deep, and is framed as above described. The hammer used for beating the first packet is called the flat, or the enlarging hammer; its head is round, about 5 inches in diameter, and very slightly convex. It is 6 inches high, and tapers gradually from its head to the other extremity, which gives it the form of a hexagonal truncated pyramid. It weighs 14 or 15 pounds.

The French gold-beaters employ besides this hammer, three others of the same form; namely, 1. The *commencing hammer*, which weighs 6 or 7 pounds, has a head 4 inches in diameter, and is more convex than the former. 2. The *spreading hammer*, (*marteau à chasser*); its head is two inches diameter, more convex than the last, and weighs only 4 or 5 pounds. 3. The *finishing hammer*; it weighs 12 or 13 pounds, has a head four inches diameter, and is the most convex of all.

The beating processes do not differ essentially from the English described above.

GOLD, CHLORIDE OF. Trichloride of gold. This salt is formed when gold is dissolved in nitro-muriatic acid. It is much used in photography.

GOLD COINAGE. The current gold coins of the United Kingdom are the sovereign and the half-sovereign. See Mint; Sovereign.

GOLD LACE. Gilt silver wire, woven into a lace.

GOLD-LEAF. See Gold-Beating.

GOLD, MANNHEIM. A brass composed of from 3 to 4 ounces of zinc to 1 pound of copper. See Brass.

GOLD, MOSAIC. A brass of very fine colour used in common jewellery. Hamilton and Parker's patent Mosaic gold consists of 16½ ounces of zinc to 16 ounces of copper. It is of a dark colour when first cast, but on dipping assumes a beautiful golden tint. The patentees say, 'when cooled and broken, all yellowness must cease, and the tinge vary from reddish fawn or salmon colour, to a light purple or lilac, and from that to whiteness.' See Brass; Alloys.

GOLD-PURPLE. See Purple of Cassius.

GOLD, SALTS OF. The bromide, cyanide, iodide, phosphide, sulphide, and some other salts of gold which are rarely used in the arts, are fully described in Watts's 'Dictionary of Chemistry.'

GOLD OF PLEASURE. A plant cultivated on the Continent for its seeds, which yield a fine oil, while its fibres can be employed in the manufacture of sail-cloth, packing, and other coarse articles. It is the *Camelina sativa* of botanists. It has not attracted much attention in this country.

GOLD THREAD, or *spun gold*, is a flatted silver-gilt wire, wrapped or laid over a thread of yellow silk by twisting with a wheel or iron bobbins. By the aid of a mechanism like the braiding machine, a number of threads may thus be twisted at once by one master wheel. The principal nicety consists in so regulating the movements that the successive volutions of the flatted wire on each thread may just touch one another, and forms a continuous covering. The French silver for gilding is said to be alloyed with 5 or 6 pennyweights, and ours with 12 pennyweights, of copper in the pound troy. The gold is applied in leaves of greater or less thickness, according to the quality of the gilt wire. The smallest proportion formerly allowed in this country by Act of Parliament was 100 grains of gold to one pound, or 5,760 grains of silver; but more or less may now be used. The silver rod is incased in the gold-leaf, and the compound cylinder is then drawn into round wire down to a certain size, which is afterwards flatted in a rolling mill, such as is described under Mint.

The liquor employed by goldsmiths to bring out a rich colour on the surface of their trinkets is made by dissolving 1 part of sea-salt, 1 part of alum, 2 parts of nitre, in 3 or 4 of water. The pickle or sauce, as it is called, takes up not only the copper alloy, but a notable quantity of gold; the total amount of which in the Austrian Empire has been estimated annually at 47,000 francs. To recover this gold the liquor is diluted with at least twice its bulk of boiling water, and a solution of very pure green sulphate of iron is poured into it. The precipitate of gold is washed upon a filter, dried, and purified by melting in a crucible along with a mixture of equal parts of nitre and borax.

GOLD-THREAD. The bitter root of the *Coptis trifoliata*, used in North America as a tonic.

GOLD WIRE is formed by drawing a cylindrical rod of the metal, as pure as may be, through a series of holes punched in an iron plate, diminishing progressively in size. The gold, as it is drawn through, becomes hardened by the operation, and requires frequent annealing.

GOLDEN MARCASITE. A name given at one time to the metal zinc. Albertus Magnus calls it *Marchasita aurea*. 'This was properly a stone, the metallic particles of which were so entirely sublimated by fire, that nothing but useless ashes remained behind. It contained fixed quicksilver, communicated a colour to metals, on which account it was well known to the alchemists, burned in the fire, and was at length entirely consumed. It was found in various parts, but that at Goslar was the best, because the copper it contained seemed to have in it a mixture of gold. To give this copper, however, a still greater resemblance to gold, some tin was added to it, by which means it became more brittle. This *marchasita* also rendered copper white as silver. Thus far Albertus. It obtained without doubt the name of *Marchasita aurea* because zinc communicates a yellow colour to copper; and for the same reason the Greeks and the Arabians called *Cadmia* golden, or *aurea*.'—*Beckmann.*

GOLDEN SULPHURET OF ANTIMONY. *Stibium Sulphuratum Aurantiacum.* The pentasulphide of antimony, a golden yellow powder, its formula being SbS^{5} (**$Sb^{2}S^{5}$**). See Antimony.

GONG-GONG, or *Tam-tam* of the Chinese. A kind of cymbal made of a copper-alloy. See Copper.

GONIOMETER. An instrument employed to measure the angles of crystals. The most perfect instrument is the reflecting goniometer of Wollaston. The angle of the crystal is measured by determining through what angular space the crystal must be turned so that two rays reflected from two surfaces successively shall have the same direction. A simpler form of the instrument consists merely of a semicircular graduated scale of degrees with a moveable and a fixed radius. It is a most important instrument to the scientific mineralogist.

GOOSEBERRY. The fruit of the *Ribes grossularia*, a plant belonging to the natural order *Ribesiaceæ* or *Grossulariaceæ*.

GOOSEBERRY-GARNET. A name for Grossularia. See GARNET.

GOSLARITE. Native hydrous sulphate of zinc, named from its occurrence in the Rammelsberg mine, near Goslar, in the Hartz.

GOSSAN, *a Cornish mining term.* An oxide of iron, mixed with other matters. Gossans are found on the upper portions of lodes, and according to their characters are regarded by the miners as favourable or unfavourable indications. The gossans are probably the result of the slow decomposition of the sulphate of iron from the fluid in which the metalliferous matter, deposited in the lode, has been precipitated, or of the sulphides which may have been previously formed. The gossans are frequently very rich in silver, and sometimes they contain gold.

GOSSYPIUM. The cotton-tree. See COTTON.

GOULARD LOTION or **WATER.** A solution of the acetate of lead. See LEAD, ACETATE OF.

GOURDS. The hard integument of the fruit of several species of cucurbitaceous plants, used in the East for vessels, musical instruments, &c. See CALABASH.

GOVERNOR. A mechanical arrangement, usually attributed to Watt, for regulating the motion of a steam-engine.

GRADUATOR. A vessel employed in vinegar-manufacture. See ACETIC ACID.

GRAINS OF PARADISE. The fruit of several zingiberaceous plants; sometimes it is called *Mallaguetta pepper.* Pereira distinguishes between the two; but it appears that they commonly pass for the same in commerce. Grains of paradise are imported in casks, barrels, and puncheons from the coast of Guinea. They are used to give a factitious strength and pungency to beer and cordials.

By 56 Geo. III. c. 58, no brewer or dealer in beer shall have in his possession or use grains of paradise, under a penalty of 200*l.* for each offence: and no druggist shall sell it to a brewer under a penalty of 500*l.* for each offence.

GRAIN TIN. The purest kind of metallic tin. See TIN.

GRAMMATITE. A variety of Tremolite. See HORNBLENDE.

GRANITE, in the common and original acceptation of the term, denotes a rock, composed of felspar, quartz, and mica. It oftentimes contains, in addition to these, some other minerals.

These component minerals of granite, both essential and accidental, are united together by a confused crystallisation, not only mutually penetrating and interfering with each other, but sometimes the small crystals of one are completely enveloped in the large crystals of a different kind of mineral, and it is a very common occurrence for one or even more of these minerals to be developed in large crystals, in a granular basis of the whole, so as to constitute a porphyritic granite. This character is generally imparted by the felspar, and rarely by the quartz or mica.—*Boase.*

The chemical composition of ordinary granite is generally as follows:—

Silica	72·3
Alumina	15·3
Alkalis	7·4
Lime, magnesia and iron	5·0

This rock consists generally of about 40 per cent. of felspar, 30 or 40 per cent. of quartz, and from 10 to 20 per cent. of mica.

The granites of Cornwall and Devonshire have been long celebrated for their exceeding durability. Sir Henry de la Beche thus describes the situation of the workable granites:—

'There is much good granite on Dartmoor, though it is not always sufficiently accessible to be carried long distances: the chief places where it is worked in large quantities and afterwards exported are, Hey or High Tor on the east, and near King Tor on the west. The granite from the former place is conveyed by a tram-road to the Stover canal, down which it is carried in boats, and afterwards down the Teign to Teignmouth, to be shipped for its destination. That from the west side of the moor is conveyed by the Prince's Town and Plymouth tram-road to the latter place and shipped.

'The continuation of the Hingston Down granite is worked up the Tamar near New Bridge and exported from Morwellham. A very hard variety is obtained upon the higher part of the Down, and has been employed advantageously for pavements. . . . The chief quarries in the eastern or hard part of the Hensborough mass of granite are those of (the late) Mr. Austin Treffry, up the Par Valley, commonly known as Lostwithiel granite. Extensive quarries are there worked, and the stone is brought to the head of the canal near Pons-mill, upon which it is conveyed to Par harbour, and there shipped. . . . The Carn Menelez mass has furnished the granite most commonly known as Cornish. It is nearly altogether shipped at Penryn, where it is brought variable distances from different quarries in the vicinity, many situated in the parish of Mabe;'—also in Constantine, Budock, and Stithians.

Since the above report was written, the quarries at Cheeswring near Liskeard have been opened, and stone of a beautiful quality is raised and exported in large quantities. The Lamorna quarries have also been worked; the stone obtained from them is of excellent quality, and it can be obtained of almost any size.

The following great works, amongst many others, have been constructed entirely, or in part, of Cornish granites. The Penryn and Lamorna granites have supplied Portland Breakwater; Keyham Docks for the Steam Navy; Commercial Docks, London; the Hull, Great Western, and Birkenhead Docks, and the National Works at Chatham and Portsmouth, together with the Scutari Monument. The plinth for the railings of the British Museum was from the Carnsew quarries, and the towers, including the lodge, for gates, &c., from Constantine. From Lamorna blocks of 12 feet square are readily obtained; these quarries produce about 60,000 feet per annum; some stones have been raised 25 feet in length and 11 feet in diameter.

The Wellington Memorial, erected at Strathfieldsaye, from the design of the Baron Marochetti, is constructed of granite entirely from the Constantine quarries. This monument contains stones of unusual character, the die being a single stone 9 ft. 6 in. high and 7 ft. square, weighing nearly 40 tons. The shaft of the column is 30 ft. in height in one stone, and some of the mouldings are in stones of nearly 11 ft. square. The whole of the surfaces above the plinth are finely polished, and have all the appearance of being carved from a single block.

The Cheeswring granite has been used in the London Docks, Westminster Bridge, the Thames Embankment, Rochester Bridge, the Docks at Copenhagen, the Great Basses Lighthouse near the island of Ceylon, and for the Tomb of the Duke of Wellington in the crypt of St. Paul's Cathedral. These quarries produce from 8,000 to 10,000 tons of stone per annum, and about a similar quantity is annually shipped from the quarries near Par.

The granites of Scotland are chiefly produced from the county of Aberdeen.

The granite of Aberdeen, especially from the quarries of Dancing Cairn, Rubislaw, and Tyrebagger, is much used in the metropolis for kerb and paving stones; some red granite is also quarried. Around Peterhead the red granite prevails, hence it is usually distinguished as the *Peterhead granite*. The principal quarries are those of Black Hill, four miles west of Peterhead, belonging to the Governors of the Merchant Maiden Hospital of Edinburgh; those on the estates of the Earl of Errol—at Boddam, at Longhaven, at Cairngall, and at Rova. The Sheerness Docks were built mostly with stone from these quarries. The Stirling Hill quarries, at Boddam, furnished the pillar of the Duke of York's Monument; the Seafield quarries the abacus. The beautiful pillars in the library of the British Museum were obtained from Longhaven; the cost for transport, at the time they were worked, being something almost fabulous, so great were the difficulties attending their removal. The pillars in Fishmongers' Hall are from the Stirling quarries, as are also the bases of the monuments of Pitt and Fox; and the polished pillars of the Carlton Club House, in Pall Mall, are from the quarries near Peterhead.

Granite of excellent quality is obtained in Argyleshire, especially in the island of Mull, where it may be obtained in blocks of enormous size. The quarries are situated on the west side of the island; a fine pink granite being worked at North Bay, and a dark red variety at Tormor. The Mull granites are especially adapted, by their beauty of colour and uniformity of grain, for purposes of ornament; and have been largely employed in the construction of the Albert Memorial, recently erected in Hyde Park.

Granite is also worked to a limited extent in several of the islands round our coast. In the Isle of Man, the grey granite of South Barrule forms a gigantic boss penetrating the surrounding schistose rocks, and furnishing a stone worked for local consumption; in Lundy Island, which consists almost entirely of granite, quarries have recently been opened; and in the Channel Islands, certain syenitic varieties have long been worked, and are largely employed as London road-metal.

The granites of Ireland.—The most extensive granite district in Ireland stretches south from Dublin, through the counties of Wicklow and Carlow into Kilkenny; it occurs on the south-eastern coast of Down, and around Newry; the range of the Mourne mountains is granite, which again appears in small and isolated protrusions in Derry and Tyrone, and in Cavan. In the western portion of Donegal there is a large extent of this rock, which here partakes of a gneissose character; and again, in the west of Galway, granite covers a considerable area. The granite of the Wicklow range is the most extensively used. It varies in its quality, that near Kingston being coarse and hard, while that from Ballyknocken, or Golden Hill, is much finer, and therefore fitted for ornamental work. The granite of Down is of a darker colour and finely crystallised. It is extensively quarried at Newry, and sent by water to the north of Ireland.

The Galway granite is of a reddish colour, containing large crystals of flesh-red felspar. That of Mayo is of a dark bluish grey colour, while that of Tyrone is reddish.

The Irish granite averages 170 lbs. per cubic foot, its extreme weights being 143 lbs. and 176 lbs. After 88 hours' immersion in water, it was found that a cubic foot of the granite of Newry and Kingston absorbed about ¼ lb., that of Carlow nearly 2 lbs., and the granite of Donegal 4 lbs. of that fluid. These facts are important in connection with the use of these rocks for building purposes.—*Wilkinson's Practical Geology and Ancient Architecture of Ireland.—Sir R. Kane's Industrial Resources of Ireland.—Hull's Building and Ornamental Stones.*

Granite is worked to a small extent at Shap Fell in Westmoreland, and at Mount Sorrell in Leicestershire. The rocks worked as and called the Grooby granite may perhaps more properly be termed Syenites, in some cases assuming the character of a syenitic granite, in others of a syenitic greenstone. These are worked extensively for 'pitching' and for macadamising roads.

Until recently it was an opinion almost universal among geologists that granite had been formed by igneous fusion, and had solidified from a molten condition, under enormous pressure; the theory being supported partly by the crystalline and unstratified character of the rock, but chiefly by the fact that almost every large mass of granite gives off numerous ramifications or veins which penetrate the surrounding rocks, and which appear to have been formed by injection of the molten granite into neighbouring fissures. Evidence has, however, accumulated during the last few years tending to modify this theory very materially. Thus, it has been found that the specific gravity of quartz which has undergone fusion is never higher than 2·3, whilst that of the quartz in granite reaches 2·6; but it should be remembered that the pressure under which granite has evidently been formed must, as Dr. Haughton has pointed out, tend to increase the density of the silica. Again, many minerals occurring in granite, either as essential or as accessory constituents, are such as could not have existed at a high temperature; some of them, indeed, containing a notable proportion of water. Many of these minerals, moreover, are so highly basic that it is difficult to understand how they could have been fused in the presence of free quartz without entering into chemical combination with the silica. Finally, the constituent minerals of granite have, in most cases, not solidified in the order of their relative infusibility; the quartz, which is the most infusible, having evidently solidified last, since it commonly bears the impress of the felspar crystals.

Much light has also been thrown upon the probable origin of granite by the researches of Mr. H. C. Sorby on the microscopical structure of crystals: a subject which has been followed up by Dr. Zirkel and other observers. The crystals of many minerals contain cavities partially filled with liquid, which has evidently been caught up and mechanically enclosed during the formation of the crystal: a phenomenon frequently witnessed in the crystallisation of artificial salts in the laboratory. From the nature of their formation, it is evident that such cavities must be entirely filled with liquid at the temperature at which they have been formed; any vacuities that afterwards appear being due to subsequent contraction, resulting usually from a reduction of temperature. If the crystal, therefore, be exposed to heat until the liquid, by its expansion, entirely fills the cavity, the temperature at which the crystal was originally formed will be at once indicated. Such results will, however, require considerable modification if the mineral should have been formed under the effects of great pressure, as was certainly the case with granite. As crystals deposited from aqueous solution contain *fluid*-cavities, so those obtained by sublimation enclose bubbles of vapour, giving rise to *gas-* or *vapour*-cavities; whilst substances solidifying from fusion, such as glass or slag, contain portions of solid matter, in what are termed *glass-* or *stone*-cavities, according to the nature of the enclosed solid. Now, when the constituent minerals of granite are subjected to microscopical examination, they exhibit numerous cavities, of which some contain liquids, others enclose solids, and a few merely vapour. These cavities are most abundant in the quartz, some varieties of which contain more than a thousand millions to the cubic inch. Since the presence of fluid-cavities indicates formation by the wet way, whilst stone-cavities point to fusion, and gas-cavities to sublimation, the co-existence of all these varieties in granite leads Mr. Sorby to believe that this rock has been formed under highly complex physical conditions, 'combining at once both igneous fusion, aqueous solution, and gaseous sublimation. The proof of the operation of water is quite as strong as that of heat.'

GRANITITE. A granite, containing oligoclase, orthoclase, quartz, and a magnesian mica.

GRANULATION is the process by which metals are reduced to minute grains. It is effected by pouring them, in a melted state, through an iron cullender, pierced with small holes, into a body of water; or directly upon a bundle of twigs immersed in water. In this way copper is granulated into bean-shot, and silver-alloys are granulated preparatory to refining. It has recently been proposed to granulate pig-iron before introducing it into Danks's rotatory puddling-furnace.

GRAPES. The fruit of the grape-vine (*Vitis vinifera*). They are largely used as fruit, both fresh and dried; forming, in the latter case, raisins and currants. The juice of the grape yields wine, brandy, wine-vinegar, &c. The residue of the expression of the juice is known as *marc*, and is used in the preparation of verdigris, or acetate of copper. Oil is prepared from the seed of the grape, whilst the lees are burnt for the sake of the potash they contain.

GRAPE SUGAR. A sugar so called from its being produced in the grape; but it also occurs in many other fruits, and it forms the crystalline portion of honey. A great quantity of grape-sugar is now prepared from starch. The formula of grape-sugar is $C^{12}H^{12}O^{12}.2HO$ ($\mathbf{C^6H^{12}O^6.H^2O}$).

GRAPHIC GRANITE. A peculiar form of granite, in which some of the crystalline constituents are so disposed in the matrix as to suggest a resemblance to some forms of oriental characters.

GRAPHIC TELLURIUM. A name applied to sylvanite, in allusion to the curious forms in which its crystals are generally arranged. See SYLVANITE.

GRAPHITE, *Plumbago*, or *Black-lead.* (*Plombagine*, Fr.; *Reissblei*, Ger.) A mineral substance of a lead or iron-grey colour, a metallic lustre, soft to the touch, and staining the fingers with a lead-grey hue. H = 1 to 2. Specific gravity, 2·08 to 2·45. It is easily scratched or cut, and affords a black streak, displaying the metallic lustre in its interior. B.B. infusible both alone and with reagents; but burns with great difficulty in the outward flame without flame or smoke, generally leaving a residue of oxide of iron. It consists of carbon in a peculiar state of aggregation, with an extremely minute and apparently accidental impregnation of iron. Graphite occurs in gneiss, mica slate, and their subordinate clay-slates and limestones, in the form of masses, veins, and kidney-shaped disseminated pieces. It has been found also among the coal-strata, as near Cumnock in Ayrshire. This substance is employed for counteracting friction between rubbing surfaces of wood or metal, for making crucibles and portable furnaces, for giving a gloss to the surface of cast iron, &c.

The following report of the late Von Haidinger and others, of Vienna, on the origin of graphite, contains much that is valuable.

Iron, after long remaining buried in the earth, at last entirely decomposes, leaving a black, porous, eminently combustible residuum, known as graphite or pure carbon. Haidinger's report on the ferruginous masses of Kokitzau and Gotta, near Dresden, masses of uncertain origin, lends support to this general fact.

One word on the formation, still so little known, of graphite. The presence of graphite in granite, gneiss, and diorite, has renewed the disputes between the Neptunists and Plutonists. Graphite is well known to be nearly pure carbon, for it leaves in burning but a very small quantity of ash. Now, if these primitive crystalline rocks are of igneous formation, it is impossible to explain how graphite could co-exist with silicates of protoxide of iron without having reduced these salts. Judging merely by what takes place in blast-furnaces, carbon reduces all oxides of iron at a high temperature. It must, then, be admitted that granite, gneiss, and diorite did not contain graphite when the mineral elements of these rocks, such as mica, hornblende, and other ferrous silicates, were in a state of fusion. Graphite, then, must have been subsequently introduced into these rocks, but when and how? Questions such as these are very difficult to answer satisfactorily. The most plausible hypothesis is that graphite has been introduced by the wet way into the crystalline rocks, and substituted for one of the mineral components. Thus in the gneiss of Passau (Bavaria) it takes the place of mica.

Graphite is frequently to be met with in granular limestone, a fact particularly interesting to geologists. Is limestone a product of eruption, or is it a sediment transformed by the action of heat? The presence of graphite is explicable by neither hypothesis. For, at a certain temperature, which need not be very high, carbon decomposes carbonate of lime. This salt may, no doubt, under strong pressure, be heated to the melting-point without losing its carbonic acid; this is a laboratory experiment often cited by the Plutonists. But it is quite a different thing with a mixture of carbon and carbonate of lime at a high temperature. If we reject the Neptunian origin of granulated limestone, we must then, as with crystalline rocks, suppose that graphite has been introduced by the wet way at a more recent period. The same remark applies to magnetic pyrites (sulphide of iron), often very rich in plumbago kerns.

Does graphite, like all carbon, belong to the organic kingdom? It is certain that anthracite, lignite, and coal are the result of a slow decomposition of an enormous quantity of vegetables, the impressions found on them often indicate the kind of vegetables, most of them extinct, which have contributed to these carbonaceous formations. Graphite, if not formed in precisely the same way as coal and anthracite, nevertheless bears signs of an organic origin. The formation of nuclei and veins of graphite in crystalline rocks is sufficiently explained by the decomposition of carburetted hydrogen gas at a high temperature; this gas, disengaged from organic matters, and penetrating the fissures of the burning rock, would undergo decomposition into hydrogen and carbon.

It is this deposited carbon which forms graphite. If in our laboratories we do not obtain exactly the same product, it must be remembered that Nature has means at her command which escape our researches. We find it impossible to make coal from wood. The wood may be carbonised by the dry or by the wet way. In the first case the carbonisation is very rapid; in the latter it is extremely slow, as is shown by the blackened points of piling sunk in water.

Finally, graphite has been found in meteorites and aerolites. Attempts have been made to explain its presence here by the continuance of these stones in soil more or less rich in carbonised principles. But with regard to newly-fallen stones, this explanation is inadmissible. If it be maintained that graphite is an organic product, it must be admitted that in the case of newly-fallen meteorites it can proceed only from organic matters belonging to another world than our own.

In his report on Alibert graphite, M. Dumas presents some considerations on the probable origin of graphite and of the diamond. M. Despretz and others ascribe to fire the change of carbon into diamond. Newton ascribed it to the coagulation of a fatty or oily body; Liebig says the diamond is slowly formed by processes which determine the prolonged putrefaction of a liquid body rich in carbon and in water; then, contrary to M. Despretz's method, a high temperature would be unfavourable to a successful attempt. Adopting Newton's hypothesis, M. Göppert states, in a 'Memoir on the solid bodies entering into the composition of the diamond, and considered with regard to their organic or inorganic origin,' that he is disposed to class the diamond among the produce of the decomposition of organic matters. All these hypotheses M. Dumas rejects; according to him the diamond is crystallised carbon, at the moment of its production, and in the midst of a mass which has been exposed merely to the heat necessary to soften it, provided this condition is sufficiently prolonged.

Finally, M. Dumas frankly admits that nothing positive is known as to the true origin of the diamond, though the substance most allied to it, silicium, is perfectly known, and very beautiful crystals of it are obtained.

However, it is positively ascertained that the diamond and graphite have not the same origin, and that the residue of every carboniferous substance, treated at a high temperature, proves to be but a variety of graphite. The graphite found by M. Alibert in the mines of Marinski, situated at the summit of Batougol, on the Siberian frontiers, is, then, a graphitoid carbon of the most beautiful kind, formed by volcanic phenomena. M. Jaquelain, after carefully comparing the external characteristics of Alibert graphite with that obtained by his process, concludes that the conditions under which they are produced must be analogous.

In fact, on comparing the texture of the two carbons, they will be found sometimes of a metallic, mirror-like lustre; at another time the surface will be of shining steel-grey, mammillated as if it had been half fused, and had passed through a pasty stage. This appearance is similar to that of oxide of iron, nodular, brilliant, with mammillated surface, known by the name of brown hematite.

M. Jaquelain is inclined to admit that tarry and pyrogenated products, transformed in immense proportions into carbon and hydrogen under the influence of igneous rocks, become accumulated in rents and excavations, causing an aggregation of carbon and inducing a fusion analogous to that of carbon in retorts for lighting gas, and of graphitoid carbon destined to form the pencils used for the electric light.

On this point M. Jaquelain narrates one of his own recent experiments. On decomposing some sulphide of carbon in a porcelain tube in presence of pure copper, heated to about 800°, sulphide of copper and graphite were formed, the latter externally similar to natural graphite.—*Cosmos*, 1864, pp. 720, 725.

Some of the latest researches of Gustav Rose, published just before his death in 1873, were directed to the natural forms of carbon, including graphite. For these the reader may be referred to the 'Proceedings of the Berlin Academy of Sciences.'

GRAPHOTYPE. By this new process of engraving (discovered in the summer of 1860 by Mr. De Witt Clinton Hitchcock) the artist becomes his own engraver, and thus overcomes the difficulties met with in most other processes, arising from the impossibility of two individuals working out the same idea in exactly the same way. A short description of the circumstance which led to this discovery will give a good idea of the nature of the new method called 'Graphotype.' Mr. Hitchcock was engaged in making a drawing on boxwood, and finding it necessary to erase a portion of his work and re-whiten his block, he took a visiting-card (the white material used for the surface of the wood engraver's block being of the same composition as the enamel of the said card) and commenced rubbing off the enamel with the aid of a brush and water, when, to his astonishment, he found the printed letters remained in relief. The ink in combining with the enamel had become sufficiently hard to resist the action of the brush, and thus he had accidentally prepared a sort of block upon which the letters stood out. This circumstance led him to the discovery that by taking a slab of chalk, reducing its surface to as smooth a condition as possible, drawing on it with an ink composed of silicate of potash (water-glass) and indigo, then, when the sketch was dry, by brushing away the surface with a dry brush (the lines of the drawing being virtually converted into stone, they will withstand the friction of the brush, while the intervening particles are easily removed), and saturating the mass of chalk with liquid glass, he had a block ready for printing from in the ordinary way of burnishing.

This experiment was successful, and after several trials the following method has been adopted as the most perfect:—A chalk surface upon a metallic plate is now adopted. French chalk is ground to the finest powder, then the coarser particles separated from the finer by being thrown into water, the sediment which first subsides is removed and ground again; this is repeated several times. Next, the powder is repeatedly passed through a wire cloth which contains 10,000 holes to the square inch, and is then laid between a smooth metallic (zinc) plate and a smooth steel plate, and submitted to intense hydraulic pressure, then, after the chalk-surface is sized, it is ready for the artist. The pencils employed by the artist are of sable-hair, and the ink is composed of lamp-black and glue. When the drawing is finished the surface is gently rubbed with silk velvet, or fitch hair-brushes, until the chalk between the inked lines is all removed to the depth of about the eighth of an inch. After this the block has only to be hardened, which is done by soaking it into a solution of an alkaline silicate (water glass); by this means the whole of the chalk is converted into stone.

This petrified block is not used to print with, as it would not stand the wear and tear it would be subjected to in the printing press, but a mould is taken of it, from which a type-metal cast (a stereotype) is made, and it is this stereotype from which the impressions are taken.

One of the great merits of this new process is the extreme delicacy and precision with which the finest lines are produced, and the accuracy and rapidity of production are the two great recommendations of the graphotype. A sketch made in the morning may be multiplied by thousands by the evening. The graphotype is a most valuable invention; and it seems probable that it will supersede the old wood-engraving to a considerable extent: it is cheaper, more accurate, and more rapid of production, but still it possesses all the advantages of the ordinary block.

GRASS-OIL. A fragrant oil which is extracted from a peculiar Indian grass; it is generally called the *grass oil of Nemaur*. Grass-oil, on account of its odour, is often termed lemon-grass or verbena; it is derived from the *Andropogon Nardus*, a species of grass which is now regularly cultivated in Ceylon for the sake of the essential oil which it yields by distillation, about 10,000 lbs. of which are imported annually. *A. citratum* has been considered to be the source of the oil of lemon-grass.

GRATE, *a mining term.* A metal plate pierced with small holes: it is fixed in front of the stamps in which the ore is pounded, and through the holes the finely-divided matter makes its escape.

GRAUWACKE or **GREYWACKE.** (*Grau*, grey; *wacké*, clay.) A German name, often adopted by geologists for some of the most ancient fossiliferous strata. The rock is often of a grey colour, hence *grau*, German for *grey*; *wacké* being a provincial miner's term. Although at one period, the term *grauwacké* or *greywacké*, was employed to include the Cambrian and Silurian slates, the term has now nearly dropped out of the geological nomenclature.

GRAVE-WAX. A familiar term for adipocere. See ADIPOCERE.

GRAVITY. The term usually applied to the action of the earth's gravitation.

GRAVITY, SPECIFIC. The specific gravity of a body is represented by the ratio which the weight of a given volume of the body bears to the weight of an equal volume of a certain substance chosen as a standard of comparison. Water is the standard for solids and liquids, and air the common standard for gases, but modern chemists frequently refer the specific gravity of gases to hydrogen as unity. If, therefore, the specific gravity of platinum is stated to be 19·5 (water = 1), or 19500 (water = 1000), it is simply meant that a given bulk—say a cubic inch—of platinum will weigh 19½ times as much as a cubic inch of water weighs. In like manner the specific gravity of oxygen is said to be 1·1056 (air = 1), or 16 (hydrogen = 1), by which is meant that a certain volume of oxygen weighs $1\frac{1056}{10000}$ times greater than the same volume of air, or 16 times as much as an equal bulk of hydrogen; all the weights being determined under like conditions of temperature and pressure. Specific gravity is sometimes called 'relative weight,' and is commonly regarded as the same thing as 'density.' For a description of the several methods by which the specific gravity of any body, either solid, fluid, or aeriform, may be determined, we must refer to Watts's 'Dictionary of Chemistry,' or to any works treating of the manipulatory details of physics or chemistry. The following Table may be found useful:—

Table of Specific Gravities.

Metals				Stones, Earths, &c.			
Names	Weight, water being 1000	Number of cubic inches in a lb.	Weight of a cubic inch, in lbs.	Names	Weight, water being 1000	Number of cubic feet in a ton	Weight of a cubic foot, in lbs.
Platinum . .	19500	1·417	·7053	Marble, average	2720	13	170·00
Pure gold . .	19258	1·435	·6965	Granite ,,	2651	13½	165·68
Mercury . .	13560	2·038	·4904	Purbeck stone .	2601	13¾	162·56
Lead . . .	11352	2·435	·4105	Portland ,, .	2570	14	160·62
Pure silver .	10474	2·638	·3788	Bristol ,, .	2554	14	159·62
Bismuth . .	9823	2·814	·3552	Millstone . .	2484	14½	155·25
Copper, cast .	8788	3·146	·3178	Paving stone .	2415	14¾	150·93
,, sheet .	8910	3·103	·3225	Craigleith ,, .	2362	15	147·62
Brass, cast .	7824	3·533	·3036	Grindstone .	2143	16¾	133·93
,, sheet .	8396	3·293	·3037	Chalk, British .	2781	12¾	173·81
Iron, cast . .	7264	3·806	·263	Brick . .	2000	17	125·00
,, bar . .	7700	3·592	·279	Coal, Scotch .	1300	27½	81·15
Steel, soft . .	7833	3·530	·2833	,, Newcastle	1270	28¼	79·37
,, hard .	7816	3·537	·2827	,, Staffordsh.	1240	29	77·50
Tin, cast . .	7291	3·790	·2636	,, Cannel .	1238	29	77·37
Zinc, cast . .	7190	3·845	·26				

GREBE. A water-bird, *Podiceps cristatus*, the great crested or tippet grebe. It is about the size of a goose, and a native of England, being found in the fens of Shropshire, Cheshire, and Lincolnshire, where they are called gaunts. The bird, which is valued for the plumage of its breast, so much admired by ladies for muffs, and used for trimmings, is a large Swiss and Central European species.

GREEN EARTH. An earthy mineral occurring in cavities in amygdaloidal melaphyres, especially at Monte Baldo, near Verona, whence it is procured for use as a pigment, being sold under the name of *Terre verte de Verone.*

GREEN EBONY of Jamaica. This is a wood of a brown-green colour. It is derived from the *Amerimnum Ebenus*, and is used in turnery and for marquetry-work. See MARQUETRY; PARQUETRY.

GREENHEART. A wood brought from Jamaica and Guiana, the produce of the *Laurus chloroxylon.* It is used in shipbuilding. Bancroft, in his 'Guiana,' thus describes it: 'The Sipiera or Greenheart tree is in size like the locust-tree, about 60 or 70 feet high; there are two species, the black and the yellow, differing only in the colour of their bark and wood.'

GREEN IRON ORE. A native phosphate of iron. See DUFRENITE.

GREEN LEAD ORE. An arsenio-phosphate and chloride of lead. See Pyromorphite.

GREEN LINNETS. A miner's name for green lead-ore or pyromorphite.

GREENOCKITE. Native sulphide of cadmium. It occurs in small, but very perfect and brilliant, short hexagonal crystals, in a porphyritic greenstone, on prehnite, and associated with calcite. It has been found in a railway-cutting at Bishopstown, near Paisley, and at Bowling, near Old Kirkpatrick. It was first observed by the late Lord Greenock, afterwards Earl Cathcart, hence its name. See Cadmium.

GREEN PAINTS. (*Couleurs vertes*, Fr.; *Grüne Pigmente*, Ger.) Green, which is so common a colour in the vegetable kingdom, is rare in the mineral. There is only one metal, copper, which affords in its combinations the various shades of green in general use. The other metals capable of producing this colour are, chromium in its sesquioxide, nickel in its hydrated oxide, as well as its salts, the selenate, arsenate, and sulphate; titanium in its prussiate; and some of the salts of uranium.

GREEN PIGMENTS. Under the name of 'green cinnabar,' Vogel described a new colour. Prussian blue is dissolved in oxalic acid, chromate of potash is added to this solution, which is then precipitated with acetate of lead. The precipitate, well washed, dried and levigated, gives a fine green powder. By varying the proportions of the three solutions, different shades of green may be produced. Another method has been given by Dr. Elsner. Make a solution of yellow chromate of potash and another of yellow prussiate of potash; then mix the two, dissolve separately in water some acetate of lead and iron, and add this solution to the others. By precipitating the first two solutions by the third, a green deposit is obtained, the tint depending on the proportions employed.

Green pigments are prepared also by the mixture of yellows and blues; as, for example, the green of Rinman and of Gellert, obtained by the mixture of cobalt-blue and flowers of zinc; that of Barth, made with yellow lake, prussian blue, and clay; but these paints seldom appear in the market, because the greens are generally extemporaneous preparations of the artists.

Mountain green consists of the hydrate, oxide, or carbonate of copper, either factitious or as found in nature.

Bremen or *Brunswick green* is a mixture of carbonate of copper with chalk or lime, and sometimes a little magnesia or ammonia. It is improved by an admixture of white lead. It may be prepared by adding ammonia to a mixed solution of sulphate of copper and alum.

Frise green is prepared with sulphate of copper and sal-ammoniac.

Mittis green is an arsenate of copper, made by mixing a solution of acetate or sulphate of copper with arsenite of copper. It is in fact *Scheele's green.*

Sap green is the inspissated juice of buckthorn berries. These are allowed to ferment for 8 days in a tub, then put in a press, adding a little alum to the juice, and concentrated by gentle evaporation. It is lastly put up in pigs' bladders, where it becomes dry and hard. See Colours, *Table of.*

GREENSAND. The term 'Greensand' applies to the strata lying between the Chalk and the Wealden deposits. They are of marine origin, as is denoted by the presence throughout their entire thickness of sea-shells, and are divided into an upper and lower series, separated by a stratum of clay, called gault. The *Upper Greensand*, which underlies the Chalk Marl, is composed chiefly of calcareous sand in the lower, and of sandstone and layers of chert (a compact flinty rock) in the uppermost part. The sandstone affords a good and durable building stone. The chert is well adapted from its toughness for making roads, and the sandy portion, in addition to its usefulness as a component of mortar, furnishes an excellent agricultural soil, from the calcareous matter it contains, in addition to the large percentage of soluble silica entering into its composition, which sometimes amounts to more than 40 per cent. In Sussex, Surrey, and Kent, the land based upon the Upper Greensand is known by the name of malm, and produces the greater part of the hops for which those counties are celebrated. In the neighbourhood of Godstone and Merstham, in Surrey, extensive quarries are driven into the hills, at the base of the chalk downs, for the purpose of procuring the soft and chalky stone which occurs there in the higher portion of the Upper Greensand, for which there is a large demand in London, for cleaning door-steps and stonework in the fronts of houses, under the name of *hearthstones.* A plentiful supply of pure water is borne up by the impermeable strata, forming the uppermost part of the Upper Greensand, which finds its way out of the ground near the base of the Chalk, and forms the sources of many streams and rivers.

The *Lower Greensand* consists of alternations of sands, sandstones, and clays, which are often very ferruginous, so much so sometimes as to constitute a siliceous ore of iron, as is the case of Seend in Wiltshire, and Shotover in Oxfordshire. The ferruginous sands form the iron-sand of Dr. Smith. The Lower Greensand, also, contains beds of Fuller's Earth, which are worked at Reigate, and they furnish a durable and useful building stone, known by the name of Kentish Rag, and quarried extensively in the neighbourhood of Maidstone.

The term 'Greensand,' though applied to deposits of considerable thickness, is, in fact, only strictly applicable to certain minor portions of them, which are marked by the presence of minute grains of green silicate of iron (the *glauconite* of American mineralogists), These impart a colour to the beds in which they occur, which has given the name to the entire formation.—H.W.B. See Chert; Firestone; Gault.

GREEN, SCHEELE'S. An arsenite of copper. See Copper.

GREEN SLOKE. *Ulva latissima*, the broad green laver. See Algæ.

GREENSTONE. 'Greenstone is a dark and heavy blackish green or brownish rock, consisting of felspar and hornblende; it usually has a crystalline texture, but is sometimes compact.'—*Dana.* The term has been loosely applied by geologists to a number of rocks of similar general appearance, but of different mineralogical composition. See Diabase; Diorite.

GREEN ULTRAMARINE. This is artificially prepared in France and Germany, and employed, instead of the arsenical greens, for printing upon cotton and paper. See Ultramarine.

GREEN VITRIOL. Sulphate of iron, or copperas. See Iron, Sulphate of.

GREISEN. A rock composed of a granular mixture of quartz and mica—generally lithia-mica—in fact, a granite without felspar, or a mica-schist in composition, but without foliation. It is frequently associated with tin-ore in the mining districts of Saxony and Bohemia.

GRENADA COCUS or **GRENADILLO.** This wood, imported from the West Indies, is called red ebony by the French cabinet-makers.

GREY ANTIMONY. The native trisulphide of antimony. See Antimony.

GREY COPPER. A native disulphide of copper. See Copper.

GREY DYE. (*Teinture grise*, Fr.; *Graufärbe*, Ger.) The grey dyes, in their numerous shades, are merely various tints of black, in a more or less diluted state, from the deepest to the lightest hue.

The dyeing materials are essentially the tannic and gallic acid of galls or other astringents, along with the sulphate or acetate of iron, and occasionally wine-stone or crude tartar. *Ash-grey* is given for 30 pounds of woollen stuff, by one pound of gall nuts, ½ lb. of wine-stone, and 2½ lbs. of sulphate of iron. The galls and the wine-stone being boiled with from 70 to 80 pounds of water, the stuff is to be turned through the decoction at a boiling heat for half an hour, then taken out, when the bath being refreshed with cold water, the copperas is to be added, and, as soon as it is dissolved, the stuff is to be put in and fully dyed. Or, for 36 pounds of wool; 2 pounds of tartar, ½ pound of galls, 3 pounds of sumach, and 2 pounds of sulphate of iron are to be taken. The tartar being dissolved in 80 pounds of boiling water, the wool is to be turned through the solution for half an hour, and then taken out. The copper being filled up to its former level with fresh water, the decoction of the galls and sumach is to be poured in, and the wood boiled for half an hour in the bath. The wool is then taken out, while the copperas is being added and dissolved; after which it is replaced in the bath, and dyed grey with a gentle heat.

If the grey is to have a yellow cast, instead of the tartar, its own weight of alum is to be taken; instead of the galls, one pound of old fustic; instead of the copperas, ¾ of a pound of Salzburg vitriol, which consists, in 22⅝ parts, of 17 of sulphate of iron, and 5⅝ of sulphate of copper; then proceed as above directed. Or the stuff may be first stained in a bath of fustic, next in a weak bath of galls with a little alum; then the wool being taken out, a little vitriol (common or Salzburg) is to be put in, previously dissolved in a decoction of logwood; and in this bath the dye is completed.

Pearl-grey is produced by passing the stuff first through a decoction of sumach and logwood (2 lbs. of the former to 1 of the latter), afterwards through a dilute solution of sulphate or acetate of iron; and finishing it in a weak bath of weld containing a little alum. *Mouse-grey* is obtained when, with the same proportions as for ash-grey, a small quantity of alum is introduced.

For several other shades, as tawny-grey, iron-grey, and slate-grey, the stuff must receive a previous blue ground by dipping it in the indigo vat; then it is passed first through a boiling bath of sumach with galls, and lastly through the same bath at a lower temperature, after it has received the proper amount of solution of iron.

For dyeing silk grey, fustet, logwood, sumach, and elder-tree bark, are employed instead of galls. Archil and annotto are frequently used to soften and beautify the tint.

The mode of producing grey dyes upon cotton has been explained in the articles Calico-Printing and Dyeing.

GREYWACKE, *Grauwacke.* A German term, used to designate the coarse slaty strata of the transition rocks. It is now employed to designate the brecciated beds which occur in those formations.

GRINDING AND CRUSHING MACHINERY. See Dressing of Ores.

GRINDSTONE. Grinding-stones or grit-stones are varieties of sandstone, most of those which are celebrated being obtained from the sandstones and millstone grits of the coal-measures. Mr. Knight describes the best known varieties, which are the following:—

Newcastle Grindstones.—These abound in the coal districts of Northumberland, Durham, Yorkshire, and Derbyshire. They are selected of different degrees of coarseness and density, according to the work for which they are required.

Bilston Grindstone is a similar description of stone, of great excellence, of a lighter colour, much finer, and of a very sharp nature, and at the same time not too hard. It is confined to a small spot of limited extent near Bilston in Staffordshire, where it lies above the coal.

Wickersley Grindstones.—These are obtained from a village about nine miles east of Sheffield, and are much used for the finer description of edge-tools.

Sheffield Grindstone.—A hard, coarse gritstone, used for grinding large files and the like; it is obtained from Hardsley, about fourteen miles north of Sheffield.

Devonshire Batts are obtained near Collumpton.

Yorkshire Grit and *Congleton Grit* are other varieties from which grindstones are manufactured.

Burr Stones.—These are very celebrated; they are found at La Ferté-sous-jouarre (Seine et Maine), and are said to be unequalled for grist-mills. The combined roughness and hardness of this tertiary quartz-deposit give it immense advantages. The stones formed of this rock are usually pieced, which renders them very expensive.

Artificial grindstones have been successfully made of late by Ransome's method of manufacturing artificial stone. They are said to form excellent and economical substitutes for the natural grindstones.

GRIS-PERLE. The name given by the French dyers to a grey produced by the action of sulphuric acid on aniline violet. It is much used in dyeing silk. See Aniline.

GRIT. A peculiar hard sandstone. See Millstone Grit.

GROATS, EMBDEN. When oats are deprived of their integuments, they are called *groats*, and when these are crushed, they are known as *Embden groats.* Oatmeal is prepared by grinding the grains.

GROS DE NAPLES. A plain silk fabric woven of organzine silk, prepared with much neatness and care.

GROSSULARIA. Gooseberry-garnet. See Garnet.

GROUND IVY. *Nepeta Glechoma.* The leaves of this plant were formerly thrown into a vat with ale, to clarify it and give it a flavour.

GROVE or **GROOVE.** A mining term in Derbyshire. 'The mine, or work that a man is employed in. Hence it is, if a question be asked, Where is Tom today?—He is gone to the groove, he is at the groove. Sometimes it is used for the shaft, and mines are commonly called *groovers.*'—*Hooson's Miner's Dictionary.*

GROWAN. A local term applied in Cornwall to granite in an imperfect state, either through decomposition, or irregular formation. It is said that the term is sometimes applied to the solid granite. We have never heard it so used, and the miners and the quarrymen draw a well-defined line between a granite and a growan.

GUAIACUM. (*Gaïac*, Fr.; *Guajaharz*, Ger.) Both the wood and resin are imported; they are used medicinally. It is known that, after the discovery of the New World, when the first syphilitic diseases showed themselves in Europe, the origin of which was erroneously ascribed to Santo Domingo, the guaiacum wood was considered as specific against this disease. The historian Herrera informs us that one pound of the wood was at that period paid in Spain with seven piastres. The gum which exudes from the wood, and possesses, as it may be conceived, the medicinal qualities in a much higher degree, is now valued at 7*d.* per pound.

GUANINE. $C^{10}H^5N^5O^2$ ($\mathbf{C^5H^5N^5O}$). An organic base, found by Unger in guano. Guano contains about 6 per cent of it.

GUANO. This extraordinary excrementitious deposit of certain sea-fowls, which occurs in immense quantities upon some parts of the coasts of Peru, Bolivia, and Africa, has lately become an object of great commercial enterprise, and of intense interest to our agricultural world. More than thirty years ago it was exhibited and talked of merely as a natural curiosity, but the quantity imported into England alone rose from 30,000 to 350,000 tons (in 1858), the value of which was estimated at no less than 3,000,000*l.* But during the last few years the quantity imported has somewhat diminished, and hence the rise in price from 11*l.* to 14*l.* per ton.

Our importations of guano since 1868 have been as follow:—

	1868		1869		1870	
	Imports	Value	Imports	Value	Imports	Value
From	tons	£	tons	£	tons	£
Portugal: Azores .	1,381	6,905	...	...	...	...
Western Coast of Africa, not particularly designated . . .	1,859	11,619	3,220	20,126	2,980	19,370
Islands in Pacific .	8,397	48,283	368	2,116	13,616	78,294
Hayti and St. Domingo	4,329	17,316	...	...	6,721	40,326
Peru	155,766	1,890,219	199,122	2,581,024	243,434	3,248,293
Bolivia . . .	4,025	26,393	1,612	11,284	...	...
Chili	3,198	20,788	830	5,810	3,594	27,854
Uruguay . . .	825	6,600	...	...	...	...
Tortola . . .	...	...	2,292	9,168	...	...
Australia . . .	...	...	...	...	5,905	35,430
Other parts . . .	2,563	11,355	2,566	11,455	4,061	27,113
Total .	182,343	2,039,478	210,010	2,640,983	280,311	3,476,680

	1871		1872	
	Imports	Value	Imports	Value
From	tons	£	tons	£
Portugal: Azores	...	...	...	...
Western Coast of Africa, not particularly designated	2,445	29,805	3,201	37,641
Islands in Pacific	9,893	77,032	17,475	113,073
United States of America	3,024	17,337	458	3,546
Dutch West India Islands. . . .	...	...	1,562	9,012
Peru	142,365	1,711,176	74,401	875,882
Bolivia	10,045	75,033	14,068	108,150
Chili	2,370	26,500	503	4,259
Brazil	...	...	1,232	9,721
St. Helena	...	...	981	8,155
Australia	3,873	24,657	1,168	8,595
British West Indies	...	...	1,050	6,974
Other parts	4,793	25,449	2,545	16,034
Total	178,808	1,986,989	118,764	1,201,042

The conditions essential for the preservation of these excrements appear to be the existence of a soil consisting of a mixture of sand and clay, in a country where the birds are allowed to live for ages undisturbed by man or man's works, and where, moreover, the climate is very dry, free not only from rain, but also from heavy dews.

These conditions appear to have been combined to a remarkable extent on the coasts of Peru and Bolivia, between latitudes 13° north and 21° south of the equator, for although beyond this region the flocks of cormorants, flamingoes, cranes and other sea-fowl, appear to be equally numerous, yet the excrement is rapidly carried away by the rain or dew.

It is then the dryness of the climate chiefly which has permitted the guano to accumulate on these coasts, for, says Mr. Darwin [1]—'In Peru real deserts occur over wide tracts of country. It has become a proverb that rain never falls in the lower part of Peru.' And again:—'The town of Iquique contains about 1,000 inhabitants, and stands on a little plain of sand at the foot of a great wall of rock, 2,000 feet in height, the whole utterly desert. A light shower of rain falls only once in very many years.' Indeed, since three-fifths of the constituent parts of guano are soluble in

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[1] 'Researches in Geology and Natural History,' p. 421.

cold water, Prof. Johnstone very justly observes[1] that, 'A single day of English rain would dissolve out and carry into the sea a considerable portion of one of the largest accumulations; a single year of English weather would cause many of them entirely to disappear.'

Such being the case, we might expect to find similar accumulations in other hot and dry climates, as in Egypt, and in Africa, *e. g.* in the neighbourhood of the Great Desert; and only a few years since a considerable deposit of guano was found in the Kooria Mooria Islands.

In Peru the natives have employed it as a manure from the remotest ages, and have by its means given fertility to the otherwise unproductive sandy soils along their coasts. While Peru was governed by its native Incas, the birds were protected from violence by severe laws. The punishment of death was decreed to the persons who dared to land on the guaniferous islands during the breeding period of these birds, and to all persons who destroyed them at this time. Overseers were appointed by the Government to take care of the guano districts, and to assign to each claimant his due share of the precious dung. The celebrated Baron Von Humboldt first brought specimens to Europe in 1804, which he sent for examination to Fourcroy, Vauquelin, and Klaproth, the best analytical chemists of the day; and he spoke of it in the following terms:—'The guano is deposited in layers of 50 or 60 feet thick upon the granite of many of the South-sea islands off the coasts of Peru. During 300 years the coast birds have deposited guano only a few lines in thickness. This shows how great must have been the number of birds, and how many centuries must have passed over in order to form the present guano beds.'

There appear to be three varieties in Peru: the white, grey, and red, the first being the most recent, and the last the oldest; and in the midst of the great accumulations of the last kind, bones and feathers of birds are found (*Frezier*), as if to remove any doubt which might still remain as to its origin.

Cincha Island Guano.—Much of the so-called Peruvian guano is exported from the Cincha Islands. They are three in number, and lie in one line from north to south about half a mile apart. Each island is from 5 to 6 miles in circumference, and consists of granite covered with guano in some places to a height of 200 feet. in successive horizontal strata, each stratum being from 3 to 10 inches thick, and varying in colour from light to dark brown. No earthy matter whatever is mixed with this vast mass of excrement. At Mr. Bland's visit to these islands in 1842, he observed a perpendicular surface of upwards of 100 feet of perfectly uniform aspect from top to bottom. In some

1124

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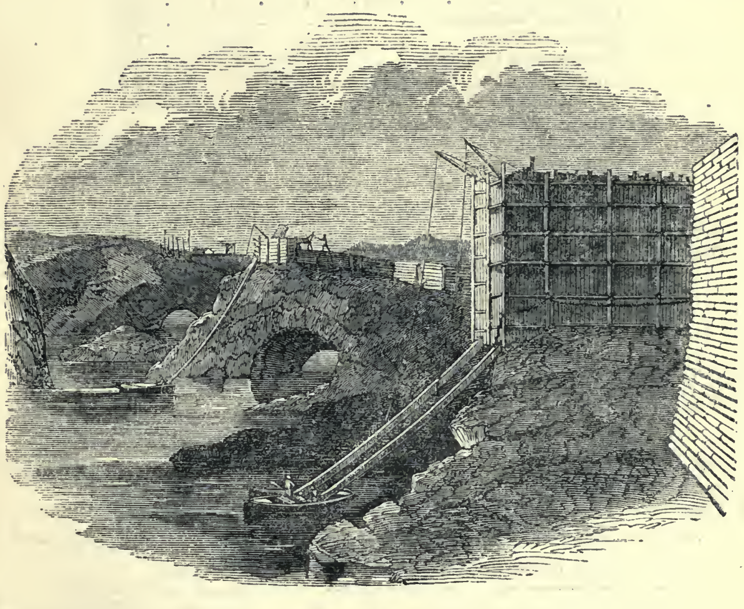
[1] 'On Guano.' 'Journal of the Agricultural Society of England,' vol. ii. p. 315.

parts of these islands, however, the deposit does not exceed 3 or 4 feet in thickness. In several places, where the surface of the guano is 100 feet or more above the level of the sea, it is strewed here and there with masses of granite, like those from the Alpine mountains, which are met with on the slopes of the Jura chain. These seem to indicate an ancient formation for the guano, and terraqueous convulsions since that period. No such granite masses are found imbedded within the guano, but only skeletons of birds.

The accompanying wood-cut, *fig.* 1124, shows the nature of the formation.

The export of the guano has not increased during the last few years: between 200,000 and 400,000 tons are the annual amount, which is effected by the aid of 900 working hands, 320 of them being Chinese, who enter into contracts to serve their employer (the Government contractor), for about 4 dollars a month, renewing it, if they choose, with the increase of 4 dollars monthly, and a bonus of 120. Those who work on their own account are paid 8 and 10 rials, 4 and 5 shillings, for each cart that they load. They live in a collection of dirty huts made of bamboo and mud; they, nevertheless, appear to be happy and contented, and in general are well conducted. The men with pickaxes work their way into the guano, leaving a sort of wall on either side; here it is so hard that it requires a heavy blow to remove it. It is then conveyed in wheelbarrows, either direct to the mouths of the shoots on the edge of the cliffs, or to the huge carts running on tramways for the same purpose. The colour varies very much—in some parts being as dark as warm sepia, and in others as light as that of a Bath brick.

1125



The smell of ammonia is said to be very powerful, so much so, in fact, as to affect the eyes of the workmen; crystalline deposits of various ammoniacal salts are also found amongst the guano. The guano heaps are surrounded by a high fence to prevent its being blown away by the wind, near the mouths of the canvas tubes or shoots, which are sometimes 70 feet long, through which it is conducted to the boats. See *fig.* 1125.

As in Peru, the surface of the guano is covered with skeletons of birds and bones of seals. It is also perforated by numberless holes, running in every direction, like a rabbit-warren. These are made by a bird about the size of a pigeon, which remains hidden during the day, sallying forth at dark to fish. Gold and silver ornaments are also discovered occasionally, having been buried by the ancient inhabitants more than three centuries ago.

It is quite unnecessary here to insist on the value of guano as a manure. This is a point established beyond all question by nearly every agriculturist in the kingdom;

and recorded by all classes of writers on agricultural subjects. It has been the means, moreover, of converting the sandy desert around Lima into a soil capable of raising abundant crops of maize; hence the Peruvian proverb, 'Huano, though no saint, works many miracles.'

Commercial varieties.—The following appear to be the chief:—

1. Peruvian.
2. Augamos.
3. Ichaboe.
4. Patagonian.
5. Saldanha Bay.
6. Kooria Mooria.
7. African.
8. Indian.

Chemistry.—Guano being an article of so great value to the agriculturist as a manure, and being liable not only to adulteration to a very great extent, but also varying when genuine considerably in quality, it is highly important to have some means of ascertaining its value. This cannot be done satisfactorily by ever so experienced a dealer by mere inspection, and therefore, both for the buyer and the seller, resort is necessary, for a knowledge of its compound parts, to the analysis of the chemist.[1] Such being the case, we must first ascertain the composition of genuine guano, and then inquire upon which of its several constituents its value as a manure depends.

The following is one of the earliest analyses by Fourcroy and Vauquelin, of a sample of guano presented to them by Baron Von Humboldt, showing the composition in 100 parts:—

Urate of ammonia	9·0
Oxalate of ammonia	10·6
Oxalate of lime	7·0
Phosphate of ammonia	6·0
Phosphate of ammonia and magnesia	2·6
Sulphate of potash	5·5
" soda	3·3
Sal-ammoniac	4·2
Phosphate of lime	14·3
Clay and sand	4·7
Water and organic matter	32·2

But perhaps the *constitution* of guano is better exhibited by the following analysis of three sorts by Denham Smith:—

AMERICAN GUANO.—*Analysis of three sorts by Denham Smith.*

1. *Constituents soluble in hot water* (*in* 100 *parts of Guano*).

	I.	II.	III.
Phosphate of lime	0·186	...	0·110
" soda	0·120	...	...
" ammonia and magnesia	0·564	0·784	0·133
Uric acid	2·516	...	...
Urate of ammonia	15·418	...	...
Organic matter	1·180	0·860	0·756

2. *Constituents soluble in cold water* (*in* 100 *parts*).

	I.	II.	III.
Water	22·200	20·420	7·700
Sulphate of potash	8·00	...	...
" soda	...	23·944	19·177
Phosphate of potash	...	7·732	4·947
" soda	...	...	3·60
" ammonia	6·33	6·124	...
" lime	...	...	...
Oxalate of ammonia	7·40	9·39	...
" soda	...	...	10·563
Chloride of potassium	...	...	4·163
" sodium	...	...	28·631
" ammonium	2·55	...	3·030
Organic matter	1·500	0·668	2·553

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[1] Liebig's 'Chemistry in its Applications to Agriculture and Physiology,' p. 272.

3. *Constituents insoluble in water* (*in* 100 *parts*).

	I.	II.	III.
Phosphate of lime	19·750	6·270	13·113
„ magnesia	2·030	0·874	2·580
Oxalate of lime	2·560	10·958	...
Sand, &c.	15·60	0·720	0·420
Peroxide of iron and alumina	...	...	0·150
Humus	2·636	0·862	0·826
Organic matter	3·456	...	...
Water	...	4·974	...
Loss	0·044	0·498	...

We may also quote the following analysis by Dr. Ure, of guano, imported from Bolivia, by the 'Mary Anne,' being the first cargo thence imported.

It was of a pale yellow-brown colour, dry, partly pulverulent, partly concreted, in small lumps. Its mean specific gravity was 1·63.

The *soluble* portion was found to contain :—

Urea	5·0
Sulphate of potash	7·9
Chloride of sodium	5·0
Phosphate of ammonia	5·5
Oxalate of ammonia	0·6
	24·0

The *insoluble* portion contained :—

Silica	2·25
Phosphate of lime	9·00
Phosphate of magnesia and ammonia	1·25
Urate of ammonia	15·27
Undefined nitrogenised organic matter, yielding by combustion with soda-lime 17·05 parts of ammonia	41·73
	69·50

The total quantity of ammonia yielded by it was 20·95 per cent.

Analysis of Cincha Island Guano. (*Ure.*)

		Ammonia
Matter soluble in water	47·00	
consisting of—		
Sulphate of potash, with a little sulphate of soda	6·00	
Muriate of ammonia	3·00	0·95
Phosphate of ammonia	14·32	4·62
Sesquicarbonate of ammonia	1·00	0·34
Sulphate of ammonia	2·00	0·50
Oxalate of ammonia	3·23	0·89
Water	8·50	
Soluble organic matter and urea	8·95	
	47·00	
Matter insoluble in water	53·00	
consisting of—		
Silica	1·25	
Undefined organic matter	9·52	
Urate of ammonia	14·73	1·23
Oxalate of lime	1·00 ?	
Subphosphate of lime	22·00	
Phosphate of magnesia and ammonia	4·50	0·32
	53·00	8·35

Valuable as these elaborate analyses are in a scientific point of view, they are quite unnecessary for practical purposes in ascertaining the value of any given sample, for on which of these various constituents does the chief efficacy of guano depend?

Ammonia.—Undoubtedly *one of the most*, if not *the most*, important constituents of guano is the *ammonia*. Authors differ as to the precise manner in which ammonia and its salts act in promoting the growth, and especially in the development of the nitrogenised compounds of plants; but the fact is placed beyond dispute, whether it be that the ammonia contained in the air is decomposed by the leaves, or that the salts of ammonia are absorbed by the spongioles of the roots in solution in water. Now, it is quite possible that, in the mysterious economy of the life of the plant, the ammonia may perform a slightly different function when in different states of combination, either with hydrochloric, sulphuric, nitric, phosphoric, carbonic, uric, humic, or oxalic acids; and although, as a general rule, we should be inclined to yield the palm in point of utility to the more soluble combinations, yet all experience goes to show that the value of an ammoniacal manure may be measured chiefly, if not entirely, by the *quantity* of that compound present, and is in a great measure independent of its state of combination.

The *amount of ammonia* corresponding to the total quantity of nitrogen in the *several varieties of guano* ranges as follows:—

	Maximum	Minimum	Mean
1. *Peruvian.*			
(From 9 analyses by Way[1]) of samples imported in 1847–8	18·94	16·40	17·67
From Mr. Way's analyses of 10 samples imported in 1848–9	17·81	15·98	16·189
From Mr. Way's analyses of 14 samples imported in 1849	18·94	16·82	17·88
Mean	...	...	17·246
So that the average quantity of ammonia, either existing in, or capable of being yielded by genuine Peruvian guano, may be estimated at about 17 per cent.			
2. *Angamos* guano.			
Ammonia (actual and potential) from two analyses by Dr. Ure	20·89	20·40	20·64
So that this variety is slightly richer in ammonia and nitrogenised compounds than the Peruvian.			
3. *Ichaboe* guano.			
Ammonia (actual and potential) from 11 analyses by Dr. Ure and Mr. Teschemacher	9·5	4·5	7·3
Showing that this variety, as far as regards nitrogenised compounds, is far inferior to the preceding; and the same remark applies to the succeeding varieties, *e.g.*:—			
4. *Patagonian* guano.			
From analyses of 14 samples by Dr. Ure and Mr. Teschemacher	4·68	1·60	2·54
5. *Saldanha Bay* guano.			
From results of analyses of 9 samples by Mr. Way	2·49	0·94	1·68
From results of 9 analyses by Dr. Ure and Mr. Teschemacher	2·10	1·25	1·56
6. *Kooria Mooria.*			
From results of 3 analyses by Mr. Nesbit	0·34	0·17	0·25
From results of 3 analyses by Mr. Apjohn	0·318	0·127	0·22

So that the average quantity of ammonia in the several varieties is—

Peruvian	17 per cent.	Patagonian	2·5 per cent.
Angamos	20 „	Saldanha Bay	1·5 „
Ichaboe	7 „	Kooria Mooria	0·25 „

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[1] 'On the Composition and Money Value of the different kinds of Guano.' By S. Thomas Way, &c. 'Journal of the Agricultural Society of England,' p. 202, &c.

Dr. Ure drew a distinction between what he called the *actual* and *potential* ammonia, *i.e.* between ammonia and ammoniacal salts ready formed, and compounds, such as uric acid, which during their decay are gradually converted into ammonia. It appears that recent guano contains from 3 to 5 per cent. of uric acid, whilst the older deposits contain generally less than 1 per cent. No doubt the guano at the time of its deposition consisted chiefly of uric acid; and it is this uric acid which has become converted into salts of ammonia; for the excrements of birds which live chiefly on fish are found to contain from 50 to 80 per cent. of uric acid. It is also an established truth in agricultural chemistry that a manure which contains bodies capable of *gradually* yielding up any valuable compound, such as ammonia, are more useful than those which contain that compound ready formed, and in the state of soluble combinations, which the first storm of rain may wash away from the roots of the plants, where they are required. Nevertheless, admitting the truth of all this, the writer is of opinion (and he believes this is the general experience of agriculturists) that the importance of this distinction between *actual* and *potential* ammonia has been rather exaggerated; and that generally it is enough for all practical purposes, in estimating the value of a guano, to determine the total quantity of nitrogen present in every form, and to consider it as representing an equivalent quantity of ammonia '*in esse*' or '*in posse*.'

Potash.—Of the two alkalis, potash and soda, the soil usually contains more than sufficient soda for the supply of vegetation; it is therefore chiefly potash which it is necessary to add in the form of manure.

Besides, even the best guano always contains a considerable quantity of common salt, viz. from 1·0 to 2·5 and even 5 per cent.

Mr. Way, in his valuable paper, 'On the Composition and Value of Guano,' only gives the quantity of alkaline salts, not having determined the potash; but the average quantity of potash in genuine guano may be seen by referring to the analyses before given in detail, and will be found to vary from 3 to 4 per cent.

However, in estimating the value of guano the knowledge of the quantity of potash is by no means of the same importance as of the ammonia, or of the phosphoric acid.

Phosphoric acid.—The phosphoric acid is second in importance to no other constituent than the ammonia; being essential for the development of the seeds and all those parts of the vegetable organism which serve as foods in the production and restoration of the flesh and bones of animals. It exists in the guano (as is shown by the preceding detailed analyses) in combination with ammonia, potash, soda, and lime.

In most analyses the quantity of phosphate of lime, $3CaO,PO^5$, is given instead of phosphoric acid, PO^5 or $3HO,PO^5$; but 156 parts of phosphate of lime ($3CaO,PO^5$) correspond to 72 of phosphoric acid (PO^5), or as 13 to 6.

The amount of phosphate of lime in the several varieties of guano is as follows:—

	Maximum	Minimum	Mean
Peruvian.			
From analyses of 9 samples by Way, imported in 1847–8	34·45	19·46	26·95
From Mr. Way's analyses of 10 samples, imported in 1848–9	25·30	21·31	23·30
From Mr. Way's analyses of 14 samples, imported in 1849	28·98	21·28	25·13
Angamos.			
From 2 analyses by Dr. Ure	22·00	18·50	20·25
Ichaboe.			
From 11 analyses by Dr. Ure and Mr. Teschemacher	37·00	26·00	31·50
Patagonian.			
From analyses of 14 samples by Dr. Ure and Mr. Teschemacher	65·5	29·3	47·4
Saldanha Bay.			
From analyses of 9 samples by Mr. Way	60·96	49·01	54·98
From analyses of 9 samples by Dr. Ure and Mr. Teschemacher	62·5	51·0	56·7
Kooria Mooria.			
From analyses of 3 samples by Mr. Nesbit	25·50	2·80	14·15
From analyses of 3 samples by Mr. Apjohn	28·50	5·84	17·17

So that the average quantity of phosphate of lime in the several specimens is as follows:—

Peruvian	25·12	Patagonian	47·4
Angamos	20·25	Saldanha Bay	55·84
Ichaboe	31·50	Kooria Mooria	15·66

These facts are very suggestive as showing how guano, by exposure to air and moisture, has the ammoniacal salts washed out, at the same time, as a consequence, increasing the *ratio* of phosphates.

Organic Matter.—The amount of organic matter in guano, other than ammonia and its salts, is of no great importance in estimating its value as a manure. Not unfrequently the amount of organic matter, containing uric acid or ammoniacal salts, is stated in analyses, as organic matter '*rich in*' or '*containing ammonia*;' but it is obvious such analyses are nearly worthless, the value of the guano depending essentially on the quantity of *nitrogen*, either existing as ammoniacal salts or capable of being converted into them. Good guano contains on an average about 50 per cent. of ash (mineral matter) and 50 per cent. of combustible (organic) matters.

Sand.—The knowledge of the proportion of sand in a guano is of some importance as determining its purity or otherwise. It is easy to understand how a deposit like guano, existing often near the sea-shore, and frequently on a sandy soil, should contain a certain admixture of sand. Some specimens are almost free from it, and few genuine specimens contain more than from 1 to 2 per cent.

Common salt.—The presence of common salt in a guano need not surprise us. It is doubtless derived from the sea, partly through the medium of the birds themselves, and partly from the evaporation of the salt spray continually driven upon the coasts by the wind. It is variable in quantity, as we should expect from a knowledge of its origin, ranging in samples of genuine guano from 1 to 5 per cent. Although common salt has been shown[1] to possess a certain power of absorbing ammonia, yet this is but transient, and the efficacy of guano cannot be said to depend to any extent upon the sea-salt present in it. The knowledge of its amount is of great importance, since the guano is not unfrequently adulterated with salt.

Water.—Obviously the greater the amount of water present in guano, the smaller will be the proportion of valuable constituents in a given weight. Genuine guano contains on an average from 10 to about 20 per cent. of water. Many of the salts in guano are likewise deliquescent, so that it has a tendency to become moist by exposure to the air: and this tendency to absorb moisture is an element of value in the manure, especially in dry seasons.

Calculation of the money value of guano from the results of analyses.—In a most important and interesting paper 'On the Value of Artificial Manures,'[2] Mr. Way arrives at certain money values for ammonia, phosphoric acid, and the various constituents of guano and other manures, by a comparison with the cost of these several compounds in their ordinary commercial salts. These numbers will be found most valuable to the agriculturist in drawing his own conclusions respecting the value of a guano or other manure from the results of analysis furnished to him by the chemist. They are as follows:—

	£	
Ammonia	56	per ton.
Potash	31	,,
Phosphate of lime (insoluble)	7	,,
Phosphate of lime (soluble)	32	,,
Organic matter	1	,,

and the following example of their application may prove useful.

Calculation of the money value of guano, as deducted from the cost of its several constituents in their commercial salts, applied to the mean composition of Peruvian guano deduced by Mr. Way from 78 analyses:—

100 tons contain		£		£
Ammonia	16·5	at 56	per ton	930
Organic matter	52·0	,, 1	,,	52
Potash	3·5	,, 31	,,	108
Insoluble phosphate of lime	23·0	,, 7	,,	161
Soluble phosphate of lime	7·0	,, 32	,,	224
		Value of 100 tons		£1,475

Or, per ton . . 14*l.* 15*s.*

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[1] A. B. Northcote, on the Function of Salt in Agriculture, Phil. Mag. x. 179.

[2] Agricultural Journal, xvi. 533.

Hence it is obvious that whilst guano was selling at 11*l.* per ton, it was more economical and convenient to employ it than to make an artificial mixture of its chemical constituents; but now that the price has risen, it becomes a question whether it will not be possible to produce an artificial compound having equal value as a manure which will compete in price with the guano.

Impurities and adulterations.—In consequence of the high price of guano, the great demand for it, and the ease with which the unwary farmer may be imposed upon, guano is adulterated with various substances, and to a great extent. Impositions even have been practised by selling as genuine guano artificial mixtures, made to look so much like guano that the farmer would scarcely detect it. The writer recollects examining a guano which contained 50 per cent. of sand, and no less than 25 per cent. of sea-salt; and Dr. Ure gives the following analysis of an article sent to him, which had been offered to the public by advertisement as Peruvian guano, which contained—

Common salt	32·0
Sand	28·0
Sulphate of iron	5·2
Phosphate of lime	4·0
Organic matter (from bad guano, to give it smell)	23·3
Moisture	7·5
	100·0

In fact, so numerous and various are the tricks played with guano, that unless a sample is submitted to a skilful chemist for analysis before purchase, we would strongly recommend the agriculturist to purchase of no one but dealers of unquestionable honour.

Professor Johnstone observes:—'Four vessels recently sailed hence for guano stations, ballasted with gypsum, or plaster-of-Paris. This substance is intended for admixture with guano, and will enable the parties to deliver from the vessel, a nice-looking and light-coloured article. The favourite material for adulterating guano at the present moment is umber, which is brought from Anglesea in large quantities. The rate of admixture is, we are informed, about 15 cwts. of umber to about 5 cwts. of Peruvian guano, from which an excellent-looking article, called African guano, is manufactured.'

Analysis of Guano.

The following is Dr. Ure's method for the complete analysis of guano:—

1. In every case I determine, first of all, the specific gravity of the guano; which I take by means of spirits of turpentine, with a peculiar instrument contrived to render the process easy and precise. If it exceeds 1·75 in density, water being 1·0, it must contain sand impurities, or has an excess of earthy phosphates, and a defect of azotised animal matter.

2. I triturate and digest 200 grains of it with distilled water, filter, dry the insoluble matter, and weigh it.

3. The above solution, diffused in 2,000 gr. measures, is examined as to its specific gravity, and then with test-paper, to see whether it is acid or alkaline.

4. One half of this solution is distilled along with slaked lime in a matrass connected with a small quintuple globe condenser, containing distilled water, and immersed in a basin of the same. As the condensing apparatus terminates in a water-trap, no part of the ammonia can be lost; and it is all afterwards estimated by a peculiar meter, whose indications make manifest one hundredth part of a grain.

5. The other half of the solution is mixed with some nitric acid, and divided into three equal portions:

a, the first portion, is treated with nitrate of baryta, and the resulting sulphate of baryta is collected, ignited, and weighed.

b, the second portion, is treated with nitrate of silver, and the resulting chloride of silver ignited and weighed.

c, the third portion, has a certain measure of a definite solution of ferric nitrate mixed with it, and then ammonia in excess. From the weight of the precipitated subphosphate of iron after ignition, the known amount of oxide used being deducted, the quantity of phosphoric acid in the soluble portion of the guano becomes known.

d, the three above portions are now mixed, freed by a few drops of dilute sulphuric and hydrochloric acids from any baryta and silver left in them, and then tested by nitrate of lime for oxalate of ammonia. The quantity of oxalate of lime obtained determines that point.

6. The last liquor filtered, being freed from any residuary particles of lime by oxalate of ammonia, is evaporated to dryness and ignited, to obtain the fixed alkaline matter. This being weighed, is then dissolved in a little water, neutralised with acid, and treated with soda-chloride of platinum. From the quantity of potash-chloride of platinum, which precipitates, after being filtered, dried, and weighed, the amount of potash present is deducted; the rest is soda. These bases may be assigned to the sulphuric, hydrochloric, and phosphoric acids, in proportions corresponding to their respective affinities.

7. The proportion of organic matter in the above *solution* of guano, is determined directly by evaporating a certain portion of it to dryness, and igniting. The loss of weight, minus the ammonia and oxalic acid, represents the amount of organic matter.

8. A second portion of a solution of the guano is evaporated to dryness by a gentle steam heat, weighed, inclosed in a stout well-closed phial along with alcohol of 0·825, and heated to 212°. After cooling, the alcoholic solution is decanted or filtered clear, evaporated to dryness by a gentle heat, and weighed. This is urea, which may be tested by its conversion into carbonate of ammonia, when heated in a test-tube or small retort. In this way I have obtained from Bolivian guano 5 per cent. of urea; a certain proof of its entire soundness.

9. *Analysis of the insoluble matter.*—One third of it is digested with heat in abundance of borax-water, containing $\frac{1}{100}$ of the salt, filtered, and the filter dried by a steam heat. The loss of weight indicates the amount of uric acid, which is verified by supersaturating the filtrate with acetic or hydrochloric acid, thus precipitating the uric acid, throwing it upon a filter, drying, and weighing it. This weight should nearly agree with the above loss of weight, the small difference being due to soluble organic matter, sometimes called geine and ulmic acid. The uric acid is evidenced, 1, by its specific gravity, which I find to be only 1·25, as also that of the urate of ammonia; 2, by its affording fine purple *murexide* when heated in a capsule along with nitric acid, and then exposed to the vapour of ammonia from a feather held over it; 3, by its dissipation when heated, without omitting an empyreumatic odour.

10. Another third of the solid matter is distilled along with half its weight of slaked lime, and 10 times its weight of water, in the apparatus already described, and the ammonia obtained from it estimated.

11. The remaining third having been ignited, is digested with a gentle heat in weak hydrochloric acid, and the undissolved silica and alumina washed on a filter, dried, and weighed. To the hydrochloric solution, dilute sulphuric acid is added, and the mixture is heated till all the hydrochloric acid be expelled, with the greater part of the water. Alcohol of 0·850 is now poured upon the pasty residuum, and the whole, after being well stirred, is thrown upon a filter. The phosphoric acid passes through, as also the magnesia in union with sulphuric acid. The sulphate of lime, which is quite insoluble in spirits of wine, being washed with them, is dried, ignited, and weighed. From the weight of sulphate of lime, the quantity of phosphate of that earth that was present becomes known.

12. Ammonia in excess is now added to the filtrate, which throws down the granular phosphate of ammonia and magnesia. After washing and drying this powder at a heat of 150°, its weight denotes the quantity of that compound in the guano.

13. To the filtered liquor (of 12), if a little ammonia be added, and then chloride of magnesium be slowly dropped in, phosphate of ammonia and magnesia will precipitate, from the amount of which the quantity of phosphoric acid may be estimated.

14. The proportion of oxalate of lime is determined by igniting the washed residuum (of 9), and placing it in an apparatus for estimating the quantity of carbonic acid given off in dissolving carbonate of lime. I have rarely obtained more than ½ gr. of carbonic acid from the insoluble residuum of 100 gr. of good guano, and that corresponds to less than 1½ per cent. of oxalate of lime in the guano. Sometimes no effervescence is at all to be perceived in treating the washed residuum with acid after ignition.

15. The carbonate of ammonia in guano is readily determined by filtering the solution of it in cold water, and neutralising the ammonia with a test or alkalimetrical acid.

16. Besides the above series of operations, the following researches must be made to complete our knowledge of guano. The insoluble residuum (of 10), which has been deprived by two successive operations of its uric acid and ammonia, may contain azotised organic matter. It is to be therefore well dried, mixed with 5 times its weight of the usual mixture of hydrate of soda and quicklime, and subjected to gentle ignition in a glass or iron tube closed at one end, and connected at the other with an ammonia-condensing apparatus. The amount of ammonia, being estimated by a proper ammonia-meter, represents the quantity of azote, allowing 14 of this element for 17 of ammonia, being the potential ammonia corresponding to the undefined

animal matter. In a sample of Peruvian guano I obtained 5 per cent. of ammonia from this source.

17. The whole quantity of ammonia producible from guano is to be determined by gently igniting 25 gr. of it well dried, and mixed with 10 times its weight of the mixture of hydrate of soda and quicklime (2 parts of the latter to 1 of the former). The ammonia disengaged is condensed and measured, as described above.

18. The ready-formed ammonia is in all cases determined by distilling a mixture of 100 gr. of it with 50 gr. of slaked lime, condensing the disengaged ammonia, and estimating it exactly by the meter.

19. The relation of the combustible and volatile to the incombustible and fixed constituents of guano, is determined by igniting 100 gr. of it in a poised platinum capsule. The loss of weight denotes the amount of combustible and volatile matter, including the moisture, which is known from previous experiments.

20. The insoluble matter is digested in hot water, thrown upon a filter, dried, and weighed. The loss of weight is due to the fixed alkaline salts, which, after concentrating their solutions, are investigated by appropriate tests: 1, nitrate of baryta, for the sulphates; 2, nitrate of silver, for the chlorides and sulphates; and 3, bichloride of platinum, for distinguishing the potash from the soda salts.

21. The insoluble matter (of 20) is digested with heat in dilute nitric or hydrochloric acid, and the whole thrown upon a filter. The silica which remains on the filter is washed, ignited, and weighed. The lime, magnesia, and phosphoric acid may be determined as already pointed out.

If, however, the remarks made in an earlier part of this article be correct, it is altogether unnecessary, in order to ascertain the commercial value of a sample of guano, to perform so elaborate a series of operations as that described above.

The following points are all that are required to be investigated:—

The amount of water; organic matter; nitrogen; proportion of ash; analysis of the ash as to phosphoric acid and alkalis—potash and common salt; sand.

1. *Water.*—The most delicate and troublesome operation is perhaps the determination of the amount of water. If the substance be dried in the water-oven, as is the usual practice, at 212° F., a very large quantity of ammonia is expelled: so that it becomes necessary to desiccate by protracted exposure under a bell-glass, over a vessel of sulphuric acid. Even in this manner, the error is not entirely eliminated, and Mr. Way suggests treating the specimen in a shallow platinum dish, with a few drops of hydrochloric acid, which is allowed to soak through the whole: he states, that it may then be dried at 212° F., without loss.

2. *Organic matter.*—The proportion of organic matter is determined in the usual way, by burning it off in an open platinum crucible, until nothing is left but the white or brownish white ash, which is then weighed.

3. *Determination of nitrogen.*—This is best performed by Will and Varrentrapp's process. See Watts's 'Dictionary of Chemistry.'

4. *Phosphoric acid.*—The phosphoric acid in the ash of the guano is determined by conversion into perphosphate of iron, and then separation as ammonia-magnesia phosphate, in the usual way. Under the head of ASH OF ORGANIC BODIES, in Watts's 'Dictionary of Chemistry,' will be found the general method for the complete analysis of the ashes of organic bodies, which, if it be thought desirable, may be carried out, *in extenso*, in the case of the ash of guano.

5. *Alkalis.*—This is, however, scarcely necessary, so long as the alkalis are determined to ascertain the amount of the valuable alkali potash, and the extent of contamination with common salt.

6. *Sand.*—The quantity of sand is determined by treating a portion of the dried guano with hydrochloric acid and water, till nothing more is dissolved, then igniting, and weighing the residue.

Statistics of the guano trade at Peru.—We extract the following from an article published in the official journal at Lima:—The exportation of guano began in 1841, under the contract with the house of Messrs. Quiros, Allier, and Co. Up to the end of 1856, the exportation from the Cincha Islands has been 1,967,079 tons, of which 1,626,405 tons were sold, and 23,885 were lost at sea. The stock in hand of the company was 316,789 tons. The gross proceeds of all these sales came to $100,263,518; the charges amounted to $ 61,008,881, leaving net proceeds, $ 39,254,647; say at 1*l.* per $ 5—7,850,927*l.* In the year 1857 the exportation amounted to 472,965 tons, which, added to 316,789 tons, left on hand in the previous year, gives 789,754 tons; of these 304,589 tons were sold, and 19,156 were lost at sea, leaving 466,009 tons. The net profit that year was $ 12,531,016, or at $ 5 per 1*l.*—2,507,703*l.*

In addition to the importation of guano already given on p. 741, the Trade and Navigation Returns for 1872 give the following statement under the head of 'Manures unenumerated,' which will evidently comprehend some guanos—the remainder being chiefly phosphates of lime:—

	Tons	Value £
From Germany.	38,592	102,737
„ France	13,905	52,641
„ Portugal, Azores, and Madeira	15,656	61,498
„ Spain	1,649	5,894
„ United States of America .	35,446	88,811
„ Dutch West India Islands .	3,131	12,080
„ Hayti and St. Domingo . .	11,269	41,241
„ British West India Islands .	8,305	33,173
„ Other countries . . .	3,983	22,664
Total . . .	131,936	420,739

GUARANIN. In the preparation of caffeine from guarana, an alkaline compound was obtained, to which this name was given. See CAFFEINE.

GUAVA. This fruit is a native of the two Indies and the Brazils. There are two well-known varieties, the *Psidium pomiferum*, or apple-fruited guava; and the *P. pyriferum*, the pear-fruited variety. The pulpy fruits of these trees make, with sugar, excellent preserves, which are imported as Guava jelly.

GUIGNET'S GREEN. A basic hydrate of chromium, used as a pigment. See CHROMIUM.

GUINEA CORN. The grain of *Holcus Sorghum*.

GUINEA PEPPER. Another name for the Grains of Paradise.

GUIPURE. A lace made at Limerick by cutting out the pattern from cambric; the flowers and ornamental parts being formed of the cambric, and the open part of stitches which resemble the antique lace.

GUM (*Gomme*, Fr.; *Gummi, Pflanzenschleim*, Ger.) is the name of a proximate vegetable product, which forms with water a slimy solution, but is insoluble in alcohol, ether, and oils. It is converted by strong sulphuric acid into oxalic and mucic acids.

There are six varieties of gum: 1, gum arabic; 2, gum senegal; 3, gum of the cherry and other stone-fruit trees; 4, gum tragacanth; 5, gum of Bassora; 6, the gum of seeds and roots. The first five spontaneously flow from the branches and trunks of their trees, and sometimes from the fruits in the form of a mucilage which dries and hardens in the air. The sixth kind is extracted by boiling water. In commerce, under the name of gum, very different substances are confounded; thus we have *gum elemi* and *gum copal*, which are true resins; and *gum ammoniacum*, which is a gum resin; and *gum elastic* (caoutchouc), which is a peculiar body, differing from either.

Gum arabic and gum senegal consist almost wholly of the purest gum called *arabine* by the French chemists; our native fruit-trees contain some *cerasine*, along with arabine; the gum of Bassora and gum tragacanth consist of arabine and bassorine.

Gum arabic, flows from the *Acacia arabica*, and the *Acacia vera*, which grow upon the banks of the Nile and in Arabia. It occurs in commerce in the form of small pieces, rounded upon one side and hollow upon the other. It is transparent, without smell, brittle, easy to pulverise, sometimes colourless, sometimes with a yellow or brownish tint. It may be bleached by exposure to the air and the sunbeams, at the temperature of boiling water. Its specific gravity is 1·355. Moistened gum arabic reddens litmus-paper, owing to the presence of a little supermalate of lime, which may be removed by boiling alcohol; it shows also traces of the chlorides of potassium and calcium, and the acetate of potash. 100 parts of good gum contain 70·40 of arabine, 17·60 of water, with a few per cents. of saline and earthy matters. Gum arabic is used in medicine, as also to give lustre to crapes and other silk-stuffs. See ACACIA.

Gum senegal is collected by the negroes during the month of November, from the *Acacia senegal*, a tree 18 or 20 feet high. It comes to us in pieces about the size of a partridge's egg, but sometimes larger, with a hollow centre. Its specific gravity is 1·436. It consists of 81·10 arabine; 16·10 water; and from 2 to 3 of saline matters. The chemical properties and uses of this gum are the same as those of gum arabic. It is much employed in calico-printing.

Cherry-tree gum consists of 52·10 arabine; 34·90 cerasine; 12 water; and 1 saline matter. It is used by hatters for smoothing the nap.

Gum tragacanth is gathered, about the end of June, from the *Astragalus tragacantha* of Crete and the surrounding islands. It has the appearance of twisted ribands; is white or reddish; nearly opaque, and a little ductile. It is difficult to pulverise, without heating the mortar. Its specific gravity is 1·384. When plunged in water, it dissolves in part, swells considerably, and forms a very thick mucilage. 100 parts of it consist of 53·30 arabine; 33·30 bassorine and starch; 11·0 water; and from 2 to 3 parts of saline matters. It is employed in calico-printing, and by shoemakers.

Gum of Bassora. See Bassorine.

Gum of seeds, as linseed, consists of 52·70 arabine; 28·9 of an insoluble matter; 10·3 water; and 7·11 saline matter. Neither bassorine nor cerasine seems to be present in seeds and roots.

GUM, BRITISH. See Dextrine.

GUM ELASTIC. See Caoutchouc.

GUM LAC. See Lac.

GUM-RESINS. (*Gomme-résines*, Fr.; *Schleimharze*, Ger.) When incisions are made in the stems, branches, and roots of certain plants, a milky juice exudes, which gradually hardens in the air; and appears to be formed of resin and essential oil, held suspended in water charged with gum, and sometimes with other vegetable matters, such as caoutchouc, bassorine, starch, wax, and several saline matters. The said concrete juice is called a gum-resin; an improper name, as it gives a false idea of the nature of the substance. They are all solid; heavier than water; in general opaque and brittle; may have an acrid taste, and a strong smell; their colour is very variable. They are partially soluble in water, mostly soluble in alcohol; and the solution in the former liquid seldom becomes transparent. Many of the gum-resins are medicinal substances, and but little employed in the arts and manufactures. The following is a list of such:—assafœtida; gum ammoniac; bdellium; euphorbium; galbanum; gamboge; myrrh; olibanum or frankincense; opoponax; and scammony. The gum-resins which are employed in the arts or manufactures are described in this work under their peculiar names.

The following Tables give our importations of Gum and Gum-Resins from 1868 to 1870:—

Gum	1868		1869		1870	
	Cwts.	Value	Cwts.	Value	Cwts.	Value
		£		£		£
Animi . . .	527	4,030	3,048	29,930	857	9,715
Copal	10,415	40,451	21,738	74,383	20,507	67,902
Arabic . . .	59,324	249,805	67,989	300,433	71,963	264,590
Kowrie . . .	45,904	101,601	45,352	122,176	54,248	146,769
Lac dye . . .	11,441	78,489	14,275	102,376	14,131	103,919
Shellac . . .	30,589	114,411	46,180	179,875	31,912	146,452
Benzoin . . .	3,102	24,400	2,914	24,193	4,310	31,208
Mastic . . .	56	2,254	318	12,021	661	24,986
Other kinds . .	30,563	114,740	34,913	125,815	34,905	167,025

Gums and Gum-Resins imported in 1871-1872	1871		1872	
	Quantities	Value	Quantities	Value
Gum Arabic:	cwts.	£	cwts.	£
From France	1,409	7,318	...	...
„ Austrian Territories	3,737	19,969	3,159	15,602
„ Turkey	2,779	11,399	774	3,520
„ Egypt	58,939	184,588	30,131	81,255
„ Morocco	2,775	7,137	3,140	7,602
„ United States of America . .	1,026	5,175	...	...
„ British India	2,596	8,584	1,821	6,746
„ Other countries	2,875	5,954	3,812	8,355
Total	76,136	250,088	42,873	123,080

Gums and Gum-Resins imported in 1871–1872	1871		1872	
	Quantities	Value	Quantities	Value
Kowrie Gum:	cwts.	£	cwts.	£
From Australia	85,779	155,190	49,675	93,572
,, Other countries	...	...	73	132
Total	...	...	49,748	93,704
Lac, Seed, Shell, Stick, and Dye:				
From British India	59,353	343,224	72,180	434,542
,, Straits Settlements	788	2,612	2,363	9,042
,, Other countries	524	2,853	1,155	6,415
Total	60,665	348,689	75,698	449,999
Gums Unenumerated:				
From Germany	1,094	10,991	326	2,464
,, Holland	2,168	9,486	5,639	12,294
,, France	7,553	24,894	6,300	24,360
,, Portugal	2,173	7,520	3,249	8,789
,, Austrian Territories	1,416	6,000	2,376	10,657
,, Turkey	2,976	25,388	2,272	16,677
,, Egypt	19,130	63,612	20,243	66,810
,, Morocco	5,147	17,306	5,927	20,430
,, East Coast of Africa: Native States	972	6,855	3,033	22,475
,, Philippine Islands	12,362	22,690	9,593	16,055
,, Borneo	2,670	7,310	...	...
,, Australia	...	...	2,552	6,124
,, United States of America	730	3,155	...	...
,, Sierra Leone	5,121	12,588	4,768	12,463
,, British India	13,625	47,142	16,501	51,081
,, Straits Settlements	12,903	44,794	13,901	40,250
,, Other countries	5,116	14,498	6,891	19,241
Total	95,426	324,229	103,571	330,170

GUM-WOOD. *Eucalyptus piperata*, or blue-gum tree of New South Wales. The wood is sent over in large logs and planks; the colour of dark Spanish mahogany, with a blue and sometimes a greyish cast. See EUCALYPTUS.

GUN BARRELS. See FIRE ARMS.

GUN COTTON. (Syn. *Pyroxyline; Fulmicoton*, Fr.) In 1833 M. Braconnot discovered that starch, by the action of monohydrated nitric acid, became converted into a peculiar substance which dissolved in excess of the acid, and was re-precipitated in a granular state on the addition of water. This substance, known as xyloidine, when washed and dried, was found to explode on contact of a light, and even if heated to 356°. It also exploded if subjected to a smart blow. The subsequent researches of M. Pelouze indicated this singular body to be starch, $C^{12}H^{10}O^{10}$ ($\mathbf{C^6H^{10}O^5}$), in which one equivalent of hydrogen is replaced by peroxide of nitrogen, or hyponitric acid. The formula of xyloidine would consequently be $\left.\begin{matrix} C^{12}H^{9} \\ NO^{4} \end{matrix}\right\} O^{10}$ [$\mathbf{C^6H^9(NO^2)O^5}$]. On the supposition of this being the correct formula, 100 parts of starch should yield 127·7 of xyloidine, and M. Pelouze obtained from 128 to 130. About thirteen years subsequently to the discovery of xyloidine, M. Schönbein announced his discovery of gun-cotton. Chemists immediately saw the analogy between the two substances, for while xyloidine appears to be derived from starch by the substitution of one equivalent of hyponitric acid for one of hydrogen, gun-cotton is derived from cellulose, $C^{12}H^{10}O^{10}$ ($\mathbf{C^6H^{10}O^5}$), isomeric with starch, by the substitution of two or three equivalents of hyponitric acid for the same number of equivalents of hydrogen.

4½ ounces pure dry nitre in fine powder.
30 drams (fluid measure) sulphuric acid, sp. gr. 1·845.
120 grains of well-carded cotton.

The cotton is to be well pulled out and immersed in the mixture of the nitre and sulphuric acid. The contact with the acid, &c., is to be insured by stirring and pulling out the cotton with two glass rods. As soon as perfect saturation is effected, which, with good management, will be in about a minute, the cotton is to be thrown into a large pan of water, and well rinsed. The vessel is to be continued under a tap until litmus-paper is no longer reddened. The cotton is to be squeezed in the folds of a clean towel, and exposed (after being again well pulled out) to a gentle heat to dry. It is curious that the most soluble cotton is often the least explosive, although there is reason to believe that the most soluble cotton is that which nearest approaches in constitution to tri-nitro-cellulose.

M. Schönbein recommends a mixture of one measure of nitric acid with three measures of sulphuric acid as the best bath for the cotton. The liquid is to be allowed to cool previous to its immersion. He also saturates the cotton with nitrate of potash, by immersing it in a solution of that salt before drying. Cotton prepared in this manner is not adapted for photographic purposes, but it is highly explosive, and therefore well fitted for blasting rocks.

The true constitution of gun-cotton is by no means well established. It appears to be very liable to differ in composition according to the method of preparation. According to M. Béchamp it is essential, in order to obtain a cotton both fulminating and soluble in ether, to operate upon the mixture of nitre and sulphuric acid before the temperature (which rises on the ingredients being mingled) has fallen. If cooling has taken place previous to the immersion of the cotton, the resulting pyroxyline is fulminating, but insoluble in ether.

The analyses of MM. Domonte and Ménard, and also of M. Béchamp, agree best with bi-nitro-cellulose; while those of Gladstone, Vankerchoff, and Reuter, Schmidt, and Hecker, and Pelouze are more in accordance with a tri-nitro-cellulose. To add to the difficulty of forming a conclusion on the subject, M. Péligot's analyses agree best with the expression $\left.\begin{matrix} C^{12}H^{10} \\ (NO^4)^2 \end{matrix}\right\} O^{12}$, which is that of bi-nitro-glucose.

According to M. Béchamp xyloidine and pyroxyline are acted on by protoacetate of iron, the original substance being regenerated. Thus xyloidine affords starch, and pyroxyline cotton. The regenerated cotton was analysed with the following result:—

Experiment		Calculation		
Carbon .	. 43·35	C^{12} =	72	44·44
Hydrogen	. 6·31	H^{10}	10	6·17
Oxygen .	. 50·34	O^{10}	80	49·39
	100·00		162	100·00

Béchamp (and others) regarded gun-cotton as containing nitric acid. The former supported his views with numerous experiments; but there are several disturbing influences preventing the products of the decomposition of gun-cotton by alkalis, &c., being regarded as sufficiently known to enable us to express a decided opinion as to its true constitution, It may be mentioned in evidence of this that during the action of caustic potash upon gun-cotton, M. Béchamp observed sugar to be produced. The latter chemist, in common with many others, doubles the formula which we, following M. Gerhardt, have provisionally adopted for cellulose; he, moreover, formulates the latter substance and its nitro-derivatives thus:—

$C^{24}H^{17}O^{17},5NO^5,2HO$ = pentanitric cellulose.
$C^{24}H^{16}O^{16},4NO^5, HO$ = tetranitric cellulose.
$C^{24}H^{17}O^{17},3NO^5$ = trinitric cellulose.
$C^{24}H^{20}O^{20}$ = cellulose.

Explosive substances analogous to gun-cotton may be prepared from many organic bodies of the cellulose kind, by immersing them in the same bath as for gun-cotton. Among these may be mentioned paper, tow, sawdust, and calico.

When collodion is wanted for an application to cut surfaces, and the cotton is with difficulty soluble in alcoholic ether, a solution may easily be obtained if the cotton be first moistened with acetic ether, and the alcoholic ether be afterwards added.

Several of the nitro-derivatives of starch and cellulose undergo spontaneous decomposition when kept for some time in stoppered bottles (*Gladstone*).—C. G. W.

When cotton wool is immersed in a mixture of strong nitric and sulphuric acids, substitution takes place immediately, and the product has only to be freed from adhering acid by washing with water, and then dried. But in order to insure the uniform production of the most highly nitrated compound, Von Lenk adopts several precautions, the most important of which are:—

1. The cleansing and perfect desiccation of the cotton previously to its immersion in the mixed acids.

2. The employment of the strongest acids procurable in commerce.

3. The steeping of the cotton in a fresh strong mixture of acids after the first immersion and partial conversion into gun-cotton.

4. The continuance of the steeping for forty-eight hours.

5. The thorough purification of the gun-cotton thus produced from every trace of free acid, by washing the product in a stream of water for several weeks; subsequently a weak solution of potash may be used, but this is not essential.

The prolonged application of these processes is absolutely necessary to ensure the thorough nitration of the cotton, and the subsequent purification of the product; for each cotton fibre is a long narrow tube, often twisted and even doubled up, and the acid has first to penetrate to the inmost depths of these tubes and afterwards to be soaked out of them; hence the necessity of time.

Sometimes, to render the gun-cotton less spontaneously explosive, and to remove the last lingering traces of free acid, it is impregnated with a solution of silicate of soda (soluble glass) which is forced into it by means of a centrifugal machine, having a central tube for supplying the solution. It is then dried by exposure to the air, whereby carbonate of soda is formed, and silica separated, and the carbonate of soda is afterwards washed out with water while the silica remains attached to the fibres.

Sometimes, again, to render the fibres soft, and diminish the danger of explosion from violent friction, the gun-cotton, after being treated with soluble glass, is immersed in a soap-ley, the excess of which is then squeezed out, and the gun-cotton finally dried.

Gun-cotton was prepared on a large scale by a process essentially the same as that of Von Lenk, at the manufactory of Messrs. Prentice at Stowmarket, previous to its destruction by fire. Preparations are now (1874) being made for resuming the manufacture in this place.

Gun-cotton prepared by Von Lenk's process is not liable to explosion by percussion; it may detonate between iron and iron if a heavy blow be struck, but only that part explodes which is hit, without communicating ignition to the surrounding particles. If a heavy blow be struck on gun-cotton with an iron hammer, upon bronze or any other comparatively soft metal, no detonation takes place. Otto found, on the other hand, that pyroxyline, prepared with nitric acid alone, explodes like fulminating mercury when struck with a hammer.

The temperature at which gun-cotton explodes has been very accurately determined by Baron von Ebner, who fixes the lowest temperature at 136° C. (2770° Fahr.); but the heat required is usually stated to be greater than this. According to Melsens, gun-cotton which has been washed with soda and retains a small quantity of the alkali, does not explode till heated to 180° C., and similar observations have been made by Payen, Pelouze, Piobert, Vankerchoff, and others.

Von Lenk's system of manufacturing gun-cotton is briefly as follows:—

'1. The carded cotton is spun into a loose yarn, varying in size and strength according to the applications it is to receive; and the yarn is made up into hanks of convenient size (weighing about three ounces).

'2. The cotton is submitted to preliminary purification, by boiling it for a few minutes in a solution of potassic carbonate, of specific gravity 1·02, separating the alkaline liquid by means of a centrifugul extractor, and washing the cotton thoroughly in water.

'3. The cotton is perfectly dried by artificial heat, immediately before its treatment with acid.

'4. The acid used for the production of the gun-cotton is prepared by mixing one part by weight of nitric acid (of specific gravity 1·52) with three parts of sulphuric acid (of specific gravity 1·84). This mixture is allowed to become perfectly cold before use.

'5. The dry cotton is immersed by small quantities (about six ounces, or two hanks at one time) in a bath of the mixed acids, which is kept as cool as possible. When the cotton has become thoroughly saturated, and has been moved about in the acid for a few minutes, it is removed from the bath to a ledge placed over it, where a portion of the acid absorbed is separated by gentle pressure. The hanks are then transferred to small covered stoneware vessels, in which they are preserved for forty-eight hours; the proportion of acid with which they are allowed to remain saturated for that period being 10·5 parts by weight to 1 of the original cotton. The vessels containing the gun-cotton and acid are kept as cool as possible by being surrounded with water.

'6. The acid removed from the bath by each successive quantity of cotton immersed is replaced by the addition of a corresponding quantity of the fresh mixture, before another quantity of cotton is treated.

'7. After the lapse of forty-eight hours, the acid is separated from the gun-cotton, as completely as possible, by mechanical means (*i. e.*, by means of the centrifugal extractors). The expressed acids are not employed again.

'8. The hanks are then drenched with water, singly, as rapidly as possible; they are afterwards washed by hand till no longer acid to the taste, and are afterwards placed in crates or perforated boxes, and kept immersed in flowing water for about three weeks.

'9. At the expiration of that time, the water is separated mechanically from the gun-cotton, and the moist skeins are boiled for fifteen minutes in a solution of potassic carbonate (of specific gravity 1·02). When the alkaline liquor has been expressed, the skeins are once more immersed, in flowing water, for a few days. The finished gun-cotton is then dried by exposure to air.

'10. It is afterwards allowed to soak for about one hour in a cold solution of sodic silicate (of specific gravity 1·072). The liquid is then expressed from the hanks in the usual manner; after which they are allowed to dry thoroughly, again washed, for five or six hours, in running water, and finally by hand. The thorough desiccation of the gun-cotton then completes its manufacture.

'The employment of the cotton in the form of hanks of loosely-spun yarn, instead of simply in the loose carded condition, considerably facilitates its conversion and purification. The proper impregnation of the cotton by the acids is more rapidly accomplished with the hanks; such manipulations as attend the separation of the main quantity of acid from the converted material, and its first rapid and complete immersion (while still saturated with the concentrated acids) into water, and are much more readily carried out with the cotton in the spun form; and, again, the exposure of the latter to the full purifying effects of a current of water, is much more simply and perfectly effected than if carded cotton be used, while the mechanical loss of wool and of gun-cotton, in the several operations of washing and expressing, is much reduced.'

Professor Abel perfectly satisfied himself of the advantages just pointed out, by operating upon considerable quantities of carded cotton wool. In these experiments it was found impracticable, moreover, except by application of very powerful pressure, to reduce the proportion of the acid which the wool retained after immersion (and which had to be left in contact with it, as prescribed) below that of fourteen parts to one of cotton; whereas with the yarn there is no difficulty in reducing the quantity, by moderate pressure, to ten parts, or even lower. The consumption of acid is therefore economized by using the cotton in a spun form.

'The preparation of the mixture of nitric and sulphuric acids, as directed by Von Lenk, involves no important point of novelty. The necessity of employing the mixture cold, and therefore of either submitting it to refrigeration before use, or of preparing a stock of the mixture some time before it was required, was well known to the earlier operators.[1]

'In the treatment of the cotton with the mixed acids, the following precautions, namely, the immersion of uniform quantities of the perfectly dry cotton in the bath of acid, the adherence to a fixed proportion in weight between the cotton and the acid with which it is left in contact, and the regular replacement of the acids removed from the bath at each successive immersion of the cotton, by a corresponding quantity of fresh mixture, combine to exert no unimportant influence upon the uniformity of the product. That such is the case has been established by manufacturing experiments. For example, on one occasion some hanks of cotton were immersed in the bath of acids without addition to the latter, of the quantity of fresh acid proportionate to the amount removed in the previous operation of immersion. The resulting product, which was in all other respects treated as usual, exhibited a decided difference, both in its composition and its explosive powers, when compared with gun-cotton previously produced, strictly according to rule, in the same bath of acids.'

Effects of heat upon gun-cotton.—The behaviour of gun-cotton under exposure,

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[1] An observation made by Béchamp, in his Papers on Pyroxylin, that the production of a soluble or insoluble product was determined simply by conditions of temperature when the conversion was effected by means of sulphuric acid and saltpetre, induced me to ascertain by experiment whether the solubility, in alcohol and ether, of the product obtained with the employment of the prescribed mixture of nitric and sulphuric acids, increased, if the temperature of the latter was raised to about 70° C. That temperature was fixed upon for the experiment as being the average of the freshly-prepared mixture of nitric and sulphuric acids, usually employed for producing gun-cotton for photographic purposes, and which, in experiments instituted, furnished soluble gun-cotton, yielding transparent collodion. The products obtained by the action of the warm mixture upon the cotton wool exhibited no difference as regards its insolubility from the ordinary products furnished by the cold mixture. Neither was insoluble gun-cotton rendered at all soluble by being submitted to treatment with the warm mixture. Hadow has shown that a more dilute mixture of acids, which when cold, furnishes an almost insoluble product, will, if employed at a temperature of 55° C., yield perfectly soluble gun-cotton, giving a fluid transparent collodion.

even to comparatively high temperatures, is subject to very considerable modifications, which may be in great measure determined by the conditions of treatment. Illustrations of this were obtained at an early period of these investigations, in experiments instituted with the view to ascertain the average temperature at which gun-cotton explodes.

The following is a summary of the observations made on this head by Mr. Abel.

Exploding-point of gun-cotton.—The apparatus employed in the experiments on this subject consisted of a small air-bath, fitted with a thermometer, and closed with a mica-plate, having a circular opening in the centre, through which the gun-cotton might be introduced, and which was kept closed, when not in use. The mode of operating was modified in various ways. In the first instance, the gun-cotton was combed out into a very loose condition, and allowed to rest upon metal in the air-bath. The temperature of the latter was then raised very gradually from 15° C. to 204° or 205° C. When the time occupied in the passage to the maximum temperature was two hours and upwards, the gun-cotton did not explode at all (in six experiments), but gradually became dark brown, quite friable, and deprived of all explosive properties. When a considerably shorter time (about one hour) was occupied in the attainment of the maximum temperature, the gun-cotton exploded on one or two occasions, but not until its temperature had reached 205° C.

In the next experiments, the gun-cotton was employed in very small compact masses, and resting upon a wooden support, was exposed to a continuously-increasing temperature. The passage from 15° C. to the exploding-point ranged in these experiments from 45 minutes to 2 hours.

Temperature at commencement of experiment = 26° C.

No. of Experiment	Time occupied	Exploding-Point
8	45 minutes	137°·5 C.
9	1 hour 25 minutes	136°.
10	1 hour	137°·5 C.
11	1 hour	138°·5 C.
12	2 hours	138°.

Another series of experiments was instituted for ascertaining in what particular mechanical condition the gun-cotton exploded most readily, and at most uniform temperatures; and ultimately the material was employed in the form of pieces of loosely-twisted strand about 20 millimeters long, and its exploding-point was determined by first raising the atmosphere of the air-bath to 105° C., then allowing the specimen to fall upon a diaphragm of wire gauze in the air-bath, at once increasing the temperature as rapidly as possible; and carefully reading the thermometer until the explosion occurred. The results of eight observations thus conducted were as follow:—

No. of Experiments	Exploding-Point
13	151°·5 C.
14	151°
15	151°
16	150°·5 C.
17	150°·5 C.
18	148°·5 C.
19	151°
19*a*	147°

These last experiments, which appear the most trustworthy, indicate that the average temperature at which the gun-cotton explodes, when in a condition most favourable to its rapid heating, is about 150° C. For two observations, in which the gun-cotton was in a very open condition, the temperature being raised more rapidly than usual, the explosions occurred when the thermometer indicated 145° and 143°·5 C.; and in the experiments preceding these, which were differently conducted, compact gun-cotton being exposed to heat for a considerable time, the point of ignition ranged between 136° and 138°·5 C. Schrötter, Redtenbacher, and Schneider, in their report upon Von Lenk's gun-cotton, mention that 136° C. is the *lowest* temperature fixed by Von Ebner, at which this material explodes.

Action of light on gun-cotton.—The following are the results obtained up to the present time by exposure to light, under various circumstances, of gun-cotton prepared and purified, according to Von Lenk's directions.

Exposure to strong daylight and to sunlight, either in the open air, or in confined spaces for a few days (two or four), developes in the gun-cotton a very faint aromatic odour; and if litmus-paper be allowed to remain in close contact with the confined material, it acquires a rose-coloured tinge similar to that produced by carbonic acid, and recovers its original colour after brief exposure to air. If, after exposure to light in open air for some days, the gun-cotton be placed in the dark, in cases which are not air-tight, the odour becomes gradually fainter, and the effect upon litmus-paper slighter; if the packages containing the gun-cotton are air-tight, the odour and action upon litmus do not increase during storage for several years (the actual experience gained at Woolwich extends over nearly four years).

If the gun-cotton be exposed for protracted periods to daylight with free access of air, it speedily loses all odour and power of affecting litmus. If exposure to diffused daylight in confined spaces be continued, the first results of the action of light are, of course, retained; but up to the present time no single indication of their increase has been observed; indeed, the very faint acid reaction described, which was developed at first, has frequently disappeared, probably in consequence of the neutralising action of small quantities of earthy carbonates contained in the gun-cotton.

But if the material be exposed continuously in a perfectly confined space to the action of sunlight or strong daylight, it furnishes, after a time much greater evidence of change than that already described. The acidity gradually becomes more manifest; the odour increases, and becomes in time somewhat pungent, and indicative of the presence of very small quantities of nitrous acid; and litmus-paper, if confined in a vessel with gun-cotton thus exposed, becomes entirely bleached after two or three months. Although specimens of gun-cotton always undergo some spontaneous change under these very special circumstances, the decomposition proceeds with extreme slowness; and the results of the observations are, therefore, in this respect quite at variance with those recently published by De Luca, who states that the specimens operated upon by him decomposed upon exposure to sunlight, some on the first day of the experiment, others after several days' exposure.

The advantages arising from the reduction of gun-cotton fibre to a state of fine division are thus explained by Mr. Abel:—

Abundant proofs have been obtained that the long-continued wasting and the treatment with an alkaline liquid to which gun-cotton is submitted, do not completely separate from it products of the partial oxidation of organic impurities retained by the cotton up to the time of its conversion. This is unquestionably due in great measure to the tubular structure of the fibre. If the impurities were merely upon the surface of the fibre, their perfect removal by the action of solvents should be accomplished without difficulty; but it does not appear that even long-continued digestion of gun-cotton in alcohol has the effect of completely freeing it of the impurities soluble in that liquid which are locked within the fibre. The action of a warm or cold alkaline liquid upon the material might perhaps eventually result in the complete removal of these bodies; but the loss of product and destructive effect upon the fibre, resulting from any other than a brief digestion in a very dilute alkaline bath, are too considerable to admit of such a treatment. The following experiments may be quoted in illustration of this:—

A quantity of gun-cotton, which had already been submitted to the usual purification with water and a hot alkaline bath, was boiled for ten minutes in a solution of potassic carbonate, of the strength usually employed (of specific gravity 1·02). By this treatment the material sustained a loss of 3·7 per cent.; the bath having assumed an amber colour. Upon being again boiled for twenty minutes in the same alkaline bath, which thereby became considerably deepened in colour, the sample sustained a further loss of 12·09 per cent. The strength of the fibre had been considerably reduced by this treatment.

6·5 grms. of gun-cotton and 0·4 grm. of sodic carbonate were placed together with 50 cubic centims. of water in a flask, to which a vertical condenser was attached, and were heated to 100° for twelve hours. The alkali was then found to have become nearly neutralised, and the dark brown liquid contained sodic nitrate in abundance. The gun-cotton was washed and twice treated in the same manner, the alkali being neutralised on each occasion, as in the first instance.

But though it is evident that the treatment of gun-cotton with warm alkaline baths cannot be advantageously extended, satisfactory proof has been obtained that the stability of gun-cotton which has been purified as far as is possible by the present system, may be importantly increased by submitting the material to a special process of washing.

In the experiments instituted upon the application of gun-cotton as a substitute for gunpowder, some very advantageous results have attended the conversion of the material into homogeneous masses of any desirable form or density by preparing it according to the method commonly employed for converting rags into paper. In reducing the material to a very fine state of division by means of the ordinary beating and pulping machines, the capillary power of the fibres is nearly destroyed, and the gun-cotton is for a considerable period very violently agitated in a large volume of water. It would be very difficult to devise a more perfect cleansing process than that to which the gun-cotton is thus submitted; and the natural result of its application is that the material thus additionally purified acquires considerably increased powers of resisting the destructive effects of heat. Samples of the pulped gun-cotton, even in the most porous condition have been found to resist change perfectly upon long-continued exposure to temperatures, which developed marked symptoms of decomposition in the gun-cotton purified only as usual.

The pulping process applied to gun-cotton affords, therefore, important additional means of purifying the material, the value of which may be further enhanced by employing a slightly alkaline water in the pulping machine.

Shortly after the discovery of gun-cotton in 1846, attempts were made to increase the explosive force of that substance by impregnating it with a solid oxidising agent such as saltpetre. The preparations of gun-cotton were saturated in a solution of the salt, and the water was subsequently evaporated, but the quantity of the 'nitrate' or 'chlorate' which could be introduced by this, the only practical mode of treatment, was so small as to be of little value. The system of reducing gun-cotton to a fine state of division by the pulping process has, however, afforded the means of readily incorporating this substance with an agent sufficiently rich in oxygen to oxidise the whole of the carbon in the gun-cotton preparation. This requires a comparatively large proportion of saltpetre, or other analogous salt, and Mr. Abel succeeded in obtaining some very promising results in this direction.

The general mode of producing 'nitrate' or 'chlorate' preparations of gun-cotton may be briefly described as follows:—

The requisite proportion of the oxidising agent, such as saltpetre, is reduced to a very fine powder, and is then intimately mixed with the finely-divided or pulped gun-cotton, by steeping the latter in a saturated solution of the salt. The mixture is then granulated or compressed into any desired form by the usual method employed in the preparation of Abel's compressed gun-cotton.

The products obtained in this way, especially in the disc or compressed state, possess several important advantages over ordinary compressed gun-cotton. The nitrated material forms very hard masses, which are much less liable to break up or give off dust when roughly handled than the ordinary substance. This comparative hardness is probably due to the particles of the mass becoming firmly cemented together by the crystallisation of the salt on the evaporation of the water during the process of drying. Indeed, it has been found that the application of considerably less pressure than is required to produce very compact cakes of ordinary gun-cotton suffices to furnish masses decidedly superior both in hardness and compactness. Moreover, the cakes, or discs, of the nitrated preparation, when dry, are found to have become coated with a hard film of the salt, which acts as an additional protective against mechanical injury and renders the surface less dusty, and thus less readily inflammable, than the ordinary kind.

Again, it has been conclusively demonstrated by several experiments, continued for considerable periods, that the nitrated preparation is more stable when exposed to the action of high temperatures than the unimpregnated gun-cotton.

So far, therefore, as concerns the question of storage and transport, the nitrated material possesses several important advantages over ordinary compressed gun-cotton, but, on the other hand, it has two drawbacks.

It has now been decided—wisely, we think—to store all large supplies of gun-cotton in the wet state, in which condition the material is perfectly uninflammable by ordinary heat. For this purpose the discs of gun-cotton are packed in large wooden waterproof tanks, fitted with means of drainage. A tank holds a ton of gun-cotton discs, each disc being three inches in diameter by about two inches in depth, and the ordinary material is wetted by simply filling the tank with water, and allowing the latter to drain off.

With the nitrated preparation, however, it is desirable that a weak solution of saltpetre instead of pure water should be used in wetting the gun-cotton.

We do not urge this as a serious drawback; but it is evident that the process of wetting, and re-wetting when necessary, a store of ordinary gun-cotton is a comparatively simple process, whereas the same operation might, in the case of nitrated gun-cotton, be attended with more or less difficulty under certain circumstances of storage.

Again, the wet nitrated preparation does not dry so readily as the ordinary material; but, on the other hand, this objection is almost negatived by the fact that wet gun-cotton, whether nitrated or not, can be detonated, and made to produce equal, if not superior, effects to the substance in the dry state. Gun-cotton has been detonated with most destructive effect under water, by simply filling a bag net with discs, and exploding them by means of one dry disc enclosed in a waterproof envelope. The detonating fuse is inserted in the dry disc, and its detonation determines that of all the remaining discs, although the latter are absolutely immersed in, and in contact with, the water.

In comparing the explosive action of equal weights of compressed gun-cotton and of the 'nitrate' mixture, it must be borne in mind that a considerable percentage of the total mass of the latter is formed of a material of about one-sixth the cost of pure gun-cotton. Thus a 'nitrate' mixture, prepared with the full theoretical proportion (about 38 per cent. by weight) of the oxidising agent, will not quite equal the effects obtained from the same total weight of ordinary compressed gun-cotton. In other words, the force of the explosion of, say, 100 lbs. of a material which consists of 38 lbs. of nitre and 62 lbs. of gun-cotton will not equal that of 100 lbs. of pure gun-cotton. Here the loss of force due to the replacement of about one-third of the gun-cotton by the salt used is not fully compensated for by the extra work obtained from the complete oxidation of the remaining two-thirds of gun-cotton. If, however, about three-fourths of the theoretical amount of the salt be employed, the mixture will, weight for weight, equal ordinary compressed gun-cotton in explosive effect, although, as we have said, a considerable proportion of the gun-cotton has, in the nitrated preparation, been replaced by a comparatively inexpensive substance. Thus the use of nitrated gun-cotton will be attended by material advantage in point of economy.

But if equal *volumes* of highly-compressed gun-cotton, and of the 'nitrate' or 'chlorate' mixture, similarly compressed, are compared, the explosive force of the latter will be found to be much greater. Chlorated gun-cotton is decidedly more violent in its action than the nitrated mixture, but it is more costly to manufacture, and more dangerous to store and use. The 'chlorate' salt is comparatively high in price, and more of it is required to furnish the requisite amount of oxygen; it is, moreover, very susceptible of ignition by friction or percussion, and is, therefore, comparatively dangerous. For these reasons it does not compare favourably with the 'nitrated' preparations. Of the latter the best is that in which saltpetre is used. It is the most readily prepared, and its tendency to absorb moisture is not appreciably greater than that of ordinary compressed gun-cotton.

Important experiments have been instituted jointly by the Special Committee on Gun-cotton, the Torpedo Committee, and the Royal Engineers Committee, on the comparative explosive properties of ordinary gun-cotton, both in the dry and wet states, and of nitrated gun-cotton under similar conditions.

Some of these experiments are made by exploding under water equal weights of the several substances under identical circumstances, and registering the resulting pressure or blow by a 'crusher' gauge somewhat similar to the pressure gauge used by the Committee on Explosives in determining the explosive force of gunpowder in the chamber of a gun.

Experiments have also been made to ascertain the rapidity of detonation; in other words, the rate at which a string or row of gun-cotton discs placed close to one another will successively explode if detonated at one extremity. For this purpose the beautiful chronoscope invented by Captain Andrew Noble, F.R.S., has been successfully employed. This instrument is designed to measure very minute portions of time, and by arranging the primary conducting wires at equal intervals along a long row of gun-cotton discs a register is obtained of the time occupied in successively breaking the wires as the explosive wave flashes along the row. It has thus been ascertained that the rapidity of the detonation of gun-cotton is about 20,000 feet per second.

The expansive velocity of the gases generated by the explosion of gunpowder has been reckoned at about 7,000 feet per second, so that, according to this estimate, gun-cotton has about three times the explosive rapidity of gunpowder. It is probable that the destructive force of an explosive substance bears a close analogy to the rapidity with which the explosion is transmitted, and the experiments we allude to may furnish most interesting and valuable results. But, whatever may be the method followed in experiments, the considerable advantage which the nitrated gun-cotton possesses, both in point of cost and power, added to the fact that it is so readily susceptible of ignition by detonation, renders it highly probable that this preparation of gun-cotton will be largely substituted for the ordinary compressed material in many of its applications.

Moreover, the circumstance that carbonic oxide, a poisonous gas which is produced in considerable amount upon the explosion of ordinary gun-cotton, is present in the products of explosion of nitrated gun-cotton in scarcely higher proportion than in those of gunpowder, appears likely to remove that objection to the employment of gun-cotton in military mines, which arose from the large quantity of carbonic oxide developed when heavy charges of gun-cotton were exploded.

Abel has made a series of ingenious experiments on the combustion of gun-cotton. He finds that when quantities of gun-cotton, varying from one to two grains, in the form of a loose twist laid double, are ignited by means of a platinum wire in highly rarefied atmospheres, they burn very slowly, presenting by daylight an appearance as if they smouldered. The pressure in the case described must not exceed 8 inches of mercury, but the rarefaction necessary for the result varies with the quantity of gun-cotton, its mechanical condition, its position with reference to the source of heat, the quantity of heat applied, and the direction of its application.

Gun-cotton, when ignited in small quantities in rarefied atmospheres, may exhibit during its combustion three distinct luminous phenomena. In the most highly rarefied atmospheres, the only indication of combustion is a beautiful green glow, or phosphorescence, which surrounds the extremity of the gun-cotton, as it is slowly transformed into gases or vapours. When the pressure of the atmosphere is increased to one inch (with the proportion of gun-cotton indicated), a faint yellow flame appears at a short distance from the point of decomposition; and as the pressure is increased, this pale yellow flame increases in size, and eventually appears quite to obliterate the green light. Lastly, when the pressure of the atmosphere and consequent proportion of the oxygen in the confined space is considerable, the cotton burns with the ordinary bright yellow flame. There can be no doubt that this final result is due to the almost instantaneous secondary combustion, in the air supplied, of the inflammable gases evolved by the explosion of the gun-cotton. The pale yellow flame will take place in rarefied nitrogen.

In a series of experiments made under gradually-diminished pressures, oxygen being used, instead of air, it was found that the gun-cotton exploded instantaneously with a bright flash until the pressure was reduced to 1·2 inch; from this pressure to that of 0·8 inch, it still burned with a flash, but not instantaneously, and at pressures below 0·8 inch, it no longer burned with a bright flash, but exhibited the comparatively slow combustion, accompanied by the pale yellow flame. In atmospheres of carbonic anhydride, carbonic oxide, hydrogen, and coal-gas, this pale yellow flame is seen as in nitrogen; but the two latter gases have a great tendency to extinguish the combustion, doubtless on account of their high cooling power by convection.

The slow kind of combustion of gun-cotton, in the form of twist, may be obtained also in a powerful current of atmospheric air, if the thread of cotton be placed in a somewhat narrow glass tube. Indeed, it was found that if, even for the briefest space of time, the gases resulting from the first action of heat on gun-cotton upon its ignition in open air are impeded from completely enveloping the burning extremity of the gun-cotton twist, their ignition is prevented, and the gun-cotton continues to burn in the slow and imperfect manner, undergoing a transformation similar in character to destructive distillation. By proper arrangements, these gases may be burnt at the mouth of a tube while the gun-cotton is burning in the interior. There is little doubt that these products of decomposition vary as greatly as the phenomena themselves; thus, in the instance of the most imperfect metamorphosis of gun-cotton, the products included a considerable proportion of a white vapour, slowly dissolved by water, as also small quantities of nitrous acid, and a very large proportion of nitric oxide; cyanogen, too, is always found. This contrasts strongly with the simpler products of decomposition found by Karolyi when the gun-cotton was exploded under the pressure of a confined space.

Abel considers that the remarkable facility with which the combustion of gun-cotton in the air or other gases may be modified, might be taken advantage of to produce a variety of mechanical effects; and he states, that by enclosing in suitable cases solid cords made up of two or more strands of gun-cotton more or less compactly twisted, he has succeeded in producing fuses and slow-matches, the time of burning of which may be accurately regulated. See Watts's 'Dictionary of Chemistry.'

GUN-METAL. The Austrians introduced a gun-metal, called, from its inventor, *Aich metal.* It is composed of copper, 600 parts; zinc, 382 parts; iron, 88 parts. Its tenacity is said to be excessive; it is easily forged and bored; when cold, it may be bent considerably without breaking, and we are told its resistance is far greater than iron of the best quality. See BRASS and COPPER.

GUNNERY. Under the heads of ARTILLERY and FIRE-ARMS, we have included all which appears necessary in a work of this description.

GUNNY CLOTHS or **BAGS.** The coarse sacking made in India, which is used for wrapping rice, spices, &c. The Bengal gunny cloth is made of the fibre of a species of *Corchorus*, while that of Bombay and Madras is manufactured from different kinds of sunn fibre, the *Crotolaria juncea.—Simmonds.*

GUNPOWDER. The discovery of gunpowder has been claimed for Roger Bacon and Schwartz. The ground for this appears to be no more than this. In their writings the earliest recorded mention of the discovery is made in any European language. Roger Bacon, unquestionably antecedent to his German rival, was born 1214 and died 1292; and his work, 'De Nullitate Magiæ,' appears to have been writen about 1270, while Kircher's account gives 1354 as the date of the discovery by Schwartz. It appears, however, that an Arabic manuscript exists in the collection of the Escurial which unmistakeably describes gunpowder and its properties, the date of which is anterior to 1250.—*Mallet.*

This-well known composition is employed for charging the numerous varieties of fire-arms. Its use depends upon the fact that, at the moment of ignition, violent deflagration takes place, accompanied by the evolution of a large volume of gas. It is evident that if the explosion occurs in a limited space, a vast pressure accumulates and becomes a propulsive force. The gas produced by the explosion of good gunpowder occupies nearly 900 times the volume of the powder itself; but, owing to the high temperature, the space occupied by the gas at the moment of formation is probably nearly 2,700 times greater than the volume of the powder. One of the most popular errors regarding the projectile force of explosive substances arises from the extremely vague meaning generally attached to the words strong, powerful, and other equivalent terms. It is this which leads so many to imagine the possibility of attaining marvellously long ranges by means of the various fulminating substances known to chemists. The latter are unfit for use in fire-arms, owing to a variety of circumstances. One of them is the extreme rapidity of their explosion. The whole mass appears to be converted into gas at once, whereas in gunpowder the ignition proceeds from particle to particle. The action of fulminates is also too local; if a portion of any of the more violently explosive substances be fired on a piece of metal, the latter will be perforated or depressed exactly at the spot occupied by the substance, and if it be attempted to use it to charge fire-arms, they will be destroyed, and yet, in all probability the bullet not projected. Moreover, it is impossible to use fulminates successfully for charging shells, because the latter, instead of being blown into pieces of moderate size, capable of inflicting large wounds and throwing down buildings, become converted into fragments so small as to be far less destructive.

It has been found that no composition fulfils so many requisites for charging fire-arms as a mixture, in due proportions, of sulphur, nitre, and charcoal. It is this composition which, in the form of small grains, more or less polished, constitutes gunpowder. The latter should possess several properties which, although sometimes tending in opposite directions, are not entirely incompatible, and may therefore be nearly attained in practice. Some of the principal of these are the following:—1. The proportions should be so adjusted that the combustion may be complete, and little residue be left after explosion. 2. The powder should be as little hygrometric as possible. 3. It should be sufficiently, but not too explosive. 4. It should be hard and dense enough to bear carriage without breakage of the grains.

Too great a proportion of carbon and sulphur will cause rapid fouling of the gun, and the explosive force will be less than it should be; too small a proportion of sulphur will render the powder too hygrometric. The presence of soda or chloride of potassium in the nitre will lead to the same fault. The powder must be sufficiently stamped, or it will not possess the fourth requisite.

The history of gunpowder may be conveniently studied under the following heads:—

Preparation of the ingredients.
Mixture and granulation.
Modes of estimating projectile force.
Analysis of gunpowder.

PREPARATION OF THE INGREDIENTS.

Preparation of the Nitre.—The nitre employed for powder is always in a state of almost absolute purity, especially as regards the presence of the chlorides of potassium or sodium. The crude nitre of commerce contains several impurities, among which are found nitrates of soda and lime, chlorides of potassium and sodium, and sulphates of potash and soda. They are all removed by crystallisation. The principal impurity is common salt. The process of purification is founded on the fact, that the latter substance is almost equally soluble in hot or cold water, whereas nitre is far more soluble in hot than in cold water. The following is the French mode of refining saltpetre:—1,200 kilogrammes are gently heated with 600 litres of water in a copper boiler. The solution is constantly stirred and skimmed, and more nitre is added, until the total quantity is 3,000 kilogrammes. As soon as the whole is added, and it is presumed that all the nitre is dissolved, the common salt is removed from the bottom of the boiler. The solution is now to be clarified with glue. For this purpose 400 litres of water are added by small portions, and then 1 kilogramme of the glue dissolved in hot water. The scum, which soon rises, is removed, and the fluid is boiled until clear. The whole is then allowed to cool to about 194°, and the solution of nitre is carefully decanted from the layer of common salt into the crystallising vessel. The latter is a large shallow pan with sloping sides. The fluid is constantly stirred as it cools, in order that the crystals formed may be very small; this is done in order to facilitate the washing process, and also because the fine powdery crystals are well adapted for admixture with the other ingredients. When the crystallising solution is cold, the nitre is removed to boxes containing false bottoms, pierced with holes. The aperture in the bottom of the box (below the false bottom) being closed, a saturated solution of pure nitre is poured on the crystals to dissolve out the chloride of sodium. Being already saturated, it is evident it cannot dissolve any of the nitre. After remaining two hours in contact with the nitre, the solution is allowed to run off, and when the dropping has almost entirely ceased, the process of washing is repeated, substituting pure water for the solution of nitre. The product is dried at a gentle heat, being constantly stirred to enable it to retain the pulverulent form. The power (above alluded to) possessed by a saturated solution of nitre, of dissolving other salts, has been taken advantage of in one of the processes for analysing saltpetre. Some manufacturers fuse the nitre after it has been purified by crystallisation; this process has several disadvantages, among others that of necessitating machinery to reduce it again to a pulverulent state.

Preparation of the Sulphur.—Sulphur may be purified for the gunpowder-maker by two processes. In the first the crude article is fused in an iron pot, so contrived that the fire does not play directly on the bottom, but only round its sides. The lighter impurities are to be removed by skimming, while the heavier sink to the bottom. The temperature should not be allowed to rise much above 232°, for it then becomes sluggish, and at 320° it is so thick as to prevent the impurities from being removed.

Sulphur may be more readily and economically purified by distillation. The apparatus for the purpose is exceedingly simple in principle; but the process requires care, and is not entirely free from danger. As it is not intended to obtain the sulphur in the state of flowers, the apparatus for condensation is not required to be kept cold; in fact, the still is purposely placed so near to the chamber of condensation that the sulphur may be received in the fluid state. There are several points which must be attended to in the construction of an apparatus for the distillation of sulphur; they are as follow:—1. The crude sulphur must be capable of being introduced, and the refined product removed easily, without air being, at the same time, permitted to enter the still or condenser. 2. Free means of egress for the heated air must be provided. 3. The contrivance for the latter purpose must not allow fresh air to return. 4. The process must be continuous. The still and condenser employed in France for the purification of crude sulphur fulfils all these conditions. The still is in the form of a very wide-necked tubulated retort, made of cast iron. It is set in brickwork over a furnace, and opens into a square brick chamber surmounted by a dome. The latter has a rather short chimney over it, containing a valve opening upwards to permit escape of the heated air, but not allowing anything to return. Over what may be termed the tubulature of the retort or still, is placed an iron pot with a tube communicating with it. The pot is heated by the same fire that works the still. The crude sulphur is placed in the pot, where it melts, and by raising a plug, which closes the tubulature, may be made to enter the still. The pipe forming the tubulature rises a short distance above the bottom of the iron supply-pot. This is in order that any heavy mechanical impurities may sink to the bottom, and not enter the still, and unnecessarily clog it. If the pot be always kept full of melted sulphur, and the latter is permitted to enter by raising the plug, it is evident that no air will find its way into either the retort or condenser. It is exceedingly important that this should be the case, because violent explosions are liable to occur if the highly-heated vapour of sulphur comes in contact with an oxidising medium, such as atmospheric air, which would convert it into sulphurous acid. The melted sulphur which collects on the floor of the chamber is allowed to flow out when desired, by means of an iron plug attached to a rod of the same metal. The sulphur is not allowed to run out entirely, so as to permit air to enter, for the reason stated above. The loss occurring during the purification is owing partly to oxidation, resulting in the formation of sulphurous acid, and partly to the fixed impurities contained in the crude material. See also the article SULPHUR.

Preparation of the Charcoal.—Of the three ingredients of gunpowder, the most important is generally considered to be the charcoal. Unfortunately the woods which are best adapted for the production of pyroligneous acids are not fitted for the manufacture of gunpowder; the charcoal must, therefore, be prepared specially. The following are the essential properties of good charcoal for powder:—1. It should be light and porous. 2. It should yield little ashes. 3. It should contain little moisture. The woods yielding good powder-charcoals are black alder, poplar, spindle tree, black dogwood, and chestnut. Hemp-stalks are said to yield good charcoal for gunpowder.

The operation of preparing the charcoal naturally divides itself into three processes:— 1. The selection of the wood. 2. Preparation of the wood previous to carbonisation. 3. The carbonisation.

In selecting the wood, care is to be taken to avoid the old branches, as the charcoal made from them would yield too much ashes. The bark is to be rejected for the same reason. The wood is then cut into pieces from 4½ feet to 6 feet long. If the branches used are more than ¾ of an inch in diameter, they are to be split. If the wood be too large, great difficulty will be found in uniformly charring it.

There are two methods employed in the charring of wood for gunpowder. In one, the operation is conducted in pits; but the process more commonly resorted to is distillation in cylindrical iron retorts. There are certain advantages in the pit-process, but they are more than counterbalanced by the convenience and economy of distillation. The stills used are about 6 feet long and 2 feet 9 inches in diameter. The ends of the cylinders are closed by iron plates, pierced to admit tubes of the same metal. Some of the latter are for the introduction during the carbonisation of sticks of wood, which are capable of being moved to indicate the stage of the decomposition, while another communicates with the condenser. The more freely the volatile matters are allowed to escape, the better the quality of the resulting charcoal. If care be not taken in this respect, especially as the distillation reaches its close, the tarry matters become decomposed, and a hard coating of carbon is deposited on the charcoal, which greatly lowers its quality. The process of burning in pits is considered to yield a superior coal, owing to the facility with which the gases and vapours fly off.

The degree to which the burning distillation is carried, materially influences the nature of the resulting powder. If the operation be arrested before the charcoal becomes quite black, so that it may retain a dark brownish hue, the powder will be more explosive than it would be if it were pushed until the charcoal had attained a deep black colour. When it has been found that no more volatile products are being given off, the fire is damped, and in a few hours the contents of the cylinders are transferred to well-closed iron boxes to cool. See Carbon.

Mixture and Granulation.

A very considerable number of methods have been employed at various times, for effecting that thorough incorporation of the ingredients necessary for the production of a good powder. The oldest method consists in stamping the materials in wooden mortars. The pestles are square shafts of wood ending in brass beaters. The mortars are of wood, and so shaped that any of the composition which may be forced upwards by the blows of the stampers, falls back to the bottom. In order to prevent fracture of the mortars, a piece of wood of the toughest kind should be let in on the spot where the pestle falls. The pestles are raised by means of cogs fixed on a shaft, driven by a water-wheel or steam-engine.

One of the many methods adopted to mix the nitre, sulphur, and charcoal, is by means of drums containing metallic balls; but this arrangement is inferior to that where edge-stones are employed. This last is superior to all others, the product being not only very dense and, therefore, capable of enduring, without becoming pulverulent, the motion unavoidable in carrying it about; but it is also thoroughly incorporated. It is, of course, essential that the stones, and the bed on which they work, should not strike fire during work. To secure this, they are sometimes made of calcareous stone, and sometimes of cast iron. Previous to being subjected to the action of the mill, the ingredients must be pulverised and mixed. The pulverisation may conveniently be effected in wooden drums, containing metallic balls. The pulverised materials, after being sifted or bolted, and weighed out in the proper proportions, are to be inserted in a mixing drum, containing on its inside pieces of wood projecting inwards, so that, as it revolves, complete admixture gradually takes place. The product of the last operation is now ready to be laid on the bed of the mill. During the grinding, the cake is kept moist by the addition, at proper intervals, of enough water to make it cohere. As the stones revolve, a scraper causes the material to take such a position that it cannot escape their action. The cake produced by the action of the stones is ready for graining or corning. For this purpose the cake is subjected to a powerful pressure, by means of a hydraulic press. The mass is then broken up and transferred to a species of sieve of skin or metal pierced with holes. A wooden flail is placed on the fragments, and the sieves are violently agitated by machinery. By this means the grains and dust produced by the operation fall through the holes in the skin or metal discs, and are afterwards separated by sifting. Sometimes the machinery is so arranged that the graining and separation of the meal-powder are effected at one operation. The meal powder is re-worked, so as to convert it into grains. The next operation to which the powder is subjected is glazing. Its object is to render it less liable to injury, by absorption of moisture or disintegration during its carriage from place to place. The glazing is effected by causing the grained powder to rotate for some time in a wooden drum or cylinder, containing rods of wood running from end to end. The grains as they rub against each other and against the wooden ribs, have their angles and asperities rubbed off, and at the same time the surface becomes harder and polished. It is finally dried by exposure to a stream of air, heated by means of steam.

A vast number of experiments have been made, at various times, to discover the proportions of nitre, sulphur, and charcoal best adapted for the production of gunpowder. It has been found, as might have been anticipated, that no general rule can be given, no admixture can be made which shall fulfil every requirement. Those powders which contain the largest quantities of charcoal are, it is true, as powerful as others in projectile force; but they have the disadvantage of attracting more humidity from the air. It is very singular that all nations appear to have found, by trial, the proportions most generally useful for ordinary purposes, and it is worthy of remark, that they all approximate to the percentages required by the very simple formula, $KO,NO^5 + S + 3C$. In fact, the Prussian powder approaches so closely the theoretical numbers, that they fall within the limits of the errors of analysis, thus:—

Prussian powder.		Theoretical proportions.		
Nitre	75·0	KO,NO^5	93 or 1 equivalent	74·8
Sulphur	11·5	S	16 ,, ,,	11·9
Charcoal	13·5	C	18 or 3 equivalents	13·3
	100·0		127	100·0

When a powder constituted as above is fired, the decomposition is probably as follows (represented in symbols):—

$$KO,NO^5 + S + 3C = 3CO^2 + N + KS.$$

$$[\mathbf{2(KNO^3) + S + 3C = 3CO^2 + 2N + K^2S}]$$

That is to say, the explosion of one equivalent of powder results in the formation of three equivalents of carbonic acid, one of nitrogen, and one of sulphide of potassium. It is evident that these theoretical relations are not *absolutely* the true expression of the phenomena; because, in the first place, gunpowder is merely a mechanical mixture, and not a definite chemical compound; and, in the next, the charcoal is represented by the symbol C as if it were pure carbon, whereas, in fact, even the purest and best-made charcoals contain variable amounts of hydrogen, ashes, and oxygen. The hydrogen is partly converted into water and partly into hydrosulphuric acid (sulphuretted hydrogen).

The following are the proportions of the ingredients used in various countries:—

Table of the Composition of various Gunpowders.

	Nitre	Sulphur	Charcoal
English war-powder	75	10	15
,, sporting ditto . . .	77	9	14
French war-powder	75	12·5	12·5
,, sporting ditto	76·9	9·6	13·5
,, blasting ditto	62	20	18
,, ,, ditto (another kind) .	65	20	15
United States war-powder . . .	75	12·5	12·5
Prussian war-powder	75	11·5	13·5
Russian ,, ,, ...	73·8	12·6	13·6
Austrian ,, ,, ...	75	10	15
Spanish ,, ,, ...	76·5	12·7	10·8
Swedish ,, ,, ...	75	16	9
Chinese ,, ,, ...	75·7	14·4	9·9

Blasting powders contain less nitre than others, the combustion is therefore less perfect, and if used for artillery or small arms, not only is the piece very soon rendered foul, but the ball is projected to a much less distance than is required in practice. In France, where a heavy tax is laid on sporting powders, this difference of composition prevents the cheap blasting powder from being used in fowling-pieces.

MODES OF ESTIMATING THE PROJECTILE FORCE OF GUNPOWDER.

The usual mode of determining the propulsive force of powder is by ascertaining the distance to which it can throw a ball of known weight. The instrument used in this country for this purpose consists of an 8-inch mortar charged with 2 ounces of powder, the balls being in each case of the same size and weight. The French use for the purpose an iron mortar, elevated at an angle of 45°. The mortar is 7·5 inches in diameter. The ball is of bronze, and is only 0·067 inch smaller than the bore of the gun; the windage is, consequently, very small. The charge of powder being 3·2 ounces, and the weight of the ball 65 lbs., the latter should be thrown not less than 437·5 yards.

The force of powder may also be estimated by means of an instrument, called a pendulum-gun. It consists of a gun-barrel hung at the lower end of a pendulum, so arranged that the amount of angular deviation caused by the recoil may be measured; the balls may also be fired into a cup suspended to a similiar pendulum. The data obtained serve to enable the rapidity of motion of the ball, at the moment of discharge, to be calculated by means of formulæ contrived for the purpose.

ON THE ANALYSIS OF GUNPOWDER.

Several methods have been given by various chemists for the analysis of gunpowder: the following, on the whole, appears the most effective:—The percentage of water is, in the first place, to be determined by drying *in vacuo* over sulphuric acid, until no more diminution of weight occurs. The dried powder, or a fresh quantity, is then to be washed on a filter with boiling water, until nothing more is dissolved out. The residue is to be dried below 212° and weighed; the loss is the nitre. If preferred, the solution of the nitre may be evaporated to dryness, and the residue weighed. The mixture of charcoal and sulphur is then to be digested in a stoppered flask, with bisulphide of carbon; this will dissolve out the sulphur, and leave the charcoal. The loss of weight of the dry mixture of sulphur and charcoal will enable the percentages of sulphur and charcoal to be calculated. If it be desired to know the quality of the charcoal, a combustion of it may be made with a mixture of chromate of lead and bichromate of potash. Ordinary charcoal contains from 69 to 74 of carbon, 3·9 to 5·5 hydrogen, 0·5 to 3·0 per cent. ashes. It has been attempted to dissolve out the sulphur with sulphite of soda, or caustic potash; but these methods involve several sources of error.

Good gunpowder should not lose more than 1 per cent. of moisture on drying. It should not leave alkaline globules, when exploded on a clean metallic plate. The specific gravity of a good powder should not be less than 1·755; it is sometimes as high as 1·840. The denser the powder the better it endures transportation. As the density cannot be taken in water, owing to the solubility of the nitre, turpentine or benzole must be substituted, a correction being made for the difference in density of the fluid medium.

Horsley's and Erhardt's Gunpowder.—In the 'Chemical News,' August 16, 1862, we find a short paper 'On an Explosive Compound,' by John Horsley, F.C.S. 'If nine parts of well-dried and finely-powdered chlorate of potash be mixed with three parts of fine powdered galls, a highly explosive compound is formed, which needs no granulation. As it will not admit of trituration in a mortar, the mixture should be made on paper by means of a bone spatula, or by passing it through a fine brass sieve. The strength of common gunpowder may be increased by working up with the powdered meal about 12 per cent. of powdered galls, and regranulating it. I have been acquainted with this for several years, but never published it before.'

Dr. Erhardt has yet more recently patented a powder, the peculiarity of which is that the ingredients are kept apart until they are required for use. This appears to be in one packet (chlorate of potash), and in the other, tannin. These are mixed together in certain proportions, and diluted with powdered anthracite, according to the purpose for which it may be required. As a blasting powder in quarries, Dr. Erhardt's powder is said to possess extraordinary power.

Schultze's White Gunpowder is a tri-nitro-cellulose, prepared from sawdust by the following process. The sawdust is first boiled for three or four hours with a weak solution of soda, and then boiled a second time with a fresh lot of the same solution. It is then washed in running water, afterwards steamed for fifteen minutes, and then again washed in running water for twenty-four hours. It is now bleached with chlorine or chloride of lime, boiled in water, once more washed in a stream, and then dried. The sawdust is now ready to be treated with nitric acid. For this purpose a mixture of 40 parts strong nitric acid (1·48 to 1·50) is mixed with 100 parts of sulphuric acid (1·84); and the mixture is allowed to stand two hours to cool. One hundred parts of this mixture are then placed in an iron vessel, around which a stream of cold water circulates, and six parts of the sawdust are gradually added, stirring all the time. The sawdust is allowed to remain in the acid two or three hours, the stirring being continued. After this time the whole is transferred to a centrifugal machine, and the acid separated. The wood is then washed for two or three days in cold water, afterwards boiled in a weak soda solution, again well washed in cold water, and then dried. It is now ready for the final operation, which consists in soaking it for ten or fifteen minutes in a solution of 26 parts of nitrate of potash in 220 parts of water. After this it is carefully dried at a temperature not exceeding 44° C.; the very fine dust is then separated by means of a drum sieve, and the remainder is ready for market.—'Chem. Central Blatt.,' No. 44, p. 704.

About six years since, M. Hochstädter made a comparatively safe application of chlorate of potash to explosive purposes. Unsized paper was thoroughly soaked in, and coated with, a thin paste consisting of chlorate of potash, finely-divided charcoal, a small quantity of sulphide of antimony, and a little starch, gum, or some similar binding material, water being used as the solvent and mixing agent. The paper was rolled up very compactly, and dried in that form. In this manner very firm rolls of an explosive material are obtained, which burns with considerable violence in the open air, and the propelling effect of which in small arms, has occasionally been found greater than that of a corresponding charge of rifle-powder. Moreover, the material, if submitted in small portions to violent percussion, exhibits but little tendency to detonation. But as no reliance can be placed on a sufficiently uniform action of these explosive rolls in a fire-arm, this alone sufficed to prevent their competing with powder. The same description of explosive preparation, differing only from that of Hochstädter in a trifling modification of its composition, has recently been brought forward in this country by M. Reichen and Mr. Melland.

An explosive composition was patented in this country, in which spent tan broken into small fragments was saturated with the oxidising agents, nitrate and chlorate of potash, and then dusted over with sulphur. This composition deflagrates slowly when ignited in the open air, but when confined in blast holes it exhibits sufficient explosive force to do good work.—See Abel's Lecture 'On Recent Progress in the History of Proposed Substitutes for Gunpowder,' Royal Institution, May 4, 1866, and Watts's 'Dictionary of Chemistry.'

Gunpowder rendered non-explosive: Mr. Gale's Patent. The rapidity of burning of gunpowder—which is only another name for its degree of explosiveness—depends, *cæteris paribus*, upon the facility afforded to the propagation through the mass of the heated gases generated by the first ignited portion. The requisite facility is afforded in ordinary gunpowder by breaking it up into grains, thus creating a number of crevices through which the gases can pass from grain to grain with a rapidity proportioned to the size and number of the interstices. Mr. Gale's process—which is not, we believe, employed in any country—consisted merely in filling up these crevices with finely-powdered glass or other suitable substances, thus shutting off the communication between the grains, and destroying the explosive character of the powder. He diluted the powder with so much incombustible dust as may be required to prevent the gunpowder from burning; and he restored its explosive character by simply sifting out the diluent and once more opening the pores of the powder.

Considering that nobody acquainted with the nature of gunpowder was ignorant of the simple facts upon which Mr. Gale's process was based, and that these facts were experimentally proved on a large scale by M. Piobert as far back as 1835, and by the Russian chemist Fadeieff between 1841–4; that the results of these experiments are detailed in Piobert's *Traité d'Artillerie*, and that similar experiments have been made more recently in this country, Mr. Gale could hardly claim for this proposition the originality which was at first popularly supposed to attach to it. Indeed, it seems that his process differed from that of Piobert and Fadeieff only in the employment of a different quality and larger quantity of protective powder. But the question of the probable value of the process is distinct from that of its originality. While hesitating to pronounce an opinion as to its possible occasional value for the storage of merchants' or mining powder, we may confidently assert what we believe to be the opinion of the majority of naval and military men, that for military purposes or for the treatment of powder on board our ships of war, the discovery had no practical value. It was at once open to the very definite objection that it entailed an increase of storage room to three and a half times that ordinarily required, while the transport of so much additional dead weight, whether on sea or on land, was regarded as absolutely impracticable. Such experiments as were made, moreover, exhibited a decided tendency to unmix in travelling; in other words, a tendency on the part of the powder, resulting from the different size of its grain as compared with the grains of glass-dust, to resume to a dangerous extent its explosive character; and there is little doubt that the delicate surface of powder is liable to be sensibly affected and fouled by the protective medium, while strong doubts are expressed as to the keeping qualities of the mixture, which lengthy and careful experiments alone could solve. It would always be necessary also, on service, to keep so large a supply of powder ready for immediate use as to render quite insignificant the degree of additional security which might be afforded by having the remainder non-explosive. The formidable objection to the process on the score of its entailing a considerable amount of extra manipulation of gunpowder, which would always be attended with more or less danger, delay, and uncertainty, has never, that we are aware, been satisfactorily disposed of; and officers whose opinions are entitled to every consideration object generally to a system which tends to establish in men's minds a feeling of security about a substance which, however harmless it may temporarily be rendered, must finally and frequently be handled in its explosive form.

How far, or how many of, these objections may apply to the process for civil use cannot be decided without reference to the particular circumstances of each case; but, together, they certainly appear sufficiently formidable to preclude the employment of the process for military or naval powders, either in transport or in store.

An experiment made in 1866 in a martello tower near Rye, with five tons of gunpowder rendered non-explosive by the process proposed by Mr. Gale, attracted sufficient attention to render acceptable these few words on the rationale of this so-called discovery and its probable value for military or other purposes.

The magnitude of the Rye experiment gave it a specious importance, to which it had no real claim. But when five tons of gunpowder are seen slowly burning away without any explosive effect, it is difficult to make people understand that a great practical result has not been achieved. And this was the sight by which visitors to Pett Level near Rye were rewarded. Five tons of cannon powder had been mixed with twenty tons of glass-dust, and stowed in barrels in the magazine and on the basement-floor of a martello tower. An attempt was first made to cause an explosion or a conflagration by firing one barrel, and when this failed, a sort of bonfire was ignited within the tower, which rapidly communicated from barrel to barrel, and burnt steadily, with a dense acrid smoke from the door and windows of the tower. But there was no explosion—nothing more than an occasional dull, muffled puff as the contents of a fresh barrel caught fire.

The experiment placed beyond doubt the efficiency of the method of protection proposed, even for a large mass closely stowed in a confined space; but it left the question of the wisdom of adopting that particular method precisely where it was before.

The above remarks, which completely embrace the question, are borrowed from an excellent article in the 'Pall Mall Gazette.' Little need be added to them. It will be gathered from the first paragraph that the gunpowder is not rendered really non-explosive, but that its rate of combustion is retarded. Confined in a cask or any vessel preventing the escape of the gases formed, the result would be, after a little time, an explosion.

This mixture of powdered glass with gunpowder has been recommended also for protecting gunpowder from damp; it having been forgotten that all porous bodies, and powdered glass especially, have the property of condensing moisture from the atmosphere within their pores.

Our gunpowder *Exports* have been as follow:—

Years	Lbs.	Value
		£
1868	16,721,002	394,458
1869	15,453,576	368,320
1870	17,357,668	427,229
1871	18,678,487	438,782
1872	19,889,628	485,434

GUNPOWDER, GERMAN. See EXPLOSIVE AGENTS.

GUNPOWDER, WHITE. See EXPLOSIVE AGENTS.

GUTTA-PERCHA. Although the trees yielding this substance abound in the forests of the Indian Archipelago, the first notice taken of it appears to have been by Dr. W. Montgomerie, in a letter to the Bengal Medical Board, in the beginning of

1843, wherein he recommends the substance as likely to prove useful for some surgical purposes, and supposes it to belong to the fig-tribe. In April 1843 the substance was taken to Europe by Dr. D'Almeida, who presented it to the Society of Arts of London, but it did not at first attract much attention, as the Society simply acknowledged the receipt of the gift; whereas, its value becoming known, they awarded a gold medal to Dr. W. Montgomerie.

The gutta-percha tree, or gutta turban, as it ought more properly to be called, according to Mr. Oxley, belongs to the natural family *Sapoteæ*, but differs much from all described genera, having alliance with both *Achras* and *Bassia*, yet differing in some essentials from both. It is the *Isonandra gutta* of Hooker, and is described in the 'London Journal of Botany,' 1848, where it is figured, and in Pereira's *Materia Medica.*

The tree is of a large size, from 60 to 70 feet in height, and from 2 to 3 in diameter. Its general appearance resembles the genus *Durio*, or well-known *Doorian*, so much so as to strike the most superficial observer. The under surface of the leaf, however, is of a more reddish and decided brown than in the durio, and the shape is somewhat different.

Only a short time ago the gutta-percha tree was tolerably abundant on the island of Singapore; but already all the large timber has been felled, and few, if any, other than small plants, are now to be found. The range of its growth, however, appears to be considerable, it being found all up the Malayan Peninsula, as far as Penang. The tree also occurs in Borneo, and, there is little doubt, is to be found in most of the islands adjacent.

The localities it particularly likes are the alluvial tracts along the foot of hills, where it flourishes luxuriantly, forming, in many spots, the principal portion of the jungle. But, notwithstanding the indigenous character of the tree, its apparent abundance and wide-spread diffusion, the gutta will soon become a very scarce article, if some more provident means be not adopted in its collection than those at present in use by the Malays and Chinese.

Montgomerie says, 'a magnificent tree of 50, or more probably 100 years' growth, is cut down, the bark stripped off, and the milky juice collected and poured into a trough formed by the hollow stem of the plantain-leaf; it quickly coagulates on exposure to the air; but from one tree I am told not more than 20 lbs. or 30 lbs. are procured.'

The mode in which the natives obtain the gutta is by cutting down the trees of full growth, and ringing the bark at distances of about 12 to 18 inches apart, and placing a cocoa-nut shell, spathe of a palm, or such like receptacle, under the fallen trunk, to receive the milky sap that immediately exudes upon every fresh incision. This sap is collected in bamboos, taken to their houses, and boiled, in order to drive off the watery particles and inspissate it to the consistence it finally assumes. Although the process of boiling appears necessary when the gutta is collected in large quantities, if a tree be freshly wounded, a small quantity allowed to exude, and it be collected and moulded in the hand, it will consolidate perfectly in a few minutes, and have all the appearance of the prepared article.

When it is quite pure the colour is of a greyish white; but, as brought to market, it is more ordinarily found of a reddish hue, arising from chips of bark that fall into the sap in the act of making the incisions, and which yield their colour to it. Besides these accidental chips, there is a great deal of intentional adulteration by sawdust and other materials. Some specimens brought to market do not contain much less than ¼ lb. of impurities: and even in the purest specimens, one pound of the substance yielded, on being cleansed, one ounce of impurities. Fortunately, it is not difficult to detect or clean the gutta of foreign matter, it being only necessary to boil it in water until well softened, roll out the substance into thin sheets, and then pick out all impurities, which is easily done, as the gutta does not adhere to anything, and all foreign matter is merely entangled in its fibres, not incorporated in its substance. The quantity of gutta-percha obtained from each tree varies from 5 to 20 catties, so that, taking the average at 10 catties, which is a tolerably liberal one, it will require the destruction of ten trees to produce one picul. How much better would it, therefore, be to adopt the method of tapping the tree, practised by the Burmese in obtaining the caoutchouc from the *Ficus elastica* (viz. to make oblique incisions in the bark, placing bamboos to receive the sap which runs out freely). True, they would not at first get so much from a single tree, but the ultimate gain would be incalculable, particularly as the tree seems to be one of slow growth; by no means so rapid as the *Ficus elastica.*

Properties of the Gutta-percha.—This substance, when fresh and pure, is of a dirty white colour, and of a greasy feel, with a peculiar leathery smell. It is not affected by boiling alcohol, but dissolves readily in boiling spirits of turpentine, also in naphtha and coal-tar. A good cement for luting bottles and other purposes is formed by boiling together equal parts of gutta and coal-tar and resin. When required for use, it can always be made plastic by putting the pot containing it over the fire for a few minutes. The gutta-percha itself is highly inflammable; a strip cut off takes light, and burns with a bright flame, emitting sparks, and dropping a black residuum in the manner of sealing-wax, which in its combustion it very much resembles. But the great peculiarity of this substance, and that which makes it so eminently useful for many purposes, is the effect of boiling water upon it. When immersed for a few minutes in water above 150° Fahr. it becomes soft and plastic, so as to be capable of being moulded to any required shape or form, which it retains upon cooling. If a strip of it be cut off and plunged into boiling water, it contracts in size both in length and breadth.

It is this plasticity when plunged into boiling water that has allowed of its being applied to so many useful purposes, and which first induced some Malays to fabricate it into whips, which were brought into Singapore, and led to its further notice. The natives subsequently extended their manufactures to buckets, basins, and jugs, shoes, traces, vessels for cooling wines, and several other domestic uses. Its easy plasticity and power of retaining any shape given to it when cool, at once pointed it out as suitable for the manufacture of bougies; and accordingly Dr. W. Montgomerie availed himself of this, made several of the above instruments, and recommended the use of it to the Bengal Medical Board. It also answers very well for the tubes of syringes, which are always getting out of order in hot climates, when made of caoutchouc.

Mr. T. Oxley, surgeon, Prince of Wales Island and Malacca, whose remarks are of much value from his acquaintance with the production of which he writes, says:—

'I observed in the "Mechanics' Magazine" for March 1847, a notice of several patents taken out for the working of this article by Mr. Charles Hancock, in which an elaborate process is described for cleaning the gutta, as also mention of its having a disagreeable acid smell. The gutta, when pure, is certainly slightly acid, that is, it will cause a very slight effervescence when put into a solution of soda, but is unaffected by liquor potassæ. The smell, although peculiar, is neither strong nor unpleasant, so that the article experimented on must have been exceedingly impure, and possibly derived a large portion of its acidity from the admixture and fermentation of other vegetable substances. Again: it appears to me that, if the gutta be pure, the very elaborate process described as being necessary for cleaning it, is superfluous. The gutta can be obtained here in a perfectly pure state by simply boiling it in hot water until well softened, and then rolling it out into thin sheets, when all foreign matter can be easily removed. I would recommend that the manufacturers at home should offer a higher price for the article if previously strained through cloth at the time of being collected, when they will receive the gutta in a state that will save them a vast deal more of trouble and expense than the trifling addition necessary to the original prime cost.'

In February 1847, Mr. Charles Hancock obtained a patent for improvements in the manufacture of gutta-percha. In the first place, for the construction of a slicing machine, consisting of a circular iron plate, formed with three radial slots, in which knives are fixed in a similar manner to the irons of an ordinary plane or spokeshave; the shaft which carries the plate is caused to rotate by steam or other power. The lumps of gutta-percha drop against the knives, by which they are cut into slices, of a degree of thickness corresponding to the projection given to the knives. These slices are then soaked in a vessel of hot water till they become pliable. Instead of a circular revolving cutter, a vertical cutter or chopper may be used; curved knives may be had recourse to for refractory lumps. The softened slices are next subjected to the action of breakers or rollers with serrated blades, which are mounted transversely over the tank. In front of each breaker there is a pair of fluted feeding-rollers; and the pieces of gutta-percha are passed to the rollers of the first breaker. There is an inclined endless web mounted upon two rollers, the front one of which is immersed in the water, and the other is situated opposite the space between the feeding-rollers of the second breaker. There is a second inclined web placed before the third breaker. There is also a mincing-cylinder, with radial blades working partly in the water. The feeding-rollers, and the carrying-rollers of the endless webs, are made to revolve in a forward direction, while the breakers, the mincing-cylinder, and the agitator, are made to revolve in the opposite direction. The breakers and mincing-cylinder should revolve at the rate of from 600 to 800 revolutions per minute, but the feeding-rollers and endless webs need not move faster than about one-sixth of that rate. Thus, the substance is reduced to fragments and washed in the water, the heavy impurities falling to the bottom of the tanks, and the light purer matter floating. The water should be used cold. When the gutta-percha has a fetid smell, it is treated with carbonate of soda or chloride of lime. The same apparatus may be used for purifying caoutchouc.

Mr. Hancock combined sulphur with gutta-percha in the following manner:—He found that if a minute portion of sulphur be used along with a sulphide, the best result is obtained; the proper proportions being 6 parts of sulphide of antimony, or hydrosulphide of lime, and 1 part of sulphur to 48 parts of gutta-percha. When these materials have been mixed, the compound is put into a boiler and heated under pressure to a temperature of from 260° to 300° Fahr., and it is to be left in this state for a period varying from half an hour to two hours, according to the thickness of the materials. He prefers, for effecting the union of the sulphurous constituent, the following method to the masticating machine:—1. He subjects the purified gutta-percha to the combined action of steam and the fumes of orpiment and sulphur mixed in the proportions stated, in a metal chamber, provided with a steam-tight cover secured by screw-bolts. There is also a steam-boiler connected therewith, and when the heat in it is raised to about 280° Fahr., a fire is lighted beneath the pot containing the sulphurising materials. But the gutta-percha, &c., should be heated with the steam before it is sulphurised. In from half an hour to two hours the sulphurising is finished. Or, the gutta-percha may be rubbed strongly over with the sulphurous mixture and then heated, either dry or with the aid of steam, or it may be coated in the form of a paste.

Another of Mr. Hancock's inventions is to expose the gutta-percha to the deutoxide of azote (nitric oxide), or to chloride of zinc, concentrated and boiling hot, and then washing with an alkaline solution or mere water. Gutta-percha thus treated by the action of the gas, as it is evolved from nitric acid and copper, iron, or zinc, becomes exceedingly smooth, and of a lustre approaching to metallic; the same effect is produced upon common unsulphurised caoutchouc. Gutta-percha is thus also freed from all stickiness; and if sulphurised it acquires under this treatment the downy softness of velvet. Chloride of zinc and nitrous gas remove the smell of vulcanised caoutchouc in a great measure, especially if it be afterwards washed.

Another invention is that of masticating gutta-percha in the proportion of 6 parts with 1 of chloride of zinc; which compound may be afterwards sulphurised. A further modification consists in producing a spongy gutta-percha for stuffing sofas, &c. 48 parts of it moistened with oil of turpentine, coal-naphtha, bisulphide of carbon, or other proper solvent; 6 parts of hydrosulphide of lime, sulphide of antimony, or other analogous sulphide; 10 parts of carbonate of ammonia, carbonate of lime, or other substance that is either volatile or capable of yielding a volatile product; and 1 part of sulphur. Mr. Hancock mixes these materials together in a masticator, and then subjects them to a high degree of heat, observing the same conditions which are stated in the former description, except only that the heat may be pushed with advantage several degrees higher, say from 260° to 300°.

Various articles are manufactured of ordinary gutta-percha, such as single and double texture waterproof fabrics, boots, galoshes, belts, bandages, trowsers and other straps, capes, life-preservers, tubes, knapsacks, caps, cups and other vessels of capacity, hammer-cloths, cotton-spinning rollers, backs of cards for carding wool, pianoforte-hammers, paper-holders, springs, trusses, &c. By taking the gutta-percha after it has been sulphurised, and brushing it with a solution of resin in boiling oil (linseed?), placing it in a chamber heated to from 75° to 100° Fahr., and afterwards polishing it by the means usually employed by the japanners, it acquires the lustre of japanned wares.

Mr. Hancock has also contrived a machine for cutting gutta-percha into strips or riband, threads, or cord of any required shape. It consists of two grooved rollers of iron or steel, mounted in a suitable framework. The grooves of each roller are semicircular, and the projecting divisions between the grooves are made with knife-edges, so as to divide readily any sheet or mass of gutta-percha presented to them. The under roller is flanged at both ends, and the upper roller is made to fit inside of these flanges, in order to keep the cutting-edges from shifting or being damaged. To cut thin sheets of gutta-percha with this machine into strips or ribands, the material is passed through it in a cold state, and only the cutting-edges are brought into operation. To make round cord or thread by means of it, either a sheet of gutta-percha of a thickness equal to the diameter of the holes formed by the grooves, and at a temperature of 200° Fahr. (produced by supplying it from a feeding-chamber heated to that degree) is passed through the machine, and the threads or cords are received in a tank of cold water, from which they are led away to be wound on reels or drums; or the gutta-percha is employed in a plastic state, and passed under a gauge before it enters the machine. If it be desired to produce a cord of a semicircular form in the transverse section, a plane-roller is substituted for the lower grooved-roller; or should cord of a square, triangular, or hexangular, or any other form, be required, the two rollers must be shaped to suit.

Gutta-percha Tubes.—A series of interesting experiments have been made at the Birmingham Waterworks, relative to the strength of gutta-percha tubing, with a view to its applicability for the conveyance of water. The experiments were made (under the direction of Henry Rose, Esq., engineer), upon tubes, ¾ and ⅛th of an inch diameter, of gutta-percha. These were attached to the iron main, and subjected for two months to a pressure of 200 feet head of water, without being in the slightest degree deteriorated. In order to ascertain, if possible, the maximum strength of the tubes, they were connected with the Water Company's hydraulic proving-pump, the regular load of which is 250 lbs. on the square inch. At this point the tubes were unaffected, and the pump was worked up to 337 lbs., but to the astonishment of every one the tubes still remained perfect. It was then proposed to work the pump up to 500 lbs., but it was found that the lever of the valve would not bear this weight. The utmost power of the hydraulic pump could not break the tubes.

The gutta-percha being somewhat elastic, allowed the tubes to become slightly expanded by the extraordinary pressure which was applied, but on its withdrawal they resumed their former size.

This tubing is such an extraordinary conductor of sound, that its value, not only to deaf persons, but to the public generally, has been fully appreciated. It has been fitted up in dwelling-houses, in lieu of bells. As speaking-tubes for giving and receiving messages in mines, railway stations, prisons, workhouses, hotels, and all large establishments, it is invaluable.

Properties of Common Gutta-percha.—The gutta-percha, purified for manufacturing purposes, is of a reddish brown colour; it readily becomes electrical by friction and is a bad conductor of both electricity and heat. At the ordinary temperature of our climate, say from 32° to 77°, it possesses about as much tenacity as thick leather, with rather less flexibility; it softens and becomes sensibly doughy towards 120°, although still very tough. Its ductility is such, at a temperature of from 110° to 241°, that it is readily extended into thin sheets, or drawn into threads or tubes; its flexibility and ductility diminish as the temperature becomes lower. It does not possess at any temperature the peculiar elastic extensibility which characterises caoutchouc. Exposed for an hour to a temperature of 14°, its flexibility is slightly diminished.

In its various forms, gutta-percha possesses a peculiar porosity, as may be shown in the following manner:—A drop of its solution in sulphuret of carbon is to be placed on a glass slip; the spontaneous evaporation soon reduces this solution to a whitish plate; if it be then examined with the microscope, the numerous cavities with which it is pierced may be distinctly perceived. These cavities may be rendered still more visible by means of a drop of water; the liquid gradually insinuates itself, the mass appears more opaque, and by means of the microscope the cavities are seen to be enlarged.

Similar results are obtained by keeping thin transparent laminæ, obtained by the evaporation, by heat, of a solution of gutta-percha, immersed in water for a considerable time.

The preceding observations lead us to think, that this substance retaining, in consequence of its porosity, a great many minute particles of air, owes to this circumstance its appearance of possessing a less density than that of water, namely 0·979. In fact, on stretching gutta-percha under strong pressure, and immediately cutting the strips thus produced into very small pieces under water, the greater part of the fragments fall to the bottom of the vessel—some immediately, others after absorbing a certain quantity of water. The same result is also obtained by keeping very thin leaves of gutta-percha, prepared by different methods, immersed for a month in water deprived of air: their pores becoming gradually filled with the liquid, they became heavier than the water, and then ceased to float. Gutta-percha is also heavier in proportion to the length of time it has been exposed to the air, particularly in thin leaves.

The porous structure of gutta-percha becomes changed into a fibrous texture when it is drawn out so as to double its length: then retaining but little extensibility, it supports, without breaking, the action of a force equal to double that required for its elongation in the first instance.

Common gutta-percha resists cold water, damp, and also the various influences which excite fermentation; but it can be softened, and it experiences a sort of superficial doughy fusion by the action of the solar rays in summer.

It is not attacked by alkaline solutions, even when caustic and concentrated; ammonia, saline solutions, water containing carbonic acid, the various vegetable and mineral acids, do not act upon it; the weaker alcoholic liquors (wines, beer, &c.) do not touch it; and even brandy scarcely dissolves a trace of it. Olive-oil does not appear to attack gutta-percha when cold; when hot, it dissolves a small portion of it, which is again precipitated on cooling.

Sulphuric acid with one equiv. of water colours it brown, and disintegrates it with a sensible evolution of sulphurous acid.

Muriatic acid, in its saturated solution in water at a temperature of 68° F., attacks gutta-percha slowly, and gives it a more or less deep brown colour, at length rendering it brittle.

Monohydrated nitric acid attacks it rapidly, with effervescence and an abundant evolution of fumes of hyponitrous acid; the substance is decomposed, and coloured of a brownish orange-red: it becomes doughy, and afterwards solidifies by degrees and remains friable.

In the cold, and even by heat, only a part of the gutta-percha (0·15 to 0·22) is dissolved by anhydrous alcohol or ether. Benzine and spirits of turpentine dissolve it partially when cold, but nearly completely if aided by heat. Sulphide of carbon and chloroform dissolve gutta-percha when cold; the solutions may be filtered beneath a bell-glass to prevent evaporation; the filter retains the foreign matters of a reddish brown colour, whilst the solution passes perfectly clear, and almost colourless. The filtered liquid, exposed to the air in a saucer, allows the solvent to escape, and deposits the white gutta-percha in a plate of greater or less thickness, which shrinks gradually in proportion to the evaporation of the liquid.

Except the colour, which has disappeared, the gutta-percha then offers the characters and properties mentioned above as belonging to the commercial substance. Submitted to a gradually-raised temperature, it softens and melts, and may be made to boil without acquiring a sensible colour; the transparent fluid gives off abundant vapours, which are condensible into a nearly colourless oily liquid. The portions last distilled have a brownish orange colour, and a thin layer of carbonaceous deposit remains adherent to the sides of the vessel.

Analysis.—We have said above that alcohol and ether can dissolve only a portion of gutta-percha; this is because that substance consists, in fact, of three proximate principles, the separation of which has required very delicate observation, although they are very clearly distinguished by several of their properties.

When gutta-percha in thin leaves is brought into contact, in a close vessel, with 15 to 20 vols. of cold anhydrous alcohol, and the temperature raised slowly by means of the water-bath to the point of ebullition (172° F.), and kept at this point during several hours, the liquid, if filtered whilst boiling and left in a closed flask, will, at the end of from 12 to 36 hours, begin to deposit on the sides of the vessel and on the surface of the solution white opaline granules, distant from one another, but some of them in groups; their size will gradually increase for some days. These granules, carefully examined under the microscope, will be found to have the form of spherules truncated by the sides of the vessel. Their surface is either smooth, or bristling with very small transparent, elongated, lamellar crystals. Some superficial fissures appear to indicate that these spherules are formed of a sort of transparent yellow kernel covered with a white pellicle.

Perhaps no other example is known of this singular crystalline structure. In fact, cold anhydrous alcohol dissolves the whole of the yellow spheroidal substance, whilst the superficial pellicle, in the interior of which the alcohol has substituted itself for the solid globule, appears whiter and less transparent.

The alcoholic solution, which has been for some days depositing this complex spheroidal crystallisation, can again take up by heat a portion of the two proximate principles remaining in the substance, allowing a fresh quantity to crystallise on cooling. The extraction is completed by returning the boiling alcohol several times upon the gutta-percha until it no longer dissolves anything.

The solid substance which has resisted the action of the solvent, possesses, with some modifications, the principal properties of crude gutta-percha; we shall here call it *pure gutta.* As to the two other organic principles, one is a *yellow resin*, which is much more soluble in cold alcohol than the other, the *white crystalline resin.*

By taking advantage of these different degrees of solubility, we are enabled with time and patience to effect the complete purification of these three principles. The separation may also be effected by treating finely-divided gutta-percha with cold ether, which dissolves the mixture of the two resins more abundantly than alcohol; they are afterwards separated from one another by the same treatment already described for alcohol.

The tendency of the white resin to form itself into radiated groups is manifested in a rather remarkable circumstance, which it is easy to reproduce. Narrow ribands cut from a thin leaf of ordinary gutta-percha are to be placed in a tube, and immersed in anhydrous alcohol. The tube is then closed, and left for twenty or thirty days, when a few whitish points appear here and there on the ribands, and afterwards on the sides of the tube. These points, which become gradually larger, are formed of crystalline tufts of the white resin. Thus this proximate principle is separated directly, and in the cold, even when the atmospheric temperature is gradually rising, for instance during the spring or early summer.

The crystalline white resin, when completely purified by washings with alcohol, and then redissolved in anhydrous alcohol, is deposited by slow spontaneous evaporation in the air, in radiated crystals, forming sometimes symmetrical tufts arranged in stars, and then presenting the appearance of a sort of efflorescence.

Distinctive characters and properties of the three proximate principles which constitute common Gutta-percha.—The most abundant of these three principles, forming at least from 75 to 82 per cent. of the whole mass, is the pure gutta-percha, which presents the principal properties of the commercial substance; it is white, transparent at a temperature of 212° F., when all its parts are melted together; opaque or semi-transparent when cold, from its then acquiring a structure which causes the interposition of air, or of a liquid possessing a different refraction from its own. This structure appears still more distinct than in the natural substance containing all three principles.

In thin sheets, and at a temperature of 50° to 68° F., it is supple, tough, extensible, but not very elastic. At 112° F., it softens and turns back upon itself, and becomes more and more adhesive and translucent in proportion to the elevation of temperature, undergoing a sort of doughy fusion, which becomes more distinct towards 212° to 230°. Heated beyond this point, it melts, boils, and distils, furnishing a pyrogenous oil and carburetted gases.

Soubeiran believes the composition of perfectly pure gutta-percha to be $C^{12}H^{10}$, corresponding to 87·8 carbon and 12·2 hydrogen. Faraday found caoutchouc to contain 87·2 carbon, 12·8 hydrogen; hence their chemical composition is identical.

Pure gutta-percha, like the other two proximate principles, is quickly rendered electrical by friction, and is a bad conductor of heat; it generally floats on water, but sinks to the bottom as soon as its pores are filled with this liquid. It is insoluble in alcohol and ether, almost completely insoluble in benzine at 32° F.; it is soluble at 77°, and becomes more and more so in proportion as the temperature is raised. The saturated solution at 86° forms itself into a semi-transparent mass when cooled below 32°; alcohol precipitates the pure gutta-percha from its solution in benzine.

At 82°, spirits of turpentine dissolves very little gutta-percha, whilst it disintegrates and dissolves it readily when hot.

Chloroform and sulphide of carbon dissolve gutta-percha in the cold.

After the extraction by means of ether of the two resins interposed in the thin leaves of the white gutta-percha, leaving the last portion of ether with which they were impregnated to evaporate in the open air, these leaves, enclosed in a flask, experienced, after remaining there for two months at a temperature of from 68° to 82° F., an alteration which appeared to depend on their porosity, the action of the air, and perhaps the ether retained in their pores. However it be, these leaves had then acquired new properties; they were brittle; exhaled a very distinct sharp odour; brought into contact with an excess of anhydrous ether, they were partially dissolved; the soluble portion, obtained by the evaporation of the ether and dessication at 194° F., was glutinous and translucent; it became opaque and hard by cooling down to 14° F.

Sulphide of carbon, renewed three times in six days, and evaporated each time after two days' contact, left as residue a white flexible leaf. The portion not dissolved, swelled and transparent, did not appear to undergo any change when left in sulphide of carbon for ten days.

This kind of spontaneous transformation would perhaps become complete if more prolonged; its study will require much time; it will perhaps put us in the way of ascertaining the causes of certain changes observed in some small objects formed of gutta-percha. It has already been ascertained, that thin leaves, exposed for eight consecutive days to the action of the sun in moist air, were discoloured, and that their substance had become in great part soluble in ether.

Monohydrated sulphuric acid disintegrates, and communicates a brown colour to the pure gutta, with evolution of sulphurous acid; after eight days' contact, the deep brown liquid, on dilution with water, becomes turbid, and furnishes a brown flocculent precipitate. Nitric acid, with a single equivalent of water, attacks the pure gutta with a lively effervescence, and the evolution of orange-vapours of hyponitrous acid. Muriatic acid, in its saturated solution, slowly attacks the thin leaves of gutta, giving them a deep brown colour; at the end of eight days it becomes friable. The reaction of muriatic acid establishes an additional distinctive character between this proximate principle and the two others.

M. Payen has carefully examined the chemical and physical peculiarities of the three principles which he has discovered in gutta-percha. These have, however, no interest for the manufacturer, and we refer the chemical student to M. Payen's Memoir.

The juice of Muddar has been proposed as a substitute for gutta-percha, but we are not aware that it has in any manufacture taken its place. Dr. Falconer describes a new kind of gutta-percha, which grows in the most southern British possession of the Merguin Islands, Indian Ocean.

If a solution of gutta-percha in chloroform be mixed with 3 parts of ether, and exposed for some time to a temperature below 15°, the gutta-percha is precipitated as a white powder, forming when washed and dried a soft white mass. On spreading this solution on a plate of glass, a skin is formed, resembling kid-glove leather, which becomes transparent on the application of heat. These films are beautifully white, if carefully prepared, and they have been employed in the manufacture of the finest kinds of artificial flowers.

In 1848, Dr. Faraday drew the attention of experimentalists to the highly insulating power of gutta-percha, which not only possesses this property under ordinary circumstances, but likewise retains it under atmospheric conditions which would make the surface of glass a good conductor. This has led to its almost universal adoption as the insulator for the wires of the electrical telegraph. When buried in the earth, unless it is attacked by insects, or by a fungus, it retains its highly insulatory power, and we have every reason for believing that gutta-percha does not undergo a change when immersed in sea-water. It has, however, been found, that when it has been exposed to the intense sunshine of India, it undergoes a remarkable change; oxygen is absorbed, the gutta-percha loses its coherence, and at the same time its powers of insulation.

Some idea of the progress made in the applications of gutta-percha will be found by the following Table of Imports. The demand for this substance is still increasing, and it is to be feared that a destructive process is adopted in collecting the juice from the trees to meet the demand:—

	cwts.		cwts.
1850	11,130	1858	19,641
1851	10,778	1859	18,593
1852	13,652	1860	21,321
1853	21,792	1861	19,749
1854	24,696	1862	18,284
1855	23,535	1863	21,655
1856	15,557	1864	35,636
1857	17,420	1865	36,760

The gutta-percha *imported* in 1871 and 1872 was from the following countries:—

	Quantities	Value	Quantities	Value
Raw:	cwts.	£	cwts.	£
From Holland	1,498	10,749	5,202	51,432
„ France	346	3,377	621	5,416
„ Egypt	778	6,601	9,814	59,745
„ Madagascar	482	4,700		
„ British India: Bengal and Burmah	...	...	2,892	31,000
„ China	1,068	11,031	1,660	18,951
„ Straits Settlements	21,227	153,999	23,487	225,789
„ Other countries	812	8,880	921	7,622
Total	26,211	199,337	45,597	399,955
Manufactures of: From all countries	145	1,235	488	3,445

Substitutes for Gutta-percha.—Sir William Holmes forwarded to the Council of the Society of Arts from Demerara, some other specimens of a gum termed 'Balata,' the produce of the bullet-tree (*Sapota Mulleri*) which grows in that colony, and which, he states, possesses the properties of gutta-percha, and may be used as a substitute for it. Sir William Holmes says in his communication: 'I was Commissioner, representing the colony of British Guiana, at the International Exhibition of 1862. Among the varied contributions from the colony was a specimen of the dried milk of the bullet-tree; it weighed perhaps half a pound. Amongst the numerous individuals who visited the Guiana department was Mr. Charles Hancock, who is well known in the gutta-percha trade. This gentleman was struck with the appearance of the specimen, and obtained a portion for experiment. He reported most favourably as to its utility and value, a result most gratifying to me, as I had received adverse opinions from less experienced persons. This happened, I think, in July 1862: from that time to the present, I have been engaged in investigations how to produce the material cheaply, and how to dry or coagulate it rapidly. In both particulars I believe I have succeeded so far as to warrant the importation of steam-machinery to be applied to its extraction; and by a fortunate accident I have discovered how to dry or coagulate it, preserving the characteristic of elasticity, at a single operation, by the addition of a simple ingredient not very costly. . . . .

'Amongst the useful properties of the *Balata*, I believe the fresh milk of the bullet-tree to be the best waterproofing material yet discovered. The bullet-tree is a magnificent timber-tree, often squaring 30 to 40 inches, and is much used, especially in Berbice, for building purposes. The milk, when quite fresh, is so bland that it is sometimes used as a substitute for cows' milk, and the fruit is delicious.'

Mr. Ondaatjie, surgeon, forwarded to the same Society, from Ceylon, a specimen of the *Alstonia scholaris*, which he supposes may be used as a substitute for gutta-percha. The tree abounds with milky juice like the gutta-percha, has a fleshy bark and porous wood, and belongs to the natural order *Apocyneæ*. The natives believe that the tree is poisonous, but Mr. Ondaatjie has proved it not to be so.

GYLE. A brewer's vat or utensil. The vinegar-maker's fermented wort.

GYPSUM. This natural production, which in its varieties is known as *alabaster*, *selenite*, and *satin spar*, is a sulphate of lime, containing sulphuric acid, 46·51; lime, 32·56; water, 20·93.

The *anhydrite* from Derby is a mineral like gypsum, but, as its name indicates, containing no water; its composition being, lime, 41·2; sulphuric acid, 58·8; this is also called *muriacite* and *tripe-stone*. It absorbs moisture and changes to gypsum. When gypsum is carefully burnt, it loses its water of composition, and forms the well-known *plaster-of-Paris*.

The transparent varieties of gypsum are called *selenite;* its fine massive varieties are *alabaster*, and its fibrous kinds *satin spar*. There is another variety in small scales of a pearly lustre, known as *Schaumkalk*.

The fibrous forms of gypsum are cut and polished for small ornamented objects, and are sometimes known as *satin spar*.

The gypsum of our own country is found, in apparently inexhaustive quantities, in the Red Marl formation in the neighbourhood of Derby, and has been worked for many centuries. The great bulk of it is used for making plaster-of-Paris, and as a manure; and it is the basis of many kinds of patented cements, as Keene's, Martin's, and others.

To get it for these purposes, it is worked by mining underground, and the stone is blasted by gunpowder; but this shakes it so much as to render it unfit for working into ornaments, &c.; to procure blocks for which it is necessary to have an open quarry. By removing the superincumbent marl, and laying bare a large surface of the rock, the alabaster being very irregular in form, and jutting out in several parts, allows of its being *sawn* out in blocks of considerable size, and comparatively sound (as is illustrated by the large tazza in the Museum of Practical Geology). This stone, when protected from the action of water, is extremely durable, as may be seen in churches all over the country, where monumental effigies, many centuries old, are now as perfect as the day they were made, excepting of course wilful injuries; but exposure to rain soon decomposes the stone, and it must be borne in mind that it is perfectly unsuited for garden vases or other out-door work in this country.

In working, it can be sawn up into slabs with toothed saws, and for working mouldings and sculptures, fine chisels, rasps, and files are the implements used; the polishing is performed by rubbing it with pieces of sandstone, of various degrees of fineness, and water until it is quite free from scratches, and then giving a gloss by means of polishing powder (oxide of tin) applied on a piece of cloth, and rubbed with a considerable degree of friction on the stone. This material gives employment in Derby to a good many hands in forming it into useful and ornamental articles, and is commonly called Derbyshire Spar; most of the articles are turned in the lathe, and it works something like very hard wood.

Another kind of gypsum also found in Derbyshire is the fibrous or silky kind; it occurs in thin beds, from one to six inches in depth, and is crystallised in long needle-like fibres; being easily worked, susceptible of a high polish, and quite lustrous, it is used for making necklaces, bracelets, brooches, and such like small articles.

Gypsum is commonly found in this country, in irregular deposits, in the New Red Marls, especially at Chellaston in Derbyshire, Fauld in Staffordshire, and Newark in Nottinghamshire. A deposit of white crystalline gypsum has been recently discovered in the prosecution of the experimental boring at Netherfield, near Battle in Sussex, undertaken by the Sub-Wealden Exploration Committee. The gypseous deposits are upwards of fifty feet in thickness, and occur in beds, which are probably of Purbeck age. No gypseous deposits of equal extent, on this geological horizon, had been previously known in this country. The great deposits of gypsum worked at Montmartre and elsewhere in the neighbourhood of Paris—from which 'Plaster-of-Paris' borrows its name—occur in the Eocene beds of the Paris basin, equivalent to certain strata represented in this country in the Isle of Wight. See ALABASTER; PLASTER-OF-PARIS.

H

HABANA BROWN. This name has been given to aniline-brown. See ANILINE-BROWN.

HACKLE. A flax comb. See FLAX.

HADDOCK. The *Morrhua æglefinus*, one of the *Gadidæ*, or cod tribe.

HADE. A miner's term, used in Derbyshire and some of the northern counties, signifying the inclination or deviation from the vertical of any mineral vein or lode. *Hadings* signify that some parts of the veins incline, while others are vertical.

HÆMATIN. A product of the decomposition of *hæmoglobin*, or the red-colouring matter of the blood. The name *hæmatin* was also given by Chevreul to a crystalline substance, of a pale pink colour, and brilliant lustre when viewed in a lens, which he extracted from logwood. See HÆMATOXYLIN.

Scientific terms with prefixes similar to that of *hæmatin* are derived from the Greek *αἷμα*, *blood.*

HÆMATINONE. A kind of glass used by the ancients for making ornamental vessels, mosaics, &c. It is described by Pliny, and has been found pretty abundantly in the excavations of Pompeii. This glass is of a beautiful red colour, but the colour disappears on melting. Von Pettenkofer obtained a similar glass, which he has called *astralite*, by melting a mixture of silica, lime, calcined magnesia, litharge, soda, copper-hammerings, and smithy-scales. See ASTRALITE.

HÆMATITE. Native peroxide of iron. In true hæmatite, sometimes called for distinction's sake *red hæmatite*, the oxide is anhydrous, whilst in the so-called *brown hæmatite* it is hydrated.

The hæmatite proper occurs in a remarkable manner in irregular deposits in carboniferous limestone, at Whitehaven in Cumberland, and at Ulverstone in Lancashire. The following analysis of the Whitehaven ore of Cleator Moor by Mr. A. Dick, shows its peculiar character:—

Peroxide of iron	95·16
Protoxide of manganese	0·24
Lime	0·07
Phosphoric acid	trace
Sulphuric acid	trace
Bisulphide of iron	trace
Insoluble residue	5·68
	101·15
Iron, total amount	66·60

The following analysis of the Ulverstone ore is by the same chemist:—

Gillbrow Ore.

Peroxide of iron	86·50
Protoxide of manganese	0·21
Lime	2·77
Magnesia	1·46
Carbonic acid	2·96
Phosphoric acid	trace
Sulphuric acid	0·11
Insoluble residue	6·55
	100·56
Iron, total amount	60·55

Another ore, that of Lindale Moor, near Ulverstone, was analysed by Mr. J. Spiller, with the following results:—

Peroxide of iron	94·23
Protoxide of manganese	0·23
Alumina	0·51
Lime	0·05
Magnesia	trace
Phosphoric acid	minute trace
Sulphuric acid	0·09
Bisulphide of iron	0·03
Water, hygroscopic	0·39
,, combined	0·17
Insoluble residue	5·18
	100·88
Iron, total amount	65·98

The production of the red hæmatite in Cumberland and Lancashire has been during the last few years as follows:—

	1868 Tons	1869 Tons	1870 Tons	1871 Tons	1872 Tons
Whitehaven ore	725,248	848,974	1,014,143	976,874	954,505
Furness ore	767,625	784,507	871,938	931,048	909,077

Some of the Furness ore is smelted with charcoal at furnaces in the district, and in 1872 about 600,000 tons were used at the Barrow Hæmatite Works.

The Cleator Moor, Workington, and other Cumberland furnaces, in 1872, used 572,329 tons of the Whitehaven iron-ore.

All the remainder was sent into the other great iron-making districts for mixing with the argillaceous carbonates, and other ores of iron. Hæmatite is highly valued for making pig-iron well adapted for conversion into steel by the Bessemer process. See IRON.

HÆMATOGLOBULIN. Synonym of HÆMOGLOBIN.

HÆMATOSIN. A substance at one time regarded as the red-colouring matter of the blood.

HÆMATOXYLIN. The colouring matter of logwood, the *Hæmatoxylon Campechianum* of botanists. It is, in fact, the characteristic principle of this dye-wood. To procure hæmatoxylin, digest, during a few hours, ground logwood in water heated to a temperature of about 130° Fahr.; filter the liquor, evaporate it to dryness by a steam-bath, and put the extract in alcohol of 0·835 for a day. Then filter anew, and after having inspissated the alcoholic solution by evaporation, pour into it a little water, evaporate gently again, and then leave it to itself in a cool place. In this way numerous crystals of hæmatoxylin will be obtained, which may be purified by washing with alcohol and drying.

When subjected to dry distillation in a retort, hæmatoxylin affords all the usual products of vegetable bodies, along with a little ammonia; which proves the presence of azote. Boiling water dissolves it abundantly, and assumes an orange-red colour, which passes into yellow by cooling, but becomes red again with heat. Sulphurous acid destroys the colour of solution of hæmatoxylin. Potash and ammonia convert into a dark purple tint the pale solution of hæmatoxylin; when these alkalis are added in large quantity, they make the colour violet-blue, then brown-red, and lastly, brown-yellow. By this time the hæmatoxylin has become decomposed, and cannot be restored to its pristine state by neutralising the alkalis with acids.

The waters of baryta, strontia, and lime exercise an analogous power of decomposition; but they eventually precipitate the changed colouring matter.

A red solution of hæmatoxylin subjected to a current of sulphuretted hydrogen becomes yellow; but it resumes its original hue when the sulphuretted hydrogen is removed by a little potash.

The protoxide of lead, the protoxide of tin, the hydrate of peroxide of iron, the hydrate of oxides of copper and nickel, and oxide of bismuth, combine with hæmatoxylin and colour it blue with more or less of a violet cast.

Hæmatoxylin precipitates glue from its solution in reddish flocks. This substance has not hitherto been employed in its pure state; but as it constitutes the active principle of logwood, it enters as an ingredient into all the colours made with that dye-stuff.

These colours are principally violet and black. See LOGWOOD.

HÆMOGLOBIN. The red-colouring matter of the blood. See Blood.

HAIDINGERITE. A hydrated arsenate of lime, named after the late Von Haidinger, of Vienna.

HAIR (*Cheveu*, *Crin*, Fr.; *Haar*, Ger.) is of all animal products the one least liable to spontaneous change. It can be dissolved in water only at a temperature somewhat above 230° F., in a Papin's digester; but it appears to be partially decomposed by this heat, since some sulphuretted hydrogen is disengaged. By dry distillation, hair gives off sulphuretted gases, while the residuum contains sulphate of lime, common salt, much silica, with some oxide of iron and manganese. It is a remarkable fact that fair hair affords magnesia, instead of these latter two oxides. Horse-hair yields about 12 per cent. of phosphate of lime.

We have no recent analysis of hair. Vauquelin found nine different substances in black hair; in red hair, a red oil instead of a greenish black one.

Hairs are tubular, their cavities being filled with a fat oil, having the same colour with themselves. Hair plunged in chlorine gas is immediately decomposed and converted into a viscid mass; but when immersed weak in aqueous chlorine, it undergoes no change, except a little bleaching.

Living hairs are rendered black by applying to them for a short time a paste made by mixing litharge, slaked lime, and bicarbonate of potash, in various proportions, according to the shade of colour desired. The ordinary mode of dyeing human hair is first to saturate the hair with the sulphide of potassium in solution; then, when this has been well absorbed and is partially dry, a solution of nitrate of silver is to be applied. By varying the proportions of the sulphide, and the strength of the silver solution, almost any tone of colour, from a brown to a black, can be produced.

The salts of silver, mercury, lead, bismuth, as well as their oxides, blacken hair, or make it of a dark violet, by the formation, most probably, of metallic sulphurets (sulphides).

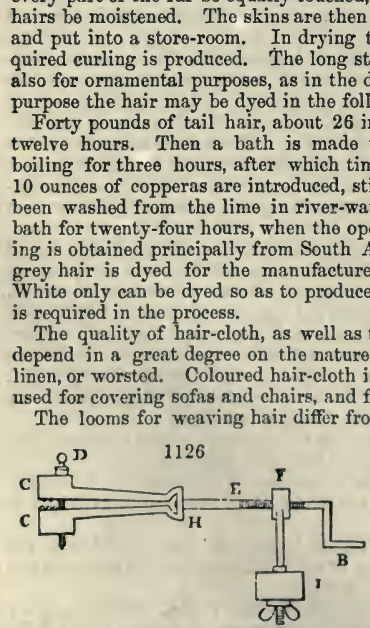
Hair as an object of manufacture is of two kinds, the *curly* and the *straight*. The former, which is short, is spun into a cord, and boiled in this state, to give it the tortuous springy form. The hairs of rabbits and hares are prepared for the hatmaker by a process called *sécrétage*, so as to render them fit for felting. The skins with the hair still upon them are laid upon a table, and with a brush, made from the bristle of the wild boar, a solution of nitrate of mercury is applied many times in succession, till every part of the fur be equally touched, and till about two-thirds of the length of the hairs be moistened. The skins are then placed together to complete the impregnation, and put into a store-room. In drying there is a retraction of the hairs, and the required curling is produced. The long straight hair is woven into cloth for sieves, and also for ornamental purposes, as in the damask hair-cloth of chair-bottoms. For this purpose the hair may be dyed in the following way:—

Forty pounds of tail hair, about 26 inches long, are steeped in lime-water during twelve hours. Then a bath is made with a decoction of 20 lbs. of logwood, kept boiling for three hours, after which time the fire is withdrawn from the boiler, and 10 ounces of copperas are introduced, stirred about, and the hair is immersed, having been washed from the lime in river-water. The hair should remain in this cooling bath for twenty-four hours, when the operation will be finished. Hair used for weaving is obtained principally from South America and from Russia. All the black and grey hair is dyed for the manufacture of black hair-cloth for covering furniture. White only can be dyed so as to produce what are called fancy colours, and great care is required in the process.

The quality of hair-cloth, as well as the brilliancy and permanency of the colours, depend in a great degree on the nature of the warp, which may be either of cotton, linen, or worsted. Coloured hair-cloth is made at Worcester, Sheffield, and Paris, and used for covering sofas and chairs, and for railway carriages.

The looms for weaving hair differ from the common ones, only in the templet and the shuttle. Two templets of iron must be used to keep the stuff equably but lightly stretched. These templets, of which one is represented in *fig.* 1126, are constructed in the shape of flat pincers; the jaws, C C, being furnished with teeth inside. A screw, D, binds the jaws together, and hinders the selvage from going inwards. Upon the side cross-beam of the loom, seen in section at I, a bolt is fixed which carries a nut F at its end, into which a screwed iron rod E enters, on one of whose ends is the handle B. The other extremity of the screw E is adapted by a washer and pin to the back of the pincers at the point H, so that by turning the handle to the right or the left, we

1126



draw onwards or push backwards the pincers and the stuff at pleasure. The warp of the web is made of black linen yarn. The weft is of hair, and it is thrown with a long hooked shuttle, or a long rod, having a catch hook at its end. The length of this shuttle is about three feet; its breadth half an inch, and its thickness one sixth. It is made of boxwood. The reed is of polished steel; the thread warps are conducted through it in the usual way. The workman passes this shuttle between the hairs of the warp with one hand, when the shed or shuttle way is opened by the treddles; a child placed on one side of the loom presents a hair to the weaver near the selvage, who catches it with the hook of his shuttle, and by drawing it out passes it through the warp. The hairs are placed in a bundle on the side where the child stands, in a chest filled with water to keep them moist, for otherwise they would not have the suppleness requisite to form a web. Each time that a hair is thrown across, the batten is driven home twice. The warp is dressed with paste in the usual way. The hair-cloth, after it is woven, is hot calendered to give it lustre. In the Great Exhibition of 1851, J. Bardoffsky (Russia) exhibited a collection of bowls, dishes, plates, &c., formed of the hair of the rabbit, hare, and other animals, which were felted and afterwards varnished. They had the appearance of papier-maché, and were very light.

The chief kinds of hair used in the arts are *horse-hair*, used for stuffing seats and for hair-seating; *cow-hair*, for making felt and for mixing with mortar; *goats'-hair*, *mohair*, &c., for weaving into textile fabrics; *camels'-hair*, *mohair*, &c., for artists' pencils; *hog-hair* and other coarse kinds for common brushes; and *human hair* for wigs, chignons, and other articles of head-dress.

Hair *imported* in the years 1871 and 1872:—

	1871		1872	
	Cwts.	£	Cwts.	£
Cow, ox, bull, or elk	87,492	188,154	98,231	270,322
Goats' hair or wool, lbs.	8,815,364	1,055,248	6,404,490	762,364
Horse	21,365	202,103	15,830	188,726
Unenumerated	...	187,701	...	238,255
Manufactures of, not being of goats' hair or wool	...	14,020	...	6,798
Manufactures of goats' hair or wool . .	...	28,616	...	44,310

HAIR BRUSHES. The *hair brushes* are manufactured with coarse hair, as that of the swine, the wild boar, the dog, &c., and these are usually attached, by binding with cord or by securing them with a piece of tin plate, to a wooden handle. The manufacture of hair brushes, clothes brushes, tooth and nail brushes, is necessarily very large, and of considerable importance. The technical details of this manufacture would occupy space to the exclusion of more important matter.

HAIR PENCILS, for artists. *Hair pencils* are composed of very fine hairs, as those of the sable, the miniver, the marten, the badger, and the polecat. These are usually mounted in a quill, but sometimes they are secured as in the former case with tinned iron.

The most essential quality of a good pencil is to form a fine point, so that all the hairs without exception may be united when they are moistened by laying them upon the tongue, or drawing them through the lips. When hairs present the form of an elongated cone in a pencil, their point only can be used. The whole difficulty consists, after the hairs are cleansed, in arranging them together so that all their points may lie in the same horizontal plane. We must wash the tails of the animals whose hairs are to be used, by scouring them in a solution of alum till they be quite free from grease, and then steeping them for twenty-four hours in lukewarm water. We next squeeze out the water by pressing them strongly from the root to the tip, in order to lay the hairs as smooth as possible. They are to be combed in the longitudinal direction, with a very fine-toothed comb, and finally wrapped up in fine linen, and dried. When perfectly dry, the hairs are seized with pincers, cut across close to the skin, and arranged in separate heaps, according to their respective lengths.

Each of these little heaps is placed separately, one after the other, in small tin pans with flat bottoms, with the tips of the hair upwards. On striking the bottom of the pan slightly upon a table, the hairs get arranged parallel to each other, and their delicate points rise more or less according to their lengths. The longer ones are to be picked out and made into so many separate parcels, whereby each parcel may be composed of equally long hairs. The perfection of the pencil depends upon this equality; the tapering point being produced simply by the attenuation of the tips.

A pinch of one of these parcels is then taken, of a thickness corresponding to the intended size of the pencil; it is set in a little tin pan, with its tips undermost, and is shaken by striking the pan on the table as before. The root end of the hairs being tied by the fisherman's or seaman's knot, with a fine thread, it is taken out of the pan, and then hooped with stronger thread or twine; the knots being drawn very tight by means of two little sticks. The distance from the tips at which these ligatures are placed is of course relative to the nature of the hair, and the desired length of the pencil. The base of the pencil must be trimmed flat with a pair of scissors.

Nothing now remains to be done but to mount the pencils in quill or tin-plate tubes, as above described. The quills are those of swans, geese, ducks, lapwings, pigeons, or larks, according to the size of the pencil. They are steeped during twenty-four hours in water, to swell and soften them, and to prevent the chance of their splitting when the hair-brush is pressed into them. The brush of hair is introduced by its tips into the large end of the cut quill, having previously drawn them to a point with the lips, when it is pushed forwards with a wire of the same diameter, till it comes out at the other and narrower end of the quill.

The smaller the pencils, the finer ought the hairs to be. In this respect the manufacture requires much delicacy of tact and experience.

HALIOTIS. *The sea ear-shell.* A genus of molluscous animals belonging to the class *Gasteropoda.* These shells, possessing a fine nacre, are extensively used in the ornamentation of papier-maché articles, and mother-of-pearl ornaments.

HALITE. A mineralogical name for rock-salt.

HÄLLEFLINTA. An old Swedish name still retained for certain felstones. See Felspathic Rocks.

HALLOYSITE. An earthy hydrated silicate of alumina, closely related to clay.

HALOGEN, is a term employed by Berzelius to designate those substances which form compounds of a saline nature by their union with metals; such are chlorine, iodine, bromine, fluorine, and cyanogen; the salts thus formed being called *haloïd salts,* from their resemblance to common salt ($NaCl$), (ἅλς, sea salt, and εἶδος, form). Since the discovery of the compound halogen, *Cyanogen,* some chemists have been led to view all salts as under the type of haloïd salts; assuming in the different acids certain compound halogens, as in sulphuric acid the halogen (SO^4), in nitric acid the halogen (NO^6), &c.; which in combination with hydrogen form the acids; the different salts being formed by the displacement of the hydrogen by the metal, as follows: sulphuric acid (HSO^4), sulphate of potash (KSO^4); nitric acid (HNO^6), nitrate of soda ($NaNO^6$), &c.—H.K.B.

HALOÏDS. Salts formed by combination of a metal with a radical, or halogen. Modern ideas on the constitution of salts have greatly tended to weaken the old distinction between haloïd salts and oxysalts.

HALOTRICHITE. A hydrous sulphate of alumina and sesquioxide of iron. See Alum, Feather.

HANDSPIKE. A strong wooden bar, used as a lever to move the windlass and capstan in heaving the anchor, or raising any heavy weights aboard ship. The handle is round, smooth, and somewhat taper. The other end is squared to fit the holes in the head of the capstan or the barrel of the windlass.

HANGING-WALL. In *mining,* the upper wall of an inclined vein; the rock which hangs over the lode.

HARDENING. The processes by which metals are rendered harder than they are when they first leave the hands of the workman.

Some metals are hardened by hammering or rolling; but care is required not to carry this too far, as brittleness may be induced. Sudden cooling is had recourse to with some metals. Pure hammered iron appears after annealing to be equally soft, whether suddenly or slowly cooled; some of the impure kinds of malleable iron harden by immersion. Steel, however receives by sudden cooling that extreme degree of hardness combined with tenacity, which places it so incalculably beyond every other material for the manufacture of cutting-tools.

In hardening and tempering steel there are three things to be considered, namely, the means of heating the objects to redness, the means of cooling the same, and the means of applying the heat for *tempering,* or 'letting them down.'

Steel pens are hardened by being heated in large quantities in iron trays within a furnace, and then plunged into a oily mixture; generally they are likewise tempered in oil, or a composition, the boiling-point of which is the same as the temperature suited to 'letting them down.'

Saws and springs are hardened in various compositions of oil, suet, wax, and other ingredients, 'which however lose their hardening property after a few weeks' constant use.' Steel plates are hardened occasionally by allowing water to fall on them when hot.

Case-hardening is the process by which wrought iron is first converted exteriorly into steel, and is subsequently hardened to that particular depth, leaving the central parts in their original condition of soft and fibrous iron. The principal agents used for case-hardening are animal matters, as the hoofs, horns, bones, and skins of animals. The prussiate of potash, which contains a compound of carbon and nitrogen, is also employed for case-hardening. In principle its action is the same as that of the animal substances. The iron is heated in the open fire to a dull red, and the prussiate is either sprinkled upon it or rubbed on in the lump; it is returned to the fire for a few minutes, and immersed in water. In the volume of Lardner's 'Cyclopædia,' on *Iron and Steel*, edited by Robert Hunt, the subjects of hardening and tempering are treated in a practical manner. See Iron.

HARDNESS. (*Dureté*, Fr.; *Härte*, *Festigkeit*, Ger.) A hard body will *scratch* one that is softer than itself. This method of determining the hardness of minerals is employed by mineralogists. A good steel file is commonly used for trying the respective hardness of minerals.

Mohs introduced a scale of hardness which shows the gradual increase in hardness through 10 minerals:—

1. *Talc*; common laminated light green variety.
2. *Gypsum*; crystallised variety.
3. *Calcite*; transparent variety.
4. *Fluor spar*; crystalline variety.
5. *Apatite*; transparent variety.
6. *Feldspar* (orthoclase; white cleavable variety).
7. *Quartz*; transparent.
8. *Topaz*; ditto.
9. *Sapphire*; cleavable varieties.
10. *Diamond.*

The following table, compiled by Dr. Ure for the early editions of his Dictionary, will still be found very useful as representing, relatively, the hardness of the mineral named, although the numbers which express the degree of hardness do not agree with the scale of Mohs:—

Substances	Hardness	Sp. grav.	Substances	Hardness	Sp. grav.
Diamond, from Ormus	20	3·7	Sardonyx . . .	12	2·6
Pink diamond . .	19	3·4	Occidental amethyst .	11	2·7
Bluish diamond . .	19	3·3	Crystal . . .	11	2·6
Yellowish diamond .	19	3·3	Carnelian . . .	11	2·7
Cubic diamond . .	18	3·2	Green jasper . .	11	2·7
Ruby.	17	4·2	Reddish-yellow ditto.	9	2·6
Pale ruby, from Brazil	16	3·5	Schorl . . .	10	3·6
Deep blue sapphire .	16	3·8	Tourmaline . .	10	3·0
Ditto, paler . .	17	3·8	Quartz . . .	10	2·7
Topaz . . .	15	4·2	Opal. . . .	10	2·6
Whitish topaz . .	14	3·5	Chrysolite. . .	10	3·7
Ruby spinel . .	13	3·4	Zeolite . . .	8	2·1
Bohemian topaz . .	11	2·8	Fluor . . .	7	3·5
Emerald . . .	12	2·8	Calcareous spar. .	6	2·7
Garnet . . .	12	4·4	Gypsum . . .	5	2·3
Agate . . .	12	2·6	Chalk . . .	3	2·7
Onyx. . . .	12	2·6			

One of the most ready means of discriminating between different kinds of precious stones is to be found in their different degrees of hardness, coupled with their specific gravities. These are given in the article on Gems. In many of the mineralogical articles in this Dictionary, the letter H is used as an abbreviation of 'hardness.'

HARDWARE. Under this term are comprehended the articles manufactured of any of the baser metals. See these respectively.

HARE. The common hare (*Lepus timidus*) not only furnishes an article of food, but the skin is used as a fur, and was formerly employed to a large extent in making the felt bodies of hats.

HARE WOOD. See Sycamore.

HARICOTS. The seeds of certain species of *Phaseolus*, or beans.

HARMALA RED. A red-colouring matter, obtained from the seeds of *Peganum Harmala*, a plant found in the Crimea. It is obtained by digesting the seed in alcohol for some days. This colouring matter unites with acids, forming red-salts, and dyes wool or silk mordanted with the salts of alumina a light rose-red or a deep scarlet. The colours are said to be fugitive.

HARMALINE. An organic alkaloïd extracted from the seeds of the *Peganum Harmala.* A base obtained by the oxidation of harmaline has been called *harmine.*

HARMOTOME. A hydrous silicate of alumina and baryta. This zeolite crystallises in the rhombic system, often in twins crossing each other, whence the common name 'Cross-stone.'

It accompanies lead-ore at Strontian in Argyleshire, and at Andreasberg in the Hartz. It is also found, with other zeolites, in cavities in amygdaloidal rocks.

HARRISITE. A variety of copper-glance, with cubic cleavage; supposed to be a pseudomorph after galena.

HARTITE. A hydrocarbon, found in brown-coal near Vienna.

HARTSHORN, SPIRIT OF, is the old name for the solution of ammonia in water, the weak Liquor ammonia of the London Pharmacopœia.

HASSOCK. A term given to a kind of sandstone occurring in the quarries of Kentish Ragstone in Kent. When of good quality, it is employed in building the interior walls of churches. The following is an analysis of hassock, by Dr. Plomby, of Maidstone: carbonate of lime, 53; alumina, 4; oxide of iron, 8; silica, 32; small quantities of phosphate of lime, soda, magnesia, chlorine and sulphuric acid, 3: =100.

HATCHETTINE. One of the native hydrocarbons. It occurs in the crevices of septaria of clay-ironstone from the coal-measures at Ebbw Vale, in masses resembling wax. It is also found in Argyleshire. According to Johnston its composition is: carbon, 85·91; hydrogen, 14·62: =100·53. It is also known as *mineral tallow.*

HAT MANUFACTURE. (*L'art de chapelier*, Fr.; *Hutmacherkunst*, Ger.) Hat is the name of a covering for the head worn by both sexes, but principally by men.

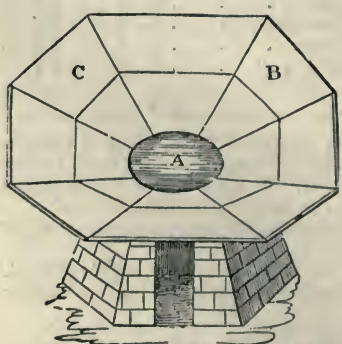
As the art of making hats does not involve the description of any curious machinery, or any interesting processes, we shall not enter into minute details upon the subject. It will be sufficient to convey to the reader a general idea of the methods employed in the manufacture of beaver and silk hats.

The materials used in making stuff hats are the furs of hares and rabbits freed from the long hair, together with wool and beaver. The beaver is reserved for the finer hats.

The fur is first laid upon a hurdle made of wood or wire, with longitudinal openings; and the operator, by means of an instrument called the bow (which is a piece of elastic ash, six or seven feet long, with a catgut stretched between its two extremities, and made to vibrate by a bowstick), causes the vibrating string to strike and play upon the fur, so as to scatter the fibres in all directions, while the dust and filth descend through the grids of the hurdle.

After the fur is thus driven by the bow from one end of the hurdle to the other, it forms a mass called a *bat*, which is only half the quantity sufficient for a hat. The bat or *capade* thus formed is rendered compact by pressing it down with the *hardening skin* (a piece of half-tanned leather), and the union of the fibres is increased by covering them with a cloth, while the workman presses them together repeatedly with his hands. The cloth being taken off, a piece of paper, with its corners doubled in, so as to give it a triangular outline, is laid above the bat. The opposite edges of the bat are then folded over the paper, and, being brought together and pressed again with the hands, they form a conical cap. This cap is next laid upon another bat, ready hardened, so that the joined eges of the first bat rest upon the new one. This new bat is folded over the other, and its edges joined by pressure as before; so that the joining of the first conical cap is opposite to that of the second. This compound bat is now wrought with the hands for a considerable time upon the hurdle between folds of linen cloth, being occasionally sprinkled with clear water, till the hat is *basoned*, or rendered tolerably firm.

1127



The cap is now taken to a wooden receiver, like a very flat mill-hopper, consisting of eight wooden planes, sloping gently to the centre, which contains a kettle filled with water acidulated with sulphuric acid. The technical name of this vessel is the *battery*. It consists of a kettle A, *fig.* 1127; and of the planks, B, C, which are sloping planes, usually eight in number, one being allotted to each workman. The half of each plank next the kettle is made of lead, the upper half of mahogany. In this liquor the hat is occasionally dipped, and wrought by the hands, or sometimes with a roller, upon the sloping planks. It is thus fulled or thickened during four or five hours; the knots or hard substances are picked out by the workman, and fresh felt is added by means of a wet brush to those parts that require it. The beaver is applied at the end of this operation. In the manufacture of beaver hats, the grounds of beer are added to the liquor in the kettle.

Stopping, or thickening the thin spots, seen by looking through the body, is performed by daubing on additional stuff with successive applications of the hot acidulous liquor from a brush dipped into the kettle, until the body be sufficiently shrunk and made uniform. After drying, it is stiffened with varnish composition rubbed in with a brush; the inside surface being more copiously imbued with it than the outer; while the brim is peculiarly charged with the stiffening.

When once more dried, the body is ready to be *covered*, which is done at the *battery*. The first cover of beaver or napping, which has been previously *bowed*, is strewed equably over the body, and patted on with a brush moistened with the hot liquor, until it gets incorporated; the cut ends towards the root being the points which spontaneously intrude. The body is now put into a coarse hair-cloth, then dipped and rolled in the hot liquor, until the root ends of the beaver are thoroughly worked in. This is technically called rolling off, or *roughing*. A strip for the brim, round the edge of the inside, is treated in the same way; whereby everything is ready for the second cover (of beaver), which is incorporated in like manner; the rolling, &c., being continued till a uniform, close, and well-felted hood is formed.

The hat is now ready to receive its proper shape. For this purpose the workman turns up the edge or brim to the depth of about 1½ inch, and then returns the point of the cone back again through the axis of the cap, so as to introduce another inner fold of the same depth. A third fold is produced by returning the point of the cone, and so on till the point resembles a flat circular piece having a number of concentric folds. In this state it is laid upon the plank, and wetted with the liquor. The workman pulls out the point with his fingers, and presses it down with his hand, turning it at the same time round on its centre upon the plank, till a flat portion, equal to the crown of the hat, is rubbed out. This flat crown is now placed upon a block, and, by pressing a string called a *commander*, down the sides of the block, he forces the parts adjacent to the crown, to assume a cylindrical figure. The brim now appears like a puckered appendage round the cylindrical cone; but the proper figure is next given to it, by working and rubbing it. The body is rendered waterproof and stiff by being imbued with a varnish composed of shellac, sandarach, mastic, and other resins dissolved in alcohol or naphtha.

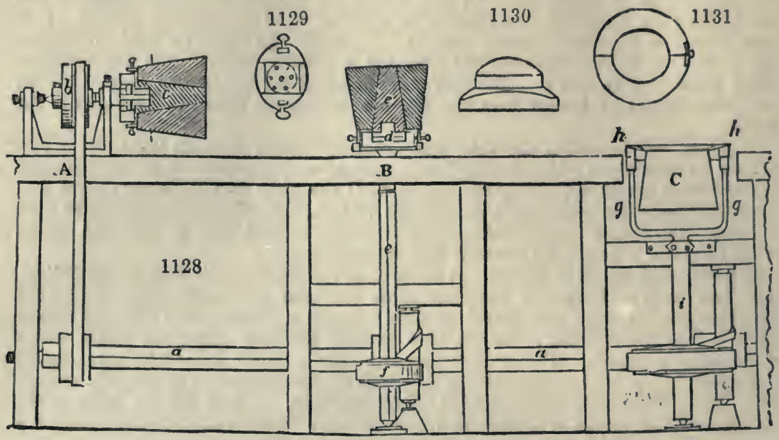
The hat being dried, its nap is raised or loosened with a wire brush or card, and sometimes it is previously pounced or rubbed with pumice, to take off the coarser parts, and afterwards rubbed over with seal-skin. The hat is now tied with pack-thread upon its block, and is afterwards dyed.

The dyed hats are now removed to the stiffening shop. Beer-grounds are next applied on the inside of the crown, for the purpose of preventing the glue from coming through; and when the beer-grounds are dried, glue (gum Senegal is sometimes used), a little thinner than that used by carpenters, is laid with a brush on the inside of the crown, and the lower surface of the brim.

The hat is then softened by exposure to steam, on the steaming-basin, and is brushed and ironed till it receives the proper gloss. It is lastly cut round at the brim by a knife fixed at the end of a gauge, which rests against the crown. The brim, however, is not cut entirely through, but is torn off so as to leave an edging of beaver round the external rim of the hat. The crown being tied up in a gauze paper, which is neatly ironed down, is then ready for the last operations of lining and binding.

The furs and wools of which hats are manufactured contain in their early stage of preparation, *hemps* and *hairs*, which must be removed in order to produce a material for the better description of hats. This separation is effected by a sort of winnowing machine, which wafts away the finer and lighter parts of the furs and wools from the coarser.

The annexed figures represent Mr. Ollerenshaw's machine, generally employed for ironing hats. *Fig.* 1128 is the framework or standard upon which three of these lathes are mounted, as A, B, C. The lathe A is intended to be employed when the crown of the hat is to be ironed. The lathe B, when the flat top, and the upper side of the brim is ironed, and lathe C, when its under side is ironed; motion being given to the whole by means of a band passing from any first mover (as a steam-engine, water-wheel, &c.) to the drum on the main-shaft *a a*. From this drum a strap passes over the rigger *b*, which actuates the axle of the lathe A. On to this lathe a sort of chuck is screwed, and to the chuck the block *c* is made fast by screws, bolts, or pins. This block is represented in section, in order to show the manner in which it is made, of several pieces held fast by the centre wedge-piece, as seen at *fig.* 1129.


1129 1130 1131 1128

The hat-block being made to turn round with the chuck, at the rate of about twenty turns per minute, but in the opposite direction to the revolution of an ordinary turning lathe, the workman applies his hot iron to the surface of the hat, and thereby smooths it, giving a beautiful glossy appearance to the beaver; he then applies a plush cushion, and rubs round the surface of the hat while it is still revolving. The hat, with its block, is now removed to the lathe B, where it is placed upon the chuck *d*, and made to turn in a horizontal direction, at the rate of about twenty revolutions per minute, for the purpose of ironing the flat top of the crown. This lathe B moves upon an upright shaft *e*, and is actuated by a twisted band passing from the main-shaft round the rigger *f*. In order to iron the upper surface of the brim, the block *c* is removed from the lathe, and taken out of the hat, when the block, *fig.* 1130, is mounted upon the chuck *d*, and made to turn under the hand of the workman, as before.

The hat is now to be removed to the lathe C, where it is introduced in an inverted position, between the arms *g g* supporting the rim *h h*, the top surface of which is shown at *fig.* 1131. The spindle *i* of the lathe turns by similar means to the last, but slower: only ten turns per minute will be sufficient. The workman now smooths the under side of the brim, by drawing the iron across it, that is, from the centre outwards. The hat is then carefully examined, and all the burs and coarse hairs picked out, after which the smoothing process is performed as before, and the dressing of the hat is complete. This description of the manufacture of the beaver hat has been retained, though it is now but little practised, the silk hat having taken its place.

Silk hats, for several years after they were manufactured, were liable to two objections: first, the body or shell over which the silk covering is laid, was, from its hardness, apt to hurt the head; second, the edge of the crown being much exposed to blows, the silk nap soon got abraded, so as to lay bare the cotton foundation, which is not capable of taking so fine a black dye as the silk; whence the hat assumed a shabby appearance. Messrs. Mayhew & White, of London, proposed to remedy these defects, by making the hat-body of stuff or wool, and relieving the stiffness of the inner part round the brim, by attaching a coating of beaver upon the under side of the brim, so as to render the hat pliable. Round the edge of the tip or crown, a quantity of what is called stop-wool is to be attached by the ordinary operation of bowing, which will render the edge soft and elastic. The hat is to be afterwards dyed of a good black colour, both outside and inside; and being then properly stiffened and blocked, is ready for the covering of silk.

The plush employed for covering silk hats is a raised nap or pile woven usually upon a cotton foundation; and the cotton, being incapable of receiving the same brilliant black dye as the silk, renders the hat apt to turn brown whenever the silk nap is partially worn off. To counteract this evil, the foundation of the plush is now frequently made entirely of silk. To these two improvements, now pretty generally introduced, the present excellence of the silk hats may be ascribed.

Fig. 1132 is a side view of the carding-engine, employed in preparing the silk for hats, with a horizontal plan or view of the lower part of the carding-machine, showing the operative parts of the winding-apparatus, as connected to the carding-engine. The doffer-cylinder is covered with fillets of wire-cards, such as are usually employed in carding-engines, and these fillets are divided into two, three, or more spaces, extending round the periphery of the cylinder, the object of which division is to separate the sliver into two, three, or more breadths, which are to be conducted to and wound upon distinct blocks, for making so many separate hats or caps.

The principal cylinder of the carding-engine is made to revolve by a rigger upon its axle, actuated by a band from any first mover as usual, and the subordinate rollers or cylinders belonging to the carding-engine, are all turned by pulleys, and bands, and gear, as in the ordinary construction.

The wool or other material is supplied to the feeding-cloth, and carried through the engine to the doffer-cylinder, as in other carding-engines; the doffer-comb is actuated by a revolving crank in the common way, and by means of it the slivers are taken from the doffer-cylinder, and thence received on to the surfaces of the blocks *e e*. These blocks, of which two only are shown to prevent confusion, are mounted upon axles, supported by suitable bearings, in a carriage *f f*, and are made to revolve by means of a band *g g*, leading from a pulley on the axle of a conical drum beneath. The band *g* passes over a pulley *h*, affixed to the axle of one of the blocks, while another pulley *i*, upon the same axle, gives motion, by means of a band, to as many other blocks as are adapted to the machine.

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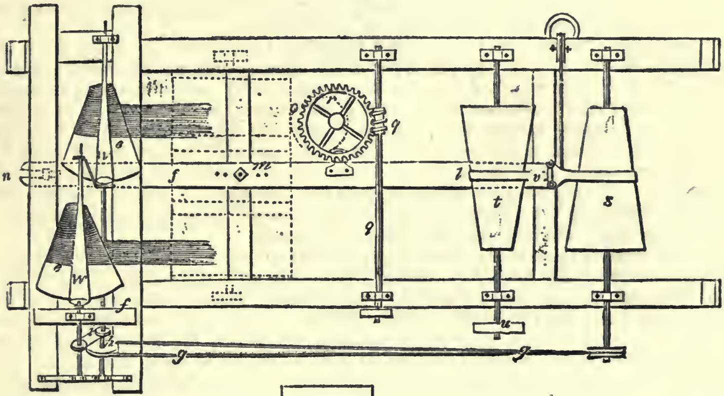

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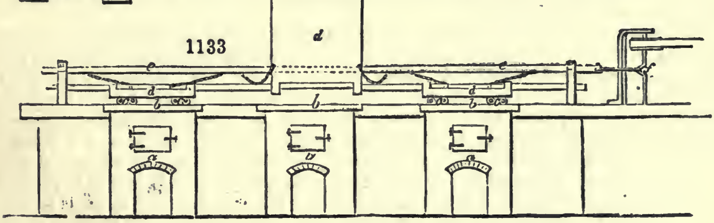

As it is necessary in winding the slivers on to the blocks, to cross them in different directions, and also to pass the sliver over the hemispherical ends of the blocks, in order that the wool or other material may be uniformly spread over the surface in forming the cap or hood for the shell or foundation of the intended hat, the carriage *f*, with the blocks, is made to traverse to and fro in lateral directions upon rollers at each end.

This alternating motion of the carriage is caused by a horizontal lever *l l* (seen in the horizontal view *fig.* 1132), moving upon a fulcrum-pin at *m*, which lever is attached to the carriage at one extremity *n*, and at the other end has a weighted cord which draws the side of this lever against a cam-wheel *o*. This cam is made to revolve by means of a band and pulley, which turns the shaft and endless screw *q*, and this endless screw, taking into a toothed wheel *r*, on the axle of the cam *o*, causes the cam to revolve, the periphery of which cam running against a friction-roller on the side of the lever *l*, causes the lever to vibrate, and the carriage *f f*, attached to it, to traverse to and fro upon the supporting-rollers, as described. By these means the slivers are laid in oblique directions (varying as the carriage traverses) over the surface of the blocks.

The blocks being conically formed, or of other irregular figures, it is necessary in order to wind the slivers with uniform tension to vary their speed according to the diameter of that part of the block which is receiving the sliver. This is effected by giving different velocities to the pulley on the axle of the conical drum *s*, corresponding with *c*. There is a similar conical drum *t*, placed in a reverse position in the lower part of the frame, which is actuated by a band from any convenient part of the machine passing over a pulley *u*, upon the axle of *t*. From the drum *t*, to the drum *s*, there is a band *v*, which is made to slide along the drums by the guidance of two rollers at the end of the lever *l*.

It will now be seen that when the larger diameter of the cam-wheel *o* forces the lever outwards, the band *v* will be guided on the smaller part of the conical drum *t*, and the larger part of *s*, consequently the drum *s* will at this time receive its slowest motion, and the band *g* will turn the blocks slower also; the reverse end of the lever *l*, having by the same movement slidden the carriage into that position which causes the slivers to wind upon the large diameter of the blocks.

When the smaller diameter of the cam is acting against the side of the lever, the weighted cord draws the end of the lever to the opposite side, and the band *v* will be guided on to the larger part of the cone *t*, and the smaller part of the cone *s*; consequently, the quicker movement of the band *g*, will now cause the blocks *e e* to revolve with a corresponding speed. The carriage *f* will also be moved upon its rollers to the reverse side, and the sliver of wool or other material be now wound upon the smaller parts and ends of the blocks, at which time the quicker rotation of the blocks is required. It may be here observed, that the cam-wheel *o* should be differently formed according to the different shaped blocks employed, so as to produce the requisite movements of the lever and carriage suited thereto.

It only remains to state that there are two heavy conical rollers, *w w*, bearing upon the peripheries of the blocks *e e*, which turn loosely upon their axles by the friction of contact, for the purpose of pressing the slivers of wool or other material on the blocks as it comes from the doffer-cylinder of the carding-engine, and when the blocks have been coated with a sufficient quantity of the sliver, the smaller end of the pressing-rollers is to be raised, while the cap is withdrawn from the block. The process being continued as before, the formations of other bodies or caps is effected in the manner above described.

After the caps or bodies of hats, &c., are formed in the above described machine, they are folded in wet cloths, and placed upon heated plates, where they are rolled under pressure, for the purpose of being hardened. *Fig.* 1133 represents the front of three furnaces *a a a*, the tops of which are covered with iron plates *b b b*. Upon these plates, which are heated by the furnace below, or by steam, the bodies wrapped in the wet cloths *c c c*, are placed, and pressed upon by the flaps or covers *d d d*, sliding upon guide-rods, to which flaps a traversing motion is given, by means of chains attached to an alternating bar *e e*. This bar is moved by a rotary crank *f*, which has its motion by pulleys from any actuating power. When any one of the flaps is turned up to remove the bodies from beneath, the chains hang loosely, and the flap remains stationary.

These caps or hat-bodies, after having been hardened in the manner above described, may be felted in the usual way by hand, or they are felted in a fulling-mill by the usual process employed for milling cloths, except that the hat-bodies are occasionally taken out of the fulling-mill, and passed between rollers, for the purpose of rendering the felt more perfect.

Mr. Carey, of Basford, obtained a patent in October 1834 for an invention of certain machinery to be employed in the manufacture of hats, which is ingenious, and seems to be worthy of notice in this place. It consists in the adaptation of a system of rollers, forming a machine, by means of which the operation of roughing or plaiting of hats, may be performed; that is, the beaver or other fur may be made to attach itself, and work into the felt or hat-body, without the necessity of the ordinary manual operations.

The accompanying drawings represent the machine in several views, for the purpose of showing the construction of all its parts. *Fig.* 1134 is a front elevation of the machine; *fig.* 1135 is a side elevation of the same; *fig.* 1136 is a longitudinal section of the machine; and *fig.* 1137 is a transverse section: the similar letters indicating the same parts in all the figures.

Upon a brick or other suitable base, a furnace or fireplace *a*, is made, having a descending flue *b*, for the purpose of carrying away the smoke. A pan or shallow vessel *c c*, formed of lead, is placed over the furnace; which vessel is intended to contain a sour liquor, as a solution of vitriolic acid and water. On the edge of this pan is erected a wooden casing *d d d*, which encloses three sides, leaving the fourth open for the purpose of obtaining access to the working apparatus within. A series of what may be termed lantern-rollers, *e e e*, is mounted on axles turning in the side casings; and another series of similar lantern-rollers, *f f f*, is in like manner mounted above. These lantern-rollers are made to revolve by means of bevel pinions, fixed on the ends of their axles, which are turned by similar bevel-wheels on the lateral shafts, *g* and *h*, driven by a winch, *i*, and gear, as shown in *figs.* 1135 and 1136.

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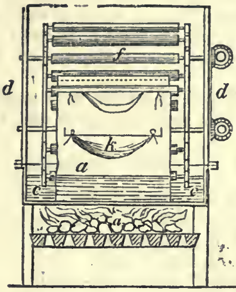

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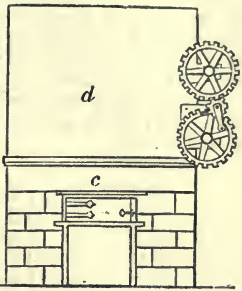

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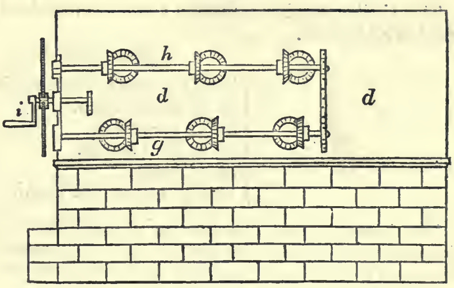

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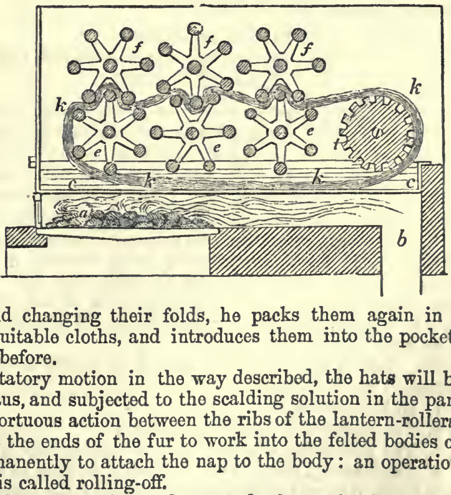

Having prepared the bodies of the hats, and laid upon their surfaces the usual coatings of beaver, or other fur, when so prepared they are to be placed between hair-cloths, and these hair-cloths folded within a canvas or other suitable wrapper. Three or more hats being thus enclosed in each wrapper, the packages are severally put into bags or pockets in an endless band of sackcloth, or other suitable material; which endless band is extended over the lantern-rollers in the machine.

In the first instance, for the purpose of merely attaching the furs to the felts (which is called slicking, when performed by hand), Mr. Carey prefers to pass the endless band *k k k*, with the covered hat-bodies, over the upper series *f f f*, of the lantern-rollers, in order to avoid the inconvenience of disturbing the fur, which might occur from subjecting them to immersion in the solution contained in the pan, before the fur had become attached to the bodies.

After this operation of slicking has been effected, he distends the endless band, *k k k*, over the lower series of lantern-rollers *e e e*, and round a carrier-roller *l*, as shown in *fig.* 1137; and, having withdrawn the hat-bodies for the purpose of examining them, and changing their folds, he packs them again in a similar way in flannel, or other suitable cloths, and introduces them into the pockets or bags of the endless bands, as before.

On putting the machine in rotatory motion in the way described, the hats will be carried along through the apparatus, and subjected to the scalding solution in the pan, as also to the pressure, and to a tortuous action between the ribs of the lantern-rollers, as they revolve, which will cause the ends of the fur to work into the felted bodies of the hats, and by that means permanently to attach the nap to the body: an operation which when performed by hand, is called rolling-off.

A varnish made by dissolving shellac, mastic, sandarac, and other resins in alcohol, or the naphtha of wood-vinegar, is generally employed as the stiffening and waterproof ingredient of hat-bodies. A solution of caoutchouc is often applied to whalebone and horsehair hat-bodies.

The following recipe has been prescribed as a good composition for stiffening hats: 4 parts of shellac; 1 part of mastic; ½ part of turpentine; dissolved in 5 parts of alcohol, by agitation and subsequent repose, without the aid of heat. This stiffening-varnish should be applied quickly to the body or foundation with a soft oblong brush, in a dry and rather warm workshop; the hat being previously fitted with its inside turned outwards upon a block. The body must be immediately afterwards taken off, to prevent adhesion.

Another method of proceeding is, first to dissolve the gums by agitation in twice the due quantity of spirits, whether of wood or wine, and then, after complete solution, draw off one half the spirit in a still, so as to bring the stiffening to a proper consistency. No sediment subsequently appears on diluting this solution, however much it may be done.

Both the spirit and alkali stiffenings for hats made by the following two recipes, have been tried by some of the first houses in the trade, and have been much approved of:—

Spirit-Stiffening.

7 lbs. of orange shellac.
2 lbs. of gum sandarac.
4 oz. of gum mastic.
½ lb. of amber resin.
1 pint of solution of copal.
1 gallon of spirit of wine or wood-naphtha.

The shellac, sandarac, mastic, resin, are dissolved in the spirit, and the solution of copal is added last.

Alkali-Stiffening.

7 lbs. of common block shellac.
1 lb. of amber resin.
4 oz. of gum thus.
4 oz. of gum mastic.
6 oz. of borax.
½ pint of solution of copal.

The borax is first dissolved in a little warm water (say 1 gallon); this alkaline liquor is now put into a copper pan (heated by steam), together with the shellac, resin, thus, and mastic, and allowed to boil for some time, more warm water being added occasionally until it is of a proper consistence.

Hat-Dyeing.—The ordinary bath for dyeing hats employed by the London manufacturers consists, for 12 dozen, of—

144 lbs. of logwood.
12 lbs. of green sulphate of iron, or copperas.
7½ lbs. of verdigris.

The copper is usually made of a semi-cylindrical shape, and should be surrounded with an iron jacket or case, into which steam may be admitted, so as to raise the temperature of the interior bath to 190° F., but no higher, otherwise the heat is apt to affect the stiffening varnish, called the gum, with which the body of the hat has been imbued. The logwood having been introduced and digested for some time, the copperas and verdigris are added in successive quantities, and the above proportions, along with every successive two or three dozens of hats, suspended upon the dipping-machine. Each set of hats, after being exposed to the bath with occasional airings during 40 minutes, is taken off the pegs, and laid out upon the ground to be more completely blackened by the peroxidation of the iron with the atmospheric oxygen. In 3 or 4 hours the dyeing is completed. When fully dyed, the hats are well washed in running water.

Mr. Buffum states that there are four principal objects accomplished by his patent invention for dyeing hats:—

1. In the operation;
2. The production of a better colour;
3. The prevention of any of the damages to which hats are liable in the dyeing;
4. The accomplishment of the dyeing process in a much shorter time than by the usual methods, and consequently lessening the injurious effects of the dye-bath upon the texture of the hat.

Fig. 1138 shows one method of constructing the apparatus. *a a* is a semi-cylindrical shaped copper vessel, with flat ends, in which the dyeing process is carried on. *b b b* is a wheel with several circular rims mounted upon arms, which revolve upon an axle *c*. In the face of these rims a number of pegs or blocks are set at nearly equal distances apart, upon each of which pegs or blocks it is intended to place a hat, and as the wheel revolves, to pass it into and out of the dyeing liquor in the vat or copper. This wheel may be kept revolving with a very slow motion, either by gear connecting its axle, *c*, with any moving power, or it may be turned round by hand, at intervals of ten minutes; whereby the hats hung upon the pegs will be alternately immersed for the space of ten minutes in the dyeing liquor, and then for the same space exposed to the atmospheric air. In this way, the process of dyeing, it is supposed, may be greatly facilitated and improved, as the occasional transition from the dye-vat into the air, and from the air again into the bath, will enable the oxygen of the atmosphere to strike the dye more perfectly and expeditiously into the materials of which the hat is composed, than by a continued immersion in the bath for a much longer time.

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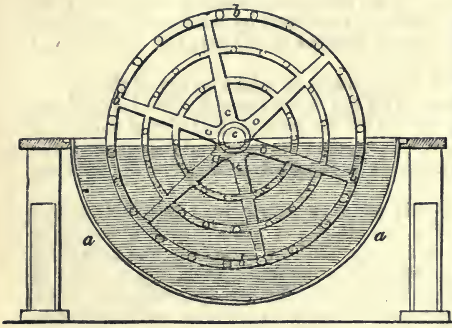

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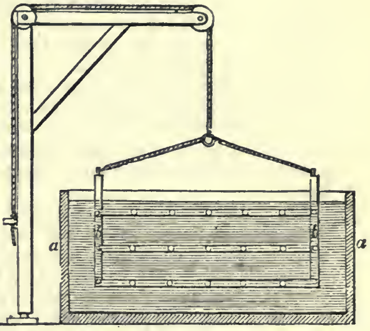

A variation in the mode of performing this process is suggested, and the apparatus *fig.* 1139 is proposed to be employed. *a a* is a square vat or vessel containing the dyeing liquor; *b b* is a frame or rack having a number of pegs placed in it for hanging the hats upon which are about to be dyed, in a manner similar to the wheel above described. This frame or rack is suspended by cords from a crane, and may in that way be lowered down with the hats into the vat, or drawn up and exposed in the air; changes which may be made every 10 or 20 minutes.

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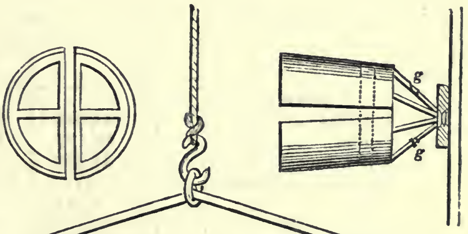


Mr. William Hodge's patent improvements in hat-dyeing, partly founded upon an invention of Mr. Bowler, consist, first, in causing every alternate frame to which the suspenders or blocks are to be attached, to slide in and out of grooves, for the purpose of more easily removing the said suspenders when required. *Fig.* 1140 represents the improved dyeing frame, consisting of two circular rims, *a a*, which are connected together at top and bottom, by three fixed perpendicular bars on the frame-work *b b b*. Two other perpendicular frames, *c c*, similar to the former, slide in grooves, *d d d d*, fixed to the upper and lower rims. These grooves have anti-friction rollers in them for the purpose of making the frames *c c*, to slide in and out more freely. The suspenders or substitutes for blocks, by these means, may be more easily got at by drawing out the frames *c c*, about half way, when the suspenders, which are attached to the frames with the hats upon them, may be easily reached, and either removed or altered in position; and when it is done on one side, the sliding-frame may be brought out on the other, and the remaining quantity of 'suspenders' undergo the same operation.

The patentee remarks, that it is well known to all hat dyers, that after the hats have been in the dyeing liquor some time, they ought to be taken out and exposed to the action of the atmospheric air, when they are again immersed in the copper, that part of the hat which was uppermost in the first immersion being placed downwards in the second. This is done for the purpose of obtaining an uniform and regular dye. The patentee's mode of carrying this operation into effect is shown in the figure: *e e* are pivots for the dyeing-frame to turn upon, which is supported by the arms *f*, from a crane above. The whole apparatus may be raised up or lowered into the copper by means of the crane or other mechanism. When the dyeing-frame is raised out of the copper, the whole of the suspenders or blocks are reversed, by turning the apparatus over upon the pivots *e e*, and thus the whole surfaces of the hats are equally acted upon by the dyeing material.

It should be observed, that when the dyeing-frame is raised up out of the copper, it should be tilted on one side, so as to make all the liquor run out of the hats, as also to cause the rims of the hats to hang down, and not stick to the body of the hat, or leave a bad place or uneven dye upon it. The second improvement described by the patentee, is the construction of 'suspenders,' to be substituted instead of the ordinary blocks.

These 'suspenders' are composed of thin plates of copper, bent into the required form, that is, nearly resembling that of a hat-block, and made in such a manner as to be capable of contraction and expansion to suit different sized hats, and keep them distended, which may be altered by the workman at pleasure, when it is required to place the hats upon them, or remove them therefrom. The dyeing-frame at *fig.* 1140, is shown with only two of these 'suspenders,' in order to prevent confusion. One of these suspenders is represented detached at *fig.* 1141, which exhibits a side view; and *fig.* 1142, a front view of the same. It will be seen by reference to the figure, that the suspenders consist of two distinct parts, which may be enlarged or collapsed by a variety of means, and which means may be suggested by any competent mechanic. The two parts of the suspenders are proposed to be connected together by arms *g g*, and at the junction of these arms a key is connected for turning them round when required. It will be seen on reference to the front view, *fig.* 1142, that the 'suspenders' or substitutes for blocks are open at the top or crown-part of the hat; this is for the purpose of allowing the dyeing liquor to penetrate.

Hats or Bonnets imported.

	1871		1872	
		£	lbs.	£
Straw:				
From Belgium	41,466	27,163	50,035	12,138
,, France	30,177	12,150	94,711	28,670
,, Italy	34,286	15,697	6,226	2,966
,, Philippine Islands . .	...	...	3,411	3,357
,, Egypt	4,623	3,515	...	...
,, China	...	...	8,954	1,797
,, Ecuador	2,310	2,180	1,907	2,966
,, Straits Settlements . .	1,506	3,301	1,136	2,275
,, Other countries . .	23,966	8,813	29,197	11,481
	138,334	72,819	195,577	65,650
Felt:	No.		No.	
From Belgium	51,539	10,770	23,096	4,966
,, France	99,465	20,798	124,943	24,787
,, Other countries . .	21,433	4,055	24,685	3,432
	172,437	35,623	172,724	33,185
Other materials:				
From all countries . . .	11,489	2,378	18,375	5,540

From the mixture of copperas and verdigris employed in the hat-dye, a vast quantity of an ochreous muddy precipitate results, amounting to no less than 25 per cent. of the weight of the copperas. This iron mud forms a deposit upon the hats, which not only corrodes the fine filaments of the beaver, bu causes both them and the felt-stuff to turn speedily of a rusty brown. There is no process in the whole circle of our manufactures so barbarous as that of dyeing stuff hats. No ray of chemical science seems hitherto to have penetrated the dark recesses of their dye-shops. Some hatters have tried to remove this corrosive brown ochre by a bath of dilute sulphuric acid, and then counteract the evil effect of the acid upon the black dye by an alkaline bath; but with a most unhappy effect. Hats so treated are most deceptive and unprofitable; as they turn of a dirty brown hue when exposed for a few weeks to sunshine and air.

HAUERITE. A bisulphide of manganese, occurring at Kalinka in Hungary. It is named after the eminent Austrian geologist, Von Hauer.

HAUSMANNITE. Native proto-peroxide of manganese. See MANGANESE.

HAÜYNE. A mineral occurring in blue or green crystals and crystalline masses, belonging to the cubic system, and presenting a complex constitution; they consist of a silicate of alumina, lime, soda, and potash, with sulphate of lime.

HAWTHORN. (*Épine blanche*, Fr.; *Weissdorn*, Ger.) *Cratægus Oxycantha*, Linn. This shrub has a hard whitish wood, but as it is small and difficult to work, it is not much used.

HAYESINE. A borate of lime, which is found abundantly on the western coast of South America, so called from its discoverer. It has been introduced for use in our glass manufacture, and is used by our potters. See BORACIC ACID.

HAYTORITE. A pseudomorph of quartz after datholite, found at Hay Tor in Devonshire.

HAZEL. (*Noisetier*, Fr.; *Haselstaude*, Ger.) The *Corylus Avellana*, a small underwood, used a little in turnery and for the manufacture of toys. The nuts are eaten.

HAZEL. A North of England term for a hard grit.

HAZEL MOULD. The name given in Hampshire to a light loamy soil.

HEARTH (*Foyer*, Fr.; *Heerde*, Ger.) is the flat or hollow space in a smelting furnace upon which the ore and fluxes are subjected to the influence of flame.

HEARTHSTONE. A soft stone employed for whitening door-steps, &c. A large quantity of hearthstones are brought to London from the quarries in the Upper Greensand at Godstone in Surrey. See GREENSAND.

HEAT. The Force or Principle upon which the conditions, relatively, of solid, fluid, and aeriform states depend. That which produces the sensation of warmth.

The discussion of the habitudes of heat with the different kinds of matter belongs to physico-chemical science, and is treated of in Watts's 'Dictionary of Chemistry.' It will suffice, in this place, to state succinctly those laws which have, more directly, a bearing on any of our manufacturing processes.

Heat and motive power are mutually convertible, and heat requires for its production, and produces by its disappearance, motive power in the proportion of 772 *foot-pounds for each Fahrenheit unit of heat.—Rankine.*

This unit of heat has been established by Dr. Joule to be the amount of heat required to raise the temperature of one pound of liquid water by one degree of Fahrenheit. A falling weight, or any other mode of motion, produces a definite quantity of heat according to this law.

If the total actual heat of a homogeneous and uniformly hot substance be conceived to be divided into any numbers of equal parts, the effect of those parts in causing work to be performed will be equal.—Rankine.

Or, in other words, of a given equivalent of heat, from whatever source produced, the work which it can effect is always an equal and constant quantity.

Heat may be produced by friction, as we see in the development of it powerfully, in the axles of railway carriages insufficiently lubricated. By the attrition of two pieces of wood ignition can be obtained.

Heat is developed in the mixture of bodies of different densities, such as spirits of wine and water, or sulphuric acid and water, there being a diminution of volume in each case.

Heat is produced by many conditions of chemical combination, in numerous cases so energetically as to produce intense combustion and even explosion.

Heat is obtained by combustion for our ordinary manufacturing processes, and domestic uses. This is a chemical union of one body with another, as carbon with oxygen; but to effect this, an excitant appears necessary or a continually increasing excitement of the energy upon which heat depends, as, the application of flame in one case and the phenomena of spontaneous combustion in another.

Electricity by its disturbing power, developes heat, and this all-important force is also rendered manifest by the processes of vitality (vital or nervous force).

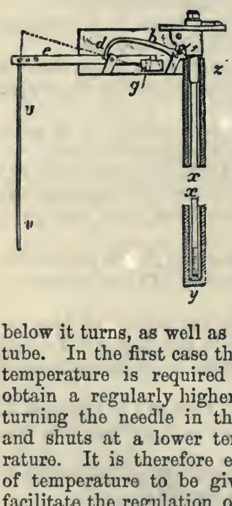
Dr. Joule has clearly shown, that whatever may be the source of heat, a certain fixed elevation of temperature is produced by a given amount of mechanical, chemical, electrical, or vital disturbance, and that the mechanical value of the *cause* producing the heat is exactly represented by the mechanical *effect* obtained.

For a full discussion of this important point, see the Memoirs of Joule, of Thomson, and of Rankine, in the 'Philosophical Transactions' of London and Edinburgh. The applications of heat will be found under the proper heads. The reader should also consult the article Heat in Watts's 'Dictionary of Chemistry.' See also Spheroidal State.

HEAT-REGULATOR, or Thermostat. The name given by M. Bonnemain to an ingenious apparatus for regulating the temperature of his incubating stove-rooms. See Incubation, Artificial, for the manner of applying the Heat-Regulator.

The construction of the regulator is founded upon the unequal distillation of different metals by the same degree of heat. A rod of iron *x*, *fig.* 1143, is tapped at its lower end into a brass nut *y*, enclosed in a leaded box or tube, terminated above by a brass collet *z*. This tube is plunged into the water of the boiler, alongside of the smoke-pipe. *Fig.* 1144, is a bird's-eye view of the dial, &c. The expansion of the lead being more than the iron for a like degree of temperature, and the rod enclosed within the tube being less easily warmed, whenever the heat rises to the desired pitch, the elongation of the tube puts the collet *z* in contact with the heel, *a*, of the bent lever *a*, *b*, *d*; thence the slightest increase of heat lengthens the tube anew, and the collet lifting the heel of the lever, depresses the other end *d* through a much greater space, on account of the relative lengths of its legs. This movement operates near the axis of a balance-bar *e*, sinks one end of this, and thereby increases the extent of the movement, which is transmitted directly to the iron skewer *v*. This, pushing down a swing-register, diminishes or cuts off the access of air to the fire-place. The combustion is thereby obstructed, and the temperature falling by degrees, the tube shrinks and disengages the heel of the lever. The counterpoise *g*, fixed to the balance-beam *e*, raises the other extremity of this beam by raising the end, *d*, of the lever as much as is necessary to make the heel bear upon the collet of the tube. The swing-register acted upon by this means presents a greater section to the passage of the air; whence the combustion is increased. To counterbalance the effect of atmospheric changes, the iron stem which supports the regulator is terminated by a dial disc, round the shaft of the needle above *h*, *fig.* 1144; on turning this needle, the stem below it turns, as well as a screw at its under end, which raises or lowers the leaden tube. In the first case the heel falls, and opens the swing-register, whence a higher temperature is required to shut it, by the expansion of the tube. We may thus obtain a regularly higher temperature. If, on the contrary, we raise the tube by turning the needle in the other direction, the register presents a smaller opening, and shuts at a lower temperature; in this case we obtain a regularly lower temperature. It is therefore easy, says M. Bonnemain, to determine *à priori* the degree of temperature to be given to the water circulating in the stove-pipes. In order to facilitate the regulation of the apparatus, he graduated the disc dial, and inscribed upon its top and bottom the words Strong and Weak heat.

1143



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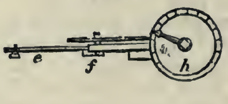
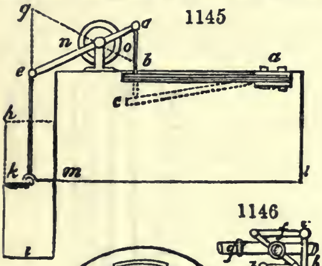


Thermostat, is the name of an apparatus for regulating temperature, in vaporisation, distillations, heating baths or hothouses, and ventilating apartments, &c.; for which I obtained a patent in the year 1831. It operates upon the physical principle, that when two thin metallic bars of different expansibilities are riveted or soldered facewise together, any change of temperature in them will cause a sensible movement of flexure in the compound bar, to one side or other; which movement may be made to operate, by the intervention of levers, &c., in any desired degree, upon valves, stopcocks, stove-registers, air-ventilators, &c.; so as to regulate the temperature of the media in which the said compound bars are placed. Two long rulers, one of steel, and one of hard hammered brass, riveted together, answer very well; the object being, not simply to *indicate*, but to *control* or *modify* temperature. The following diagrams will illustrate a few out of the numerous applications of this instrument:—

Fig. 1145, *a*, *b*, is a single thermostatic bar, consisting of two or more bars or rulers of differently expansible solids (of which, in certain cases, wood may be one): these bars or rulers are firmly riveted or soldered together, face to face. One end of the compound bar is fixed by bolts at *a*, to the interior of the containing cistern, boiler, or apartment, *a l m b*, whereof the temperature has to be regulated, and the other end of the compound bar at *b* is left free to move down towards *c*, by the flexure which will take place when its temperature is raised.

The end *b*, is connected by a link, *b d*, with a lever *d e*, which is moved by the flexure into the dotted position *b g*, causing the turning-valve, air-ventilator, or register, *o n*, to revolve with a corresponding angular motion, whereby the lever will raise the equipoised slide-damper *k i*, which is suspended by a link from the end, *e*, of the lever, *e d*, into the position *k h*. Thus a hothouse or a water-bath may have its temperature regulated by the contemporaneous admission of warm, and discharge of cold air, or water.

Fig. 1146, *a b c* is a thermostatic hoop, immersed horizontally beneath the surface of the water-bath of a still. The hoop is fixed at *a*, and the two ends *b c*, are connected by two links *b d*, *c d*, with a straight sliding rod *d h*, to which the hoop will give an endwise motion, when its temperature is altered; *e*, is an adjusting screw-nut on the rod *d h*, for setting the lever *f g*, which is fixed on the axis of the turning-valve or cock, *f* at any desired position, so that the valve may be opened or shut at any desired temperature, corresponding to the widening of the points *b*, *c*, and the consentaneous retraction of the point *d* towards the circumference *a b c* of the hoop. *g h*, is an arc graduated by a thermometer, after the screw-piece *e* has been adjusted. Through a hole at *h*, the guide-rod passes; *i*, is the cold-water cistern; *i f k*, the pipe to admit cold water; *l*, the overflow pipe, at which the excess of hot water runs off.



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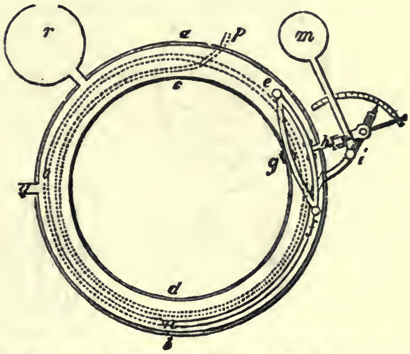

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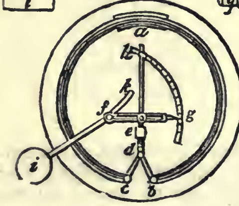

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Fig. 1147 shows a pair of thermostatic bars, bolted fast together at the ends *a*. The free ends *b*, *c*, are of unequal length, so as to act by the cross links *d*, *f*, on the stopcock *e*. The links are jointed to the handle of the turning plug of the cock, on opposite sides of its centre; whereby the plug will be turned round in proportion to the widening of the points *b*, *c*. *h g* is the pipe communicating with the stopcock.

Suppose that for certain purposes in pharmacy, dyeing, or any other chemical art, a water-bath is required to be maintained steadily at a temperature of 150° F.: let the combined thermostatic bars, hinged together at *e*, *f*, *fig.* 1148, be placed in the bath between the outer and inner vessels *a*, *b*, *c*, *d*, being bolted fast to the inner vessel at *g*; and have their sliding rod *k*, connected by a link with a lever fixed upon the turning plug of the stopcock *i*, which introduces cold water from a cistern *m*, through a pipe *m*, *i*, *n*, into the bottom part of the bath. The length of the link must be so adjusted that the flexure of the bars, when they are at a temperature of 150°, will open the said stopcock, and admit cold water to pass into the bottom of the bath through the pipe *i n*, whereby hot water will be displaced at the top of the bath through an open overflow-pipe at *q*. An oil-bath may be regulated on the same plan; the hot oil overflowing from *q*, into a refrigeratory worm, from which it may be restored to the cistern *m*. When a water-bath is heated by the distribution of a tortuous steam-pipe through it, as *i n o p*, it will be necessary to connect the link of the thermostatic bars with the lever of the turning plug of the steam-cock, or of the throttle valve *i*, in order that the bars, by their flexure, may shut or open the steam passage more or less, according as the temperature of the water in the bath shall tend more or less to deviate from the pitch to which the apparatus has been adjusted. The water of the condensed steam will pass off from the sloping winding-pipe *i n o p*, through the sloping orifice *p*. A saline, acid, or alkaline bath has a boiling temperature proportional to its degree of concentration, and may therefore have its heat regulated by immersing a thermostat in it and connecting the working-part of the instrument with a stopcock *i*, which will admit water to dilute the bath whenever by evaporation it has become concentrated, and has acquired a higher boiling point. The space for the bath, between the outer and inner pans, should communicate by one pipe with the water-cistern *m*, and by another pipe with a safety cistern *r*, into which the bath may be allowed to overflow during any sudden excess of ebullition.

Fig. 1151 is a thermostatic apparatus, composed of three pairs of bars *d d d*, which are represented in a state of flexure by heat; but they become nearly straight and parallel when cold. *a b c* is a guide rod, fixed at one end by an adjusting screw *e*, in the strong frame *f e*, having deep guide grooves at the sides. *f g*, is the working-rod which moves endways when the bars *d d d*, operate by heat or cold. A square register-plate *h g*, may be affixed to the rod *f g*, so as to be moved backwards and forwards thereby, according to the variations of temperature; or the rod *f g*, may cause the circular turning air-register, *i*, to revolve by rack and wheel work, or by a chain and pulley. The register-plate *h g*, or turning register *i*, is situated at the ceiling or upper part of the chamber, and serves to let out hot air. *k*, is a pulley, over which a cord runs to raise or lower a hot-air register *l*, which may be situated near the floor of the apartment or hot-house, to admit hot air into the room. *c* is a milled head, for adjusting the thermostat, by means of the screw at *e*, in order that it may regulate the temperature to any degree.

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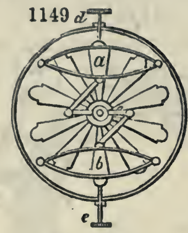

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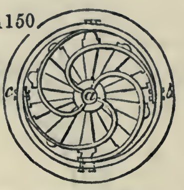

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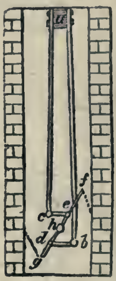

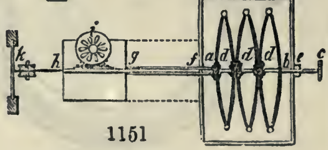

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Fig. 1152 represents a chimney, furnished with a *pyrostat*, *a b c*, acting by the links *b*, *d*, *e*, *c*, on a damper *f h g*. The more expansible metal is in the present example supposed to be on the outside. The plane of the damper-plate will, in this case, be turned more directly into the passage of the draught through the chimney by increase of temperature.

Fig. 1150 represents a circular turning register, such as is used for a stove, or stove-grate, or for ventilating apartments; it is furnished with a series of spiral thermostatic bars, each bar being fixed fast at the circumference of the circle *b*, *c*, of the fixed plate of the air-register; and all the bars act in concert at the centre *a* of the turning part of the register; by their ends being inserted between the teeth of a small pinion, or by being jointed to the central part of the turning plate by small pins.

Fig. 1149 represents another arrangement of the thermostatic apparatus applied to a circular turning register, like the preceding, for ventilating apartments. Two pairs of compound bars are applied so as to act in concert, by means of the links *a c*, *b c*, on the opposite ends of a short lever which is fixed on the central part of the turning plate of the air-register. The two pairs of compound bars *a b*, are fastened to the circumference of the fixed plate of the turning register, by two sliding rods *a d*, *b e*, which are furnished with adjusting screws. Their motion of flexure is transmitted by the links *a c* and *b c*, to the turning plate, about its centre, for the purpose of shutting or opening the ventilating sectorial apertures, more or less, according to the temperature of the air which surrounds the thermostatic turning register. By adjusting the screws *a d*, and *b c*, the turning register is made to close all its apertures at any desired degree of temperature; but whenever the air is above that temperature, the flexure of the compound bars will open the apertures.

HEAVE, *a miner's term,* expressing the dislocation of a lode. See FAULT.

HEAVY-SPAR (*Spath pesant*, Fr.; *Schwerspath*, Ger.), is an abundant mineral, which accompanies veins of lead, silver, mercury, &c., but is often found, also, in large masses. Its colour is usually white, or flesh coloured. It varies from translucent to opaque. It belongs to the trimetric system, but occurs in many crystalline forms, of which the cleavage is a right rhomboidal prism. It is met with also of a fibrous, radiated, and granular structure. Its sp. gr. varies from 4·1 to 4·7; H=2·5 to 3·5. It has a strong lustre, between the fatty and the vitreous, sometimes pearly. It melts at 35° Wedgw. into a white opaque enamel. It is a sulphate of baryta; its constituents being 65·67 baryta, and 34·33 sulphuric acid; but it is sometimes rendered impure by oxide of iron, silica, carbonate of lime, and alumina, and commonly by sulphate of strontia. It is not acted upon by acids; decrepitates before the blowpipe; and is difficultly fusible, or only on the edges. In the inner flame it is reduced to a sulphuret, and the globule when moistened smells slightly hepatic. It is decomposed by calcination in contact with charcoal at a white heat, into sulphide of barium; from which all the baryta-salts may be readily formed. Its chief employment in commerce is for adulterating white-lead; a purpose which it readily serves on account of its density. Its presence here is easily detected by dilute nitric acid, which dissolves the carbonate of lead, and leaves the heavy-spar. It is also a useful ingredient in some kinds of pottery, and glass.

The following were the quantities of barytes, both carbonate and sulphate, returned to the Mining Record Office, from the mines of Great Britain, and reported in Hunt's 'Mineral Statistics' for 1872:—

		Tons.	cwt.	qrs.	£.	s.	d.
Shropshire	Snailbeach (Sulphate)	414	1	0	310	10	0
	Snailbeach (Carbonate	2	11	3	1	19	0
	Weston (Sulphate)	384	0	0	288	0	0
	Wortherton (ditto)	1,483	0	0	1,112	0	0
Northumberland	Fallowfield (Carbonate)	2,001	18	0	1,500	0	0
	Settlingstones (Carbonate)	1,695	0	0	1,271	0	0
	Cow Green	8	0	0	17	0	0
Cumberland	Alston Moor (Carbonate)	135	9	0	101	11	9
	Foree Craig	600	0	0	600	0	0
Derbyshire	Buxton	2,012	17	1	1,609	12	9
	Golconda (Carsington)						
	Grey Mare, Wirksworth						
	Rantor, ditto						
	Croft Doghole, Middleton						
	Bradwell, ditto						
	Moors near Blakewell						
	Longstone Rake						
	Salad Hole						
	Miller's Dale						
	Castleton						
	Monsal Dale						
	Eyham						
	Wensley and Stanton						
	Wardlow						
Montgomeryshire	Van Consols (Sulphate)	356	0	0	26	0	0
	Total *ascertained* production	9,092	17	0	7,078	13	6

Derbyshire, the Isle of Arran, and Ireland produced some sulphate of baryta which has not been given in the above return.

The term *Cawk* has been applied to the opaque massive variety, of an earthy appearance, and dirty-white colour, which is found in Derbyshire and Staffordshire.

HECKLE (*Séran*, Fr.; *Hechel*, Ger.) is an implement for dissevering the filaments of flax, and laying them in parallel stricks or tresses. See FLAX.

HELICIN. A crystalline alkaloïd produced by the oxidation of *salicin*, the bitter principle of the poplar and willow.

HELIOGRAPHY was the name given by M. Niepce to his process for obtaining, through the agency of the solar rays upon plates of metal or glass covered with resins, the impression of external objects. The process has been employed of late years in preparing lithographic stones, and steel or copper plates, for receiving photographic impressions, which might be subsequently printed from. The name Heliography is a far more appropriate one than Photography; but the latter has become too permanently fixed in our language to leave any hope of our returning to the former. See PHOTOGRAPHY.

HELIOTROPE is a variety of green jasper, marked with blood-red points; whence its vulgar name of *blood-stone*. See Blood-Stone.

HELLEBORE. Several species of *Helleborus*, a genus of plants belonging to the natural order *Ranunculaceæ*, were formerly used as drastic purgatives. The *Veratrum album*, a widely different plant, is known as 'White Hellebore.'

HELVINE. A silicate of the protoxides of manganese, iron, and glucinum, with sulphide of manganese. It is commonly found in tetrahedral crystals, whence its name *Tetrahedral Garnet*. The best examples come from Saxony.

HEMATIN. See Hæmatin.

HEMATITE. See Hæmatite.

HEMATOGLOBULIN. See Hæmatoglobulin.

HEMATOSIN. See Hæmatosin.

HEMATOXYLIN. See Hæmatoxylin.

HEMIMORPHITE. A name for silicate of zinc, or smithsonite. See Calamine, Electric.

HEMLOCK. The *Conium maculatum*, a highly poisonous umbelliferous plant used in medicine. Its properties are mainly due to the presence of an oily liquid called *conia*.

HEMLOCK SPRUCE. The *Abies Canadensis*, the wood of which has been used for railway sleepers, and is employed for baths.

HEMP. (*Chanvre*, Fr.; *Hanf*, Ger.) A plant (*Cannabis sativa*), a native of India, but has been long introduced into Europe, and cultivated extensively in Italy, and in Russia and Poland; a small quantity has been cultivated in Suffolk, in Lincolnshire, and in Ireland.

Hemp is assorted into *clean hemp*, *out-shot hemp*, *half-clean hemp*, and *hemp codilla*. According to M'Culloch, a bundle of clean hemp from Russia weighs from 55 to 65 poods; of out-shot, from 48 to 55 poods; of half-clean, 40 to 45 poods—the pood being equal to 36 lbs. avoirdupois.

Hemp imported in 1871 and 1872.

	1871		1872	
	Cwts.	£	Cwts.	£
Dressed:				
From Russia	14,941	25,341	15,579	29,276
,, Germany	...	...	6,073	10,725
,, Italy	8,002	18,596	7,753	19,505
,, Philippine Islands	4,032	11,047	4,875	11,500
,, Australia	...	...	7,847	12,598
,, Other countries	3,765	8,163	4,571	9,950
Total	30,740	63,147	46,698	94,004
Rough or undressed:				
From Russia	543,390	932,671	430,986	791,067
,, Germany	43,485	71,294	129,983	239,478
,, Italy	282,743	543,381	172,070	364,524
,, Austrian Territories	22,381	44,832	13,128	25,676
,, Philippine Islands	202,646	443,270	147,931	337,820
,, Mexico	29,998	55,020	...	...
,, Australia	...	...	24,632	40,581
,, British India	43,839	49,704	57,523	66,347
,, Other countries	22,691	38,312	28,115	57,179
Total	1,191,173	2,178,384	1,004,368	1,922,672
Tow or Codilla:				
From Russia	35,883	45,589	19,319	28,478
,, Germany	5,902	7,866	7,670	12,621
,, Italy	28,951	44,945	23,390	37,954
,, Austrian Territories	2,339	3,065	...	...
,, Other countries	824	1,037	4,538	6,341
Total	73,899	102,502	54,917	85,394

Manilla hemp is the produce of the wild banana, *Musa textilis*. 'It is known,' says Mr. Craufurd, in his 'History of the Eastern Archipelago,' 'to our traders and navigators under the name of Manilla rope, and is equally applicable to cables and to standing or running rigging.'

Sunn and Jute are two varieties of hemp. Hemp is used in the manufacture of *huckaback* for towels and common tablecloths, and of the low-priced cloth worn by agricultural labourers. The largest consumption of this material is in the manufacture of sail-cloth and cordage.

From Mexico, British India, Ceylon, and other countries, we imported of *vegetable substances applicable to the same uses as hemp and flax*: in 1871, 23,106 cwts., value 26,040*l.*; in 1872, 64,880 cwts., value 94,564*l.*

HEMP SEED. (*Chènevis*, Fr.; *Hanfsaat*, Ger.) The seed of the hemp; it is used for crushing for its oil, or as food for birds.

HENBANE. The *Hyoscyamus niger.* Henbane is a plant used in medicine, from which modern chemistry has extracted a crystalline vegetable principle called *hyoscyamine*, which is very poisonous, and when applied in solution to the eye, determines a remarkable dilatation of the pupil, as *belladonna* also does. See Hyoscyamine.

HENNA. The herb used for dyeing the nails in the East. See Alkenna.

HEPAR, which signifies *liver* in Latin, was a name given by the older chemists to some of the compounds of sulphur.

HEPATIC AIR. Sulphuretted hydrogen gas.

HERMETICAL SEAL is an expression derived from Hermes, who was said to be the parent of Egyptian chemistry. It is used to designate the perfect closure of a hollow vessel, by the cementing or melting of the lips of its orifice; as in the case of a glass thermometer.

HERNANDIA OVIGERA. Hernant seeds, some of which are imported from India for tanning.

HERRINGS. The herring-family belongs to the order *Malacopterygii*, characterised by having a scaly body like the salmon, and no adipose dorsal fin. The herrings, *Clupea Harengus*, are a well-known fish inhabiting the deep water all round the British Isles. They approach the shores in the months of August and September, for the purpose of depositing their spawn, which takes place in October or November. At this period they are caught in immense numbers; upwards of 20,000,000 fish have, it is said, been taken off Lowestoft alone. By thus destroying the gravid fish, we wantonly destroy one of our most important fisheries. The quantity of herrings which appear on our coasts is becoming less and less each year; and unless some system is adopted, this fish will, in a comparatively short time become extinct, and a most important industry be destroyed.

HERSCHELITE. A hydrated silicate of alumina, soda, and potash, crystallizing in the rhombic system. It is found in lava in Sicily, and splendid examples have been recently obtained from the basalt quarries at Richmond in Victoria.

HESPERIDEÆ or *Aurantiaceæ.* A family of dicotyledonous plants. They are trees or shrubs. The leaves are dark green, glabrous, of a coriaceous texture, and dotted with numerous transparent points, caused by the presence of receptacles filled with a volatile oil which communicates the odour peculiar to the family. The species are numerous, the greater number originally natives of the tropical regions of Asia, though now cultivation has spread them over the larger portion of the globe. The flowers are usually octoriferous; the fruit has a more or less acid pulp; and the wood is generally compact and valuable. The genus *Citrus* contains the best known species of the family. Under Citrus, most of the fruits are referred to. The fruits, however, of several other genera belonging to the family are greatly esteemed in the countries which produce them. The *Wampa*, highly relished in China and the Indian Archipelago, is the fruit of *Cookea punctata*, and considered excellent. The *Oegle marmelas* is used in medicine, and a perfume is prepared from the rind of the fruit, which is itself delicious, and acts as a laxative.

HESSONITE. See Essonite.

HEULANDITE. A hydrous silicate of alumina and lime, occurring in oblique crystals in cavities in amygdaloidal rocks.

HICKORY. The *Juglans alba*; white walnut, a native of America. There are several species, all natives of North America, and growing into stately trees. The wood of the hickory, and some others of the *Juglandaceæ*, is tough and strong; therefore it is used for making shafts and springs for carriages, such screws as are employed in bookbinders' presses, for cogged wheels, and many other purposes where toughness is a desideratum. The hickory nuts are much esteemed, and form an article of trade. The heart of the wood is often red, and the bark has been recommended by Dr. Bancroft, as a yellow die.

HIDE. (*Peau*, Fr.; *Haut*, Ger.) The strong skin of an ox, horse, or other large animal. The lists of *imports* below will show to what an extent a trade in the skins of animals is carried on with this country. We receive hides largely from Russia and the north of Europe. From America there are also large quantities brought to this country.

The following Table shows the number of hides which were imported in 1871 and 1872:—

	1871		1872	
		£		£
Tanned, tawed, curried, or in any way dressed: dry . . . . .cwts.	604,302	2,083,466	808,420	3,003,920
Wet . . . . ,,	682,387	1,775,598	627,930	1,915,342
Tanned, not otherwise dressed . lbs.	15,069,179	735,763	23,574,061	1,179,746
Tawed, curried, or in any way dressed, not being varnished . . . lbs.	2,469,975	331,852	3,135,162	469,080
Varnished, japanned, or enamelled ,,	218,664	895,895	479,658	123,098

HIGHGATE RESIN. A fossil copal occurring in the London clay of Highgate, near London.

HIPPOCASTANUM. The common horse-chestnut (*Æsculus Hippocastanum*). The seeds contain much starchy matter, and have of late years been used on the Continent for the preparation of starch. When roasted they are said to form a fair substitute for coffee. In Switzerland they are used as food for sheep. It is said that the young leaves of the horse-chestnut have been used instead of hops. The American Horse-chestnut or Buck-eye (another species of *Æsculus*) is reputed to be poisonous.

HIPPOPOTAMUS TEETH. See Ivory.

HISINGERITE. A hydrous silicate of peroxide of iron, magnesia, &c.; from Sweden.

HISLOPITE. A green calc-spar coloured with glauconite; from India.

HOG-GUM. The hog-gum of Jamaica, which is used locally as a medicine, is the produce of *Rhus metopium*.

HOG-NUT. The edible fruit of *Carya porcina*.

HOG'S LARD, or *Axungi*; the latter name derived from the use to which it was put by the ancients, *i.e.* to grease the axle of a wheel. It is obtained from the hog (*Sus scrofa*) and other members of the hog tribe. Hog's lard is largely used in the manufacture of ointments, pomatum, &c. Its proximate analysis gives, according to Braconnot: stearine and margarine, 38; elaine, 62. The stearine is separated and used in the manufacture of candles, and the elaine sold under the name of Lard Oil.

HOLING. The act of cutting away the under part of a coal-seam, so as to bring down the overlying mass of coral. See Mining.

HOLLAND. A linen fabric, which is sold when unbleached as *brown holland*, and which is used when bleached for finer purposes. See Linen.

HOLLANDS. A grain spirit manufactured in Holland.

HOLLY. (*Le Houx*, Fr.; *Stechpalme*, Ger.) The *Ilex aquifolium* of Linnæus, a British plant. Its leaves yield a yellow colouring matter similar to that obtained from buckwheat. The wood is as white as ivory, very hard and fine grained, and susceptible of a high polish; it is employed for many purposes.

HOMBERG'S PHOSPHORUS. Sulphide of calcium, which after exposure to sunlight appears luminous in the dark.

HOMOGENEOUS. A uniformity of structure as applied to metals. Steel is said to be homogeneous when the particles constituting the mass are of the same size and structure throughout.

HOMOLOGOUS. A term used in organic chemistry to denote that substances differ by the constant increment C^2H^2 ($\mathbf{CH^2}$). Thus, in the great series of acids commencing with the formic and extending up to the fatty acids, each *homologue* contains C^2H^2 more than the one before, and C^2H^2 less than the one following, thus:—

Formic acid . .	$C^2H^2O^4$ ($\mathbf{CH^2O^2}$)
Acetic acid . .	$C^4H^4O^4$ ($\mathbf{C^2H^4O^2}$)
Propionic acid . .	$C^6H^6O^4$ ($\mathbf{C^3H^6O^2}$)
Butyric acid . .	$C^8H^8O^4$ ($\mathbf{C^4H^8O^2}$) &c.—C.G.W.

HONDURAS MAHOGANY. See Mahogany.

HONES AND HONE SLATES. These are slaty stones which are used in straight pieces for sharpening tools after they have been ground on revolving grindstones. The more important varieties are the following:—

The *Norway Ragstone* which is the coarsest variety of the hone slates, is imported in large quantities from Norway. In Charnwood Forest, near Mount Sorrel, in Leicestershire, particularly from the Whittle Hill quarry, is obtained the *Charnley Forest Stone*, said to be one of the best substitutes for the Turkey oilstone, and it is much in request by joiners and others. *Ayr stone*, *Snake stone*, and *Scotch stone*, are used especially for polishing copper plates. The *Welsh oilstone* is almost in equal repute with the Charnley Forest stone; it is obtained from the vicinity of Llyn Idwall, near Snowdon, and hence it is sometimes called *Idwall stone*. From Snowdon is also obtained the *cutler's green stone*. The *Devonshire oilstones*, obtained near Tavistock, which were introduced by Mr. John Taylor, are of excellent quality; but the supply of them being irregular, they have fallen into disuse.

The *German razor-hone* has been long celebrated. It is obtained from the slate mountains in the neighbourhood of Ratisbon, where it occurs in the form of a yellow vein running through the blue slate, varying in thickness from 1 to 18 inches. When quarried it is sawn into thin slabs, and these are generally cemented to slices of slate which serve as a support. Sometimes, however, the yellow and the blue slate are cut out naturally combined. There are several other hone stones, which, however, require no particular notice.

The *Turkey oilstone* is said to surpass in its way every other known substance, and it possesses in an eminent degree the property of abrading the hardest steel; it is, at the same time, of so compact and close a nature as to resist the pressure necessary for sharpening a graver, or any instrument of that description. There are white and black varieties of the Turkey oilstone, the black being the hardest, and it is imported in somewhat larger pieces than the white; they are found in the interior of Asia Minor, and are brought down to Smyrna for sale.

HONEY (*Mel*, Fr.; *Honig*, Ger.) is a sweet viscid liquor, secreted in the nectaries of flowers, collected by the working bees, and deposited by them in the waxen cells of their combs. Virgin honey is that which is collected from a hive, the bees of which have never swarmed; the common honey is obtained from the older hives. The former, which is considered the best, is whitish or pale yellow, of a granular texture, a fragrant smell, and a sweet slightly pungent taste; the latter is darker coloured, thicker, and not so agreeable either in taste or smell. Honey would seem to be simply collected by the bees, for it consists of merely the vegetable products, such as the sugars of grape, gum, and manna, along with mucilage, extractive matter, a little wax, and acid.

Narbonne honey, the flavour of which is so much admired, owes its peculiarity to the flowers on which the bees feed.

Trebizond honey has been long celebrated for its intoxicating qualities. The description given in Xenophon's 'Retreat of the Ten Thousand' is well known. Many examples of poisonous honey are on record.

Honey is collected and sold to a considerable extent in Britain, particularly in the north-western counties of Wales. At Wrexham in Denbighshire there is an annual fair, called the 'Honey Fair.' Many ale breweries employ a portion of honey to add strength and flavour to their brewings.

HONEY-COMB. The waxen cells of the bee. See WAX.

HONEY-DEW. A viscid saccharine substance, resembling manna, and occurring on the leaves of the lime, black alder, maple, rose, oak, and other trees. Its secretion appears to be due to certain abnormal conditions of the plant. Boussingault analysed the honey-dew collected in July and August 1869, from the leaves of a lime at Liebfrauenberg in the Vosges. It contained a sugar analogous to cane-sugar, together with levulose or fruit-sugar and dextrine. The proportions of these substances, as determined by optical examination with polarised light, were as follow:—

Cane-sugar	48·86	55·44
Inverted sugar	28·59	24·75
Dextrine	22·55	19·81
	100·00	100·00

The second analysis is almost identical with that of the manna of Mount Sinai, as determined by Berthelot. It has been calculated that in one day a single lime-tree may yield from 4 to 7 lbs. of honey-dew, reckoned in a dry state.

HONEY-STONE. (*Mellite*, Fr.; *Honigstein*, Ger.) A mineral of a yellowish or reddish colour, and a resinous aspect, crystallising in octahedrons with a square base; specific gravity 1·58. It is harder than gypsum, but not so hard as calc-spar; it is deeply scratched by a steel point; very brittle; affords water by calcination; blackens, then burns at the flame of the blowpipe, and leaves a white residuum which becomes blue when it is calcined, after having been moistened with a drop of nitrate of cobalt. It is a hydrous mellate of alumina, and consists of:—

	Klaproth	Wöhler	V. Iljenkoff
Mellitic acid . . .	46	44·4	42·36
Alumina	16	14·5	14·20
Water	38	41·1	44·16
	100	100·0	100·72

The honey-stone, like amber, belongs to the geological formation of lignite. It has been hitherto found only at Artern in Thuringia.; at Luschitz, near Bilin in Bohemia; and near Walchow in Moravia.

HOP (*Houblon*, Fr.; *Hopfen*, Ger.) is the name of a well-known plant of the natural family of *Urticaceæ*, and of the *Diœcia pentandria* of Linnæus. The female flowers, placed upon different plants from the male, grow in ovoid cones formed of oval leafy scales, concave, imbricated, containing each at the base an ovary furnished with two tubular open styles, and sharp-pointed stigmata. The fruit of the hop is a small rounded seed, slightly compressed, brownish coloured, enveloped in a scaly calyx, thin, but solid, which contains, spread at its base, a granular yellow substance, appearing to the eye like a fine dust, but in the microscope they seem to be round, yellow, transparent, grains; deeper coloured, the older the fruit. This secretion which constitutes the useful portion of the hop, has been examined in succession by Ives, Planche, Payen, and Chevallier. A pretty full account of the results of their researches in treating of the hop is given in the article Beer.

Number of Acres under the Cultivation of Hops in England.

Years	Acres	Years	Acres	Years	Acres	Years	Acres	Years	Acres
1807	38,218	1814	40,571	1821	45,662	1828	48,365	1835	53,816
1808	38,486	1815	42,150	1822	43,766	1829	46,135	1836	55,422
1809	38,357	1816	44,219	1823	41,458	1830	46,726	1837	56,323
1810	38,265	1817	46,493	1824	43,449	1831	47,129	1838	55,045
1811	38,401	1818	48,593	1825	46,718	1832	47,101	1839	52,305
1812	38,700	1819	51,014	1826	50,471	1833	49,187	1840	44,805
1813	39,521	1820	50,148	1827	49,485	1834	51,273	1841	45,769

Pounds weight of hops which paid duty, which were exported on drawbacks or free of duty, and retained for home consumption.

Years	Charged with duty	Exported on drawback or free of duty	Retained for home consumption
	lbs.	lbs.	lbs.
1842	35,432,142	662,832	34,769,310
1843	27,862,725	292,709	27,570,016
1844	29,285,004	153,849	29,131,245
1845	32,974,749	151,211	32,823,538
1846	50,704,025	448,497	50,255,528
1847	45,134,365	457,061	44.677,304
1848	44,343,985	357,029	43,986,956
1849	16,650,915	274,811	16,376,104
1850	48,537,669	270,511	48,267,158
1851	27,042,996	904,090	26,138,906
1852	51,102,494	955,855	50,146,639
1853	31,751,693	802,103	30,949,590
1854	9,877,126	585,168	9,291,958
1855	83,221,004	852,856	82,368,448
1856	55,868,624	1,565,249	54,303,375
1857	47,717,561	1,450,104	46,267,457
1858	53,125,100	4,177,250	48,947,850

Annual Amount of Hop Duty.

Years	Amount	Years	Amount	Years	Amount	Years	Amount	Years	Amount
	£		£		£		£		£
1711	43,437	1740	37,875	1769	16,201	1797	157,458	1825	24,317
1712	30,278	1741	65,222	1770	101,131	1798	56,032	1826	269,331
1713	23,018	1742	45,550	1771	33,143	1799	73,279	1827	140,848
1714	14,457	1743	61,072	1772	102,650	1800	72,928	1828	172,027
1715	44,975	1744	46,708	1773	45,897	1801	241,227	1829	38,398
1716	20,354	1745	34,635	1774	138,887	1802	15,463	1830	88,047
1717	54,669	1746	91,879	1775	41,597	1803	199,305	1831	174,864
1718	15,005	1747	62,993	1776	125,691	1804	177,617	1832	139,018
1719	90,317	1748	87,155	1777	43,581	1805	32,904	1833	156,905
1720	38,169	1749	36,805	1778	159,891	1806	153,102	1834	189,713
1721	61,362	1750	72,138	1779	55,800	1807	100,071	1835	235,207
1722	49,443	1751	73,954	1780	122,724	1808	251,089	1836	200,332
1723	30,279	1752	82,163	1781	120,218	1809	63,452	1837	178,578
1724	61,271	1753	91,214	1782	14,895	1810	73,514	1838	171,556
1725	66,526	1754	102,012	1783	75,716	1811	157,025	1839	205,537
1726	80,031	1755	82,157	1784	94,359	1812	30,633	1840	34,091
1727	69,409	1756	48,106	1785	112,684	1813	131,482	1841	146,159
1728	41,494	1757	69,713	1786	95,973	1814	140,202	1842	169,776
1729	48,441	1758	72,896	1787	42,227	1815	123,878	1843	133,431
1730	44,419	1759	42,115	1788	143,168	1816	46,302	1844	140,322
1731	22,600	1760	117,992	1789	104,063	1817	66,522	1845	158,008
1732	35,135	1761	79,776	1790	106,841	1818	199,465	1846	242,929
1733	70,215	1762	79,295	1791	90,050	1819	242,476	1847	215,805
1734	37,716	1763	88,315	1792	162,112	1820	138,330	1848	212,416
1735	42,745	1764	17,178	1793	22,619	1821	154,609	1849	79,791
1736	46,482	1765	73,778	1794	203,063	1822	203,724	1850	233,393
1737	56,492	1766	116,445	1795	82,342	1823	26,058	1851	130,055
1738	86,575	1767	25,997	1796	75,223	1824	148,832	1852	240,000
1739	70,742	1768	114,002						

The preceding Tables are retained, as showing the history of our hop cultivation in a way which cannot be continued. The duty on hops was repealed from September 16, 1862, so that since that period we have no means of obtaining, except through indirect channels, any accurate statements as to production.

The following is the last official return published of hops imported:—

	1871		1872	
	Cwts.	£	Cwts.	£
From Germany	74,945	336,590	36,612	221,617
„ Holland	25,209	108,656	16,675	83,759
„ Belgium	61,208	287,946	66,930	297,034
„ France	5,779	24,242	5,328	28,726
„ United States of America .	50,210	133,031	10,414	48,110
„ Other countries. . .	1,313	5,430	6	30
Total . . .	218,664	895,895	135,965	679,276

HORDEINE is the name given by Proust to the peculiar starchy matter of barley. It seems to be a mixture of the starch, lignine, and husks, which constitute barley-meal. See Beer.

HORDEUM VULGARE. See Barley.

HOREHOUND. The *Marrubium vulgare*, used in England as a simple domestic remedy for coughs.

HORIZONTAL WELLS. Having given an article on Artesian Wells (which see) it appears necessary that something should be said respecting the system proposed by Mr. Lucas, in his work on 'Horizontal Wells, a new application of Geological Principles to effect the Solution of the problem of Supplying London with Pure Water,' 1874.

In recapitulating the geological principles on which his scheme is based, Mr. Lucas refers to the obvious tendency of water absorbed by the edges of permeable sedimentary rocks to sink through these until it reaches an impervious stratum, when it flows down the dip of the beds. This is illustrated by the fact that springs which break out at the surface mostly do so from the line of junction of a porous and an impervious bed, and, of course, from the base of the former, especially where the dip is considerable. In most cases, the drainage of several porous strata is collected at one general point, and to tap this is to obtain, very much more effectually filtered than it can be by any artificial appliances, the water of a large area of natural drainage.

Extensive data on this point are given by Mr. Lucas from the experience of miners, to whom these natural incidents are the occasion of great inconvenience and cost. Some of the collieries in the Durham coal-field, sunk through the magnesian limestone, are troubled with as much as 5,000 gallons a minute. So great, however, is the imperviousness of shale, that five feet of it at the bottom of a shaft forty or fifty fathoms deep through the limestone will turn back that amount of water, allowing none of it to pass through. Mr. Lucas thus concisely indicates the principle of his plan:—'The shaft is sunk to procure a certain stratum; but were water the object, in this as in all other cases, it would certainly be followed along its bed, at the junction of the sandstones with the shales, by levels in a manner similar to that in which the ordinary water-levels of a mine are carried along the bed mined for. Nothing could exceed the purity of water that has been filtered through hundreds of feet of pure quartzose sandstone. The springs of clear water that break from the base of sandstones at their outcrop, in all formations, give striking proofs of the truth of this statement. The waters drawn from wells sunk in such beds also corroborate it. If, then, a large town requires water-supplies, and at no great distance from it there lies a formation containing alternations of porous and impervious beds, which rise above the level of the town, then there should be no difficulty in supplying water at high pressure on the constant system. Such formations occur within easy reach of London.'

The particular sources from which it is proposed to supply the metropolis are the Lower Greensands of Surrey and the underlying chalk, chiefly the former. The first-named form hills from 800 to 967 feet in height, as at Leith Hill, and Hind Head, and consist of a series of highly porous sands, sandstones, and limestones, 400 feet thick, resting upon a bed of absolutely impervious clay, upon the top of which all the water that sinks through the greensands flows down. The upper part of this latter bed is also sandy, and contains a vast amount of water. This was proved in the construction of the Sevenoaks Tunnel, when the water from the latter beds proved a source of much difficulty to the excavators, and now pours in a fully-formed stream from the tunnel's mouth. 'A tunnel driven along the strike of the beds, or water-level, must of necessity arrest all the water that is flowing down it as far as the gallery is carried.' Again, Mr. Lucas argues, 'We have, in fact, in the Lower Greensands of Surrey, a combination of the circumstances most favourable for gathering and storing water. The height of the range attracts a high rainfall, the breadth of the absorbing surface causes much of it to be absorbed. The thickness of the porous beds affords a large reservoir for water absorbed. The complete imperviousness of the retaining clays, Atherfield and Gault, prevents the escape of these waters, which are thus held in a subterraneous reservoir, whose lowest rim is at the deepest valley cutting through the Gault clays.'

Mr. Lucas proposes to collect the supply of water for London from the Leith Hill range 'by means of horizontal galleries driven along the strike of the beds on the Atherfield clay, as by that means very large quantities of water may be gained. The height of the range, and the breadth of the absorbing surface presented by it, together with the great thickness of the porous beds, all point to the suitability of the area from a geological point of view. The great natural reservoir of the chalk of the North Downs of Surrey may also be tapped in a similar manner. The galleries will be placed in a different position, as the water-bearing part of the chalk is near the top of that formation. As regards actual experience of the Lower Greensands, the case of the Sevenoaks Tunnel has already been mentioned. That tunnel was driven at right angles to the strike of the beds, and therefore cannot be viewed as a criterion of the quantity of water to be gained by a gallery of equal length carried along the strike, on the Atherfield clay. This quantity would of course be enormously larger.' See Artesian Wells.

HORN (Eng. and Ger.; *Bois*, *Corne*, Fr.), particularly of oxen, cows, goats, and sheep, is a substance soft, tough, semi-transparent, and susceptible of being cut and pressed into a variety of forms; it is this property that distinguishes it from bone. Turtle or tortoise-shell seems to be of a nature similar to horn, but instead of being of a uniform colour, it is variegated with spots. See Tortoise Shell.

Mr. Aikin ('Trans. Soc. of Arts') remarks, 'In the English language we have only one word to express two quite different substances; namely, the branched bony horns of the stag genus, and the simple laminated horns of the ox genus and other kindred genera. The bony horns are called in the French *bois*, from their likeness to the branch of a tree; they are annually renewed. The other horn, to which the French appropriate the term *corne*, is found on the ox, the antelope, the goat, and sheep kinds.'

The valuable properties of horn render it susceptible of being employed in a variety of works fit for the turner, snuff-box, and comb maker. The means of softening the horn need not be described, as it is well known to be by heat; but those of cutting, polishing, and soldering it, so as to make plates of large dimensions, suitable to form a variety of articles, may be detailed. The kind of horn to be preferred is that of goats and sheep, from its being whiter and more transparent than the horn of any other animals. When horn is wanted in sheets or plates, it must be steeped in water, in order to separate the pith from the kernel, for about fifteen days in summer, and a month in winter; and after it is soaked, it must be taken out by one end, well shaken and rubbed in order to get off the pith; after which it must be put for half an hour into boiling water, then taken out, and the surface sawed even lengthways; it must again be put into the boiling water to soften it, so as to render it capable of separating; then, with the help of a small iron chisel, it can be divided into sheets or leaves. The thick pieces will form three leaves, those which are thin will form only two, whilst young horn, which is only one quarter of an inch thick, will form only one. These plates or leaves must again be put into boiling water, and when they are sufficiently soft, they must be scraped with a sharp cutting instrument, to render those parts that are thick even and uniform; they must be put once more into the boiling water, and finally carried to the press.

At the bottom of the press employed, there must be a strong block, in which is formed a cavity, of nine inches square, and of a proportionate depth; the sheets of horn are to be laid within this cavity, in the following manner: at the bottom, first a sheet of hot iron, upon this a sheet of horn, next again a sheet of hot iron, and so on, taking care to place at the top a plate of iron even with the last. The press must then be screwed down tight.

There is a more expeditious process, at least in part, for reducing the horn into sheets, when it is wanted very even. After having sawed it with a very fine and sharp saw, the pieces must be put into a copper made on purpose, and there boiled until sufficiently soft, so as to be able to be split with pincers; the sheets of horn must then be put in the press where they are to be placed in a strong vice, the chaps of which are of iron and larger than the sheets of horn, and the vice must be screwed as quick and tight as possible; let them cool in the press or vice, or it is as well to plunge the whole into cold water. The last mode is preferable, because the horn does not shrink in cooling. Now draw out the leaves of horn, and introduce other horn to undergo the same process. The horn so enlarged in pressing, is to be submitted to the action of the saw, which ought to be set in an iron frame, if the horn is wanted to be cut with advantage, in sheets of any desired thickness, which cannot be done without adopting this mode. The thin sheets thus produced must be kept constantly very warm between plates of hot iron to preserve their softness; every leaf being loaded with a weight heavy enough to prevent its warping. To join the edges of these pieces of horn together, it is necessary to provide strong iron moulds suited to the shape of the article wanted, and to place the pieces in contact with copper-plates or with polished metal surfaces against them; when this is done, the whole is to be put into a vice and screwed up tight, then plunged into boiling water, and after some time it is to be removed from thence and immersed in cold water. The edges of the horn will be thus made to cement together and become perfectly united.

To complete the polish of the horn, the surface must be rubbed with the subnitrate of bismuth by the palm of the hand. The process is short, and has this advantage, that it makes the horn dry promptly.

When it is wished to spot the horn in imitation of tortoise-shell, metallic solutions must be employed as follows:—To spot it red, a solution of gold in aqua regia must be employed; to spot it black, a solution of silver in nitric acid must be used; and for brown, a hot solution of mercury in nitric acid. The right side of the horn must be impregnated with these solutions, and they will assume the colours intended. The brown spots can be produced on the horn by means of a paste made of red lead, with a solution of potash, which must be put in patches on the horn, and subjected some time to the action of heat. The deepness of the brown shades depends upon the quantity of potash used in the paste, and the length of time the mixture lies on the horn. A decoction of Brazil wood, or a solution of indigo, in sulphuric acid, or a decoction of saffron and Barbary wood may also be used. After having employed these materials, the horn may be left for half a day in a strong solution of vinegar and alum.

In France, Holland, and Austria, the comb-maker and horn-turners use the clippings of horn—which are of a whitish yellow—and tortoise-shell skins, out of which they make snuff-boxes, powder-horns, and many curious and handsome things. They first soften the horn and shell in boiling water, so as to be able to submit them to the press in iron moulds, and by means of heat they form them into one mass. The degree of heat necessary to join the horn clippings must be stronger than that for shell skins, and it can only be found out by experience. The heat must not, however, be too great, for fear of scorching the horn or shell. Considerable care is required in these operations, not to touch the horn with the fingers, or with any greasy body, because the grease will prevent the perfect joining. Wooden instruments should be used to move them, while they are at the fire, and for carrying them to the moulds.

In making a ring of horn for bell-pulls, &c., the required piece is to be first cut out in the flat of its proper dimensions, and nearly in the shape of a horse-shoe; it is then pressed in a pair of dies to give its surface the desired pattern; but previous to the pressure, both the piece of horn and the dies are to be heated; the piece of horn is to be introduced between the dies, squeezed in a vice, and when cold, the impression or pattern will be fixed upon the horn. One particular condition, however, is to be observed in the construction of the dies, for forming a ring. They are to be so made that the open ends of the horse-shoe piece of horn, after being pressed, shall have at one end a nib, and at the other a recess of a dovetailed form, corresponding to each other; and the second operation in forming this ring of horn is to heat it, and place it in another pair of dies, which shall bring its open ends together, and cause the dovetailed joints to be locked fast into each other, which completes the ring, and leaves no appearance of the junction.

In forming the handles of table knives and forks, or other things which require to be made of two pieces, each of the two pieces or sides of the handle is formed in a separate pair of dies; the one piece is made with a counter-sunk groove along each side, and the other piece with corresponding leaves or projecting edges. When these two pieces are formed, by first being cut out of the flat horn, then pressed in the dies in a heated state, for the purpose of giving the pattern, the two pieces are again heated and put together, the leaves or edges of the one piece dropping into the counter-sunk grooves of the other piece, and being introduced between another pair of heated dies, the joints are pressed together and the two pieces formed into one handle.

In making the knobs for drawers which have metal stems or pins to fasten them into the furniture, the face of the knob is to be first made in a die, as above described, and then the back part of the knob with a hole in it; a metal disc plate of iron is next provided, in which the metal stem or screw pin is fixed, and the stem being passed through the aperture in the back piece, and the two, that is, the back and front pieces of horn put together, they are then heated and pressed in dies as above described; the edge of the back piece falling into the counter-sunk groove of the front piece, while by the heat they are perfectly cemented together.

Mr. J. James has contrived a method of opening up the horns of cattle, by which he avoids the risk of scorching or frizzling, which is apt to happen in heating them over an open fire. He takes a solid block of iron, pierced with a conical hole, which is fitted with a conical iron plug, heats them in a stove to the temperature of melting lead, and, having previously cut up the horn lengthwise on one side with a saw, he inserts its narrow end into the hole, and drives the plug into it with a mallet. By the heat of the irons the horn gets so softened, in the course of about a minute, as to bear flatting out in the usual way.

Importation of Horns.

	1871.		1872.	
	Tons	£	Tons	£
Tips and pieces of horn and hoofs . . .	5,700	110,466	6,362	160,490

The largest quantities being from British India, the United States of America, and Australia.

HORNBEAM. The *Carpinus betulus*, sometimes called the yoke-elm. It is a stringy and tough wood, which grows in some parts of Europe, and which is imported from America. It is used by millwrights for the cogs of wheels, also for skittles, and for mallets.

HORNBLENDE. (*Amphibole*, Fr.; *Hornblende*, Ger.) The term *hornblende*, restricted originally to certain dark-coloured lamellar minerals occurring chiefly in syenite and diorite, was afterwards considerably extended in its application, and at present includes a large number of minerals allied to the original hornblendes in crystalline form, and, to a certain extent, in chemical composition; but nevertheless differing widely from the typical hornblendes, not only in colour, density, and other physical characters, but also in their mode of occurrence. The necessity for grouping these minerals together was first recognised by the French crystallographer Haüy, who proposed to name the whole species *amphibole*, and to retain Werner's term *hornblende* only for the common varieties; a nomenclature still frequently adhered to in France.

The typical hornblendes crystallize in forms belonging to the oblique system, and present a perfect prismatic cleavage; whilst other varieties occur in a columnar, fibrous, lamellar, or granular condition. The hardness is tolerably constant, being slightly below that of felspar; but the specific gravity varies with the chemical composition. All the hornblendes are anhydrous silicates of various protoxide-bases, usually lime, magnesia, and protoxide of iron; these bases being capable of replacing one another in chemical combination, without affecting the crystalline form of the compound. Many of the ferruginous varieties contain alumina, the amount of which may rise to upwards of 15 per cent.: the condition in which this compound exists in hornblende is by no means well ascertained, but it is usually supposed to replace the silica, the compounds being thus regarded as silico-aluminates. In many varieties, fluorine occurs to the extent of 2 or 3 per cent., and exists probably as a silico-fluoride of calcium and magnesium. It is interesting to note that certain hornblendes also contain titanic acid.

On the chemical composition of the hornblende depends to a great extent the general character of the mineral; thus, those varieties which contain only lime and magnesia have always a white or very pale colour and a low specific gravity, sometimes not higher than 2·9; while before the blowpipe they fuse to a nearly colourless glass. On the other hand, the ferruginous hornblendes have a dark green or black colour; a much higher density, often reaching 3·4; and are fusible with greater facility, producing a glass more or less deeply coloured. The iron-hornblendes, again, are partially decomposed by hydrochloric acid, which has scarcely any effect on the other varieties. When exceedingly rich in iron, the mineral affects the magnetic needle.

These differences of composition, and the corresponding diversity of physical characters, have given rise to numerous varieties, of which the following are the most important:—

Tremolite, so named from the Swiss valley of Tremola, is a silicate of magnesia and lime, containing silica, 58·87; magnesia, 28·19; lime, 11·00; and alumina, 1·77 = 99·83 (*Rammelsberg*). It occurs usually in slender-columnar or flat-bladed crystals of a white, grey, or pale green colour; and of specific gravity 2·93. The crystals are commonly imbedded in dolomite or granular limestone, as at St. Gothard in Switzerland, and Glen Tilt in Scotland. Other localities are the Tyrol, the Bannat, Wermland in Sweden, New England, Maine, Massachusetts, and other of the United States. Tremolite forms the *Amphibole blanche* of French mineralogists. *Grammatite* and *Calamite* are Swedish varieties, whilst *Raphilite* is a Canadian tremolite, presenting an asbestiform structure. Many of the fibrous hornblendes separate on decomposition into fibres more or less delicate, and thus form varieties of asbestus.

The occasional presence of protoxide of iron in certain tremolites furnishes a passage to the variety of hornblende called *actinolite*—the *actinote* or *Amphibole verte* of the French, the *Strahlstein* (*ray-stone*) of the Germans. It occurs in slender-columnar crystals, often disposed in radiated groups, presenting a high lustre and leek-green or black-green colour. Its specific gravity is about 3. A typical actinolite from the Zillerthal yielded to Rammelsberg's analysis: silica, 55·50; magnesia, 22·56; lime, 13·46; and protoxide of iron, 6·25 = 97·77. Actinolite is found chiefly in talcose schist, serpentine, and other magnesian rocks: in Cornwall it occurs at the Lizard, and at Botallack and other western mines. Among foreign localities may be mentioned Greiner in the Zillerthal, St. Gothard, Salzburg, Sweden, Norway, &c.

Anthophyllite is a grey or clove-brown fibrous or lamellar hornblende, occurring in Norway, Greenland, and the United States. Its composition is silica, 56·74; magnesia, 24·35; protoxide of iron, 14·40; protoxide of manganese, 2·38; and water, 1·67 = 99·54 (*Vopelius*).

Hornblende proper, the *Amphibole noire* of the French, includes the dark-coloured iron-bearing varieties to which the name was originally applied. *Common hornblende* occurs in dark green or black crystals, usually imperfectly formed, and readily distinguished by the silky lustre of its cleavage planes. It forms an essential constituent of syenite, diorite, and hornblende-rock; and occurs as an accessory mineral in many trachytes. The *basaltic hornblende* of Werner includes the black crystallised specimens usually associated with lavas and other volcanic rocks. *Noble hornblende*, or *pargasite*, is a dark green, somewhat translucent mineral, occurring in thick, stout crystals, or in granular masses, embedded in calcareous spar, at Ersby, near Pargas, in Finland. The following is Rammelsberg's analysis of a Pargas hornblende: silica, 41·26; magnesia, 13·49; lime, 11·95; protoxide of iron, 9·92; peroxide of iron, 4·83; alumina, 11·92; potash, 2·70; soda, 1·44; and water, 0·52 = 99·73.

In the hornblende called *arfvedsonite*, soda occurs in considerable quantity, as shown by the following analysis: silica, 51·22; soda, 10·58; protoxide of iron, 7·80; peroxide of iron, 23·75; lime, 2·08; magnesia, 0·90; and potash, 0·68 = 98·13 (*Rammelsberg*). Arfvedsonite is an exceedingly fusible black mineral found in Greenland; and often separated as a distinct species.

The mineral called *uralite*, discovered by the late G. Rose in the greenstones of the Ural range, is commonly regarded as a pseudomorph, since it presents the external form of augite with the cleavage and chemical composition of hornblende; thus establishing a relation between the two minerals. This relation is indeed so intimate that it has been proposed to unite them in one species. Hornblende differs, however, from augite in the angle of the prism obtained by cleavage being much more obtuse; but it has been shown that the two forms are easily derivable the one from the other. Hornblende, again, is more fusible than augite; it has a somewhat lower range in specific gravity; it often contains fluorine, an element which has never been found in augite. Hornblende, moreover, occurs in granitic and other highly-silicated rocks; whilst augite is confined to the more basic rocks, such as basalt; occasionally, however, the two minerals occur together. Experiments on the artificial formation of these minerals have rendered it probable that the same chemical compound may form augite when rapidly cooled from a state of fusion, and hornblende when slowly cooled; indeed, hornblende has been converted into augite by fusion and rapid solidification.

It has been shown by Tschermak, and independently by Mr. Allport, that hornblende may be distinguished from augite in sections of rock examined under the microscope, by the fact that hornblende is dichroic, whilst augite is not: the intensity of the dichroism varies, however, to a great extent in different hornblendes.

The hornblendic minerals, although highly important in a geological point of view, have little or no economic value. Certain Swedish hornblendes have been employed in smelting magnetic ores: and the fibrous varieties known as asbestus have received various applications. See ASBESTUS.—F.W.R.

HORNBLENDE-ROCK. (*Amphibole*, Fr.; *Hornblendfels*, Ger.) A rock, consisting chiefly of crystalline-granular, dark green, or black hornblende, associated commonly, but by no means necessarily, with felspar, quartz, and mica in small quantity. The rock often assumes a schistose structure, and then passes into *Hornblende slate* (*Schiste amphibolithique*, Fr.; *Hornblendschiefer*, Ger.). This slate usually occurs in connection with mica-schist, gneiss, and other metamorphic rocks. When the hornblende belongs to the bright green variety called actinolite, the rock becomes an *actinolite schist*, or *Strahlsteinschiefer* of the Germans. Hornblende also occurs, although to a less extent, in other rocks; such as *syenite* (a granite in which hornblende replaces mica), and *greenstone* and *diorite* (rocks consisting of hornblende and felspar). The *timazite* of Hungary and Transylvania is a trachytic greenstone, containing the peculiar hornblende called *gamisgradite*.

On exposure to atmospheric influences, hornblendic rocks easily decompose; the protoxide of iron passing into the condition of peroxide. Soils resting on such rocks are frequently remarkable for their fertility.

HORN-LEAD, or *Phosgenite*. Native chlorocarbonate of lead. See LEAD.

HORN-QUICKSILVER. Native subchloride of mercury. See CALOMEL.

HORN-SILVER, or *Luna Cornea*. Both these names were given by the alchemists to fused chloride of silver. Horn-silver is found native as kerargyrite. See SILVER.

HORNSTONE. A variety of quartz, resembling flint, but more brittle, and breaking with a more splintery fracture. It sometimes occurs imbedded in limestone. See CHERT.

HORSE. In *mining*, any large isolated mass of rock occurring in a vein, or splitting a vein or seam into two or more parts.

HORSE CHESTNUT. (*Marronnier d'Inde*, Fr.; *Gemeine Rosskastanie*, Ger.) The wood of this well-known tree is used by the Tunbridge turner; otherwise it is only employed for some large varnished works. See HIPPOCASTANUM.

HORSE-FLESH ORE. A Cornish name for purple copper-ore. See COPPER.

HORSE-POWER, in steam-engines, was estimated by Watt at 32,000 lbs. avoirdupois lifted one foot high per minute, for one horse. M. D'Aubuisson, from an examination of the work done by horses in the whims, or gigs (*machines à molettes*) for raising ore from the mines at Freiberg, the horses being of average size and strength, has concluded that the useful effect of a horse yoked during eight hours, by two relays of four hours each, in a manège or mill-course, may be estimated at 40 kilogrammes raised 1 meter per second; which is nearly 16,440 lbs. raised one foot per minute; being very nearly one half of Mr. Watt's liberal estimates for the horse-power of his steam-engines.

Frederick William Simms, M.Inst.C.E., adopted some peculiar conditions of work on which he was engaged to determine the value of *horse*-power. He had to make a tunnel for the South-Eastern Railway. This tunnel was driven in the middle bed of the Lower Greensand, between which and the surface of the ground is interposed only the upper bed of the same stratum; but in sinking the eleven shafts for the work, it was found that at the level of the top of the tunnel, the ground assumed the character of a quicksand, saturated with water, in such quantity that it could not be reduced by manual labour. Under these circumstances horse-gins were erected for drawing the water by barrels, containing 100 gallons each, weighing when full about 1,310 lbs.

The engineer's intention was, to drive simultaneously from these shafts, in the direction of the tunnel, an adit or heading to carry off the water; but the earth, which was sand mixed with fine particles of blue clay, was so filled with water as to become a mass of semifluid mud; great exertions were therefore necessary to overcome the water, without erecting pumps. At first this was accomplished by making each horse work for 12 hours and then for 8 hours per day, allowing 1 hour for food and rest: as the water increased it became necessary to work night and day, and the time of each horse's working was reduced generally to 6 hours, and sometimes to 3 hours. As all the horses were hired at the rate of seven shillings per day, the engineer, who had charge of the works, ordered a daily register to be kept of the actual work done by each horse, for the double purpose of ascertaining whether they all performed their duty, and also hoping to collect a body of facts relative to horse-power which might be useful hereafter.

Mr. Simms gives as a proposition, 'That the proper estimate of horse-power would be that which measures the weight that a horse would draw up out of a well; the animal acting by a horizontal line of traction turned into the vertical direction by a simple pulley, whose friction should be reduced as much as possible.' He states that the manner in which the work was performed, necessarily approached very nearly to these conditions; and after giving the principal dimensions of the horse-gins, he analyses each set of experiments, and by taking the mean of those against which no objections could be urged, he arrives at the following results:—

The power of a horse for 8 hours = 23,412 lbs. raised 1 foot high in one minute.
Do. 6 „ = 24,360 „ „
Do. 4½ „ = 27,056 „ „
Do. 3 „ = 32,943 „ „

Of these results he thinks the experiments for 6 hours and for 3 hours alone should be adopted as practical guides, all the others being in some degree objectionable.

As a means of comparison, the following table of estimates of horse-power is given:—

Name	Pounds raised 1 foot high in a minute	Hours of work	Authority
Boulton and Watt . .	32,000	8	Robinson's Mech. Phil., ii. 145.
Tredgold. . . .	27,500	8	Tredgold on Railroads, p. 69.
Desaguliers . . .	44,000	8	Dr. Gregory's Mathematics for Practical Men, p. 183.
„ . . .	27,500	Not stated	
Saussure	34,020	8	
More, for Society of Arts.	21,120	Not stated	
Smeaton	22,000	„	

These are much higher results than the average of his experiments, and would more nearly accord with the extremes obtained by him; but under such excessive fatigue, the horses were speedily exhausted, and died rapidly. Nearly one hundred horses were employed: they were of good quality; their average height was 15 hands ¼ inch, and their weight about 10½ cwts., and they cost from 20*l.* to 40*l.* each. They had as much corn as they could eat, and were well attended to.

The total quantity of work done by the horses, and its cost, was as under:—

	tons
Registered quantity of water drawn 104 feet, the average height, 28,220,800 gallons	128,535
Do. earth, 3,500 yds. 1 ton 6 cwts. per yard	4,550
Total weight drawn to the surface	133,085

Total cost of horse-labour, including a boy to drive each horse, 1,585*l.* 15*s.* 3*d.*, or 2·86*d.* per ton the average height of 104 ft.

Mr. Palmer made some experiments on the amount of work performed by horses tracking boats on canals. On the upper end of the mast of the boat a pulley was hung; over this the towing rope was passed, with the means of suspending to its extremity given weights, so as exactly to balance the power exerted by the horse.

The results arrived at by these means were so various, that he could not deduce any average conclusions, as the power exerted varied between 30 lbs. and 120 lbs., the power diminishing as the speed was increased. He thought that 2½ miles was too high an average estimate, and that it should not exceed 2 miles per hour, although in all estimates of horse-power, the speed was considered to be at an average of 2½ miles per hour, and all experiments were reduced to that standard.

Mr. Hawkins, some years since, had made numerous inquiries respecting the work done by horses in drawing upon common turnpike-roads, and found that four good horses could draw an ordinary stage-coach, with its complement of passengers, at the rate of 10 miles an hour; that if they ran stages 10 miles in the hour, the horses must rest one day in each week; that good horses, so worked, would last only five years, each horse drawing about half a ton. He had been informed by waggoners, that good horses would walk at the rate of 2½ miles per hour, for 12 hours out of 24, making 30 miles a day; and that they would continue to do such work day by day, each horse drawing 1 ton, for many years, provided they had not been worked hard when young.

It is desirable to know the average speed at which the different rates of work had been performed; this was essential in order to found any calculation upon the results given. Coach proprietors calculated that at a speed of 10 miles per hour, a horse was required for every mile going and returning, so that one horse was kept for every mile of road. Now supposing a four-horse coach, with an average load, to weigh 2 tons, the load for each horse was 10 cwts.; whereas in the case of a horse drawing a cart, the gross load frequently amounted to 2 tons, but the speed was reduced to 2½ miles per hour, at which pace he conceived that 16 miles per day might be considered a fair day's work; this therefore was double the distance with four times the load, or eight times the coach-work, but with a heavier horse.

The law that the quantity of work done was as the square root of the velocity,—or as the cube root of the velocity, in equal times,—is confined to work upon canals, or bodies moving through the water.

Mr. Rennie had tried some experiments on the force of traction of the boats on the Grand Junction Canal. The towing rope was attached to a dynamometer, which had previously been tested by weights.

The horse, although urged at first starting, was afterwards allowed to fall into his natural speed, which was 2½ miles per hour on the average of 20 miles. The maximum speed was 4 miles, and the minimum 2 miles, per hour. The dynamometer indicated an average of 108 lbs., which was capable of overcoming the resistance of the loaded barge of 25 tons, being in the ratio of 15·00. The weight of the horse was about 11 cwts.

He also tried many experiments upon a fast boat, lent to him in 1833 by the late Colonel Page. These experiments were principally made in order to ascertain the comparative resistance of vessels moving through water at different velocities, and the Grand Junction Canal afforded a convenient opportunity of undertaking them.

The boat was 70 feet in length, 4 feet in breadth, and drew 9 inches in water.

The traction indicated by the dynamometer the following resistance:—

Miles per hour		lbs.
At 2½	the resistance was	20
3	„	27
3½	„	30
4	„	50
4½	„	60
5	„	70 to 75

One horse was employed in these experiments.

Miles per hour		lbs.
At 6	the resistance was	97 to 214
7	„	250
8	„	336
9·69	„	411
10	„	375
11¼	„	392
	Average	336

Two horses were employed in these experiments.

Stakes were fixed near the margin of the canal, so as to ascertain the rise and fall of the wave caused by the boat in passing; and it was observed that when a boat passed with a velocity of from 4 to 6 miles per hour, the rise of the wave was 5 inches and the fall 5 inches, making a wave of 10 inches in depth; and when the velocity was 11¼ miles, the rise was reduced to 2½ inches and the fall to 2½ inches.

Great difference existed in the power of horses, their weights and structure; and the large dray-horses used by Messrs. Barclay, Perkins, and Co. did a full average duty as assumed by Boulton and Watt; but considering the average power of strong and weak animals, he had adopted 22,000 lbs. raised 1 foot high as the standard: much, however, depended on the nature of the work performed.

Mr. Davidson has given the following statement of the work performed by a London brewer's horse per day; the cost of feed and of wear and tear per horse per annum being derived from actual experience among a large number of horses at Messrs. Truman, Hanbury, and Co.'s brewery. The feed, &c., is supposed to have cost the same per quarter, per truss, &c., each year:—

Years	Pounds weight drawn 6½ miles per horse per day	Pounds weight drawn 6½ miles per horse returning per day	Average pounds weight drawn 13 miles per horse per day	Cost of feed and straw per horse per annum			Difference per horse of horses bought and sold per annum		
	lbs.	lbs.	lbs.	£	s.	d.	£	s.	d.
1835	5,148	1,716	3,342	43	2	7	10	0	3
1836	5,072	1,767	3,389	43	16	6	9	18	0
1837									
1838	5,057	1,698	3,377	41	18	0	9	15	9
1839	5,287	1,740	3,513	42	9	11	9	7	1
1840	5,786	1,820	3,803	46	11	7	7	17	11
1841	5,311	1,750	3,530	45	0	1	10	16	11
1842	5,263	1,740	3,501	47	0	9	10	8	0
Total	36,924	12,171	24,455	309	19	5	68	3	11
Average 7 yrs. nearly	5,275	1,738	3,506	44	5	7	9	14	10

Mr. Beardmore mentions a case which occurred in a work near Plymouth, which he believed would give the fair value of the work actually performed daily by a horse for a considerable period.

A quarry-waggon, weighing 2½ tons, carrying an average load of stone of 5¾ tons, was drawn by one horse along a railway 960 feet in length, 260 of it being level, and the remaining 700 feet having an inclination of 1 in 138. During 48 working days the number of trips was 1,302, or an average of 27·1 trips each day; the time of performing each trip was 4 minutes, or at a speed of 2·72 miles per hour; and the total weight drawn, including that of the waggons, was 23,959,600 lbs.

Repeated experiments proved, that upon the incline of 1 in 138 the waggons in their ordinary working state would just remain stationary; the friction was therefore assumed to be 16·2 lbs. per ton; by calculation it was found that the horse raised 39,320 lbs. 1 foot high per minute during the 8 working hours each day: the useful effect, or net amount of stone carried, being 21,738 lbs. raised 1 foot high per minute. This difference between the work done and the useful effect arose from the necessary strength and weight of the waggons.

The animal employed was a common Devonshire cart-horse, 8 years old, 15 hands high, and weighed 10¾ cwts.; he continued doing the same work throughout a whole summer, remaining in good condition; but a lighter horse was found unequal to it.

Prof. Rankine defined horse-power in a somewhat different form. 'The *power* of a machine is the energy exerted, and the *effect* the useful work performed in some interval of time of definite length, such as a second, a minute, an hour, or a day.' There is a peculiar unit of power appropriated to its expression, called a HORSE-POWER, which is in Britain—

550 foot-pounds per second,
or 33,000 foot-pounds per minute,
or 1,980,000 foot-pounds per hour.

In France the terms *Force de Cheval* or *Cheval-Vapeur* is applied to the following rate of work:—

Foot-pounds
73 kilogrammètres per second = $542\frac{1}{2}$
or 4,500 kilogrammètres per minute = 32,549
or 270,000 kilogrammètres per hour = 1,952,948,

being about one-seventieth part less than the British horse-power.

This is also called an *actual* or *real* horse-power, to distinguish it from a *nominal* horse-power.

Nominal Horse-power is a conventional mode of describing the dimensions of a steam-engine, for the convenience of makers and purchasers of engines, and bears no fixed relation to *indicated* or to *effective* horse-power. The mode of computing nominal horse-power, established amongst Civil manufacturers of steam-engines by the practice of Boulton and Watt, is as follows:—

Assume the velocity of the piston to be 128 feet per minute × cube root of length of stroke in feet. Assume the mean effective pressure to be seven pounds on the square inch.

Then compute the horse-power from these fictitious data, and the area of the piston; that is to say,

$$\text{Nominal H. P.} = 7 \times 128 \times \sqrt[3]{\text{stroke in feet}}$$

$$\times \text{ area of piston in square inches} \div 33{,}000$$

$$= \frac{\sqrt[3]{\text{stroke in feet}} \times \text{area of piston in inches}}{47 \text{ nearly}}$$

$$= \frac{\sqrt[3]{\text{stroke in feet}} \times \text{diam.}^2 \text{ in inches}}{60}$$

The indicated power of different engines usually exceeds the nominal power as computed by the above rule in proportions ranging from $1\frac{1}{2}$ to 5.

In the rule established by the *Admiralty* for computing nominal horse-power, the *real velocity of the piston* is taken into account; but the *fictitious effective power* of seven pounds on the square inch is assumed consequently by the Admiralty rules.

$$\text{Nominal H. P.} = \text{velocity of piston in feet per minute}$$

$$\times \text{ area of piston in inches} \times 7 \div 33{,}000$$

$$= \frac{\text{velocity in feet per min.} \times \text{diam.}^2 \text{ in inches}}{6{,}000}$$

The indicated power of marine engines ranges from *once* to *three times*, and is on an average about *twice* the nominal power as computed by the Admiralty rule.

Both the Civil rule and the Admiralty rule for computing the power of engines are applicable to low-pressure engines alone. For high-pressure engines there is a customary rule proposed by Mr. Bourne, which consists in assuming the effective pressure to be 21 pounds per square inch, the other data being the same as in the rule for low-pressure engines. See Rankine's 'Manual of the Steam Engine and other Prime Movers.'

HORSE-RADISH. The root of *Cochlearia Armoracia*, eaten as a condiment. For the distinctions between the roots of horse-radish and monkshood, see Aconite.

HORSESHOES. The ordinary method of making these is well known. There has, however, been introduced with much success a machine for making horseshoes; and one of these machines has been erected at Chillington Ironworks, Wolverhampton, by the inventor, Mr. Henry Burden, of Troy, New York. As early as 1835 he took out a patent for a machine for making horseshoes, which he improved upon in 1843, and this was turned to practical account by the production of a considerable number of horseshoes. The present machine, however, which was patented in 1857, is entirely different from the former ones, and is a very remarkable piece of mechanism. In the previous machines the piece of iron bar of which the shoe was to be made was rolled into shape before being bent, and the pressure of the rollers being in the direction of its length, the bar, when it was pressed, was naturally rather extended in length than width, and the widening which is required at the crown of the shoe was not properly effected. By the present plan the bar, after being heated, enters the machine by a feeding apparatus, a piece of the required length is cut off, and, by a stroke from a piece of steel, shaped like the inside of a horseshoe, is bent, and falls upon a die on a wheel beneath, corresponding to one on a cylinder above, and thus acquires by pressure the desired shape, two lateral strikers at the same moment hitting the extremities, or heels, of the shoe, and driving them inwards into the required shape. Thence it passes between another pair of dies, where it is stamped, and by an ingenious arrangement is flattened from the curled shape which the wheel gives it as it falls at the mouth of the machine. The shoes thus made are remarkable for their exactness in shape and in the position of the holes—a most important point with regard to the safety of horses' feet; and they can be produced, when the machine is in proper order, at the rate of 60 per minute, which is more than two men can forge in a day; their superiority over shoes forged by hand is very striking. As the bar is bent before being pressed in the die, the pressure at the crown is in the direction of the width, and hence the widening is readily effected.

HOSIERY. (*Bonneterie*, Fr.; *Strumpfweberei*, Ger.) The *stocking-frame*, which is the great implement of this business, though it appears at first sight to be a complicated machine, consists merely of a repetition of parts easily understood, with a moderate degree of attention, provided an accurate conception is first formed of the nature of the hosiery fabric. This texture is totally different from the rectangular decussation which constitutes cloth, as the slightest inspection of a stocking will show; for this, instead of having two distinct systems of thread, like the warp and the weft, which are woven together by crossing each other at right angles, the whole piece is composed of a single thread united or looped together in a peculiar manner, which is called stocking-stitch, and sometimes chain-work.

This is best explained by the view in *fig.* 1153. A single thread is formed into a number of loops or waves, by arranging it over a number of parallel needles, as shown at R; these are retained or kept in the form of loops or waves, by being drawn or looped through similar loops or waves formed by the thread of the preceding course of the work, S. The fabric thus formed by the union of a number of loops is easily unravelled, because the stability of the whole piece depends upon the ultimate fastening of the first end of the thread; and if this is undone, the loops formed by that end will open, and release the subsequent loops one at a time, until the whole is unravelled, and drawn out into the single thread from which it was made. In the same manner, if a thread in a stocking-piece fails, or breaks at any part, or drops a stitch, as it is called, it immediately produces a hole, and the extension of the rest can only be prevented by fastening the end. It should be observed that there are many different fabrics of stocking-stitch for various kinds of ornamental hosiery, and as each requires a different kind of frame or machine to produce it, we should greatly exceed our limits to enter into a detailed description of them all. That species which we have represented in *fig.* 1154 is the common stocking-stitch used for plain hosiery, and is formed by the machine called the common stocking-frame, which is the groundwork of all the others. The operation, as we see, consists in drawing the loop of a thread successively through a series of other loops, so long as the work is continued, as is very plainly shown for one stitch in *fig.* 1155.

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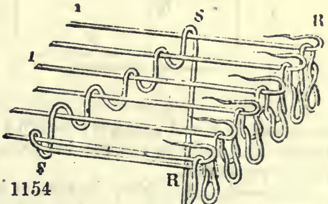
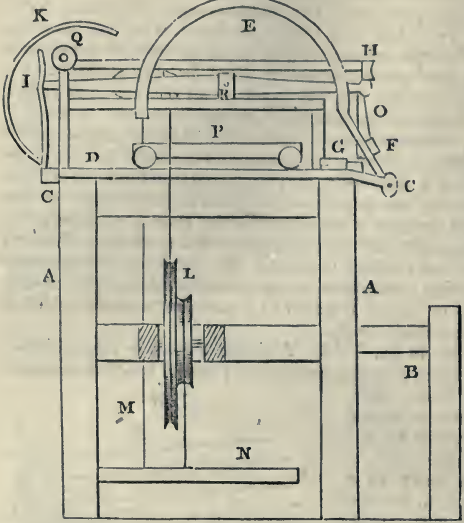


1154

The first kind of frame, which forms the foundation of all the others, is that for knitting plain hosiery, or the common stocking-frame.

Of this valuable machine, the invention of Mr. Lee of Cambridge, a side elevation is given in *fig.* 1155, with the essential parts. The framing is supported by four upright posts, generally of oak, ash, or other hard wood. Two of these posts appear at A A, and the connecting cross rails are at C C. At B is a small additional piece of framing, which supports the hosier's seat. The iron-work of the machine is bolted or screwed to the upper rails of the framework, and consists of two parts. The first rests upon a sole of polished iron, which appears at D, and to which a great part of the machinery is attached. The upper part, which is generally called the carriage, runs upon the iron sole at D, and is supported by four small wheels or trucks, as they are called by the workmen. At the upper part of the back standard of iron are joints, one of which appears at Q; and to these is fitted a frame, one side of which is seen extending to H. By means of these joints the end at H may be depressed by the hosier's hand, and it returns, when relieved, by the operation of a strong spring of tempered steel, acting between a cross bar in the frame, and another below. The action of this spring is very apparent in *fig.* 1156. In the front of the frame, immediately opposite to where the hosier sits, are placed the needles which form the loops. These needles, or rather hooks, are more or less numerous, according to the coarseness or fineness of the stocking; and this, although unavoidable, proves a very considerable abatement of the value of a stocking-frame. In almost every other machine (for example, those employed in spinning or weaving), it is easy to adapt any one either to work coarser or finer work, as it may be wanted. But in the manufacture of hosiery, a frame once finished, is limited for ever in its operation to the same quality of work, with this exception, that by changing the stuff, the work may be made a little more dense or flimsy; but no alteration in the size or quantity of loops can take place. Hence where the manufacture is extensively prosecuted, many frames may be thrown idle by every vicissitude of demand; and where a poor mechanic does purchase his own frame he is for ever limited to the same kind of work. The gauge, as it is called, of a stocking-frame is regulated by the number of loops contained in three inches of breadth, and varies very much; the coarsest frames in common use being about what are termed Fourteens, and the finest employed in great extent about Forties. The needles are of iron wire, the manufacture of which is very simple; but long practice in the art is found necessary before a needle-maker acquires the dexterity which will enable him both to execute his work well, and in sufficient quantity to render his labour productive.

1155



The process of making the needles is as follows:—Good sound iron wire, of a proper fineness, is to be selected; that which is liable to split or splinter, either in filing, punching, or bending, being totally unfit for the purpose. The wire is first to be cut into proper lengths, according to the fineness of the frame for which the needles are designed, coarse needles being considerably longer than fine ones. When a sufficient number (generally some thousands) have been cut, the wire must be softened as much as possible. This is done by laying them in rows in a flat iron box, about an inch deep, with a close cover; the box being filled with charcoal between the strata of wires. This box, being placed upon a moderate fire, is gradually heated until both the wires and charcoal have received a moderate red heat, because, were the heat increased to what smiths term the white heat, the wire would be rendered totally unfit for the subsequent processes which it has to undergo, both in finishing and working. When the box has been sufficiently heated, it may be taken from the fire, and placed among hot ashes until both ashes and box have gradually cooled; for the slower the wires cool, the softer and easier wrought they will be. When perfectly cool, the next process is to punch a longitudinal groove in the stem of every needle, which receives the point or barb, when depressed. This is done by means of a small engine worked by the power of a screw and lever. The construction of these engines is various; but a profile elevation of one of the most simple and commonly used will be found in *fig.* 1156. It consists of two very strong pieces of malleable iron, represented at A and C, and these two pieces are connected by a strong well-fitted joint at B. The lower piece, or sole of the engine at C, is screwed down by bolts to a strong board or table, and the upper piece A will then rise or sink at pleasure, upon the joint B. In order that A may be very steady in rising and sinking, which is indispensable to its correct operation, a strong bridle of iron, which is shown in section at E, is added to confine it, and direct its motion. In the upper part of this bridle is a female screw, through which the forcing screw passes, which is turned by the handle or lever D. To the sole of the engine C is fixed a bolster of tempered steel, with a small groove to receive the wire which is to be punched; and in the upper or moving part A, is a sharp chisel, which descends exactly into the groove, when A is depressed by the screw. These are represented at F, and above H. At G is a strong

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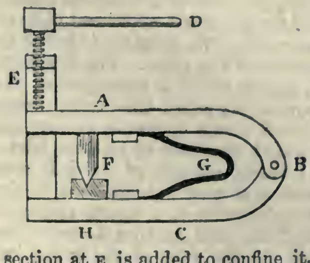

spring, which forces up the chisel when the pressure of the screw is removed. The appearance of the groove, when the punching is finished, will be rendered familiar by inspecting *fig.* 1162, p. 817. When the punching is finished, the wires are to be brought to a fine smooth point by filing and burnishing, the latter of which should be very completely done, as, besides polishing the wire, it tends greatly to restore that spring and elasticity which has been removed by the previous operation of softening. The wire is next to be bent, in order to form the hook or barb; and this is done with a small piece of tin plate bent double, which receives the point of the wire, and by its breadth regulates the length of the barb. The stem of the needle is now flattened with a small hammer, to prevent it from turning in the tin socket in which it is afterwards to be cast; and the point of the barb being a little curved by a pair of small plyers, the needle is completed.

In order to fit the needles for the frame, they are now cast into the tin sockets or leads as they are called by the workman; and this is done by placing the needles in an iron mould, which opens and shuts by means of a joint, and pouring in the tin while in a state of fusion. In common operations, two needles are cast into the same socket. The form of the needle, when complete and fitted to its place in the frame, will be seen in *fig.* 1157, which is a profile section of the needle-bar exhibiting one needle. In this figure a section of the pressure is represented at F; the needle appears at G, and the socket or level at K. At H, is a section of the needle-bar, on the fore part of which is a small plate of iron called a verge, to regulate the position of the needles. When placed upon the bar resting against the verge, another plate of iron, generally lined with soft leather, is screwed down upon the sockets or leads, in order to keep them all fast. This plate and the screw appear at I. When the presser at F is forced down upon the barb, this sinks into the groove of the stem, and the needle is shut; when the presser rises, the barb opens again by its own elasticity.

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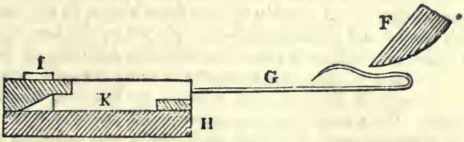

The needles or hooks being all properly fitted, the next part of the stocking-frame to which attention ought to be paid, is the machinery for forming the loops; and this consists of two parts. The first of these, which sinks between every second or alternate needle, is represented at O, *fig.* 1155, and is one of the most important parts of the whole machine. It consists of two moving parts; the first being a succession of horizontal levers moving upon a common centre, and called jacks, a term applied to vibrating levers in various kinds of machinery as well as the stocking-frame. One

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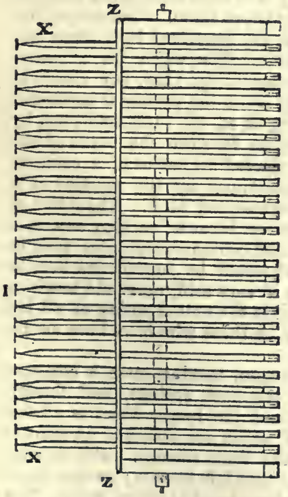

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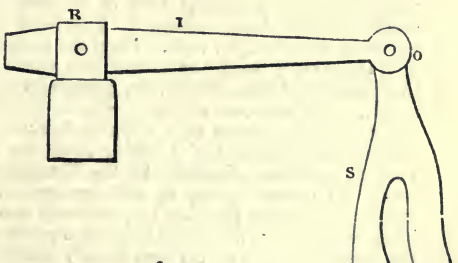

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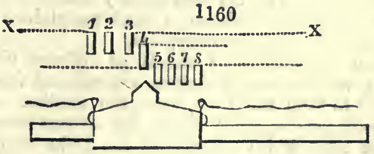

only of these jacks can be represented in the profile *fig.* 1155; but the whole are distinctly shown in a horizontal position in *fig.* 1158; and a profile upon a very enlarged scale is given in *fig.* 1159. The jack shown in *fig.* 1155, extends horizontally from O to I, and the centre of motion is at R. On the front, or right hand of the jack at O, is a joint suspending a very thin plate of polished iron, which is termed a sinker. One of these jacks and sinkers is allotted for every second or alternate needle. The form of the sinker will appear at S, *fig.* 1159; and in order that all may be exactly uniform in shape, they are cut out and finished between two stout pieces of iron, which serve as moulds or gauges to direct the frame-smith. The other end of the jack at I, is tapered to a point; and when the jacks are in their horizontal position, they are secured by small iron springs, one of which is represented at I, *fig.* 1155, each spring having a small obtuse-angled notch to receive the point of the jack, against which it presses by its own elasticity. In *fig.* 1159, the centre is at R, the pointed tail is omitted for want of room, the joint is at O, and the throat of the sinker, which forms the loop, is at S. The standards at R, upon which the jack moves, are called combs, and consist of pieces of flat smooth brass, parallel to, and equidistant from each other. The cross bar R, which contains the whole, is of iron, with a perpendicular edge or rim on each side, leaving a vacancy between them, or a space to receive the bottom part or tails of the combs. The combs are then placed in the bar, with a flat piece of brass called a countercomb, between each, to ascertain and preserve their distances from each other. These countercombs are exactly of the same shape as the combs, but have no tails. When both combs and countercombs are placed in the bar, it is luted with clay so as to form a mould, into which is poured a sufficient quantity of melted tin. When the tin has had time to cool, the countercombs having no tails are easily taken out, and the combs remain well fastened and secured by the tin, which has been fused entirely round them. Thus they form a succession of standards for the jacks; and a hole being drilled through each jack and each comb, one polished wire put through serves as a common centre for the whole.

The jack sinkers being only used for every alternate or second needle, in order to complete this part of the apparatus, a second set of sinkers is employed. These are, in form and shape, every way the same as the jack sinkers, but they are jointed at the top into pieces of tin, all of which are screwed to the sinker bar, H, *fig.* 1155; and thus a sinker of each kind descends between the needles alternately. By these sinkers the loops are formed upon all the needles, and the reason of two sets different in operation being employed, will be assigned in describing the mode of working the frame. The presser of the operation, of which something has already been said, appears at F; and of the two arms which support and give motion to it, one appears very plainly at E, its centre of motion being at C. The circular bend given to these arms, besides having an ornamental effect, is very useful, in order to prevent any part from interfering with the other parts which are behind, by elevating them entirely above them. The extremities of these arms at the termination of the bends behind, are connected by a cross bar, which has also a circular bend in the middle, projecting downwards for a reason similar to that already assigned. This bend is concealed in *fig.* 1155, but visible in the front elevation, *fig.* 1161. From the middle of the bend, the presser is connected with the middle treadle by a depending wire, appearing at M, *fig.* 1155, and thus, by the pressure of that treadle, the presser is forced down to close the barbs of the needle. The re-ascent of the presser is sometimes effected by means of a counterpoising weight passing over a pulley behind; and sometimes by the reaction of a wooden spring, formed of a strong hoop like that represented at K. The latter of these is preferred, especially by the Nottingham hosiers, because, as they assert, it makes the presser spring up with greater rapidity, and consequently saves time in working. How far this may be practically the case, it would be superfluous here to investigate; but it is obvious that the wooden spring, if very stiff, must add much to the hosier's exertion of his foot, already exercised against the united spring of all his barbs; and this inconvenience is much complained of by those who have been accustomed to work with the counterpoise.

At L are two pulleys or wheels, of different diameters, moving upon a common centre, by which the jack-sinkers are relieved from the back springs, and thrown downwards to form the loops upon the needles. About the larger wheel is a band of whipcord, passing twice round, the extremities of which are attached to what is called the slur, which disengages the jacks from the back springs. The smaller pulley, by another band, communicates with the right and left treadle; so that these treadles, when pressed alternately, turn the pulleys about in an inverted order. The directions of these bands also appear more plainly in the front elevation, *fig.* 1161. The construction of the slur, and its effect upon the jacks, will also be rendered apparent by *fig.* 1160. In this figure, eight jacks are represented in section, the tail part of three of which, 1, 2, 3, are thrown up by the slur in its progress from left to right; the fourth is in the act of rising, and the remaining four, 5, 6, 7, and 8, are still unacted upon, the slur not yet having reached them. As the slur acts in the direction of the dotted line x x, *fig.* 1160, behind the centres of the jacks, it is hardly necessary to remark, that this forcing-up of the tails must of course depress the joints by which the sinkers in front are suspended; the jack sinkers falling successively from the loops on every alternate needle, in the way represented at *fig.* 1163, where both kinds of sinkers appear in section, the light part expressing what is above the point at which the throat of the sinker operates upon the thread, and the dark part what is below. The second set, or, as they are called, the lead sinkers, from the manner of joining them, and suspending them from the bar above, appear still elevated; the position of the bar being represented by the line, A B. But when these are pulled down to the level of the former by the operator's hands, the whole looping will be completed, and the thread C D, which is still slack, will be brought to its full and proper degree of tension, which is regulated by top screws, so as to be tempered or altered at pleasure. The sinking of this second set of sinkers may be easily explained by *fig.* 1164. The direction of the sinkers is expressed by the line E; the bar from which they are suspended will be at A; the top frame is in the direction from A to B; the back standards at D; and the joint at B, is the centre of motion. If E is pulled perpendicularly downwards, the spring C will be contracted, and its upper extreme point, G, will be brought nearer to its lower extreme point F, which is fixed. Again, when the force which has depressed E is removed, the spring C will revert to its former state, and the sinkers will rise. The raising of the jack sinkers and jacks takes place at the same time, by the hosier raising his hands; and for the cause of this we must revert to *fig.* 1158. The lead sinkers in rising lay hold of notches, which raise the extreme parts of the set of jacks z, z, which are called half-jacks. Between the extremities of these at z z, is a cross bar, which, in descending, presses all the intermediate jacks behind the common centre, and restores them to their original posture, where they are secured by the back springs, until they are again relieved by the operation of the slur recrossing at the next course.

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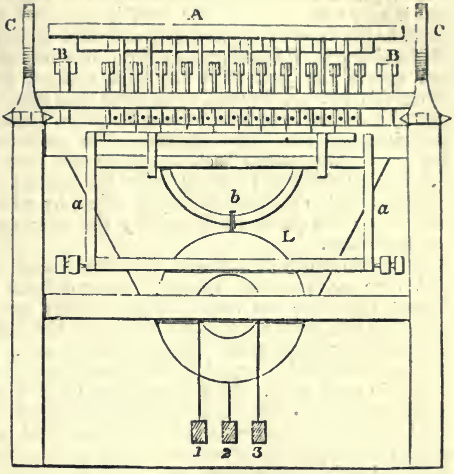

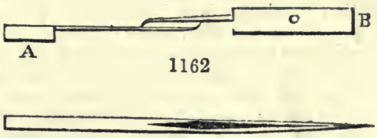

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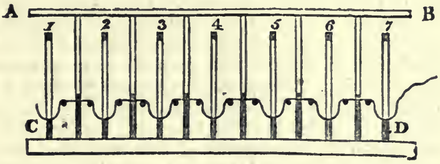

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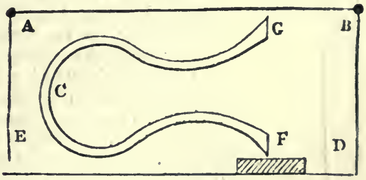


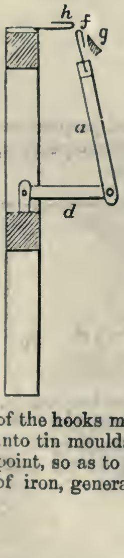
Working of the Frame.—In order to work a frame, the whole apparatus being previously put into complete order, the hosier places himself on the seat B in front, and provides himself with a bobbin of yarn or stuff. This bobbin he places loosely on a vertical pin of wire, driven into one side of the frame contiguous to the needles, so that it may turn freely as the stuff is unwound from it. Taking the thread in his hand, he draws it loosely along the needles, behind the barbs, and under the throats of the sinkers. He then presses down one of the treadles to pass the slur along, and unlock the jack from the back springs, that they may fall in succession. When this is done, the number of loops thus formed is doubled by bringing down the lead sinkers, and the new formed loops are lodged under the barbs of the needles by bringing forward the sinkers. The preceding course, and former fabric, being then again pushed back, the barbs are shut by depressing the middle treadle, and forcing down the presser upon the needles. The former work is now easily brought over the shut needles, after which, by raising the hands, both sets of sinkers are raised; the jacks are locked by the back springs, and the hosier goes on to another course.

From this it will be apparent, that the remark made in the outset is well founded, that there are in reality no complicated or difficult movements in the stocking-frame. Almost the whole are merely those of levers moving upon their respective fulcra, excepting that of the carriage which gives the horizontal motion to the sinkers, and that is merely an alternate motion on four wheels. Yet the frame is a machine which requires considerable experience and care, both to work it to advantage, and also to keep it in good order. This circumstance arises greatly from the small compass in which a number of moving parts must be included. Owing to this, the needles, unless cautiously and delicately handled, are easily bent or injured. The same circumstance applies with equal or greater force to the sinkers, which must be so very thin as to be easily injured. But as these must work freely, both in a perpendicular and horizontal direction between the needles, in a very confined and limited space, the slightest variation in either, from being truly and squarely placed, unavoidably injures the others. When a hosier, either ignorant of the mechanical laws of their relation to each other, or too impatient to wait for the assistance of another, attempts to rectify defects, he in most cases increases them tenfold, and renders the machine incapable of working at all, until repaired by some more experienced person. This circumstance has given rise to a set of men employed in this trade, and distinguished by the name of upsetters; and these people, besides setting new frames to work, have frequently more employment in repairing old ones injured by want of care or skill.

It seems unnecessary to go further into detail respecting a machine so well known, and which requires practical attention even more than most others. It may, therefore, be sufficient to describe shortly some of its varieties, the most simple and common of which is the rib stocking-frame.

Rib stocking-frame.—This frame, which, next to the common frame, is most extensively in use, is employed for working those striped or ribbed stockings, which are very common in all the different materials of which hosiery is formed. In principle it does not differ from the common frame, and not greatly in construction. The preceding general description will nearly apply to this machine with equal propriety as to the former; that part, however, by which the ribs or stripes are formed is entirely an addition, and to the application of this additional machinery it may be proper to pay the chief attention, referring chiefly to *fig.* 1161, which is a front elevation. This figure has been already referred to for the illustration of those parts of the machinery which are common to both, and those parts therefore require no recapitulation. The principle of weaving ribbed hosiery has considerable affinity to that of weaving that kind of cloth which is distinguished by the name of tweeling, for the formation of stripes, with some variation arising merely from the different nature of the fabric. In cloth-weaving, two different kinds of yarn intersecting each other at right angles, are employed; in hosiery only one is used. In the tweeling of cloth, striped as dimity, in the cotton or kerseymere, and in the woollen manufacture, the stripes are produced by reversing these yarns. In hosiery, where only one kind of yarn is used, a similar effect is produced by reversing the loops. To effect this reversing of the loops, a second set of needles is placed upon a vertical frame, so that the bends of the hooks may be nearly under those of the common needles. These needles are cast into tin moulds, pretty similar to the former, but more oblique or bevelled towards the point, so as to prevent obstructions in working them. They are also screwed to a bar of iron, generally lighter than the other, and secured by means of plates: this bar is

1165



not fixed, but has a pivot in each end, by means of which the bar may have a kind of oscillatory motion on these pivots. Two frames of iron support this bar; that in which it oscillates being nearly vertical, but inclined a little towards the other needles. *Fig.* 1165, which is a profile elevation, will serve to illustrate the relative position of each bar to the other. The lower or horizontal frame, the ends only of which can be seen in *fig.* 1161, under *a a*, appears in profile in *fig.* 1165, where it is distinguished by *d*. The vertical frame at *a* is attached to this by two centre-screws, which serve as joints for it to move in. On the top of this frame is the rib-needle bar at *f*, in *figs.* 1155 and 1165, and one needle is represented in *fig.* 1165 at *f*. At *g* is a small presser, to shut the barbs of the rib-needles, in the same manner as the large one does those of the frame. At *h* is one of the frame needles, to show the relative position of the one set to the other. The whole of the rib-bar is not fitted with needles like the other; for here needles are only placed where ribs or stripes are to be formed, the intervals being filled up with blank leads, that is to say, with sockets of the same shape as the others, but without needles; being merely designed to fill the bar and preserve the intervals. Two small handles depend from the needle bar, by which the oscillatory motion upon the upper centres is given. The rising and sinking motion is communicated to this machine by chains which are attached to iron sliders below, and which are wrought by the hosier's heel when necessary. The pressure takes place partly by

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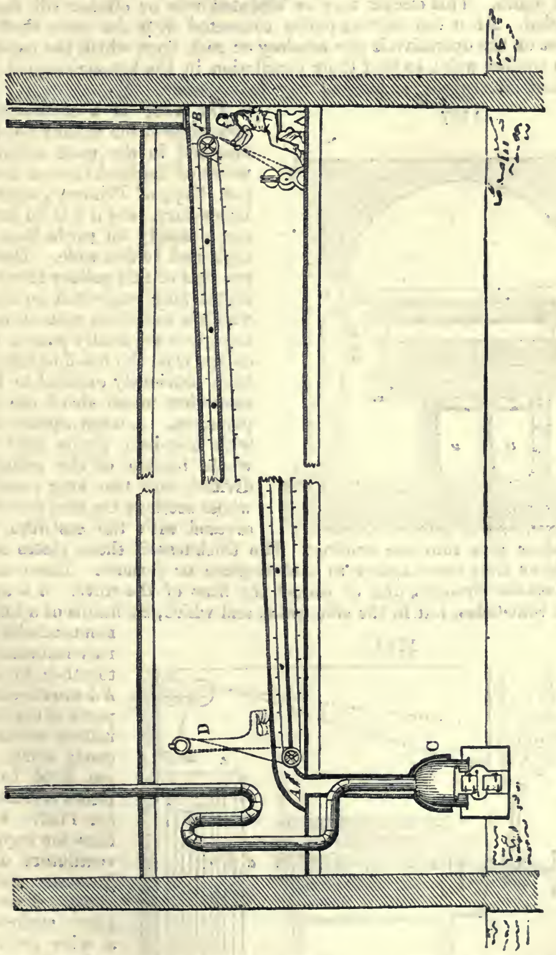

the action of the small presser, and partly by the motion of the needles in descending. A small iron slider is placed behind the rib-needles, which rises as they descend, and serves to free the loops perfectly from each other.

In the weaving of ribbed hosiery, the plain and ribbed courses are wrought alternately. When the plain are finished, the rib-needles are raised between the others, but no additional stuff is supplied. The rib-needles intersecting the plain ones, merely lay hold of the last thread, and, by again bringing it through that which was on the rib-needle before, give it an additional looping, which reverses the line of chaining, and raises the rib above the plain intervals, which have only received a single knitting.

HOT BLAST. See Iron.

HOT-FLUE is the name given in England to an apartment heated by stoves or steam-pipes, in which padded and printed calicoes are dried hard. *Fig.* 1166 represents the simplest form of such a flue, heated by the vertical round iron stove c, from whose top a wide square pipe proceeds upwards in a slightly-inclined direction, which receives the current of air heated by the body and capital of the stove. In this wide channel there are pulleys, with cords or bands which suspend by hooks and conduct the web of calico from the entrance at B, where the operative sits, to near the point A, and back again. This circuit may be repeated once or oftener till the goods are perfectly dried. At D the driving-pulley connected with the main shaft is shown. Near the feet of the operative is the *candroy* or reel, upon which the moist goods are rolled in an endless web; so that their circulation in the hot-air channel can be continued without interruption as long as may be necessary.

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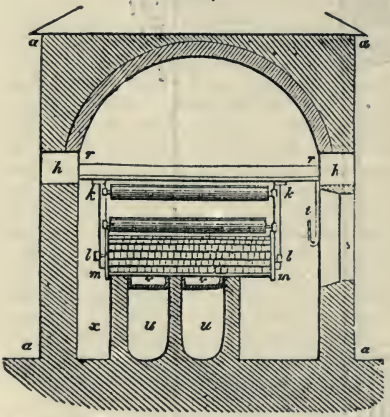

Fig. 1167 is a cross-section of the apparatus of the regular hot-flue, as it is mounted in the most scientific calico-works of England, those of James Thomson, Esq., of Primrose, near Clitheroe, Lancashire, *a a a a* is an arched apartment, nearly 30 yards long, by 13 feet high, and 10 feet wide. Through about one half of this gallery there is a horizontal floor supported on arches, above which is the driest space, through which the goods are finally passed before they escape from the hot-flue, after they have been previously exposed to the hot but somewhat moist air of the lower compartment. A large square flue covered with cast-iron plates runs along the whole bottom of the gallery. It is divided into two long parallel vaults, whose sections are seen at *u u*, *fig.* 1167, covered with the cast-iron plates *v v*, grooved at their ends into one another. The thickness of these plates is increased progressively as they come nearer to the fireplace or furnace. There are dampers which regulate the draught, and of course the heat of the stove. *h h* are the air-passages or vent-holes, left in the side walls, and which, by means of a long iron rod mounted with iron plates, may be opened or closed together to any degree. *k k* are the cast-iron supports of the tinned brass rollers which guide the goods along, and which are fixed to the cross pieces represented by *r r*, *fig.* 1167. *l l* are iron bars for supporting the ventilators or fans (see Foundry and Ventilation). These fans are here enclosed within a wire grating. They make about 300 turns per minute, and expel the moist air with perfect effect. *s* indicates the position of the windows, which extend throughout the length of the building. *t* is a

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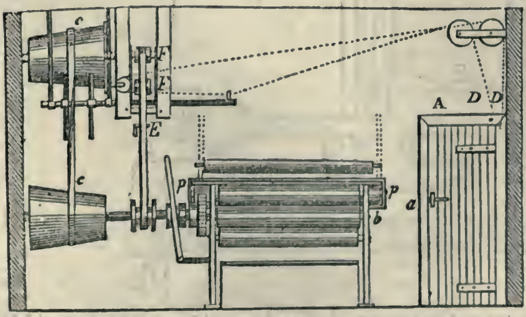

gas-light jet, placed at the side of each window to supply illumination for night-work.

The piece is stretched along the whole extent of the gallery, and runs through it in the course of one minute and a half; being exposed during its passage to the heat of 212° Fahr.

In *fig.* 1168, A is the iron door of entrance to the hot-flue gallery; at *b* is the padding-machine, where the goods are imbued with the general mordant. The speed of this machine may be varied by means of the two conical drums *c c*, which drive it; since when the band *c c* is brought by its forks and adjusting screws nearer to the narrow end of the lower drum, the cylinder upon the main shaft with the latter is driven quicker; and *vice versâ.* Over D D the cords are shown for drawing the drum mechanism into gear with the main-shaft band, F, F, E; or for throwing it out of gear. The pulleys F F carry the bands which transmit the motion to the padding machine. A cylindrical drum exterior to the hot-flue, covered with flannel, serves to receive the end of the series of pieces, and to draw them through the apartment. This mode of drying the padded calicoes requires for each piece of 28 yards three pounds of coal for the furnace when a fan is employed, and four pounds without it. See CALICO-PRINTING.

HOT-WATER APPARATUS. (*Calorifère d'eau*, Fr.; *Wasser-Heitzung*, Ger.) In the *Dictionnaire Technologique*, vol. iv. we find a description of an apparatus of late years much employed for heating conservatories, &c., by hot water circulating in pipes:—

This mode of heating is analogous to that by stove-pipes; it is effected by the circulation of water, which, like air, is a bad conductor, but may serve as a carrier of caloric by its mobility. We may readily form an idea of the apparatus which has been employed for that purpose. We adapt to the upper part of either a close kettle, or of an ordinary cylindric boiler A, *fig.* 1169, a tube B, which rises to a certain height, and descends, making several sinuosities with a gentle slope till it reaches the level of the bottom of the boiler, to whose lowest part, as that which is least heated, it is fitted at C. At the highest point of the tube F we adapt a vertical pipe, destined to serve as an outlet to the steam which may be formed if the temperature be too much raised; it serves also for the escape of the air expelled from the water by the heat; and it permits the boiler to be replenished from time to time as the water is dissipated by evaporation; lastly, it is a tube of safety.

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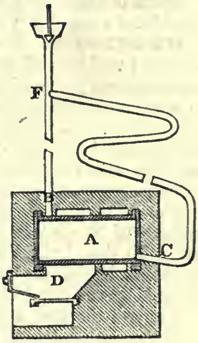


The apparatus being thus arranged, and all the tubes as well as the boiler filled with water, if we kindle fire in the grate D, the first portions of water heated, having become specifically lighter, will tend to rise: they will actually mount into the upper part of the boiler, and, of course, enter the tube B F: at the same time an equivalent quantity of water will re-enter the boiler by the other extremity C of the tube. We perceive that these simultaneous movements will determine a circulation in the whole mass of the liquid, which will continue as long as heat is generated in the fire-place; and if we suppose that the tubes, throughout their different windings, are applied against the walls of a chamber, or a stove-room, the air will get warmed by contact with the hot surfaces; and we may accelerate the warming by multiplying these contacts in the mode indicated.

This *calorifère* can be employed with equal advantage and with more safety than those with heated air, when it is wished to heat large apartments. In the present case, the temperature of the water, without pressure, in the tubes, must be always under 100° C. (212° F.), even in those points where it is most heated, and less still in all the other points, while the temperature of the flues in *air stoves*, heated directly by the products of combustion, may be greatly higher. In air stoves, however, the pipes may without inconvenience have a large diameter, and present, consequently, a large heating surface; whereas, with the water *calorifère*, the pressure exercised by liquid upon the sides of the tubes being in the ratio of the surfaces, we are obliged, in order to avoid too great pressure, to employ a multitude of small tubes, which is expensive. Lastly, if the hot-water circulation is to be carried high, as may be often necessary in lofty buildings, the pressure resulting from the great elevation would call for proportional thickness in the tubes and the boiler; for these reasons it appears that water cannot in all cases be advantageously substituted for air or steam in the applications above stated: yet this mode of heating presents very decided advantages where it is needed to raise the temperature a small number of degrees in a uniform manner.

M. Bonnemain applied, with much success, these ingenious processes of heating by the circulation of water to maintain a very equal temperature in hothouses (*serres-chaudes*), in stoves adapted to artificial incubation, and in preserving or quickening vegetation within hothouses, or outside of their walls, during seasons unpropitious to horticulture.

Since the capacity of water for heat is very great, if the mass of it in a circulation-apparatus be very considerable, and the circulation be accelerated by proper arrangements, as by cooling the descending-tube exterior to the stove-room, we may easily obtain by such means a moderately high and uniform temperature, provided the heat generated in the fire-place be tolerably regular. We may easily secure this essential point by the aid of the *fire-regulator*, an instrument invented by M. Bonnemain.

It should be clearly understood that wood will become charred and eventually take fire if kept in contact with iron pipes through which hot water circulates. This may appear contrary to ordinary experience. There are, however, numerous evidences which prove distinctly that it is dangerous to have wood in contact with even hot-water pipes, and that it is infinitely more so to have it near to pipes through which the circulation of heated air is carried on.

There are several arrangements for carrying out this system of warming; but the principle is the same in all of them. Heated water ascends from the boiler, circulates through the pipes, giving warmth to the building in its passage, and it returns cool to the boiler, to be again circulated.

HOWLITE. A hydrous borate of lime. See Boracic Acid.

HUANO. See Guano.

HUMBOLDTILITE. A silicate of alumina, lime, magnesia, soda, &c. It occurs in crystals belonging to the pyramidal system, in the ejected limestones of Monte Somma. A substance identical in chemical composition and crystalline form has been found in slags from some of the Staffordshire blast-furnaces.

HUMITE. A silicate of magnesia from Vesuvius; known also as *Chondrodite.*

HUMUS. The vegetable matter of the soil, called also *Ulmin.* By action of alkalis it yields *humic* or *ulmic acid.*

HUNGARY WATER. Supposed to be named after a queen of Hungary, who used it as a cosmetic: it is prepared by distilling rosemary. See Eau de Cologne.

HYACINTH. The name under which are included the transparent, bright-coloured varieties of zircon. Hyacinth differs from jargoon merely in colour, which is orange-red passing into poppy-red. Though not much worn at the present time, it is a valuable gem, and makes a very superb ring-stone when of a bright tint and free from flaws. The larger species are sometimes made into seals. Hyacinths occur in the sand and alluvial deposits of certain rivers in Ceylon, also in the state of sand, mingled with various other substances, in the bed of a stream at Expailly (Haute-Loire) in France, as well as in basalt near the same place. It is also found in volcanic tuff in Auvergne, in Bohemia, Saxony, the Tyrol, Transylvania, Greenland, in the zircon-syenite of Fredericksvärn, in Norway, and in the iron mines of Arendal; also at Miask in the Urals, Vesuvius, at Santa Rosa in New Grenada, at Scalpay in Harris, Scotland, Egypt, the East Indies, and elsewhere. The hyacinth-red varieties of zircon are sold by the inhabitants of Ceylon as inferior rubies.—H. W. B.

Many of the stones used in jewellery under the name of hyacinth are nothing more than hyacinth-coloured garnets, belonging to the variety known as *cinnamon-stone* or *essonite.* This false hyacinth may be readily distinguished from the true gem by difference of specific gravity; that of the cinnamon-stone being only about 3·6, whilst the specific gravity of the true hyacinth rises as high as 4·7. Moreover, zircon is a doubly-refracting mineral, and garnet singly-refracting: a distinction which may sometimes be of value in the discrimination of cut stones. Both substances have about the same degree of hardness. The red zircon loses its colour on ignition, and increases in density. Some finely-coloured hyacinths have recently been found in the form of rolled pebbles at Mudgee, in New South Wales.

HYALOGRAPHY. The art of etching on glass. The process may be effected either chemically, by the action of hydrofluoric acid; or mechanically, by means of the sand-blast. See Glass.

HYDRACIDS. A term sometimes applied to those acids which obviously contain hydrogen as an essential constituent, such as hydrochloric acid. The term was formerly used to distinguish these acids from another class called *oxyacids,* such as sulphuric acid; but as these also are now known to contain hydrogen, the old distinction has lost its significance. All acids, indeed, are hydracids.

HYDRATES are compounds of the oxides, salts, &c., with water in definite or equivalent proportions. Thus slaked lime consists of one atom of quicklime = 28, + one atom of water = 9, of which the sum is 37 on the hydrogen scale. 'The very different functions performed by water in the various modes of combination it affects render it necessary to adopt a definite principle of nomenclature in this respect. . . . I shall employ the word *hydrate* only where the water is combined with a base, such as a metallic oxide, thus, hydrate of lime, hydrate of potash, hydrated oxide of lead.' —*Kane.*

HYDRAULIC LIME. The poorer sorts of limestone, such as contain from 8 to 25 per cent. of foreign matter, in silica, alumina, magnesia, &c., form the best hydraulic limes. All the water limestones are of a bluish-grey or brown colour, which is communicated to them by the oxide of iron. They are usually termed *stone-lime* by the builders of the metropolis, to distinguish them from common chalk-lime, but so far improperly, that the Dorking limestone is not much harder than chalk, and the Halling limestone is actually a chalk, and not harder than the pure chalk of the same neighbourhood, from which it is only distinguished in appearance by being a little darker. These, though calcined, do not slake when moistened; but if pulverised they absorb water without swelling up or heating, like *fat* lime, and afford a paste which hardens in a few days under water, but in the air they never acquire much solidity.

The following analyses of different hydraulic limestones are by Berthier:—

	No. 1	No. 2	No. 3	No. 4	No. 5
A. *Analyses of limestones.*					
Carbonate of lime . . .	97·0	98·5	74·5	76·5	80·0
„ magnesia . .	2·0	...	23·0	3·0	1·5
„ protoxide of iron .	...	...	...	3·0	...
„ manganese . .	...	...	...	1·5	...
Silica and alumina . . .	...	...	...	15·2	18·0
Oxide of iron	1·0	1·5	1·2		
	100·0	100·0	98·7	99·2	99·5
B. *Analyses of the burnt lime.*					
Lime	96·4	97·2	78·0	68·3	70·0
Magnesia	1·8	...	20·0	2·0	1·0
Alumina	1·8	2·8	2·0	24·0	29·0
Oxide of iron	...	...	...	5·7	...
	100·0	100·0	100·0	100·0	100·0

No. 1 is from the fresh-water lime formation of Château-Landon, near Nemours; No. 2, the large-grained limestone of Paris; both of these afford a fat lime when burnt. Dolomite affords a pretty fat lime, though it contains 42 per cent. of carbonate of magnesia. No. 3 is a limestone from the neighbourhood of Paris, which yields a poor lime, possessing no hydraulic property; No. 4 is the secondary limestone of Metz; No. 5 is the lime-marl of Senonches, near Dreux; both the latter have the property of hardening under water, particularly the last, which is much used at Paris on this account.

All good hydraulic mortars must contain alumina and silica; the oxides of iron and manganese, at one time considered essential, are rather prejudicial ingredients. By adding silica and alumina, or merely the former, in certain circumstances, to fat lime, a water-cement may be artificially formed; as also by adding to lime any of the following native productions, which contain silicates; puzzolana, trass or tarras, pumice-stone, basalt-tuff, or slate-clay. Puzzolana is a volcanic product, which forms hills of considerable extent to the south-west of the Apennines, in the district of Rome, the Pontine marshes, Viterbo, Bolsena, and in the Neapolitan region of Puzzuolo, whence the name. A similar volcanic tufa is found in many other parts of the world. According to Berthier, the Italian puzzolana consists of 44·5 silica; 15·0 alumina; 8·8 lime; 4·7 magnesia; 1·4 potash; 4·1 soda; 12 oxides of iron and titanium; 9·2 water; in 100 parts.

The *tufa* stone, which when ground forms *trass*, is composed of 57·0 silica, 16·0 clay, 2·6 lime, 1·0 magnesia, 7·0 potash, 1·0 soda, 5 oxides of iron and titanium, 9·6 water. This tuff is found abundantly, filling up valleys in beds of 10 or 20 feet deep, in the north of Ireland, among the schistose formations upon the banks of the Rhine, and at Monheim in Bavaria.

The fatter the lime the less of it must be added to the ground puzzolana, or trass, to form a hydraulic mortar; the mixture should be made extemporaneously, and must at any rate be kept dry till about to be applied. Sometimes a proportion of common sand-mortar instead of lime is mixed with the trass. When the hydraulic cement hardens too soon, as in 12 hours, it is apt to crack; it is better when it takes 8 days to concrete. Through the agency of the water, silicates of lime, alumina (magnesia), and oxide of iron are formed, which assume a stony hardness.

Besides the above two volcanic products, other native earthy compounds are used in making water-cements. To this head belong all limestones which contain from 20 to 30 per cent. of clay and silica. By gentle calcination, a portion of the carbonic acid is expelled, and a little lime is combined with the clay, while a silicate of clay and lime results, associated with lime in a subcarbonated state. A lime-marl containing less clay will bear a stronger calcining heat without prejudice to its qualities as a hydraulic cement: but much also depends upon the proportion of silica present, and the physical structure of all the constituents.

The mineral substance most used in England for making such mortar is vulgarly called *cement-stone.* It is a reniform limestone, which occurs distributed in single nodules, or rather lenticular cakes, in beds of clay. They are mostly found in those argillaceous strata which alternate with the limestone beds of the Oolite formation, as also in the clay strata above the chalk, and sometimes in the London clay. On the coasts of Kent, in the isles of Sheppey and Thanet, on the coasts of Yorkshire, Somersetshire, and the Isle of Wight, &c., these nodular concretions are found in considerable quantities, having been laid bare by the action of the sea and weather. They were called by the older mineralogists *Septaria* and *Ludus Helmontii* (Van Helmont's coits). When sawn across, they show veins of calc-spar traversing the siliceous clay, and are then sometimes placed in the cabinets of *virtuosi.* They are found also in several places on the Continent, as at Neustadt-Eberswalde, near Antwerp, near Altdorf in Bavaria; as also at Boulogne-sur-mer, where they are called Boulogne pebbles (*galets*). These nodules vary in size from that of a fist to a man's head; they are of a yellow-grey or brown colour, interspersed with veins of calc-spar, and sometimes contain cavities bestudded with crystals. Their specific gravity is 2·59.

The Blue Lias cement-stones are considered the strongest water-limes of this country, and are found on opposite sides of the Bristol Channel, near Watchet in Somersetshire, and Aberthaw in Glamorganshire, and also in North Wales and at Lyme Regis in Dorsetshire. The Dorking or Merstham lime and the Halling lime, so termed from a village on the left bank of the Medway above Rochester, but which is also found near Burnham on the opposite side of the river, though not possessing such strong hydraulic properties as the lias, are also much esteemed.

Analyses of several cement-stones, and of the cement made with them:—

	No. 1	No. 2	No. 3	No. 4	No. 5
A. *Constituents of the cement-stones.*					
Carbonate of lime	65·7	61·6	...	82·9	63·8
,, magnesia	0·5	...	...	...	1·5
,, protoxide of iron	6·0	6·0	...	4·3	11·6
,, manganese	1·6	...	...		
Silica	18·0	15·0	...	13·0	14·0
Alumina or clay	6·6	4·8	...	trace	5·7
Oxide of iron	...	3·0	...	...	...
Water	1·2	6·6	...	...	9·4
B. *Constituents of the cement.*					
Lime	55·4	54·0	55·0	...	56·6
Magnesia	...	...	...	...	1·1
Alumina or clay	36·0	31·0	38·0	...	21·0
Oxide of iron	8·6	15·0	13·0	...	13·7

No. 1, English cement-stone analysed by Berthier; No. 2, Boulogne stone, by Drapiez; No. 3, English ditto, by Davy; No. 4, reniform limestone-nodules from Arkona, by Hühnefeld; No. 5, cement-stone of Avallon, by Dumas.

In England the stones are calcined in shaft-kilns, or sometimes in mound-kilns, then ground, sifted, and packed in casks. The colour of the powder is usually dark brown-red. When made into a thick paste with water it absorbs little of it, evolves hardly any heat, and soon indurates. It is mixed with a sharp sand in various proportions, immediately before using it; and is employed in all marine and river embankments, for securing the seams of stone or brick floors or arches from the percolation of moisture, and also for facing walls to protect them from damp.

HYDRAULIC CEMENT. This is a kind of mortar used for building piers or walls under, or exposed to, water, such as those of harbours, docks, &c. The cement of Pouilly is prepared from a Jurassic (secondary) limestone, which contains 39 per cent. of silica, with alumina, magnesia, and iron oxide. Vicat forms a factitious Roman cement by making bricks with a pasty mixture of 4 parts of chalk and 1 part of dry clay, drying, burning, and grinding them. River-sand must be added to this powder; and even with this addition, its efficacy is somewhat doubtful; though it has, for want of a better substitute, been much employed at Paris.

Prof. Kuhlmann, of Lisle, has made certain improvements in the manufacture of lime-cement, and he has prepared artificial stone possessed of a hardness and solidity fit for the sculptor. See STONE, ARTIFICIAL.

In operating by the dry method, instead of calcining the limestone with sand and clay alone, as has been hitherto commonly practised, this inventor introduces a small quantity of soda, or preferably, potash, in the state of sulphate, carbonate, or muriate —salts susceptible of forming silicates—when the earthy mixture is calcined. The alkaline salt, equal in weight to about one-fifth that of the lime, is introduced in solution among the earths.

All sorts of lime are made hydraulic in the humid way, by mixing slaked lime with solutions of common alum or sulphate of alumina; but the best method consists in employing a solution of the silicate of potash, called liquor of flints, or soluble glass, to mix in with the lime, or lime and clay. An hydraulic cement may also be made which will serve for the manufacture of architectural ornaments, by making a paste of pulverised chalk, with a solution of the silicate of potash; the said liquor of flints likewise gives chalk and plaster a stony hardness, by merely soaking them in it after they are cut or moulded to a proper shape. On exposure to the air they get progressively indurated. Superficial hardness may be readily procured by washing over the surface of chalk, &c., with liquor of flints, by means of a brush. This method affords an easy and elegant method of giving a stony crust to plastered walls and ceilings of apartments; as also to statues and busts, cast in gypsum, mixed with chalk.

The essential constituents of every good hydraulic mortar are caustic lime and silica; and the hardening of this compound under water consists mainly in a chemical combination of these two constituents through the agency of the water, producing a hydrated silicate of lime. But such mortars may contain other bases besides lime, as, for example, alumina and magnesia, whence double silicates of great solidity are formed; on which account dolomite is a good ingredient of these mortars. But the silica must be in a peculiar state for these purposes; namely, capable of affording a gelatinous paste with acids; and if not so already, it must be brought into this condition, by calcining it, along with an alkali or an alkaline earth, at a bright red heat, when it will dissolve, and gelatinise in acids. Quartzose sand, however fine its powder may be, will form no water-mortar or lime; but if the powder be ignited with the lime, it then becomes fit for hydraulic work. Ground felspar or clay forms with slaked lime no water-cement; but when they are previously calcined along with the lime, the mixture becomes capable of hardening under water.

Hamelin's Cement is composed of ground Portland stone (roe-stone), sand and litharge, in the proportion of 62 of the first, 35 of the second, and 3 of the third, in 100 parts; but other proportions will also answer the purpose. Considerable dexterity is required to make good work with it.

Limestone, which contains as much as 10 per cent. of clay, comports itself after calcination, if all the carbonic acid be expelled, just as pure limestone would do. When it is less strongly burned, it affords, however, a mass which hardens pretty speedily in water. If the argillaceous proportion of a marl amounts to 18 or 20 per cent., it still will slake with water, but it will absorb less of it, and forms a tolerably good hydraulic mortar, especially if a little good Roman Cement be added to it. When the proportion of clay is 25 to 30 per cent. after burning, it heats but little with water, nor does it slake well, and must therefore be ground by stampers or an edge millstone, when it is to be used as a mortar. This kind of marl yields commonly the best water-cement without other addition. Should the quantity of clay be increased farther, as up to 40 per cent., the compound will not bear a high or long-continued heat without being spoiled for making hydraulic mortar after grinding to powder. When more strongly calcined, it forms a vitriform substance, and should, after being pulverised, be mixed up with good lime, to make a water-mortar. If the marls in any locality differ much in their relative proportions of lime and alumina, then the several kinds should be mixed in such due proportions as to produce the most speedily-setting, and most highly-indurating hydraulic cement.

Hydraulic limes or cements require the presence of carbonate of lime with silica, or silicate of alumina, or magnesia. It is stated that dolomite calcined at a moderate heat exhibits the property of a hydraulic lime. See DOLOMITE.

If carbonate of lime be mixed with gelatinous silica, it forms a good hydraulic cement. See SILICA; and STONE, ARTIFICIAL.

If a hydraulic lime be calcined at too high a temperature, the silicate undergoes partial fusion, and will not set afterwards under water. The heat, therefore, employed for burning the hydraulic limestones should only be just high enough to expel the water from the clay and the greater part of the carbonic acid from the carbonate of lime.

Neither clay (silicate of alumina) nor lime alone will set under water, but if we carefully mix chalk and clay together, and then calcine them at a moderate heat, a good hydraulic cement is obtained.

Hydraulic limestones may be separated into two kinds, as indicated by their constituents. One set consists of the carbonates of the earths, these yield a fat lime; the other set is composed of silicates, or a mixture of silicates of alumina, lime, magnesia, or potash, although of the latter less frequently, with usually much free silica; consequently these are a kind of clay.

In burning hydraulic limestones, the silica and alumina, when the lime has once parted with its carbonic acid, react upon each other. The lime enters into feeble combination with the silica, producing a less stable compound than the original, and which is readily acted on by acids, which was not the case previous to burning.

Burnt hydraulic lime is, in nearly all cases, soluble in acids. The presence of a silicate that can be decomposed by acids is proved by the formation of a thick jelly of silica. The property of yielding gelatinous silica by solution in acids, may be regarded as one of the proofs that the limestone possesses the property of 'setting,'—becoming hard under water.

The degree of hardness acquired by hydraulic lime varies considerably. The time required for hardening differs still more widely; some hydraulic cements will set in a few minutes, others will require weeks and months. The more of the aluminous constituents which the limestone contains the more quickly will the cement prepared from it solidify.

As already remarked, too much heat in the kiln, causing partial fusion of the silica, destroys the hydraulic property of the lime. In technical phrase it renders the lime much weaker, and at last completely destroys its power as a water-cement.

Hydraulic lime should acquire a certain consistence before it is immersed in water. If this is not attended to, the hydraulic lime never hardens, the particles form a porous mass, there is no kind of agglutination; consequently, considerable care is required in every stage of the process of making and using hydraulic cements.

It is impossible in this work to do full justice to this very important subject; we must therefore refer our readers to General Pasley's works on *Limes and Cements*, to the papers of Mr. Timperly in the *Transactions of the Institution of Civil Engineers*, and to the works especially of MM. Vicat and Belidor. See PUZZOLANA; ROMAN CEMENT.

Scott's Cement.—The following remarks on hydraulic cements, and on the preparation of a new and valuable kind of these cements, are abstracted from some memoirs by Major-General Scott in the *Papers on Subjects connected with the Duties of the Corps of Royal Engineers.* General Scott's hydraulic cement has been used in the construction of the Royal Albert Hall and many other buildings, and we are given to understand, generally with satisfactory results.

The superiority of hydraulic mortars over pure lime-mortars consists very much in the former containing within themselves the property of solidifying without the assistance of the atmosphere; while the pure lime-mortars do not possess such a property, and in the absence of carbonic acid in the atmosphere, no solidification will ensue.

Many impure limestones contain a proportion of clay (silicate of alumina and iron) intimately mingled with the carbonate of lime. By burning, the carbonic acid gas is expelled from them as in the case of the pure limestones, the clay assisting in its expulsion through the affinity of its silicic acid for the lime, and also parting with its own combined water. A further action then takes place: the silicic acid of the clay and the lime, at the high temperature of the kiln, react on one another, and either form a silicate of lime, or approximate to its formation so far that on the addition of water it is formed with more or less rapidity. As, however, this action is more perfect in the water-cements, and there is much in common between them and the hydraulic limes, it will be better here to explain in what their difference consists, and then to speak of them together.

The difference between them cannot be precisely defined with reference to chemical composition, for there are some limestones which will yield cement or lime according to the temperature at which they are burned. It must rather be referred to the manner in which they behave when moistened with water. If a piece of cement be dipped in water for a few seconds until it ceases to hiss from the escape of air from its pores, it may become harder, or it may after a time partially break up, with or without sensible warmth. If a piece of fresh pure lime be similarly treated, in a few minutes it begins to heat and swell, and the violence of the action is such as to throw it abroad in a bulky impalpable powder. In the latter case one affinity only comes into play, that of the lime for the water; but with the cement, a second affinity is in operation. By the action of the heat in the process of burning, the affinity of the lime for the silicic acid of the clay is brought into play, and modifies the violence of its affinity for water, and when the temperature is sufficiently high, the lime and the silicic acid enter into chemical combination, and the compounds so formed, on being moistened with water, pass into hydrates in a gradual and quiet manner, without any of the tumultuous action which is so remarkable in the combination of pure lime with water.

The hydrated silicates resulting are not afterwards appreciably affected by water, and so much of the lime as the silicic acid can take up passes from a soluble to an insoluble condition, thus affording a cementing material suitable for hydraulic purposes. When the heat of the kiln is too far urged, vitrification ensues from the complete formation of an anhydrous silicate, and a comparatively inert substance is produced, which undergoes no change on being mixed with water, or will only unite with it after considerable periods of time.

The hydraulic limes are intermediate between the cements and the pure limes, and partake of the character and mode of action of each class of substances. The proportion of clay in them is generally smaller than in the cements, and the lime sufficiently predominates to produce by its violent affinity for water the degree of heat, expansion, and amount of vapour requisite to throw them into powder. When the quantity of clay, as compared with the lime, is small, the violence of the slaking is scarcely less than that of the pure limes, but in proportion as the clay is relatively larger in amount, the heat generated in combining with the water is less, and the lime slakes to a powder more imperfectly and with less increase of volume; until at last, on reaching the boundary of the cements, the slaking must be urged on by confining the heat generated, and the lime allowed to lie longer to ensure the completion of the action before it is mixed with sand and made into mortar.

In the ordinary kiln-burning, some portions of the hydraulic limes, by too great heat of the charge, are brought into that condition when the silicates formed combine very slowly with water. The silicic acid having undergone a great modification, the powders of such limes can unite and form new hydrated compounds, but by a process so slow that it may be measured by weeks, months, or years, instead of minutes, hours, and days, thereby, in badly-mixed mortar, doing great injury; expansion taking place after the mortar has been laid in the work, it has been known to throw down arches, and lift heavy masses of masonry.

If hydraulic limes be allowed to dry too rapidly, they will not properly harden.

With regard to cements, some portions of a charge are often spoiled by lowness of temperature in burning, and thus prevent the desired rapidity of forming silicates, and retard the solidification of the mortar without the assistance of water.

Besides the proportion of clay and lime, and the temperature of burning, the composition of the clay has much to do with the rapid setting of hydraulic limes and cements. The larger the amount of iron and alumina present, the more readily will the lime and clay pass through the different stages to the formation of a perfect cement, though temperature in burning has much to do with its character, for from the same bed of chalk-marl have been made a hydraulic lime, a quick setting cement, and a cement resembling the Portland cement. See LIME.

As the cements may, and practically always do, partake of the slow solidifying action of the hydraulic limes, so the hydraulic limes partake, when exposed to the air, of the hardening action of the carbonic acid gas of the atmosphere, to which the pure limes owe the external hard crust.

The addition of puzzolana, trass, &c., often improves the hydraulic limes. The action of these substances is similar to that of clay found naturally mingled with the carbonate of lime in hydraulic limestones. These have been calcined by volcanic heat, and though burnt clay may produce a similar effect, it is rarely so perfect.

Preparation of this Cement.—The limestone to be employed in the manufacture of the cement is burnt to quick-lime by any of the ordinary processes, avoiding over-burning, as usual. Limes burned until they assume a blue or greenish tinge require peculiar and very careful treatment to fit them for the purpose.

The quick-lime is either wheeled in barrows or carried in baskets into an oven, and is laid on the perforated arches forming the floor, to the depth of 1 foot 6 inches on the crown, and 2 feet over the haunches. With a large-sized lime this depth may increase a few inches, and when the lime is very small it must be somewhat decreased; or, in other words, the lime must not be so closely and deeply packed as to impede the draught too much. The lime-dust produced in burning the lime becomes useful in making the hatches of the oven air-tight, and if there is any excess, it may be ground down with the cement without sensibly deteriorating its strength.

When the oven is loaded, the charging hatch is closed with a double 4-inch dry brick wall, the included space being filled in with lime-dust. The whole may be made air-tight at top by means of an opening through the crown of the arch. An iron door can be employed, and with saving of labour, but a brick wall will generally be found more convenient.

The small hatch intended to assist in cooling the oven, in order to draw the charge, is better closed with an iron door on hinges, the whole being made tight with a mixture of moistened clay and sand, technically termed 'pug.'

If the lime employed is pure or feebly-hydraulic lime, it is advisable to allow it to remain, with a current of air passing through it for a period which will vary, generally, with the temperature of the air, and the draught through the oven. The object of this is that the moisture carried through by the air may open or split the lime a little, and otherwise facilitate the combination of the sulphurous acid during the subsequent process, without, however, causing it to fall abroad. Whatever the nature of the lime operated upon, such exposure renders the process more certain, and should be employed whenever the tendency to slake with heat is not readily destroyed without it. The period of exposure will vary from twelve to forty-eight hours. After this exposure, a fire of coke or coal is kindled by means of a faggot or brushwood on the fire-bars, and a slow fire is kept up until the lime immediately over the arches shows a dull glow, such as is barely visible when viewed in the dark through the pipes in the sides of the oven. The firing is then raked out, and after the lapse of a quarter or half an hour, according to the size of the oven, the ash-pit is closed, and the chimney-top covered with a slate-stone, or plate of iron, until it is judged that the heat throughout the mass of lime is pretty well equalised. When coal is used, there is sometimes a little difficulty in preventing the smoke escaping through the fire-doors after each fresh feeding of the fire, but this may be obviated with a little care and more frequent feeding. The flame of coal heats the charge more equally. A mixture of coal and coke may also be employed.

The time required for heating the lime depends on so many circumstances that no definite rule can be laid down; the dullest possible glow will sufficiently indicate when the first point is attained, that a burner acquainted with the action of his oven will not require the use of the viewing pipe at all.

When the heat in the oven is judged sufficient, and to be sufficiently equalised, the ash-pit and the chimney are opened, and iron pots containing coarse unpurified sulphur are pushed in on the fire-bars, and placed in such a manner as to distribute the fumes of the burning sulphur equally. The pots may be made of wrought iron, of sufficient capacity to hold about 25 lbs. of sulphur each, the allowance being 15 lbs. to each yard of lime. A few red-hot cinders are thrown into each pot as it is pushed in, to ignite the sulphur. In ten or fifteen minutes the sulphur will be fully ignited, and its fumes will begin to escape through the chimneys very freely; the chimneys should then be closed again perfectly, and a little clay or lime-dust used to make the cover tight. The fire-doors and ash-pits are also to be plastered at the crevices, with the exception of a small opening at the bottom of each of the latter, which opening is to be regulated by the amount of air which may be required to carry on the combustion of the sulphur, without allowing the sulphurous acid to escape, and such escape would be immediately detected by the smell.

When the sulphur is all consumed, which may be ascertained by looking from time to time, after the lapse of some hours, into the oven fire-door, the wall closing the hatch is thrown down, and all other openings made free to the passage of air, to cool the charge and oven sufficiently to allow the former to be removed.

The grinding is then commenced; a few trial samples are made up with water, and an examination made at the top, middle, and bottom of the charge, to obtain information as to temperature for future guidance. If the lime from the bottom of the charge, when moistened, remains quite dead on the outside of the lumps, a sort of crust being formed there, and at the heart the lumps retain its usual properties, this is a proof that the bottom portion, if not the whole charge, was too hot when the sulphur process was commenced; if the upper layers still retain the usual characteristics of the unprepared lime, no crust being visible on the bottom portions, this shows that the heat at the top was not great enough, and probably that the temperature throughout was too low. Some pieces will always be found insufficiently prepared, but their effect is lost in the mass, and the samples should be three or four in number from each part of the charge, top, bottom, and centre, avoiding a selection of pieces near the walls. If in any case the mass is found insufficiently prepared, and the lower layers are crusted, the upper half may be removed and employed as ordinary lime, and the lower half ground down as cement. If the process should be judged to have been quite ineffectual, the removed portion of the charge can be replaced with fresh lime, and the operations of heating the lime to a faint glow, and of burning sulphur under it, be repeated; with ordinary care a failure can hardly occur, and should the sample specimens set firmly 'in pats' six inches square and half an inch thick, but yet grow too hot in setting to be safely trusted in work, a few days' exposure on the floor of the shed will render the cement fit for use. It is better, however, that 'in pats' of the above size, made up with water to a stiff consistency and without admixture of sand, the warmth in the setting—even when the cement is quite fresh from the oven—should be barely perceptible.

The grinding of the cement is the most serious part of the manufacture. Should the extent of the works justify a considerable outlay in grinding apparatus, the flour-mill construction is to be preferred, horizontal crushing rollers being used to reduce the lumps of cement to a size which the eye of the runner mill-stone can readily take. It is better also to sift it through a sieve, the coarse particles being again passed through the stones. For grinding, on the small scale, a pair of vertical wheels of iron or stone, turning on a pivot between them by horse-power, must be resorted to, the sifting apparatus being attached by suitable machinery to the gearing of the wheel, or worked by manual labour. The wire-gauze used for the sieves should have thirty meshes to the inch. The construction of both descriptions of mills is well understood by mill-makers.

When the cement is prepared from the pure and feebly-hydraulic limes, and it becomes necessary to impart to them properties which will enable them to resist the action of water, artificial or natural puzzolanas must be restored to. If such substances are ground down with the cement to a fine powder, and intimately mixed with the cement, one part of puzzolana will give to two parts of pure lime-cement, by weight, the necessary degree of resistance; but if mixture by hand-labour be alone available, and the puzzolana be not in a fine state of division, its quantity in proportion to the cement should be increased, the amount of sand used for mortar being correspondingly diminished.

The clays best adapted for the manufacture of artificial puzzolana are such as are greasy to the touch. The temperature at which they ought to be calcined depends upon their chemical composition, but the action of the constituents is complicated, and actual trial must be resorted to for the determination of the most efficient degree of calcination. To make the trial, a portion of the clay under examination may be moulded into a cylinder five or six inches long, and one and a half inch diameter; this cylinder when dried is to be exposed, the one end in a violent fire, the other on or near the outside of it. When the more highly-heated end begins to vitrify, the cylinder is withdrawn from the fire and divided into three or four portions, according to the general appearance and colour of the different parts.

By pulverising each part, and mixing this puzzolana with the cement in the proportion of one part of burnt clay to two or three parts of cement, by measure, it is easy to determine by actual trials in water what degree of calcination gives the best results. To prevent the cylinder from breaking in the fire, it is moulded round a wire. As a general rule, it will be found that clays containing lime and other metallic oxides, especially alkalis, become energetic at low temperatures, though they may also succeed when burned at a violent heat. The poorer clays will only give good results when calcined at a very high temperature, and they have the further disadvantage of being difficult to reduce to powder.

Clay should be made ready for burning by moulding it into rounded balls of the size of an apple, and leaving it in the air to dry. A thick layer of coals is placed on the bars at the bottom, then layers of the clay balls and coal alternately; when the kiln is about two-thirds full, faggots should be placed under the bars and ignited, and as the combustible is consumed, more coals and clay should be added; the appearance of the clay will at once show whether a proper quantity of fuel has been used.

Concrete.—The following is an account, by a thoroughly practical man, of the use of hydraulic limes in the formation of concrete. It is from a paper read by George Robertson, C.E. before the Scottish Society of Arts, 'On the Concrete used in the late Extension of the London Docks.'

The great mass of the concrete was made with naturally hydraulic lime, blue lias from Lyme Regis in Dorsetshire. which requires no artificial mixture with puzzolana or minion to render it capable of setting *permanently* under water. The word 'concrete' in this paper implies, therefore, that made with blue-lias lime, unless otherwise specified. The Dorsetshire lias was the only lime burned on the works; all lias from Warwickshire or Leicestershire was bought ready burned from the merchants. Lias requires much greater care in burning than richer limes, because any sudden or extra heat, which would do little harm to Dorking lime, greatly injures lias by forming a glass between the silica and the lime in the stone, instead of only driving off the water and carbonic acid. The combination between the silica and lime, to which lias owes its hydraulic properties, ought only to take place in the humid way —*i.e.* with the assistance of water, after the application of the lime as mortar or concrete. Lias comes from Lyme Regis in two different forms, the one with a clean conchoidal fracture, and the other of a shaley nature, approaching in appearance even to clay-state, but quite soft. The shaley lias, which contains so much clay as to have the properties of a cement, is not so desirable as the hard clean stone, because it carries less sand, and is therefore more expensive. The stone cost 4*s.* 3*d.* a ton when shipped at Lyme, but 10*s.* 9*d.* before it was stacked round the kiln at London, which is as much as the same stone cost delivered at the works of the New Graving Dock at Leith. Freight to London is always heavy, for there is no steady return freight, like coal, to be had. Notwithstanding the high price of the stone delivered at Shadwell, and having to pay freight on thousands of tons of water and carbonic acid, to be afterwards driven off by the heat of the kiln, the engineer-in-chief of the Dock Company, the late Mr. Rendel, determined to burn the limestone in London, as the extra cost would be a comparatively small item in such extensive works. It was very desirable to have the best possible lime where concrete was to play so important a part.

Two egg-shaped draw-kilns of brick were therefore erected, of a total height of 43 feet from the floor to the top of the dome, and an extreme internal diameter of 14 feet, contracting to 5 feet at the fire-bars, and 11′ 6″ at 32 feet above the floor. The practical objection to having a less diameter than this at the top, is the difficulty that would arise in charging the kiln with evenly-distributed layers of coal and stone tipped in from barrows at the top through the windows in the dome. It has likewise been objected that a contracted top to a kiln prevents the escape of carbonic acid, although it has a counterbalancing advantage in confining the heat, and throwing it down with a reverberatory effect on the charge. This theoretical objection appears to be fanciful. It was found necessary, after these kilns had been working for a short time, to dome the mouth over with a brick arch, to prevent stones from flying into the neighbouring streets. The chimney at the top of this was only three feet in diameter, and yet no difference was afterwards perceptible, either in the time required for burning, or in the percentage of imperfectly-burned stone. On the other hand, there is little doubt that the dome acted economically on the coal required, for the average of 7,000 tons of limestone was little more than one ton of coal to 11½ of stone, the limits being 1 to 10, and 1 to 13. Carbonic acid came away freely after the kiln had been lighted for three hours, and it appeared to have ample room for escape. An average of 11½ tons of stone burned by one ton of coal is very high; but the coal was Welsh, and cost 1*l.* 1*s.* a ton. Newcastle coal, or bituminous coal in general, was inadmissible; for it was essential to have little or no smoke from kilns in the heart of London. At Leith, one ton of the coal of the neighbourhood appears to burn only six or seven tons of lias, but the coal is only one-third of the price of Welsh coal. The barrows of coal and properly broken stone were lifted to the top of the kiln by a hoist worked by the mortar mill engine, and were tipped in through three openings in each dome, as evenly as possible. After the kiln was lighted, these windows were kept closed with boiler-plate shutters. The cost of charging, including breaking up the stone and coal, was 1*s.* 6*d.* per ton of the two when mixed in the kiln. Unless the demand for quick-lime was very irregular, the kilns were always kept lighted; but whenever they were allowed to go out, the charge of quick-lime was left in the kiln, as the place most free from moisture. Whenever the fire is let out in draw-kilns, the next charge is nearly sure to burn irregularly, and there is a considerable loss of heat in re-warming the kiln. Draw-kilns are liable to irregularity from apparently slight causes, such as the direction of the wind, &c.; and in the Shadwell kilns there was also a permanent tendency to burn quickest down the side warmed by the adjacent kiln, for they were both in one block of building. But draw kilns are better suited for burning lias than flare kilns, as the heat is more uniformly distributed through the charge; there is, therefore, less danger of over-burning the lower half and under-burning the upper.

Each kiln held 100 tons of stone, and burnt 21 tons per diem. The two together produced 25 tons of quick-lime every day, a quantity sufficient for about 97 cubic yards of mortar, or 170 cubic yards of concrete: 9 tons of coal will burn 100 tons of stone, which produce 59·37 tons of quick-lime, or 1,583 bushels of ground lime, enough for 400 cubic yards of concrete, when the ballast is moderately dry. Drawing the lime from the kiln cost 1¼*d.* per ton of quick-lime. The total cost of the burnt lime amounted to 24*s.* per ton. When quite hot from the kiln, 26½ bushels of ground lime went to the ton; but after keeping some time, a ton swelled to 30 bushels, which is what bought lias usually weighs. A bushel of lime, ground when fresh burnt, contains, therefore, one-seventh more lime than a bushel of stale lime; and a cubic yard of concrete, of specified proportions, is so much the better when made with fresh lime.

Coke was used in the kiln for a short time, but it was found to be 8 per cent. dearer than Welsh coal; and, moreover, the heat given out by it was too quick and strong, casing many of the stones over with a vitrified silicate, which hindered the free escape of carbonic acid. When coke was burnt, therefore, the percentage of unburnt stone was raised much above the usual average of 1½ or 2 per cent.

The equally burnt and softest lumps, usually of a buff colour, were picked out for grinding; and the remainder, more of a liver colour, slaked for mortar. The lumps were first broken tolerably small by hand, and then crushed still smaller between iron rollers revolving in the hopper of the grindstones. These rollers were at first made fluted, but it was found that strong projecting cogs did the work more effectually. The hopper was fed with lumps of lime by an endless chain of small wrought-iron buckets worked by the engine. It was intended that these should be self-acting, and dredge the lime up from a well; but it was found necessary to have a man constantly feeding them with a spade, or the supply was not regular.

The lime was ground to a fine powder between two pairs of horizontal French burr millstones; the upper one revolving at a speed of 90 revolutions per minute. Each pair of stones was able to grind 3 tons of quick-lime per hour, at a total cost for grinding of 1*d.* per bushel when the consumption was 360 bushels per diem; less, if more lime was used. This is made up as follows: feeding and attending to the hopper and lift, ½*d.*; engine power, ¼*d.*; measuring the lime into bags for the contractor, and recutting the stones as the furrows became worn, the remaining ¼*d.* A bushel of lime ground fresh from the kiln weighed 84 lbs.; and at this weight the total cost was 11¾*d.* In buying ground lime from a merchant, if the purchaser buys by weight, he pays for the water absorbed from the atmosphere; if he buys by measure, he pays for the expansion caused by that moisture: the fairest way for both parties would be to specify the bushel to be of a certain average weight, say for lias from Lyme Regis, 80 lbs. This would allow for the lime not being quite fresh, but would prevent it from being too stale.

The grindstones were composed of burrs from the fresh-water beds of the Paris basin, set in two radiated rings in cement, and backed up with plaster-of-Paris and mortar. The 'skirts' or outside burrs were five inches thick; the central or 'high burrs' somewhat thicker, to allow for the 'swallow,' which is a slight depression in the centre of the upper stone, about two feet in diameter, and at most 3″ deep. This acts as a kind of distributing reservoir for the lime as it falls from the hopper between the stones.

The face of the stones was divided into ten 'quarterings' by 'master furrows,' each of them being tangential to an imaginary circle concentric with the stone, and called its 'draft.' The size of this regulated the quantity of lime passing through the stones in a given time. A radius of five inches was found to grind ninety bushels per hour of a sufficiently fine quality. The particles of lime, whirling round near the centre of the stone, by their centrifugal velocity pass towards the outside along the master furrows, being ground finer as they recede from the central depression. Each master furrow had two other distributing furrows leading out of it, parallel to the former master furrow. The furrows are shallow grooves, or rather nicks about 1¼ inch wide, with the cutting edge sharp, and the other bevelled.

The hydraulic lime being thus prepared, it was employed in the formation of the required bed of concrete. This was formed by cementing a mixture of sand and gravel such as is found in the London basin,—called 'ballast,'—in the following manner:—

When the ballast was moderately dry, 12 cubic yards of gravel and 2 cubic yards of lime made 11 cubic yards of concrete, mixed and deposited. The shrinkage from the dry materials was then 22 per cent.; but if the ballast happened to be very dry, the shrinkage was more, and the same quantities made only 10 cubic yards.

A cubic yard of concrete requires about thirty-eight gallons of water to bring the dry materials to the requisite state of fluidity. Of this quantity nearly eight gallons enter into chemical combination with the oxide of calcium in the lias, and thirty gallons are either absorbed mechanically by the pores of the lime, retained by capillary attraction between the grains of sand, or lost by evaporation. After the concrete has been mixed and deposited, a gradual expansion takes place from the chemical action of the lime slaking; the less of this swelling, however, the better, as it disturbs the setting of the mortar round the pebbles, and causes friability in the concrete. Whenever concrete is made with quick-lime (as it usually is), there must be a certain amount of friability from this cause; and therefore, when it is important to have no swelling, as in blocks of concrete which have to be lifted, recourse must be had to slaked lime, or else to cement, which contracts rather than expands in setting. In the one case the concrete is long in hardening, having more moisture in it than the lime can absorb; and in the use of cement more expense is incurred. Portland cement is, however, not so expensive as might at first appear from the cement being double the price of lime, because the proportion to the ballast may be considerably reduced.

HYDRAULIC CRANES. The application of water-pressure to cranes is due to Sir Wm. Armstrong. These are now so generally applied, that although the subject belongs properly to Engineering, it is thought advisable to include some notice of these valuable and interesting machines in this work. A statement made, by the request of the British Association in 1854, by the inventor himself, so completely explains all the peculiarities of these cranes, that the paper is reproduced from the 'Proceedings' of the Association.

'The employment of water-pressure as a mechanical agent having recently undergone a great and rapid development, I may be permitted to make a few observations on the successive steps by which its present importance has been attained. In so doing I shall commence with the year 1846, in which, after many preliminary experiments, I succeeded in establishing, upon the public quay at Newcastle-on-Tyne the hydraulic crane which has formed the basis of what has since been effected.

'This crane both lifted the weight and swung round in either direction by the pressure of water, and was characterised, like all other hydraulic cranes since made, by remarkable precision and softness of movement, combined with great rapidity of action.

'The experiment thus made at Newcastle having proved satisfactory, I soon afterwards obtained authority, through the intervention of Mr. Harley, the Dock Surveyor of Liverpool, to construct several cranes and hoists upon the same principle at the Albert Dock in that town, where they were accordingly erected, and have ever since continued in operation.

'The next place at which these cranes were adopted was Grimsby New Dock, where an important step in the advancement of this kind of machinery was made on the suggestion of Mr. Rendel, who pointed out its applicability to the opening and closing of dock gates and sluices, and instructed me to extend its application to those objects. An extensive system of water-pressure machinery was accordingly carried out at that dock, and the result afforded the first practical demonstration that the pressure of a column of water could be advantageously applied as a substitute for manual labour, not merely for the cranage of goods, but also to give safe and rapid effect to those mechanical operations which are necessary for passing ships through the entrances of docks.

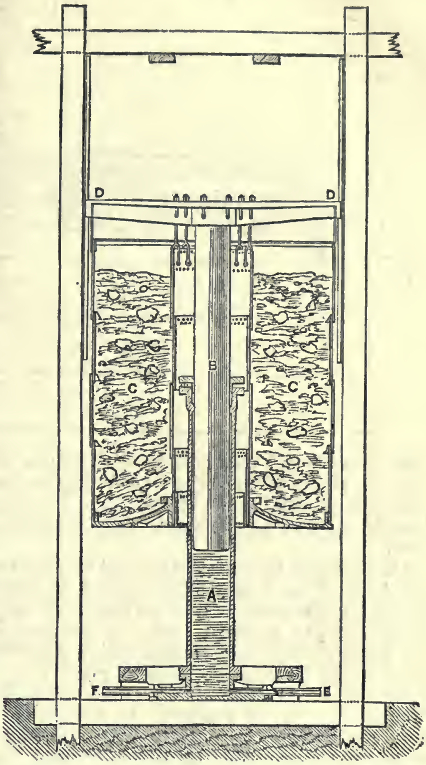
'In all these instances the moving column of water was about 200 feet in elevation. At Newcastle and Liverpool the supply was derived from the pipes communicating with the town reservoirs, but at Grimsby a tower was built for supporting a tank into which water was pumped by a steam-engine. In the former cases, the fluctuation of pressure, consequent upon the variable draught from the pipes for the ordinary purposes of consumption, proved a serious disadvantage; but this objection had no existence at Grimsby, where the tank upon the tower furnished a separate source of power, undisturbed by any interfering conditions. Nothing could be more effectual for its purpose than this tower; but, in the natural course of improvement, I was subseqently led to the adoption of another form of artificial head, which possessed the advantage of being applicable, at a comparatively small cost, in all situations, and of lessening the size of the pipes and hydraulic machinery, by affording a pressure of greatly-increased intensity.

'The apparatus thus substituted for a water tower I named "*the Accumulator*," from the circumstance of its accumulating the power exerted by the engine in charging it. The accumulator is, in fact, a reservoir giving pressure by *load* instead of by *elevation*, and its use, like that of every provision of this kind, is to equalise the strain upon the engine in cases where the quantity of power to be supplied is subject to great and sudden fluctuations.

'The construction of the accumulator is exhibited in *fig.* 1170, and needs but little explanation. A, cylinder; B, plunger; C C, loaded weight case; D, D, guides for ditto; E, pipe from pumping engine; F, pipe to hydraulic machine. It consists of a large cast-iron cylinder, fitted with a plunger, from which a loaded weight case is suspended, to give pressure to the water injected by the engine. The load upon the plunger is usually such as to produce a pressure in the cylinder equal to a column of 1,500 feet in elevation, and the apparatus is made sufficiently capacious to contain the largest quantity of water which can be drawn from it at once by the simultaneous action of all the hydraulic machines with which it is connected. Whenever the engine pumps more water into the accumulator than passes direct to the hydraulic machines, the loaded plunger rises and makes room in the cylinder for the surplus; but when, on the other hand, the supply from the engine is less, for the moment, than the quantity required, the plunger, with its load, descends and makes up the deficiency out of store.

'The accumulator also serves as a regulator to the engine; for when the loaded plunger rises to a certain height, it begins to close a throttle-valve in the steam-pipe, so as gradually to reduce the speed of the engine until the descent of the plunger again calls for an increased production of powder.

1170



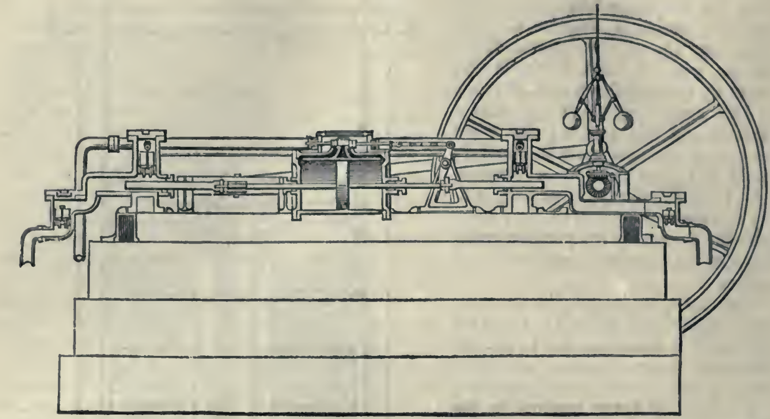
'The introduction of the accumulator, which took place in the year 1851, gave a great impulse to the extension of water-pressure machinery, which is now either already applied, or in course of being applied, to the purpose of cranage throughout all the great dock establishments in London, as also to a considerable extent in Liverpool and other places. I have also applied it extensively to railway purposes, chiefly under the direction or Mr. Brunel, who has found a multitude of cases, involving lifting or tractive power, in which it may be made available. Most of these applications are well exemplified at the new station of the Great Western Railway Company in London, where the loading and unloading of trucks, the hoisting into warehouses, the lifting of loaded trucks from one level to another, the moving of turn-tables, and the hauling of trucks and traversing machines are all performed, or about to be so, by means of hydraulic pressure supplied by one central steam-engine with connected accumulators. Mr. Rendel also, after having successfully adopted the low-pressure system to the working of the gates and shuttles at Grimsby, has since applied the high-pressure, or accumulator system, to the same purposes at other new docks, and a similar adaptation is being made by other eminent engineers at most of the new docks now in course of construction.

'I have also adapted hydraulic machinery to the opening and closing of swing-bridges and draw-bridges of large dimensions; and, in fact, there is scarcely any mechanical operation to which human labour has been hitherto applied as a mere moving power, which may not be efficiently performed by means of water-pressure emanating from a steam-engine and accumulator. Even if hand-labour be retained as the source of the power, the intervention of an accumulator will in many cases both economise labour and increase despatch. For example, a pair of heavy dock-gates requires the constant attendance of a considerable number of men, whose labour is only called into action occasionally, viz., when the gates are being opened or closed. Now, if an accumulator, charged by hand-pumps, were used, the labour employed would be constant, instead of occasional, and the power collected in the accumulator by the continuous process of pumping would be given out in a concentrated form, and thus the ultimate result would be effected with fewer hands and greater despatch than where manual labour is directly applied.

'The form of pumping-engine which I generally use for charging the accumulator is represented in *fig.* 1171. It consists of a horizontal steam-cylinder, with two force-pumps connected directly with the piston. These force-pumps are supplied with water from a cistern over the engine-room, into which the water discharged by the cranes is generally brought back by a return-pipe, so that the water is not wasted, but remains continuously in use.

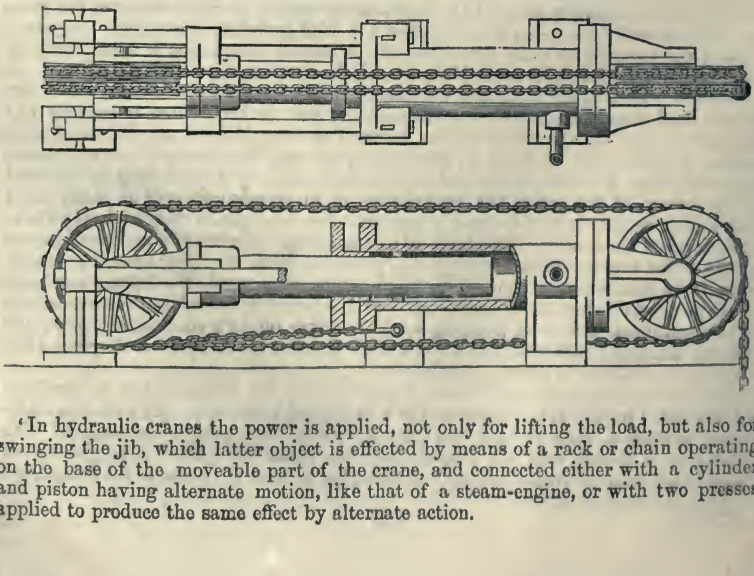
'With a pressure representing a column of 1,500 feet, the loss of head by friction in the pipes forms so small a deduction from the entire column as to be a matter of no consideration, and consequently the distance at which the engine may be situated from the points where the hydraulic machines may be placed is of little importance, except as regards the cost of the pipe. It is advisable, however, if the pipe be very long, to apply an accumulator at each extremity, so as to charge the pipe from both ends.

1171



'With regard to the mechanism of hydraulic cranes, the arrangement which I first adopted, and have ever since adhered to, consists of one or more hydraulic presses, with a set of sheaves, used in the inverted order of blocks and pulleys, for the purpose of obtaining an extended motion in the chain from a comparatively short stroke of the piston. This construction, which characterises nearly all the varieties of the hoisting and hauling machines to which I have applied hydraulic pressure is exhibited in *fig.* 1172, which represents one of these presses with sheaves attached, to multiply the motion fourfold. In cases where the resistance to be overcome varies very considerably, I generally employ three such cylinders, with rams or pistons acting either separately or conjointly upon the same set of multiplying sheaves, according to the amount of power required.

1172



'In hydraulic cranes the power is applied, not only for lifting the load, but also for swinging the jib, which latter object is effected by means of a rack or chain operating on the base of the moveable part of the crane, and connected either with a cylinder and piston having alternate motion, like that of a steam-engine, or with two presses applied to produce the same effect by alternate action.

'The absence of any sensible elasticity in water renders the motions resulting from its pressure capable of the most perfect control, by means of the valves which regulate the inlet and outlet passages of the machines; but this very property, which gives so much certainty of action, tends to cause shocks and strains to the machinery, by resisting the momentum acquired by the moving parts. Take, for example, the case of an hydraulic crane, swinging round with a load suspended on the jib, the motion being produced by the water entering on one side of a piston and escaping from the other. Under such circumstances, if the water-passages be suddenly closed by the regulating valve, it is obvious that the piston, impelled forward by the momentum of the loaded jib, but met by an unyielding body of water deprived of outlet, would be brought to rest so abruptly, as to cause, in all probability, the breakage of the machine. So also, in lowering a heavy weight with considerable velocity, if the escape-passage be too suddenly closed, a similar risk of injury would arise from the abrupt stoppage of the weight, if a remedy were not provided; but these liabilities are effectually removed by applying, in connection with the water-passages to the cylinder, a small clack-valve, opening upwards against the pressure into the supply-pipe, so as to permit the pent-up water in the cylinder to be pressed back into the pipe whenever it becomes exposed to a compressive force exceeding the pressure on the accumulator. By this means all jerks and concussions are avoided, and a perfect control over the movement of the machine is combined with great softness of action.

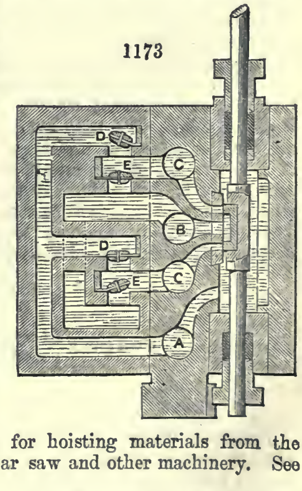
'With regard to the kind of valves used for water-pressure machines, I find that either lift-valves or slide-valves may be effectually applied, and kept tight under heavy pressures, provided that sand be excluded from the water, and the valves be made of proper material.

'In cases where a more prolonged movement is required than multiplying sheaves will conveniently afford, I employ rotative machines of various constructions. For heavy-pressures, such as an accumulator affords, an arrangement consisting of three plungers, connected with a triple crank, and bearing a general resemblance to a three-throw plunger pump, is well adapted for the purpose. The admission and exhaust valves are mitred spindles, pressed down by weights and levers, and lifted in proper rotation by cams fixed for that purpose upon a separate shaft; and these valves are associated with relief-clacks, to obviate the concussion which would otherwise be liable to take place at the turn of each stroke.

'The liability of water-pressure machinery to be deranged by frost has often been adduced as an objection to its use; and upon this point I may observe—first, that I have never experienced any interference from this cause when the machines were placed, as they generally are, beneath the surface of the ground, or within a building; and secondly, that when they are unavoidably exposed, all risk may be prevented by letting out the water in frosty weather whenever the machines cease working.

'When the moving power consists of a natural column of water, the pressure rarely exceeds 250 or 300 feet, and in such cases I have employed for rotative action a pair of cylinders and pistons, with slide-valves, resembling in some degree those of a high-pressure engine, but having relief-valves, to prevent shock at the turn of the stroke. *Fig.* 1173 shows a slide-valve adapted for the turning apparatus of a crane, but the relief-clacks of which are equally applicable to a water-pressure engine of the construction in question. Two of these clacks open against the pressure in the supply-pipe, so as to afford an escape for the water, which would otherwise be shut up in the cylinder when the exhaust port closes, and the other two communicate with the discharge-pipe, so as to draw in a portion of waste water to fill up the small vacancy which would otherwise be left in the cylinder on the closing of the admission port. A, supply pipe; B, exhaust pipe; C C, pipes to cylinder; D D, clacks opening against pressure; E E, clacks opening from exhaust. About four years ago I constructed four hydraulic engines upon this principle at Mr. Beaumont's lead mines in Northumberland, at the instance of Mr. Sopwith, Mr. Beaumont's well-known agent, and two more have recently been added at the same place. They are used for crushing ore, for hoisting materials from the mines, for pumping water, and for driving a circular saw and other machinery. See Hydraulic Machinery, for Mines.

1173



'If in progress of time railways should be generally extended into mountainous districts, so as to render them accessible for manufacturing purposes, the rapid streams which abound in such localities will probably become valuable sources of motive power, and a wider field may then be afforded for the application of water-pressure engines to natural falls.

'The object, however, which I have chiefly had in view since I first gave attention to this subject, has been to provide, in substitution of manual labour, a method of working a multiplicity of machines, intermittent in their action, and extending over a large area, by means of transmitted power produced by a steam-engine and accumulated at one central point. The common mode of communicating power by shafting could only be applied in cases where the machines were collected within a small compass, and where the accumulation of power necessary to meet varying resistance did not exceed that which a fly-wheel would afford. Compressed or exhausted air was almost equally inapplicable to the purposes I contemplated, in consequence of the many objections which its elasticity involves, as well as the liability to leakage, which, in an extended system of pipes and machines, requiring a multitude of joints, valves, and fitting surfaces, would form an insurmountable difficulty. But the use of water as a medium of transmission is free from all these objections, and its fitness for the purpose intended is now thoroughly established by the results which have been obtained.'

HYDRAULIC LIMESTONE. See Hydraulic Cement.

HYDRAULIC MACHINERY, FOR MINES. The application of a head of water to rotatory and reciprocatory engines, and the use of water in driving wheels, as well as in transmitting power from one point to another, are subjects of considerable importance in mining operations.

The power of water is derived either from its direct weight, as in the case of pressure-engines, or from its weight and impulse combined, as in overshot and breast-wheels.

In transmitting power for pumping purposes, advantage is taken of the non-compressibility of water, as well as of the facility with which water can be passed through straight or bent pipes.

Although the weight and incompressibility of water are in many ways advantageous for the purposes of the engineer, yet the use of water in pressure-engines necessitates peculiar mechanical contrivances. The valves have generally to be moved by an arrangement partially independent of the engine, whilst the shock consequent on instantly arresting the flow has to be mitigated by means of an air-vessel, momentum-plunger, or other suitable contrivance.

In Europe the rain-fall is from two to three feet per annum; about two-thirds of which is evaporated, the remainder finding its way to the sea. In Australia, where the atmosphere is exceedingly dry, and the rain-fall very much less, there are but few constant streams or rivers. The consideration which should therefore be given to the supply of water, and to the motors to be employed for mining purposes, must manifestly be governed by the hydrographic circumstances of different countries. But in lands where rain is tolerably frequent and abundant, the following remarks will admit of general application:—(1.) Mountainous countries, with a large extent of upper watershed, will furnish a tolerably constant volume of water, at a high fall, both for driving pressure-engines and turbines. (2.) Hilly localities much below the line of watershed will afford volume of water at a lesser fall, suitable for pressure-engines, turbines, and overshot wheels. (3.) A flat undulating country, with an extensive back-watershed, will frequently afford volume of water available as power through the medium of breast, undershot wheels, and low-fall turbines. (4.) Hilly localities near to the top of watersheds can only furnish an intermittent supply of water at comparatively low falls, and that to extend the use of water as power in such situations, store-dams will be requisite.

As the hydraulic engineer requires facts, data, and rules for his guidance, those deemed of practical importance will be given as concisely as possible.

Constitution of Water.

		By weight	By measure
Two gases	Oxygen	88·9	1
	Hydrogen	11·1	2
		100·0	3

Density of Water.—One cubic inch at 62°, the barometer being at 30 inches, weighs 252,458 grains, or water is 830 times heavier than atmospheric air. A cubic foot weighs 1,000 ounces, or 62½ lbs.

Expansion.—Water expands one-ninth of its bulk in freezing, and decreases in density. Under the influence of heat, from 40° to 212° Fahr., it increases in bulk to the extent of 1 cubic foot in every 23 feet.

Expansion at different Temperatures. 40° equal —·0000.

From 40° downwards	Expansion	From 40° upwards	Expansion
32°	·00022	64°	·00159
22°	.00090	102°	·00791
12°	·00236	212°	·04330

Gascous matter.—River or canal water contains $\frac{1}{20}$th of its volume.
Spring water „ $\frac{1}{14}$th „

Incompressibility.—Experiment has determined that water may be compressed about 1-46,500,000th part per atmosphere: a quantity so small that, practically speaking, water may be regarded as incompressible. The varying density and volume of water, although small, should be borne in mind by those entrusted with the construction of hydraulic apparatus. If it be allowed to freeze in cast-iron pipes, and no means be provided to allow for its free expansion, destruction of the arrangement is sure to follow, since a cubic inch of water exerts within the range of its expansion a force equal to 13⅓ tons.

Hydrostatics.—The *pressure*, weight, and equilibrium of water are included within this term.

The pressure of water at any depth is as the depth of the water; and the pressure upon the bottom of a pressure-column is as the base and perpendicular height.

Water contained within a cylinder or vessel presses equally in all directions.

To find the pressure of water upon a cylinder-piston at the bottom of a pressure-column:—

Rule.—Multiply the area of the piston in feet by the height of water in the pressure-column in feet, and their sum by the weight of a cubic foot of water, viz. 62·5 lbs.

Example.—What is the pressure upon the surface of a piston 2 feet diameter, the head of water in the pressure-column being 180 feet?

Piston, 2 feet diameter, area 3·1416. Then $3{\cdot}1416 \times 180 \times 62{\cdot}5 = 35{,}343$ lbs.

Or to find the pressure per square inch on the piston. Divide the product 35,343 lbs. by the number of square inches in the piston. Thus, area of piston 2 feet diameter is 452 square inches:

$$\frac{35{,}343}{452} = 78{\cdot}1 \text{ lbs.}$$

Thin Cylinders.—*To determine the thickness of thin hollow cylinders; the internal diameter, pressure, and tenacity of the material being given.*

Rule.—Multiply the internal diameter in inches by the pressure of water in pounds per square inch, and divide the product by the tenacity per square inch of the material.

Example.—The internal diameter of a cylinder being 30 inches, the water-pressure 250 lbs. to the square inch, and the tenacity of the material of the cylinder 12,000 lbs. per square inch, what must be the thickness of the cylinder?

$$\frac{250 \times 30}{12{,}000} = {\cdot}625, \text{ or } \tfrac{5}{8}\text{ths of an inch thick.}$$

To determine the pressure; the internal radius, thickness of cylinder, and tenacity of metal being given:—

Rule.—Divide the product of the thickness of the cylinder and tenacity of the material per square inch by the internal radius.

Example.—The thickness of the cylinder being ¼ of an inch, the tenacity 18,000, and the radius 6 inches, what pressure will the cylinder bear per square inch?

$$\frac{18{,}000 \times \frac{1}{4}}{6} = 750 \text{ lbs.}$$

Thick Cylinders.—*To determine the thickness of thick cylinders; the internal radius, the pressure, and the tenacity of the material of the cylinder being given:—*

Rule.—Subtract 1 from the square root of the quotient of the sum and difference of the tenacity per square inch of the material of the cylinder, and the pressure per square inch, and multiply this difference by the internal radius.

Example.—The internal radius of a thick hollow cylinder being 9 inches, the tenacity of the material of the cylinder 10,000, and the pressure 8,000 lbs. per square inch, what must be the thickness of the cylinder?

Sum of tenacity and fluid pressure	10,000 + 8,000 = 18,000
Difference of tenacity and fluid pressure	10,000 − 8,000 = 2,000
Quotient of sum and difference	18,000 ÷ 2,000 = 9·
Square root of quotient	$\sqrt{9\cdot}$ = 3·
Difference between root and 1	3· − 1· = 2·
Product of radius and difference	9· × 2· = 18 inches. *Ans.*

To determine the pressure per square inch which a thick hollow cylinder will withstand; the internal and external radii, and the tenacity of the material of the cylinder, being given:—

Rule.—Divide the difference of the square of the radii, and multiply the quotient by the tenacity per square inch of the material of the cylinder.

Example.—The internal and external radii of a thick hollow cylinder being respectively 9 and 27 inches, and the tenacity per square inch of the material of the cylinder 10,000 lbs., what pressure per square inch will the cylinder sustain?

Square of external radius	27 × 27 = 729
Square of internal radius	9 × 9 = 81
Difference of squares	729 − 81 = 648
Sum of squares	729 + 81 = 810

$$\text{Then } \frac{10{,}000 \times 648}{810} = 8{,}000 \text{ lbs. } \textit{Ans.}$$

Table I.—*Pressure of Water at different heads.*

Head in feet	Pressure in pounds per square inch	Head in feet	Pressure in pounds per square inch	Head in feet	Pressure in pounds per square inch	Head in feet	Pressure in pounds per square inch
1	·43	12	5·2	50	21·7	140	60·6
2	·87	15	6·5	60	26·	150	65·
3	1·3	18	7·8	70	30·3	160	69·3
4	1·73	20	8·7	80	34·7	175	76·
5	2·17	25	10·8	90	39·	180	77·9
6	2·6	30	13·	100	43·3	200	87·
8	3·47	35	15·1	120	51·9	250	108·
10	4·33	40	17·3	125	54·	300	130·

Rule.—Multiply head of water in feet by ·433 for pressure in pounds per square inch.

Example.—What pressure in pounds per square inch will be given by a head of 500 feet? 500 × ·433 = 216. *Ans.*

Table II.—*Weight of cylindrical columns of water, each one foot long, of various diameters, in pounds avoirdupois.*

Dia.	Weight	Dia.	Weight	Dia.	Weight	Dia.	Weight	Dia.	Weight	Dia.	Weight
3	3·05	6	12·23	9	27·53	12	48·94	15	76·47	18	110·13
¼	3·59	¼	13·27	¼	29·08	¼	51·	¼	79·05	¼	113·21
½	4·16	½	14·36	½	30·67	½	53·11	½	81·66	½	116·33
¾	4·78	¾	15·48	¾	32·31	¾	55·25	¾	84·31	¾	119·50
4	5·43	7	16·65	10	33·99	13	57·44	16	87·01	19	122·70
¼	6·14	¼	17·86	¼	35·71	¼	59·67	¼	89·75	¼	125·95
½	6·88	½	19·12	½	37·47	½	61·94	½	92·54	½	129·25
¾	7·67	¾	20·41	¾	39·28	¾	64·26	¾	95·36	¾	132·58
5	8·5	8	21·75	11	41·12	14	66·62	17	98·23	20	135·96
¼	9·37	¼	23·13	¼	43·01	¼	69·03	¼	101·14	¼	139·38
½	10·28	½	24·55	½	44·95	½	71·46	½	104·09	½	142·54
¾	11·24	¾	26·02	¾	46·92	¾	73·95	¾	107·09	¾	146·35

Hydraulics treats of the *motion* of water, and Hydrodynamics of the *force* with which it acts.

Descending water is actuated by the same laws as falling bodies; and will fall through 1 foot in ¼ of a second, 4 feet in ½ of a second, and through 9 feet in ¾ of a second, and so on.

The velocity of a fluid spouting through an opening in the side of a vessel is the same that a body would acquire by falling through a perpendicular space equal to that *between the top of the water and the middle of the aperture.*

Rule.—Multiply the space in feet by 64·33, and the square root of the product will be the velocity acquired in feet per second.

Example.—What is the velocity of a stream per second, issuing from a head of 10 feet?

$$\sqrt{10 \times 64{\cdot}33} = 25{\cdot}36 \text{ feet.}$$

If the velocity be 70 feet per second, what is the head?

$$70^2 \div 64{\cdot}33 = 76\tfrac{1}{10} \text{ feet.}$$

The theoretical velocity with which a liquid issues from an orifice in the bottom or side of a vessel that is kept full, is eight times the square root of the head or distance fallen in feet. The practical velocity estimated for the entire opening is considerably less than the theoretical velocity, owing to oblique currents and to friction. These oblique currents produce a contraction in the vein or stream. The minimum transverse section of the contracted vein is the plane at which the velocity is nearly equal to the theoretical velocity. The quantity of water which will be discharged in a certain time depends upon the form of the opening, as well as upon the head. Thus, by means of a conical tube of the form of the contracted vein, the velocity at the opening, or smaller end of the tube, is nearly equal to the theoretical velocity. The actual velocity estimated for the entire opening, when constructed as ordinarily, and not large, is 5·4 times the square root of the head in feet.

Table III.—*Showing the relative velocities with which water, under a constant head, will flow through differently-formed apertures:—*

Theoretical velocity	8·
Velocity through a thin plate	5·
Velocity through a tube two or three diameters in length projecting outward	6·5
Velocity through a tube of the same length, projecting inward	5·45
Velocity through a conical tube of the form of the contracted vein	7·9

Table IV.—*Table for estimating the velocity with which water will flow under a given head.*

Head		Square root of head	Head		Square root of head	Head	Square root of head	Head	Square root of head
ft.	in.		ft.	in.		feet		feet	
	1	·28867	2	4	1·52752	5	2·23607	32	5·65685
	2	·40825	2	5	1·55456	6	2·44949	33	5·74456
	3	·50000	2	6	1·58114	7	2·64575	34	5·83095
	4	·57735	2	7	1·60727	8	2·82843	35	5·91608
	5	·64549	2	8	1·63299	9	3·00000	36	6·00000
	6	·70711	2	9	1·65831	10	3·16228	37	6·08276
	7	·76376	2	10	1·68325	11	3·31662	38	6·16441
	8	·81744	2	11	1·70782	12	3·46410	39	6·24500
	9	·86602	3	0	1·73205	13	3·60556	40	6·32456
	10	·91287	3	1	1·75589	14	3·74166	45	6·70820
	11	·95743	3	2	1·77952	15	3·87298	50	7·07107
1	0	1·00000	3	3	1·80278	16	4·00000	55	7·41620
1	1	1·04084	3	4	1·82574	17	4·12311	60	7·74597
1	2	1·08012	3	5	1·84842	18	4·24264	70	8·36660
1	3	1·11803	3	6	1·87082	19	4·35890	80	8·94427
1	4	1·15469	3	7	1·89297	20	4·47214	90	9·48383
1	5	1·19024	3	8	1·91485	21	4·58258	100	10·00000
1	6	1·22474	3	9	1·93649	22	4·69042	125	11·18034
1	7	1·25830	3	10	1·95789	23	4·79583	150	12·24745
1	8	1·29100	3	11	1·97909	24	4·89898	175	13·22876
1	9	1·32288	4	0	2·00000	25	5·00000	200	14·14214
1	10	1·35400	4	1	2·02072	26	5·09902	225	15·00000
1	11	1·38444	4	2	2·04124	27	5·19615	250	15·81139
2	0	1·41421	4	3	2·06156	28	5·29150	300	17·32051
2	1	1·44339	4	4	2·08167	29	5·38516	400	20·00000
2	2	1·47196	4	5	2·10159	30	5·47723	500	22·36068
2	3	1·50000	4	6	2·12132	31	5·56776	600	24·49490

Sluices.—Rule. Multiply the square root of the depth of the water by 5·4; the product is the velocity in feet per second. This multiplied by the area of the orifice in feet, will give the number of cubic feet per second.

Example 1.—At what velocity in feet per second will water flow from a sluice under a head of 9 feet?

By Table IV., in the column 'square root of head,' opposite the head 9 feet, are the figures 3·00000.

Multiply this number by 5·4. 3·00000 × 5·4 = 16·200000 feet per second.

Note.—If the area of the opening is large compared with the head of water, take $\frac{2}{3}$rds of this velocity for the actual velocity.

Example 2.—What number of cubic feet and pounds of water will flow in one minute, under a 9-feet head, through an aperture, 2 inches wide by 84 inches long?

The velocity per second as given above is		16·2	feet.
The velocity per minute will be	16·2 × 60 =	972	feet.
The area of the opening is	84 × 2 =	168	square inches.
This area in square feet is	168 ÷ 144 =	1·16	square feet.
The velocity in feet per minute multiplied by the area of the aperture	972 × 1·16 =	1127·52	*cubic feet per minute.*
A cubic foot of water weighs 62·4 lbs., Hence	1127·52 × 62·4 =	70·357	lbs. per minute.

If it were required to determine the theoretical power which this water would exert on a water-wheel, it would only be necessary to multiply the number of pounds of water by the fall in feet. But to find the actual power, it would be requisite to multiply the theoretical power by the efficiency of the wheel; and if it were desired to express the power in units of horse-power, the number of effective pounds would have to be divided by 33,000.

As a practical illustration, take an overshot wheel, and let the fall be 40 feet. The efficiency of this wheel under the most favourable circumstances does not exceed ·68. Then 70·357 lbs. × 40 feet × ·68 = 1,913,574 foot-pounds.

1,913,574 ÷ 33,000 = 57·9 actual horse-power.

To determine how much more water will flow under one head than under another.

Rule.—Divide the square root of the greater head in feet by the square root of the less.

Example.—How much more water will flow under a 9-feet head than under a 3-feet head?

By Table IV. the square root of the 9-feet head is 3·00000, and the square root of the 3-feet head is 1·73205.

Hence 3·00000 ÷ 1·73205 = 1·15 times as much.

Vertical Apertures or Slits.—The quantity of water that will flow out of one that reaches as high as the surface, is $\frac{2}{3}$rds of that which would flow out of the same aperture if it were horizontal at the depth of the base.

$$\text{Or, } \frac{\text{velocity at bottom} \times \text{depth} \times 2}{3} \times \text{breadth of slit} = \text{number of cubic feet per second.}$$

Velocity of Streams.—In a stream the velocity is greatest at the surface and in the middle of the current.

To ascertain the velocity of water in streams.—First method. (1) Select a place where the run of water is tolerably straight. (2) Measure along the course one hundred or more feet. (3) At each end of the measurement at right angles to the flow set a straight cord. (4) Get hard wood floats or indicators not affected by the wind, and which will sail uniformly with the velocity of the stream. (5) Drop a float lightly into the stream just above the upper cord, and observe the exact time of passing from one cord to the other. (6) Repeat this experiment, starting a float both in the middle and near to the margin of the stream. (7) Take the mean of the several trials for the surface velocity, and four-fifths for the mean velocity of the water. (8) Multiply the latter velocity by the average breadth and depth of the channel, and the product will express the volume of water between the cords within the time of the observation.

Second Method. Take the number of inches that a floating body passes over in one second in the middle of the current, and extract its square root; double this root, subtract it from the velocity at top and add 1; the result will be the velocity of the stream at the bottom; and the mean velocity of the stream is equal to the velocity at the surface, less the square root of the velocity at the surface increased by $\frac{5}{10}$ths of 1.

Example.—If the velocity at the surface and in the middle of a stream be 36 inches, what is its velocity at the bottom, and what is its mean velocity?

Square root of 36 = 6.
Double this root, 6 × 2 = 12.
36 + 1 − 12 = 25 inches per second velocity at bottom. *Ans.*
Again, 36 + ·5 − 6 = 30·5 inches per second mean velocity. *Ans.*

Weirs and Rectangular Notches.—The following Table V. gives the number of cubic feet of water per minute that will pass over a weir for each inch in width, and from 1 to 19 inches in depth.

Depth of weir in inches	Depth of weir in parts of an inch							
	0	⅛	¼	⅜	½	⅝	¾	⅞
	Number of cubic feet per minute							
1	0·403	0·408	0·563	0·649	0·740	0·835	0·966	1·035
2	1·141	1·248	1·360	1·475	1·593	1·714	1·838	1·964
3	2·094	2·121	2·361	2·599	2·639	2·782	2·927	3·062
4	3·225	3·337	3·531	3·688	3·848	4·009	4·173	4·339
5	4·506	4·676	4·849	5·023	5·200	5·378	5·558	5·740
6	5·925	6·105	6·298	6·488	6·681	6·874	7·071	7·266
7	7·465	7·666	7·869	8·073	8·280	8·487	8·697	8·908
8	9·121	9·335	9·552	9·770	9·990	10·211	10·427	10·657
9	10·884	11·111	11·340	11·571	11·804	12·037	12·272	12·509
10	12·747	13·147	13·228	13·471	13·716	13·961	14·208	14·457
11	14·707	14·957	15·211	15·465	15·721	15·978	16·236	16·495
12	16·757	16·206	17·283	17·549	17·816	18·083	18·352	18·622
13	18·895	19·167	19·445	19·718	19·996	20·274	20·558	20·834
14	21·116	21·400	21·684	21·970	22·258	22·546	22·835	23·127
15	23·418	23·708	24·007	24·302	24·600	24·897	25·195	25·496
16	25·800	26·102	26·406	26·712	27·019	27·325	27·634	27·943
17	28·256	28·566	28·881	29·195	29·512	29·829	30·145	30·464
18	30·785	31·106	31·429	31·752	32·075	32·403	32·733	33·055

Let the weir be 10 inches in depth; opposite 10 inches the second column is 12·747, being the number of cubic feet discharged per minute 1 inch in width. Then again, suppose the weir 6⅜ inches deep. The figures answering to this number are 6·488, which is cubic feet discharged per minute for 1 inch in width. By multiplying the number of cubic feet discharged per inch in width by the width of the weir in inches, the total discharge per minute will be obtained. *Note.*—The water should be set back to a dead level before it passes over the weir-board, and the depth taken at a point before the curve commences.

Scour of Watercourse Beds.

Water running at a velocity of ¼ foot per second will scour *fine clay*
" " ½ " " " *fine sand*
" " ¾ " " " *coarse sand*
" " 1 " " " *fine gravel*
" " 2 feet " " *shingle* 1 inch diameter
" " 3 " " " *angular stones* as large as an egg
" " 5 " " " *conglomerate*

Discharge by Horizontal Pipes.—1st. The less the diameter of the pipe, the less is the proportionate discharge of water.

2nd. The greater the length of the discharging pipe, the greater the diminution of the discharge.

3rd. The friction of water is proportionally greater in small than in large pipes.

4th. The velocity of water flowing out of an aperture is as the square root of the height of the head of the water.

Discharge by Vertical Pipes.—The discharge of fluids by vertical pipes is augmented on the principle of the gravitation of falling bodies; consequently, the greater the length of the pipe, the greater the discharge of the fluid.

Inclined Pipes.—A pipe which is inclined will discharge in a given time a greater quantity of water than a horizontal pipe of the same dimensions.

FLOW OF WATER.—The time occupied by an equal quantity of water flowing through a pipe or gallery of equal lengths and equal falls is proportionally as follows: In a right line, as 90; in a true curve, as 100; and in passing a right angle, as 140.

TABLE VI.—*Advantageous velocities of various Water Motors as compared with the supply velocity.*

Undershot and low breast wheels at circumference	·57
Turbines at the middle of ring of bucket	·65
Reaction at circumference	·97
Overshot wheel at circumference	·50

TABLE VII.—*Comparative efficiency of various Water Motors running under favourable circumstances, as found by experience.*

Theoretical power	1·00
Undershot wheel, with flat radial floats	·35
High breast wheel	·55
Poncelet's improved undershot	·60
Turbine (Scotch reaction)	·66
„ (Jonval's)	·68
Overshot wheels	·68
Overshot and breast wheel (that part of fall acting by weights)	·78
„ „ (that part of fall acting by impulse)	·40
Water-pressure rotative engine	·70
„ reciprocating engine	·80

WATER-WHEELS.—Water as a power or force is exerted on water-wheels both by its weight and impulse. Weight and impulse are combined together on the overshot and breast wheels.

The theoretical work accomplished by *weight* is the product of its force, and the vertical distance through which it is exerted; whilst the theoretical work realised by *impulse*, is the product of the force produced by the weight of the flow of water, and the vertical head necessary to produce the velocity with which the weight moves. The *available work* depends not only upon the magnitude of the force exerted, but upon the direction of that force in reference to the direction given to the resistance; also upon the form of the buckets of the wheel, friction, and losses by leakage.

The vertical height, from the centre of the opening in the sluice to the surface of the water in the head-race or reservoir, is termed the *head of discharge*. The distance in feet from the surface of the water until it meets the wheel is the *head of contact*. The perpendicular distance, from the surface of the water in the tail-race, at the time the wheel is working, to the point when the water meets the wheel, is termed the *fall*. Half the head of contact added to the fall will give the *effective fall*.

Water-wheels are of three kinds: the *Undershot*, *Breast*, and *Overshot*. The term undershot is applied to a wheel when the water strikes at, or below, the centre; the greatest effect being produced when the periphery of the wheel moves with a velocity of one-half that of the water. Breast wheels are those that have the water applied between the centre and the vertex. Overshot, when the water is brought over the wheel, and laid on the opposite side. In either case the maximum velocity is two-thirds that of the water.

The overshot wheel is the most advantageous, as it gives the greatest power with the least quantity of water. The next in order in point of efficacy is the breast wheel, which may be considered a mean between the overshot and undershot. For a small supply of water with a high fall, the first should be employed; when the quantity of water and height of fall are both moderate, the second form should be used. For a large supply of water with a low fall, the third form must be resorted to.

To find the maximum velocity of an undershot wheel:—

RULE.—Multiply the square root, or the perpendicular height of the fall, in feet by 8; the product is the velocity of the water in feet per second. Then multiply by ·57 for obtaining the velocity of the wheel in feet per second.

Example.—Required the maximum velocity of an undershot wheel when propelled by a fall of water 6 feet in height.

$8\sqrt{6} = 2{\cdot}45 \times 8 = 19{\cdot}6$ feet, velocity of water.

$19{\cdot}6 \times {\cdot}57 = 11{\cdot}17$ feet per second for the velocity of the wheel. *Ans.*

To find the head of water proper for breast and overshot wheels, at any velocity, the maximum velocity being two-thirds that of the water:—

RULE.—As the square of 16·095 or 259 is to 4, so is the square of the velocity of the water in feet per second to the head of water, or distance between the centre of the sluice aperture and the point where the water strikes upon the wheel.

Example.—Required the head of water necessary for a wheel 25 feet diameter, moving with a velocity of 5 feet per second.

$5 \div \frac{2}{3} = 5 \times \frac{3}{2} = 7{\cdot}5$, velocity of the water in feet.

$259 : 4 :: 7{\cdot}5^2 : {\cdot}87$, or head of water $10\frac{4}{10}$ inches. *Ans.*

For wheels of from 15 to 20 feet diameter, add $\frac{1}{10}$th of the diameter -1 foot. For wheels from 20 to 30 feet diameter add $\frac{1}{20}$th of the diameter. This additional head is intended to compensate for the friction of water in the aperture of the sluice to keep the velocity as 3 of water to 2 of the wheel; thus, in place of ·87 feet of head for a 25-feet wheel, it will be ${\cdot}87 = 10\frac{4}{10}$ inches $+ 25\frac{25}{20} = 10\frac{4}{10}$ inches $+ 1{\cdot}3 = 2$ feet $1\frac{4}{10}$ inch head of water.

Rule.—(1.) Find the velocity of the water per minute by extracting the square root of the height of the head of the water, viz. from the surface to the middle of the sluice-aperture, and multiply by 8, unless when the opening is small, and the head of water great, or proportionally so, when use from 5·5 to 8 for a multiplier.

(2.) Find the number of cubic feet and pounds delivered per minute; ascertaining the area of the sluice-aperture in feet, then multiply by the velocity of the water in feet per minute; divide the product by 1,728, and multiply the quotient by 62·5 lbs.

(3.) Multiply the number of pounds delivered per minute by ·35, and divide by 33,000; the quotient is the number of horse-power.

Example.—What is the power of an undershot wheel applied to a stream 2 feet × 80 inches from a head 25 feet?

(1.) $\sqrt{25} \times 6{\cdot}5 \times 60 = 1{,}950$ feet, velocity of water per minute.

(2.) $2 \times 80 \times 1{,}950 \times 12 \div 1{,}728 = 2166{\cdot}6$ cubic feet delivered per minute.

Then $2166{\cdot}6 \times 62{\cdot}5 = 135{,}412$ lbs. of water discharged in 1 minute.

(3.) $135{,}412 \times {\cdot}35 \div 33{,}000 = 1{\cdot}4$ effective horse-power. *Ans.*

To find the power of a breast wheel.—Rule. Find the effect of an undershot wheel, the head of water of which is the difference of level between the surface and where it strikes the wheel (breast), and add to it the effect of that of an overshot wheel, the height of the head of which is equal to the difference between where the water strikes the wheel and the tail-water; the sum is the effective horse-power.

Example.—What would be the power of a breast wheel applied to a stream 2 × 80 inches 14 feet from the surface, the rest of the fall being 13 feet?

$\sqrt{14} \times 6{\cdot}5 \times 60 = 1{,}458{\cdot}6$ feet, velocity of water per minute,

and $2 \times 80 \times 1{,}458 \times 12 \div 1{,}728 = 1{,}620$ cubic feet $\times 62{\cdot}5 = 101{,}250$ lbs. water discharged in 1 minute.

Then $101{,}250 \times {\cdot}35 = 1{\cdot}07$ horse-power as an undershot.

$\sqrt{11} \times 6{\cdot}5 \times 60 = 1{,}290$ feet, velocity of water per minute,

and $2 \times 80 \times 1{,}290 \times 12 \div 1{,}728 = 1{,}433$ cubic feet $\times 62{\cdot}5 = 89{,}562$ lbs. of water discharged in 1 minute.

× 11 height of fall $\times {\cdot}35 \div 33{,}000 = 20{\cdot}3$ horses, which added to the above $=$ 21·37. *Ans.*

To find the power of an overshot wheel.—Rule. Multiply the weight of water in pounds discharged upon the wheel in one minute by the height or distance in feet from the centre of the sluice-opening to the lower edge of the wheel, then multiply by ·68 and divide the product by 33,000, the quotient will be the number of horses'-power.

Example.—The weight of water discharged on a wheel per minute is 50,000 pounds, the height of fall is 26 feet, and diameter of wheel 25 feet, what is the power of the wheel?

Total height of fall from centre of sluice—opening to bottom of tail-race, 26 ft.; deduct clearance below, 8 in. Total, 25 ft. 4 in.

$50{,}000 \times 25{\cdot}4 \times {\cdot}68 \div 33{,}000 = 26\frac{1}{10}$ effective horses'-power. *Ans.*

Circle of gyration.—The centre or circle of gyration is that point or circle in a wheel into which, if the whole quantity of matter were collected, the same moving force would generate the same angular velocity. Motion ought always to be communicated from that centre whenever it is practible.

To find the circle of gyration.—Rule. Add together twice the weight of the shrouding, buckets, &c., $\frac{2}{3}$rds of the weight of the arms and the weight of the water; multiply the sum by the square of the radius; divide the product by twice the sum of the weight of the shrouding arms added to the weight of the water, and the square root of the quotient is the radius of the circle of gyration from the centre of suspension, nearly.

Example.—Required the distance of the centre of gyration from the centre of suspension in a water-wheel 22 feet diameter, shrouding, buckets, &c. = 18 tons, arms = 12 tons, and water 10 tons.

$$\text{Then } \sqrt{\{(2 \times 18 + \tfrac{2}{3} \times 12 + 10) \times 11^2 \div [(18 + 12) \times 2 + 10]\}}$$
$$= \sqrt{\{(36 + 8 + 10) \times 121 \div (30 \times 2 + 10)\}} = \sqrt{\{(54 \times 121) \div 70\}}$$
$$= \sqrt{(6{,}534 \div 70)} = \sqrt{93{\cdot}34} = 9{\cdot}7 \text{ feet from the centre of suspension.}$$

To find the horse-power of Water-wheels according to a method employed in various parts of America:

TABLE VIII.—*Coefficients.*

Head	Coefficient	Head	Coefficient	Head	Coefficient	Head	Coefficient
ft. in.		ft. in.		ft. in.		feet	
1	12	1 7	54	3 2	76	9	128
2	17	1 8	55	3 4	78	10	135
3	21	1 9	56	3 6	80	12	148
4	25	1 10	58	3 8	82	14	160
5	28	1 11	59	3 10	84	16	171
6	30	2 0	60	4 0	85	20	191
7	33	2 1	62	4 3	88	25	213
8	35	2 2	63	4 6	90	30	233
9	37	2 3	64	4 9	93	36	256
10	39	2 4	65	5 0	95	49	298
11	41	2 5	66	5 4	98	64	341
1 0	43	2 6	67	5 8	101	81	384
1 1	44	2 7	69	6 0	104	100	426
1 2	46	2 8	70	6 6	109	121	469
1 3	48	2 9	71	7 0	113	144	511
1 4	49	2 10	72	7 6	117	169	554
1 5	51	2 11	73	8 0	121	196	597
1 6	52	3 0	74	8 6	124	225	639

RULE.—Multiply the product of the coefficients—(see Table VIII.) opposite the given head, the area of the opening in the sluice in square inches, the entire head in feet (in case of the overshot or breast, the head by 40 and the fall by 78)—by the efficiency of the class of wheel, pointing off 6 figures as decimals.

Example 1.—The dimensions of a stream are 2 inches by 200 inches, the head 2 feet 3 inches and the fall 10 feet; what is its horse-power applied to a breast wheel?

2 inches × 200 = 400 square inches opening.
Coefficient by Table VIII. opposite 2 feet 3 inches = 64.
Efficiency by Table VII. arising from weight = 78.
Efficiency by Table VII. arising from impulse = 40.
Head 2·3 = 2·25 feet.
Product of efficiency and head 2·25 × 40 = 90.
Product of efficiency and fall 10 × 78 = 780.
Sum of products 780 + 90 = 870.
Then 870 × 400 × 64 = 22·27 horses'-power. *Ans.*

Example 2.—The dimensions of a stream are 10 inches square, the head 25 feet; what is its horse-power applied to a good turbine?

Square inches in opening 10 × 10 = 100.
Coefficient by Table VIII . opposite head (25 feet) = 213.
Efficiency by Table VII. of turbine = ·68
Then 100 × 213 × ·68 × 25 = 36·21 horses'-power. *Ans.*

To find the horse-power of a single or double direct-acting pressure-engine.—RULE. Multiply the net area of the piston in inches by the vertical pressure in pounds per square inch; then, for a single-acting engine, by one-half the journey made by the piston per minute; deduct $\frac{1}{4}$ for friction and absorption of power, divide by 33,000, and the quotient will be the effective horse-power. Should the engine be double-acting, double the figures of the quotient.

Example.—What load will a single-acting pressure-engine sustain, and what will be the horse-power, the diameter of the cylinder being 20 inches, effective journey of piston 60 feet per minute, height of pressure-column 200 feet?

Pressure-column Table I. 200 feet = 87 lbs. pressure per square inch.
Diameter of cylinder 20 inches = 314·16 square inches, and
Product of efficiency in Table VII. ·80
314·16 × 87 lbs. × ·80 = 21,865 lbs. actual load which piston will sustain.
Then 21,865 × 60 ÷ 33,000 = 49·7 effective horse-power.

Charging rams.—To find the area of a ram for charging an accumulator, to work under a given load when the effective sustaining power of the charging engine is known.

Rule.—Divide the effective sustaining power of the engine by the load per square inch to be imposed on the accumulator, the quotient will be the area of the charging ram.

Example.—The effective sustaining power of a pressure-engine is 21,865 lbs., and the accumulator is to carry a load of 800 lbs per square inch. What will be the area of the charging ram?

21,865 ÷ 800 = 27·2 inches area, or $5\frac{7}{8}$ inches diameter.

Accumulator.—To ascertain the weight required on an accumulator ram of a given diameter, the charging pressure being given.

Rule.—Multiply the area of the accumulator ram by the charging pressure in pounds, the product will be the weight required on the accumulator ram less the dead weight of the accumulator ram, cross-head and weight-box.

Example.—An accumulator ram is 10 inches diameter, the charging pressure is 800 lbs. per square inch, the weight of the ram, cross-head and weight-box is 6,000 lbs.: what extra weight must be added?

	lbs.
10 inches = 78·54 × 800 lbs.	62,832
Less weight of ram, cross-head and weight-box	6,000
Ans.	56,822

Useful Memoranda.

1 cubic foot of water weighs 1,000 ounces, or	62·5 lbs.
1 cubic inch ,,	·036 lb.
1 imperial gallon = 277·274 cubic inches	10 lbs.
1 ,,	0·16 cub. ft.
1 cubic foot of water = 6,238 gallons, or approximately	$6\frac{1}{4}$ gall.
1·8 cubic foot of water	1 cwt.
11·2 imperial gallons = 1 cwt. or 224 gall.	1 ton
35·84 cubic feet	1 ton
A column of water 12 inches high one inch square	·434 lbs.
,, ,, ,, diameter	·341 lbs.
One cylindrical foot of water	4,895 imp. gall.

Sea Water.

1 cubic foot = 64·11 lbs. or 1·027 times the weight of fresh water.

Rainfall.

Inches of rainfall × 2,323,200 = cubic feet per square mile.
,, × $14\frac{1}{2}$ = millions of gallons per square mile.
,, × 3,630 = cubic feet per acre.

Sundries.

A fall of $\frac{1}{10}$th of an inch in a mile will produce a current in rivers.
Melted snow produces about $\frac{1}{8}$th of its bulk in water.
Sound passes in water at a velocity of 4,708 feet per second.

Expansion of Water.

Volume of water at 32° = 1,000.
,, at 212° = 1,046; increase in 180° = ·046.

Construction of Water-wheels.—The application of vertical wheels to the purposes of mining is copiously illustrated in Agricola's work, 'De Re Metallica,' edition 1621, where overshot and undershot wheels are shown driving pumps direct, as well as through the medium of cranks and spur-gearing.

General Rules.—When iron is used for water-wheels, curved buckets and shroudings are preferable to deal float-boards and oak starts.

In designing iron wheels care should be taken that, while attempting to form a bucket which shall carry the water as long as it can act beneficially, the opening or mouth of the buckets shall not be so contracted as to prevent the free admission of water into them, or its free egress at the bottom of the periphery. Fairbairn's rule for bucket openings in wheels of high fall is nearly as 5 to 24, that is with a bucket holding 24 cubic feet, the area of the water entrance should be 5 square feet. In breast wheels the area should be increased to 8 square feet, or in the proportion of *one* to *three.* With these proportions the depth of shrouding is regarded as three times the distance from the tip to the back of the bucket.

In wheels receiving the water below the centre of the axis, a still larger opening for the entrance and exit of the water is required.

In each variety of wheel the maximum effect of the water can only be secured by making the bucket-openings sufficiently large to allow of the ready admission and escape of the water within the limits of the vertical centre.

Undershot water-wheels.—In localities where the supply of water is large, and the fall comparatively low, the undershot wheel offers an obvious and cheap medium for utilising the power of the current. In the year 1825 Poncelet, after an extensive series of experiments found that the floats, instead of presenting a plain radial surface to the impulse of the water, ought to consist of circular arcs of assignable radii of curvature. Following this discovery certain practicable rules have been established which may be abridged as follows: (1) Let the stream act on the buckets at from 7 to 26 inches from the point where the water leaves the wheel

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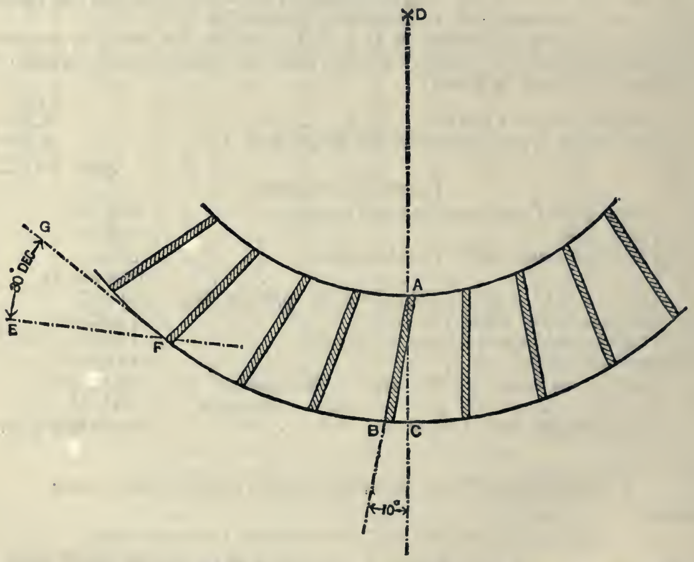
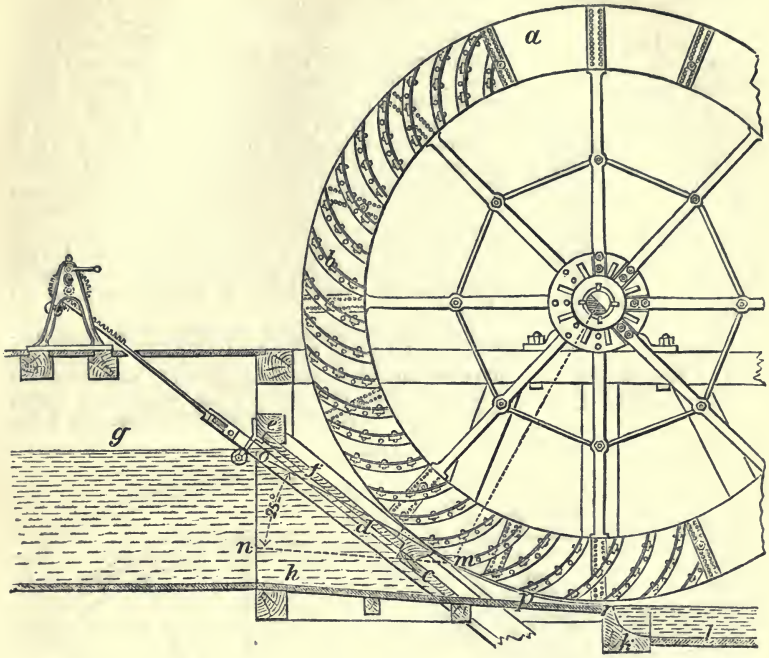


(2) The product of the square root of the perpendicular height in feet from the surface of the water in the head-race till it meets the buckets, multiplied by 4·2, will be the velocity of the skirt of the wheel in feet per second. (3) Set the sluice at the part where the water leaves it, as near the wheel as possible, with a backward inclination, and its under edge so formed as to run the water in the buckets at an angle of 30° from a tangent to the circumference. (4) Contract slightly the sides of the cistern next the sluice-frame conducting the water to the wheel. (5) Make the sluice-opening about 4 inches narrower than the wheel. (6) Make sluice and frame so that the impelling water may run freely and without obstruction to the buckets. (7) The width of wheel must not exceed width of passage for conveying the water.

The method of setting out the buckets of an undershot wheel, as also the mean direction of the water entering the buckets, is shown in *fig.* 1174. A B line of buckets inclined at an angle of 10° from the radius line C D; F E mean direction of the water entering the buckets, the line being at an angle of 30° with the tangent line F G.

Poncelet's Undershot Water-wheel.—A part elevation of this wheel is shown in *fig.* 1175: *a*, shrouding; *b*, buckets; *c*, sluice-plate; *d*, grooves for sluice-plate; *e*, transverse beams; *f*, cross-binder and planking; *g*, reservoir; *h*, floor of water-course; *k*,

1175



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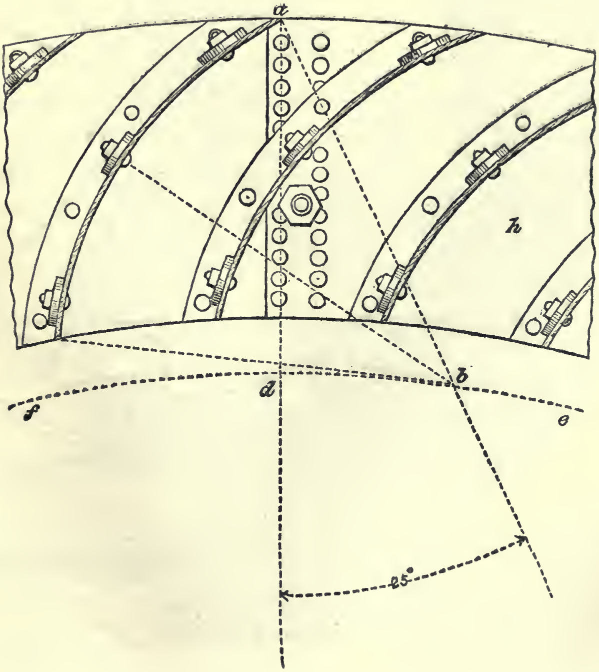
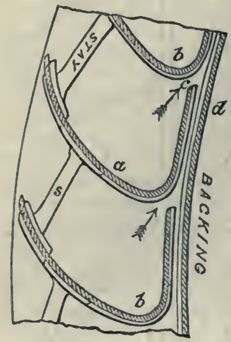


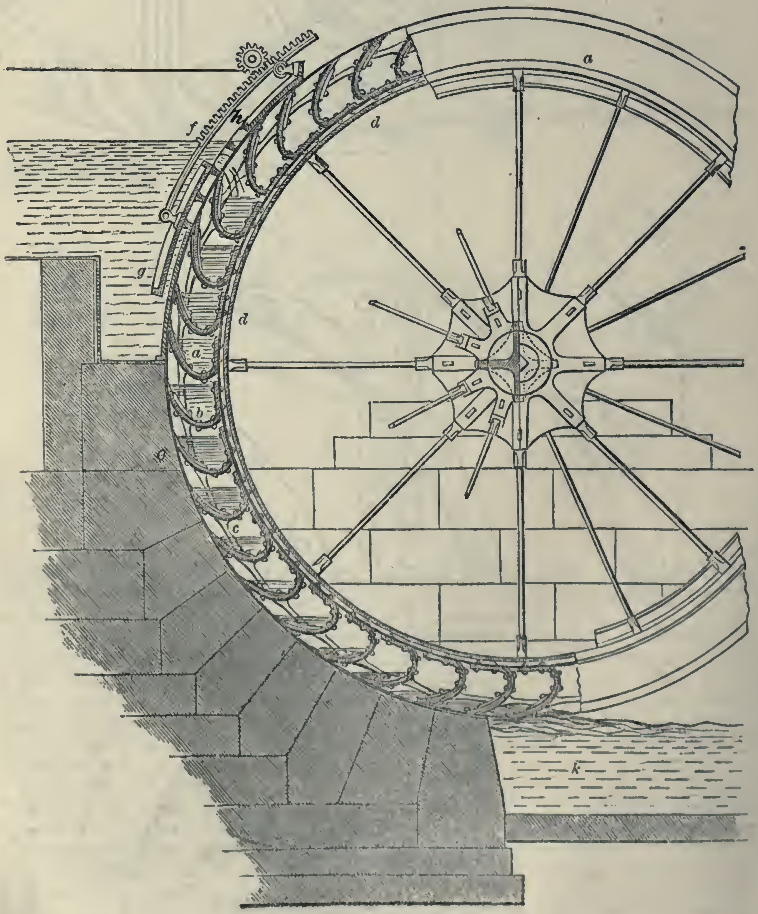
beam in which is formed an abrupt descent for the liberation of the water; *l p*, flanking of tail-race. In order that the water may impinge upon the buckets of the wheel with the least possible loss of effect, the bottom of the course, where it approaches the point of impulse, is made with a declination of from 3° to 4° from the horizontal direction. The line of direction *m n*, of that portion of the water flowing through the sluice opening *c*, ought therefore to make with the tangent line *m o*, to the circle of the wheel, an angle of 24° to 25°. The surface *p h* of the water-run is a tangent drawn to the small circular arc *p r*, which approaches close upon the circumference of the wheel at that part where it passes the vertical plane, and which should be as long as the distance between two contiguous buckets. At the point *r* the arc terminates abruptly for the width of the race, allowing a drop for the water equal to half the depth of the shrouding.

1177



Method of determining the curvature of the buckets.—From a point *a* (*fig.* 1176) in the extreme circumference draw the line *a b*, making an angle of 25° with the radius *a d*, drawn from the centre of the wheel to *a*. Then with a radius of $\frac{1}{6}$th of the depth of the shrouding *h*, less

1178



than the inner circumference; describe from the centre another circle, *e f*, cutting the line *a b* in *b*; this point *b* will be the centre from which the curve of the bucket should be drawn.

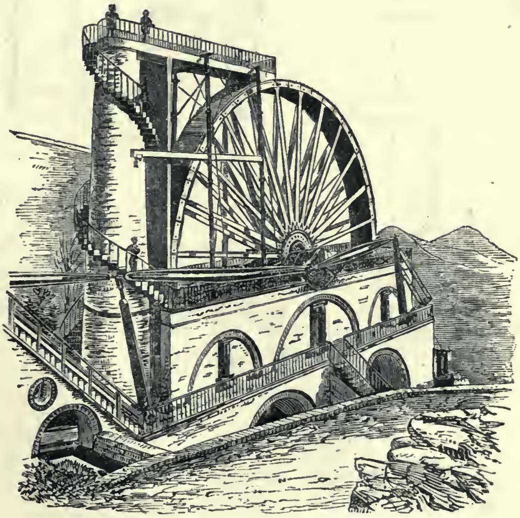
Breast Wheel.—The water acts on the periphery of this wheel both by its weight and impulse, one foot of fall affording as much power as two feet of head. The circumferential velocity is commonly about 4½ feet per second, and the speed of the water entering the buckets 6½ feet per second.

The slower the wheel revolves, and the higher it receives the water, the more the buckets may be sloped, so as to retain the water to the proper point of discharge.

For the purpose of expelling the air from the buckets, the stream should be of less width than that of the buckets, or otherwise openings should be formed in the backing ¾ of an inch wide, or the bucket constructed as shown in *fig.* 1177. A good example of the form of iron buckets employed in the breast wheel, as well as the arrangement for supplying and taking off the water, is shown in *fig.* 1178: *a*, shrouding; *b*, the buckets; *c*, stays between the buckets; *d*, sole plate or backing; *e*, breast work; *f*, cistern or mill-race; *g*, sluice-race; *h*, sluice-cover; *k*, tail-race. The distinguishing feature of the arrangement shown consists in the wheel working against a circular breast of masonry, fitted close to the outer circumference of the shrouding and ends of the buckets. The cistern leading into the wheel is likewise fitted close to its periphery. The loaded portion of the wheel is therefore enclosed, and hence, in forming the buckets, it is not absolutely necessary to contract the mouth for the purpose of retaining the water.

Overshot Wheel.—The overshot wheel receives its water a little distance to the right or left of the vertical centre line. Smeaton's experiments showed that the best effect was obtained when the circumferential speed was limited to 3½ feet per second, or 210 feet per minute. With, however, the increase of diameter in wheels, it is found that the speed may be advantageously augmented. A wheel 20 feet in diameter may move *six* feet per second, and where economy in the propelling power is not a special object, the circumference of the wheel may run at 8½ feet per second. This greater speed will be found in some cases desirable; the wheel may be lighter and cheaper than a slow-running wheel, and less gear will be required to bring the speed up to the required rate for driving machinery. In practice it is found that a fall of 7 inches will bring water upon a wheel full 3½ feet per second, and a fall of 19 inches will give a velocity to the stream of quite 6 feet per second. In reference to wheels of this class it may be observed: (1) when the volume of water is large and variable, and the fall of an intermediate height, it is found advantageous not to lay the water upon the top of the wheel, so that it may work overshot, but to make the diameter of the wheel greater than the mean height of the fall, and to lay on the water at about 45° from

1179

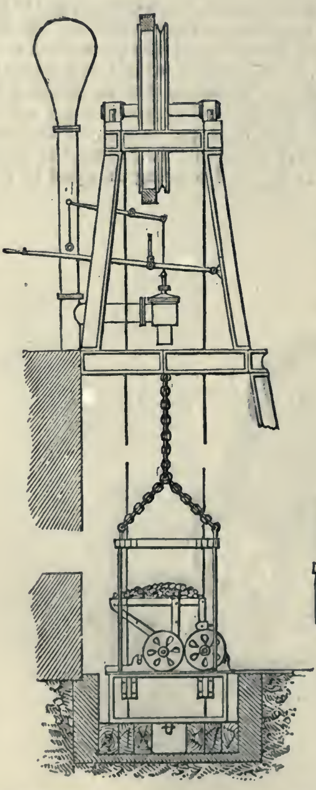


the perpendicular—or, as miners say, at *nine o'clock*; (2) when the fall exceeds 60 feet, a turbine, or water-pressure engine, will generally be found less costly and more effective; (3) wheels placed one over the other, and geared together, so as to employ a high fall of water, do not afford satisfactory results.

Fig. 1179 illustrates an overshot wheel employed in pumping at the Laxey Mines, Isle of Man. The diameter is 72 feet 6 inches; width between shroudings, 6 feet; length of shaft, 17 feet; diameter of shaft, 21 inches; length of crank, 5 feet; stroke, 10 feet; stroke in pump, 8 feet. The water is conveyed in pipes 2 feet diameter, and, after rising through the column, is carried to the top of the wheels by means of a launder. On one side of the crank a balance 'bob' is fixed; from the other is extended the sweep and 'flat rods,' reaching to the pump shaft, about 200 yards distant.

At Wheal Friendship, Tavistock, under the direction of the late Mr. Taylor, an aggregate fall of 526 feet was utilised through the medium of seventeen water-wheels, eight of which were employed in pumping. The largest wheel was 51 feet diameter, and 10 feet between the shrouding. The water ran into the buckets at the rate of 5,600 gallons per minute, consequently the horse-power expended was $\left(\frac{5,600 \times 10 \times 51}{33,000}\right)$ 86½. The wheel made 5 revolutions per minute; length of stroke in the pump, 6 feet; effective journey per minute, 30 feet; weight of water in the various lifts or columns of pumps, extending a depth of 188 fathoms, 66,415 lbs. The work performed by this wheel was therefore 69 per cent. of the power expended, or equal to 60 effective horse-power.

1180



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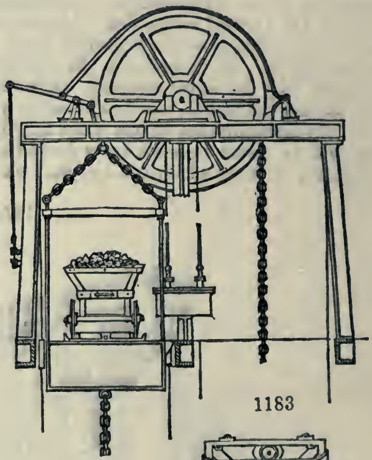

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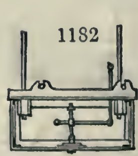

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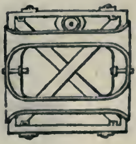


Turbine.—The use of turbines in mining operations is somewhat limited by the high speed of the wheels, and the necessity of employing intermediate shafts and wheel-gear. Without reducing gear, the apparatus cannot be directly applied either to winding, dressing, or pumping purposes, but it might be advantageously employed to run a telo-dynamic cord across country, so as to give motion to various machines. See TURBINE.

Water-balance.—This apparatus is employed at various quarries in Wales, and at numerous places on the Continent. Its chief use is in lifting stuff vertically, but there are many cases where it is applied to incline hauling.

An endless chain is passed over a head-wheel; two wrought-iron boxes are attached to this chain, so that when one is at the top, the other is at the bottom of the shaft. Each water-box is covered by a strong platform, which carries a waggon, and each box is fitted with a valve. A pipe in connection with a cistern or reservoir, laid to the mouth of the shaft, is fitted with two valve-boxes.

The box being filled with water, overbalances the empty box, and raises it with its waggon of stuff to the top of the shaft. When the full box has descended to the bottom of the shaft, the valve is opened, and the water discharged into the adit or day level. The boxes run in rope guides, and the discharging valves may be opened by an attendant, or otherwise by striking a stud set for the purpose. Rails are laid so as to run the waggons off and on the platforms. *Fig.* 1180 is a cross elevation, showing the box and waggon at bottom of the shaft, also the charging-pipe and air-vessel at surface; *fig.* 1181 a side elevation of the box at surface, charging-pipe, brake-wheel, and lever; *fig.* 1182 section of box and discharge-valve; *fig.* 1183 plan of water-box.

Water-pressure Engines.—The power of these engines is derived from the weight of a column of water acting or pressing directly on rams or pistons.

To work these engines successfully, air-vessels, momentum-plungers, or other suitable contrivances, should be applied between the cylinder and the pressure-column.

For mining purposes pressure-engines ought to be of simple construction, all parts readily accessible, and the following suggestions more or less observed:—(1) Employ cotton-packing in gland-boxes instead of single or cup leathers for iron rods above 3 inches diameter; (2) if it is designed to work under very high pressures, use brass or brass-cased rams; (3) work with balanced valves; (4) in forcing water to an accumulator, set the pump-valves higher than the pump, or otherwise let the water gravitate to the bottom clack, so as to fill the ram cases, and prevent the ingress of air.

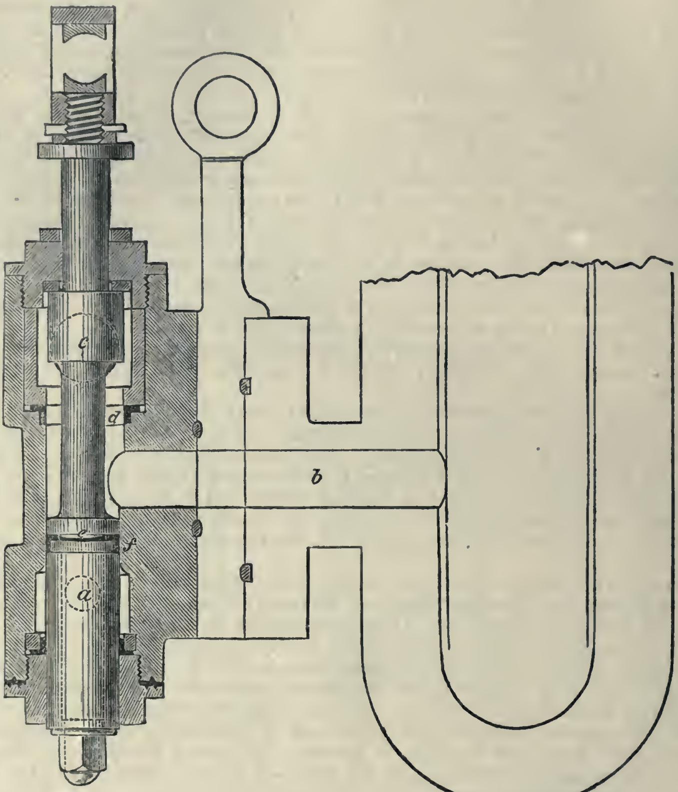
Owing to the shock communicated to the pressure pipes, as well as to other parts of the machinery, by the sudden stoppage of a flowing column of water, it is necessary to keep the piston speed very low. Long-stroke engines are also desirable.

It is exceedingly difficult to discover the original inventor of piston reciprocating water-engines, but machines of this class seem to have been first employed in Germany. In 1748 an engineer named Winderschmidt erected a water-pressure engine at the Grube Beständigkeit, Oberharz. Between 1759 and 1768 six additional engines were set to work at Schemnitz, in Hungary, and in 1767 other engines were placed at the Siegfried mine, near Freiberg, in Saxony. In Austria the first water-pressure machine was probably started about the middle of the last century. In 1765 Westgarth erected an engine at the Caldcleugh mine, Northumberland. Five years after Smeaton placed a water-pressure machine at Temple Newsam, Yorkshire. From 1798 to 1804 Trevithick erected engines at Huel Henry and Huel Druid, Cornwall, and one at the Alport mines, Youlgreave, Derbyshire. About 1835 Fairbairn constructed a water-pressure engine for the same mine. Between 1841 and 1848 Darlington designed and added three large pumping-engines, one of which, with a cylinder 50 inches diameter, was made at the Butterly Works, then under the management of the late Mr. Joseph Glynn. Subsequently Armstrong employed an accumulator and rotary engines at Allenheads. In 1833 Dean, of Hexham, and in 1862 Pattinson, Davison and Spencer, of the same town, built horizontal and vertical engines for the Leadhills Lead Mines, Lanarkshire. Darlington also designed and erected hydraulic pumping-engines at Lisburne, Cwmystwyth, Tarlargoch, and Minera, in North Wales, between the years 1843 and 1856.

Valves.—The slide-valve shown on page 863, *fig.* 1194, may be applied both to small pumping and winding engines intended to be worked under a heavy water pressure. It is an ordinary D-shaped slide made of 3½ parts of tin and 16 copper. The seating or face plate is also made of similar composite metal. The valve face is in some cases attached to the face holder in the following manner:—(1) Heat valve face holder, and wash face with a solution of chloride of zinc. (2) Re-heat valve face holder and valve face hot enough to melt tin. (3) Put melted tin on valve face and face holder, bring the two faces together and solder.

The balance valve shown in *fig.* 1184 is in use at the Wildberg mines, Prussia. The water under pressure flows through the opening *a*, then to the main cylinder through the port *b*. After having performed its work, it returns through the port *b* and passes away by the eduction opening *c*. The bar valve, as will be seen, moves into a single leather *d*, when the water flows to the cylinder, and on flowing from the cylinder the valve leather *e* passes into the cylindrical part *f* of the valve-box. Experience has shown that leathers worked in this way are thoroughly reliable, and that the valve itself is effective under very high pressures. Both valve bar and box are of gun-metal.

1184



Balance and Differential Pistons.—Under considerable pressures balance-valve pistons are necessary. Examples of their application is shown in Darlington's pressure-engine, N O, page 855 *fig.* 1187, and also in Trevithick's engine, B C, *fig.* 1188, page 856. Differential valve pistons, K I, are shown in *fig.* 1187, page 855.

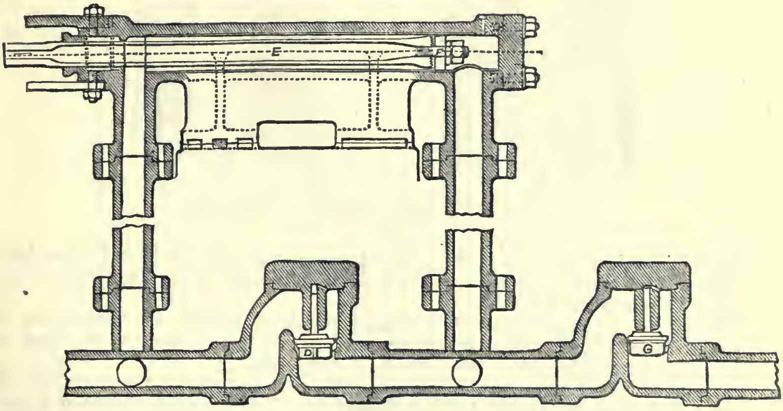
Cup Leathers.—Cup leathers are either single or double, the former are partly clipped between two metallic surfaces, the latter are supported on a loose ring. For large plungers, leathers are costly, and apt to wear quickly. Iron surfaces are readily attacked by mineral waters which produce a saw-like roughness calculated to tear the edge and face of the leathers. For brass rams, leathers may be used with the greatest advantage, since in contact with that metal they will be very durable and cause but little friction. The table at the head of p. 853 gives the friction occasioned by the use of leathers on rams the surfaces of which are in good smooth working order.

Packing.—For cylinders of very large diameter under moderately low pressures, hemp rope, or gasket may be employed. Brass packing rings are also reliable. For valve pistons, passing ports, a close working fit between the piston and cylinder will prove satisfactory. Small pistons or rams travelling under high pressures should be fitted with single or double cup leathers. Iron rods above 3 inches diameter, if packed with lamp-wick, will give less trouble than if worked in contact with cup leathers.

Diameter of ram in inches	Friction per cent.	Diameter of ram in inches	Friction per cent.
2	2	11	·38
3	1·33	12	·33
4	1	13	·30
5	·80	14	·28
6	·66	15	·26
7	·57	16	·25
8	·50	17	·23
9	·44	18	·22
10	·40	19	·21

Charging Plungers and Pistons.—For charging accumulators or effecting the transfer of power, plungers are usually employed. The advantage which a plunger offers over a piston is that any leakage is instantly seen and can almost immediately be prevented. When it is required to force water under a high pressure the valves should not only be large, but set so that air cannot pass into the plunger case. A precautionary method is to gravitate the water to the bottom valve. In addition, it will in some cases be judicious to provide the ram cases with small pet valves for discharging any intrusion of air. Unless the air be entirely excluded from the plunger cases, the cubic inches of water delivered to the accumulator will by no means correspond to the cubic inches of the stroke. A simple and effective force pump is shown in *fig.* 1185. In this arrangement the outstroke of the pump causes the water contained in the annular space surrounding the rod E to be forced into the air vessel or accumulator whilst a further supply of water enters behind the piston through the inlet G. In the other half of the stroke the water behind the piston is discharged through the valve D and half of it into the annular space on the other side of the piston. In this pump the area of the rod E is exactly half that of the piston F. Both the inlet and delivery valves are of easy access.

1185



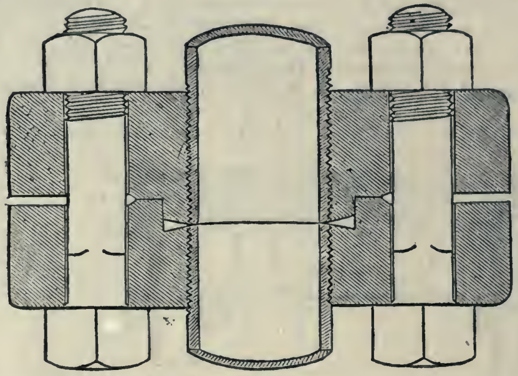
Accumulators and Air Vessels.—The accumulator is shown in *figs.* 1170 and 1189, and its use is fully explained at page 833. Air vessels may to some extent be used as a substitute for the accumulator, but this class of apparatus impose a varying resistance on the charging pumps, whilst the resistance offered by the accumulator is a constant one. Moreover, the air vessel has the serious defect of requiring frequent replenishing, owing to the absorption of air by the water. This especially occurs under high pressures, as will be gathered from the following particulars. (See Table, p. 854.)

The effective capacity of air vessels is governed by the pressure of water to which they are to be subjected. Long and capacious vessels will afford more satisfactory results than short and small ones. In most cases it will be desirable to fit the vessel with a pressure-gauge, and a gauge-glass. An example of an air vessel fitted in this way and applied for the purpose of relieving pressure and preventing shock is shown in *fig.* 1194, page 863, where D is the vessel.

	Oxygen	Nitrogen	Total
Composition of air	21 parts	79 parts	=100
Volume of air absorbed in water under a pressure of 15 lbs. per square inch . . .	·046 „	·025 „	= ·071
30 „ „ . . .	·092 „	·050 „	= ·142
45 „ „ . . .	·138 „	·075 „	= ·213
60 „ „ . . .	·184 „	·100 „	= ·284
75 „ „ . . .	·230 „	·125 „	= ·355
90 „ „ . . .	·276 „	·150 „	= ·426

Pipes and Joints.—For underground mains wrought-iron pipes pitched inside will be found advantageous, since they will be found to resist the action of ordinary water, and can be bent cold to suit the course of a level. The ends should be fitted with thick cast-iron flanges, the latter faced and formed as shown in *fig.* 1186.

1186



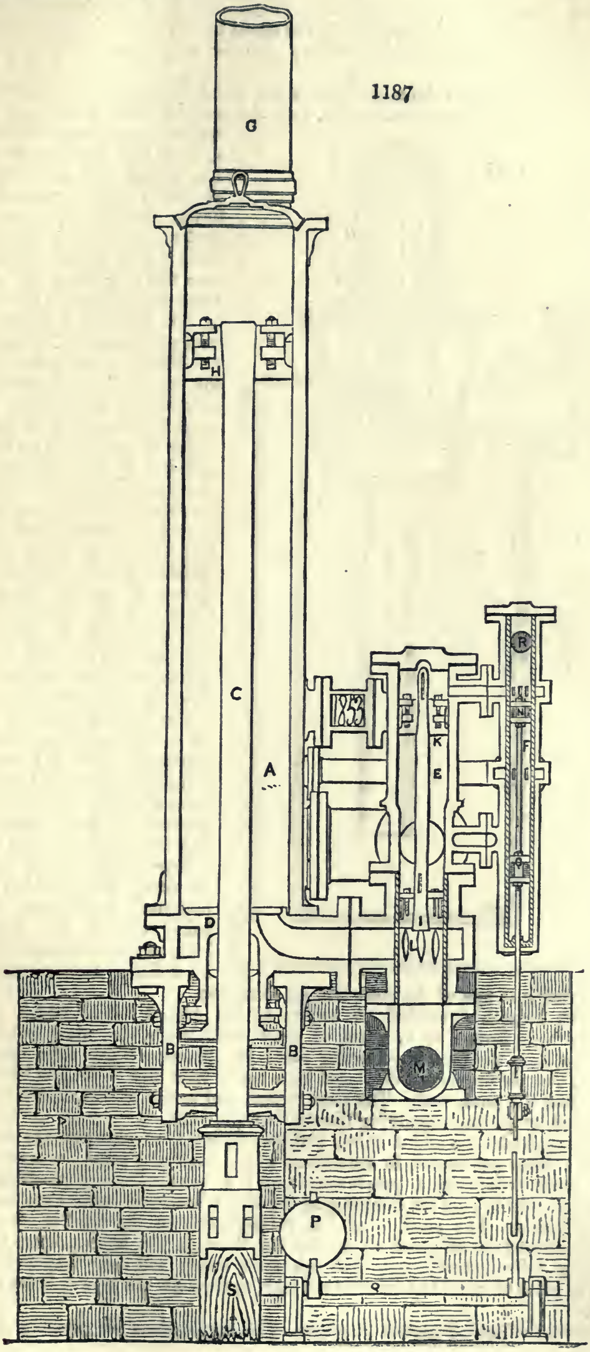
The joints should be made with a ring of gutta-percha from $\frac{3}{16}$ths to $\frac{1}{4}$ of an inch diameter, unless the main is to be charged with hot water, when it will be better to employ vulcanised rubber.

Pumping Engines.—Considerable attention has been given to the construction of pressure-engines by Mr. Darlington, who was actively engaged some years since in effecting the drainage of the Alport mines, in Derbyshire.

The first engine erected by him had a cylinder 50 inches diameter, and a stroke of 10 feet; the piston-rod passed through the bottom of the cylinder and formed a continuation with the pump-rod, whilst the valve and cataract gearing was worked by a rod connected with the top of the piston, which gave motion to a beam and plug-rod gearing. The column of water was 132 feet high, affording a pressure on the piston of about 58 pounds per square inch, or more than 50 tons on its area. The water was raised from a depth of 22 fathoms, by means of a plunger 42 inches diameter, and in very wet seasons it discharged into the adit nearly 5,000 gallons of water per minute. Water was admitted only on the under side of the piston, and in order to avoid violent concussion in working, two sets of valves were employed, the larger being cylindrically shaped, 22 inches diameter, and the smaller 5 inches diameter. In making the upstroke of the engine the cylindrical valves admitted a full flow of water for about $\frac{7}{8}$ths of the stroke, and then commenced closing, but at this stage the small valve opened, through which passed sufficient water to terminate the stroke. In this way the flow of water in the column was gradually slackened, and finally brought to a state of rest without imparting impact to the machinery. The speed of the engine was regulated by sluice-valves, one fixed between the engine and the pressure-column, and the other upon the discharge-pipe.

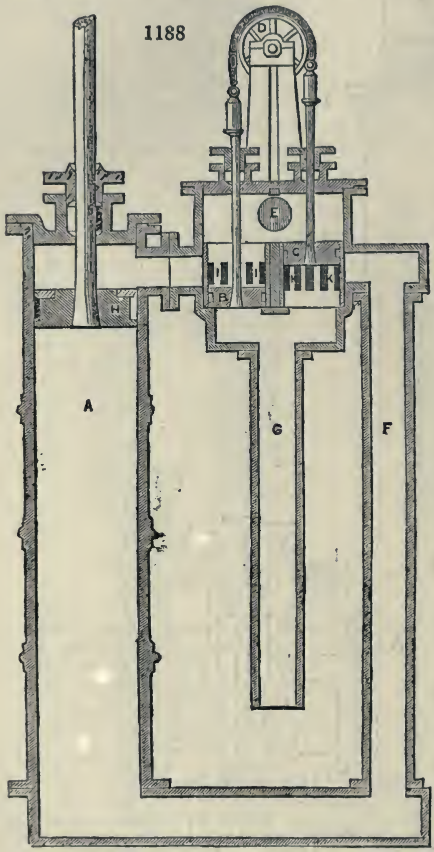
The cylindrical valves were made of brass with a thin feather-edged beat, and kept tight by a concentric boss, projecting from the nozzle, upon which hemp packing was laid. This was pressed down by a projection in the under surface of the valve bonnet. The water thus acted on the exterior of the valves between the zone of packing and the seatings, and when opened passed through the latter. Besides this engine, others of a different construction were designed and erected by Mr. Darlington, but the one to which he gave preference for simplicity, cheapness, and smoothness of action is illustrated in *fig.* 1187.

1187



This engine has one main cylinder A, resting on strong cast-iron bearers B B, fixed across the shaft. The piston-rod C is a continuation of the pump-rod S, and works through the cylinder bottom D. In front of the cylinder A is a smaller one E, with differential diameters for the admission and emission of water, and right and left are sluice valves not shown for regulating the speed of the engine. Connected with the second cylinder is a small 3-inch auxiliary cylinder F, provided with inlet and outlet regulating cocks.

1188



In starting this engine the sluice-valves and regulating cocks are opened, the water then flows from the pressure-column G, into the main cylinder A, through the nozzle cylinder E, and acts under the piston A, until the upstroke is completed. The piston I has a counter piston K, of larger diameter, and when relieved from pressure on its upper surface, the water acting between them forces it upwards, in which case the pressure is cut off from the main piston, and the water contained in the cylinder A is free to escape under the piston I, through the holes L. With the emission of water from the main cylinder through M, the downstroke is effected. The downward displacement of the pistons I and K is performed by the auxiliary cylinder F, and pistons N, O; the pressure-column is continually acting between these pistons, and by their alternate displacement by the fall-ball P, and canti-arbor Q. The water is either admitted or prevented from operating on the upper surface of the piston K. The water from the top of piston K escapes through the aperture R. The motion of the canti-arbor Q is effected by tappets fixed on the pump-rod S.

The largest cylinder erected was 35 inches diameter, stroke 10 feet, pressure-column 227 feet high. Its average speed was 80 feet, and maximum speed 140 feet per minute. The pressure of water under the piston was 98 lbs. per square inch, giving a total weight on its area of about 40 tons. The machine required no personal attendance, the motion being certain and continuous, as long as the working parts remained in order; consequently, the cost of maintaining it was of the most trifling character.

In 1803, Trevithick erected an engine at the Alport mines, which worked continuously for a period of 47 years, or until 1850, when the mines ceased working. The water from the pressure-columns acted on alternate sides of the main piston, by means of two piston valves, displaced by a heavy tumbling beam, and tilted by a projection from the pump-rod. The construction and action of this machine will be best understood by the accompanying illustration, *fig.* 1188.

A, main cylinder; B and C, valve pistons; D, chain wheel, upon the axis of which is fixed a lever not shown, in connection with a tumbling beam; E, aperture through which water enters from pressure-column; F, pipe in communication with main cylinder A; and G, pipe for discharging the water admitted both above and under the main piston H. The position of the valve-pistons in the woodcut shows that the pressure-column is supposed to be flowing through the holes I, upon the piston H, producing a down-stroke, and that the water which had been introduced under this piston in order to make the up-stroke is leaving through the pipe F, holes K, and outlet pipe G.

Accumulator and Pumping Engines.—The applications of pressure derived from

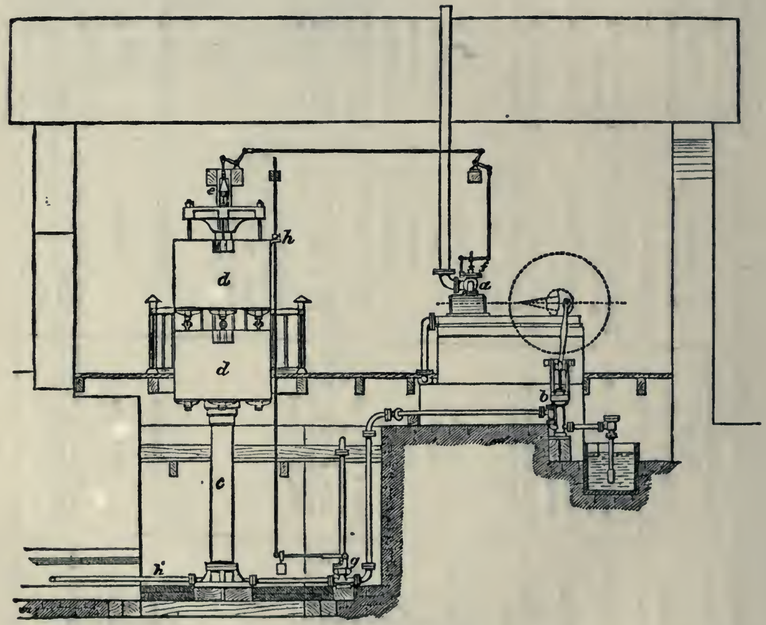
LEADHILLS *Lead Mines. Water-pressure Machinery. Furnished by J. F. Nevin, Esq.*

	No. 1 Drawing engine	No. 2 Drawing engine	No. 3 Pumping engine	No. 4 Pumping engine	No. 5 Pumping engine	No. 6 Pumping engine
Date or approximate date when engine was erected	Made and erected here about 1833	Brought here and erected about 1853	Made and erected here about 1833	Made and erected here about 1833	Brought here and erected about 1853	1862
Name of engine or designer	Deans. Hexham	Unknown; but engine came here from Wales	Deans. Hexham	Deans. Hexham	Unknown, but engine came here from Wales	Pattinson, Davison and Spencer. Hexham
Position of engine and depth from surface	Horizontally placed at Jeffrey's shaft	Horizontally placed at Hopetoun shaft	Perpendicularly placed at Cockburn's shaft, and 30 fms. below surface	Horizontally placed at Hopetoun shaft	Horizontally placed at Hillside shaft	Perpendicularly placed at Moffat's shaft
Diameter of cylinder . .	8 inches	13 inches	10 inches	15 inches	19½ inches	24 inches
Length of stroke . . .	4 feet	4 feet	6 feet	10 feet	10 feet	10 feet
Diameter of pressure-pipes .	6 inches	6 inches	6 inches	6 inches	11 inches	11 inches
Height of pressure-pipe .	90 feet	90 feet	180 feet	150 feet	210 feet	216 feet
Diameter of pumps attached to engine, and length	Lifted a tub containing a weight of 7 cwts. from a depth of 70 fathoms, in 3 minutes	Drew a tub containing a weight of 7 cwts. from a depth of 40 fms., but can do much more if required	1. 20 fms. 9 in. pumps 2. 20 „ 7 „ 3. 20 „ 6 „ 4. 10 „ 4½ „ — 70 fms. in all All these were lying on ledger wall of vein, which caused an extra amount of friction	Pumped water from 22 fms. in depth with pumps 10 inches in dia. It has never been used to its real power	One lift, 27 fms. deep, with pumps, the working barrel of which is 22 inches in diameter. Working nearly to its full power	Two lifts, 20 fms. deep each, and 12 inches in diameter. This work was a mere nothing to her actual power. She had a great shock when going at four strokes per minute. She went for months with the greatest regularity, at *one* stroke every 15 *minutes*
Maximum number of strokes made by engine per minute	20 strokes	12 strokes	8 strokes	6 strokes	5 strokes	4 strokes
Average number of strokes made per minute	16 strokes	10 strokes	5 strokes	4 strokes	3 strokes	2½ strokes
If engine is single or double acting, and composed of one or two cylinders	Double acting, with one cylinder	Double acting, with one cylinder	Single acting, one cylinder	Double acting, one cylinder	Double acting, with one cylinder	Double acting, with one cylinder

natural falls have been extended by Sir William Armstrong in the following manner:—

When the moving power consists of a natural column of water, the pressure rarely exceeds 250 or 300 feet; and in such cases he has employed, to produce rotary motion, a pair of cylinders and pistons, with slide-valves resembling in some degree those of a high-pressure engine, but having relief valves D to prevent shock at the return of the stroke, as shown in *fig.* 1173, page 835. Where the engine is single-acting, with plungers instead of pistons, the relief valves are greatly simplified, and, in fact, are reduced to a single clank in connection with each cylinder, opening against the pressure, which is the same as the relief valve in the valve chest of the hydraulic crane. The water-pressure engine erected at Mr. Beaumont's lead mines, at Allenheads in Northumberland, present examples of such engines applied to natural falls. They were there introduced under the advice of Mr. Sopwith, and are now used for the various purposes of crushing ore, raising materials from the mines, pumping water, giving motion to machinery for washing and separating ore, and driving a saw-mill and the machinery of a workshop. In all these cases nature, assisted by art, has provided the power. Small streams of water, which flowed down the steep slopes of the adjoining hills, have been collected into reservoirs at elevations of about 200 feet, and have been laid from these to the engines.

1189

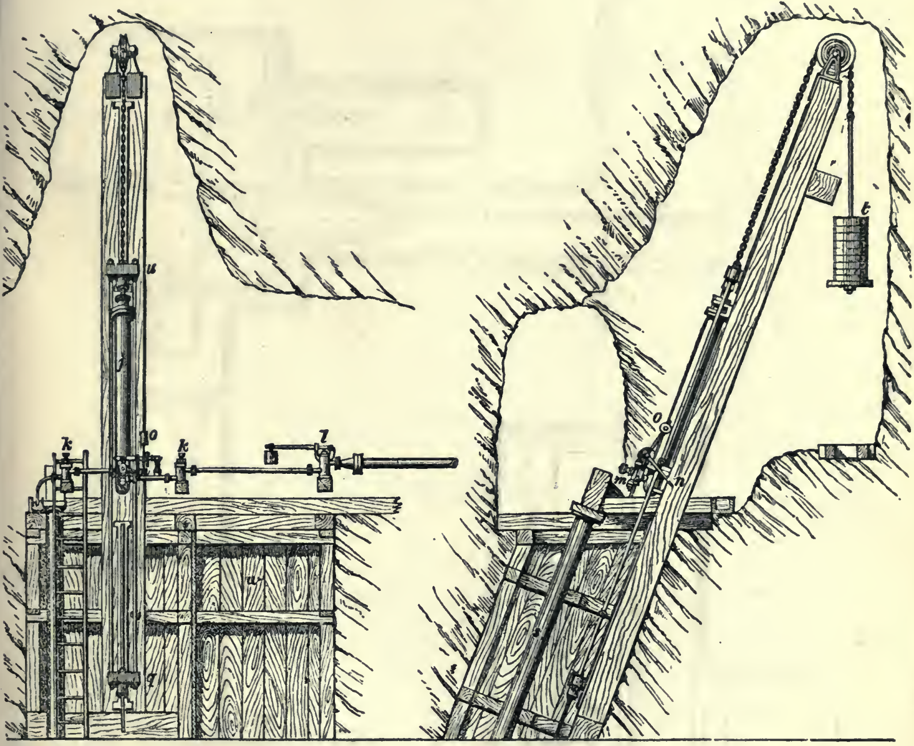


Another application of hydraulic machinery at the same mines has been made where falls of sufficient altitude for working such engines cannot be obtained. For the purpose of draining an extensive mining district and searching for new veins, a drift or level nearly six miles in length was executed. This drift runs beneath the valley of the Allen, nearly in the line of that river, and upon its course three mining establishments were formed. At each of these, power was required for the various purposes above mentioned, and it was desired to obtain this power without resorting to steam-engines. The river Allen was the only resource, but its descent was not sufficiently rapid to permit of its being advantageously applied to water-pressure engines. On the other hand, it abounded with falls suitable for overshot wheels, but these could not be applied to the purposes required without provision for conveying the power to many separate places. Under these circumstances, it was determined to employ the stream through the medium of overshot wheels in forcing water into accumulators, and thus generating a power capable of being transmitted by pipes to the numerous points where its agency was required.

A somewhat similar plan is also adopted at Portland Harbour, in connection with the coaling establishment there forming for the use of the navy. The object in that case is to provide power for working hydraulic cranes and hauling machines, and more particularly for giving motion to machinery for putting coal into war steamers. A reservoir on the adjoining height affords an available head of upwards of 300 feet; but in order to diminish the size of the pipes, cylinders, and valves connected with the hydraulic machinery, and also with a view of obtaining greater rapidity of action, a hydraulic pumping engine and accumulator are interposed for the purpose of intensifying the pressure and diminishing the volume of water acting as the medium of transmission.

Water-pressure engines erected at the Wildberg Mines, in Rhenish Prussia, are shown in *figs.* 1190 and 1191. They drain an isolated piece of ground distant from the main shaft 1,800 feet. A rotary horizontal high-pressure steam-engine is placed in connection with steam-boilers, *fig.* 1189. Two pumps, one of which is shown at *b*, force water into an accumulator, *c*. The accumulator-ram is mounted with two concentric boxes, *d*, *d*, one for affording the pumping, the other the winding, pressure.

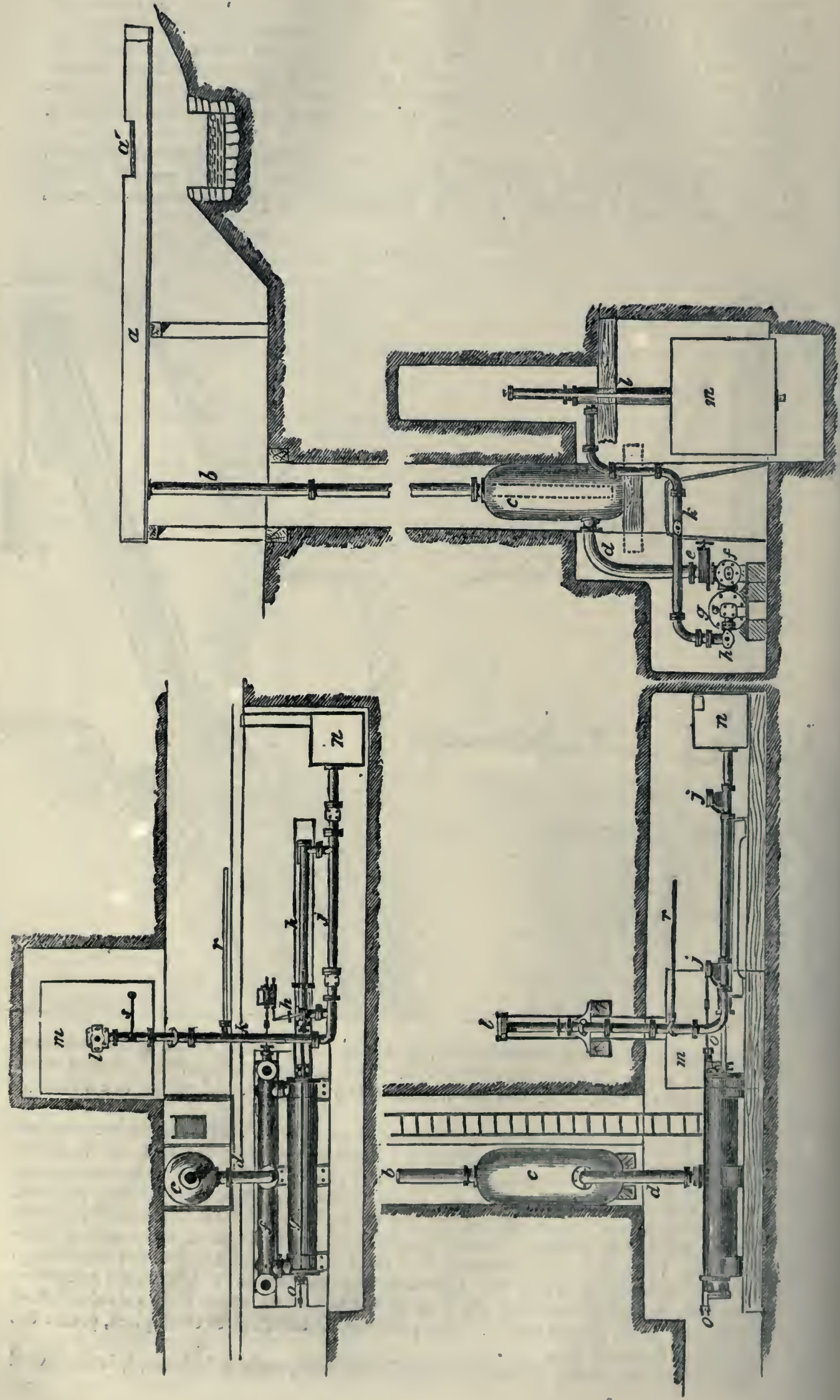
1190



As the power required is of an intermittent character, the steam-engine is controlled by the screw and weight, *e*, actuating the throttle-valve, *f*; and in order to guard against the possibility of the ram rising beyond prescribed limits, a waste-valve, *g*, is operated upon by the rod and stop, *h*. From the accumulator, wrought-iron pipes *h′*, fitted with cast-iron flanges, extend through an engine-shaft 60 fathoms in depth, and a level 1,500 feet in length. These pipes or main terminate in a reciprocating pole-engine, *fig.* 1190, *j*, having a stroke of 5 feet; *k*, *k*, are inlet and outlet regulating-valves; *l*, momentum valve, for obviating the concussion which would otherwise result from suddenly arresting the flow of the water; *m*, small slide valve, actuated by the canti-lever, *n*, and ball, *o*. The pump-rod is attached to cross-piece, *q*, and the pump itself is shown at *s*.

To compensate for any excess of weight in the pump-rods, a balance, *t*, is connected

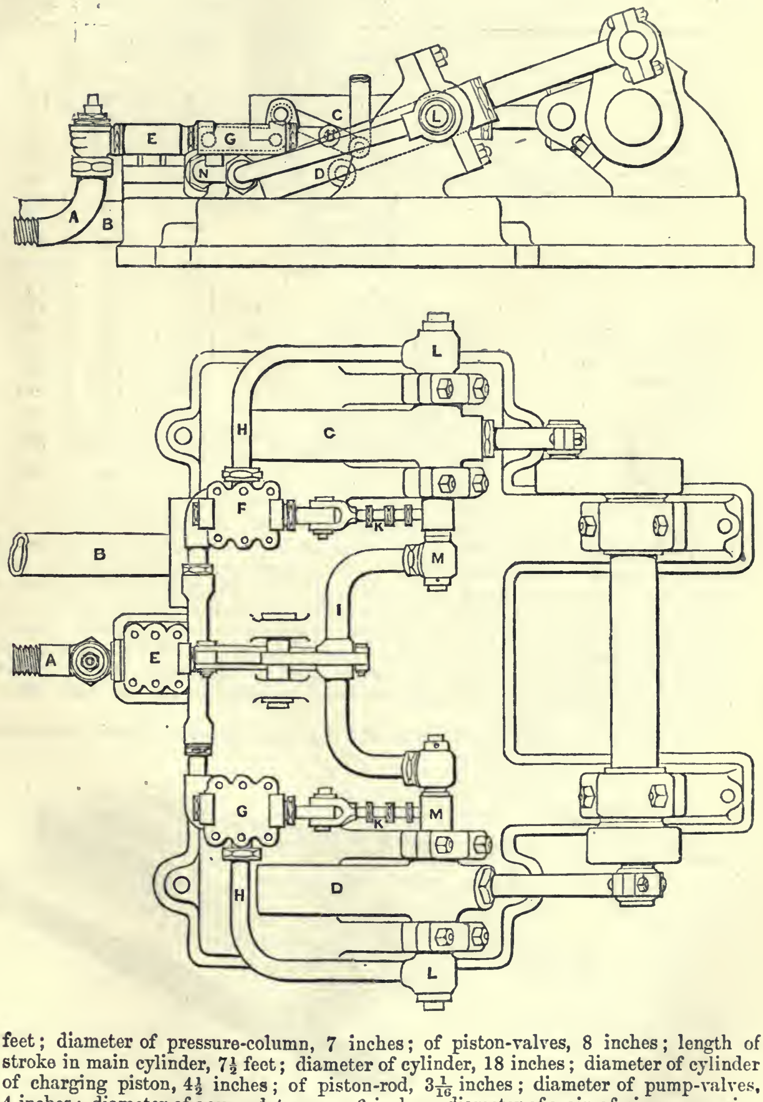
1191



by means of a chain with the cross-head, *u*. The detailed arrangement of the shaft, *w*, as well as the hydraulic winding-engine, is not shown, but this machine is also dependent on the accumulator for its power. The pressure applied is 750 lbs. per square inch. No leakage of water is experienced at the joints, and in every respect the performance of the apparatus is satisfactory.

Fig. 1191 represents one of the hydraulic engines employed at the same mines for charging an accumulator. The water for driving this engine is diverted from three different valleys into a common water-race, and passed through the pressure-column *b* into the engine, where, after having done its work, it is discharged into the day-level. The following are some particulars connected with this engine:—Available fall, 55 feet; diameter of pressure-column, 7 inches; of piston-valves, 8 inches; length of stroke in main cylinder, $7\frac{1}{2}$ feet; diameter of cylinder, 18 inches; diameter of cylinder of charging piston, $4\frac{1}{2}$ inches; of piston-rod, $3\frac{1}{16}$ inches; diameter of pump-valves, 4 inches; diameter of accumulator-ram, 6 inches; diameter of main of pipes conveying power from accumulator, 2 inches. *a*, water-launder with waste-gap a'; *b*, pressure-column; *c*, air-vessel; *d*, pipe from air-vessel to cylinder; *e*, sluice-valve; *f*, valve

1192



cylinder; *g*, main cylinder; *h*, charging-pump; *j*, valve-boxes; *k*, pipe from charging-pump to accumulator; *l*, accumulator; *m*, weight-box; *n*, water-cistern in connection with charging-pump; *o*, valve gear; *h*, small lever forming part of valve gear; *r*, pressure main, between accumulator and hydraulic engine; *s*, relief valve.

In these arrangements, intensity of pressure takes the place of magnitude of volume, and the power assumes a form susceptible of unlimited distribution and division, and is capable of being utilised by small and compact machines. The writer has recently applied engines fitted with two cylinders, each $1\frac{1}{4}$ inch diameter, and 7 inches stroke, to the winding of underground tackles or windlasses.

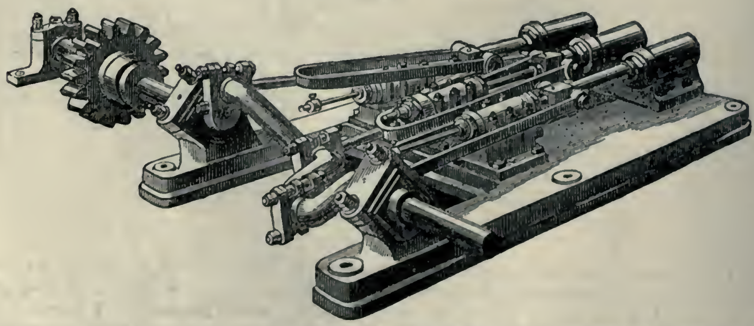
Table of Pressure Engines.

Locality	Engineer	Diameter of cylinder	Length of stroke	Speed per minute
		inches	feet	
Northumberland	Westgarth	10	...	...
Ems	unknown	$13\frac{1}{2}$	4	8
Bleiberg	...	7	$6\frac{1}{4}$	100
Chemnitz	...	11	8	48
Ebensee Salzburg	...	$9\frac{1}{2}$	$1\frac{5}{12}$	17
Clausthal	...	$16\frac{1}{2}$	6	48
Alte Mordgrube, Saxony	...	18	8	64
Alport Mines, Derbyshire	Trevithick	(double) 25	10	120
" "	Fairbairn	36	5	70
" "	Darlington	50	10	140
" "	"	18	7	154
" "	"	2 cyl. each 24	10	120
" "	"	24	10	120
Lisburn, Wales	"	20	6	96
Cwmystwyth "	"	24	10	140
Talargoch "	"	50	10	140
Minera "	"	35	10	140
Wildberg "	"	3	5	80
South Hetton Colliery	Armstrong	4 cyl. each 3	12 in.	200
Allenheads	"	" 6	18	180

Rotary Engines.—*Fig.* 1192 shows Armstrong's rotary water-pressure engine. It is rendered double-acting by bringing the force to bear four times in the crank-circle. The cylinders are made to oscillate, and the plungers are attached directly to the crank-pin. A piston is formed at the inner end of the plunger, and water is admitted behind the piston, while the front is placed in communication with the pressure-pipe. A is the pressure-pipe; B, the exhaust-pipe; E, governor-valve; F, G, slide valves for producing admission and emission to and from the cylinder, C, D; I, pressure-pipe, communicating with the cylinders, C, D, in front of the piston. The slide-valves derive motion from the oscillatory movements of the cylinders, and are of the ordinary D-shape pattern.

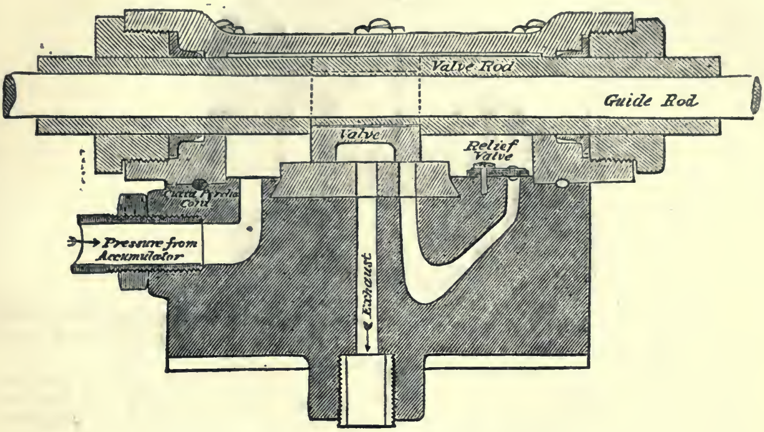
The engine, *fig.* 1193, is in use at the Wildberg Mines, in Prussia, for winding stuff from the 90 to the 50 fathom level. It consists of three rams, a three-throw crank, and three slide-valves.

1193

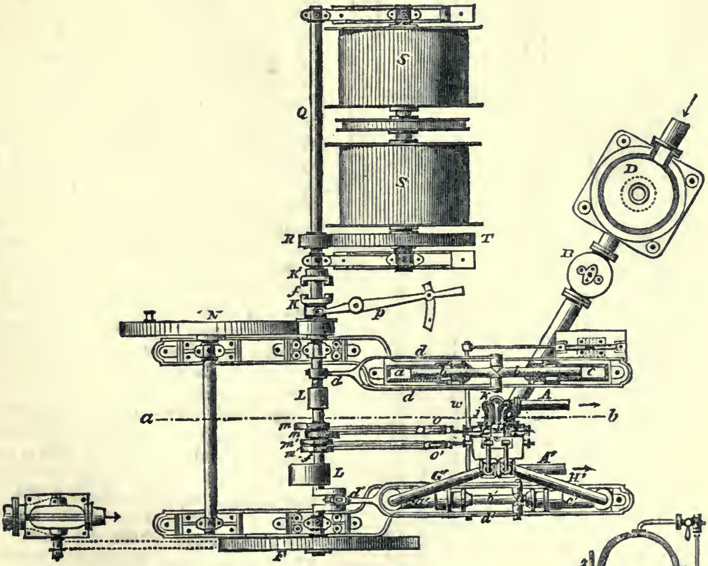


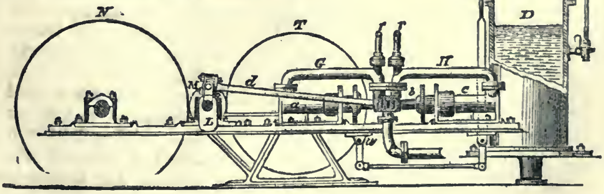
The rams are each 2½ inches diameter; length of stroke, 10 inches; speed, 60 strokes per minute. Each valve is worked direct from the rams by means of a rod ¾ inch diameter, fitted with adjustable stops. This rod passes through a tubular valve-rod moving in nut-boxes containing cup-leathers. This peculiar arrangement with the valve itself is shown distinctly in *fig.* 1194. The guide-rod is fitted with

1194



1195

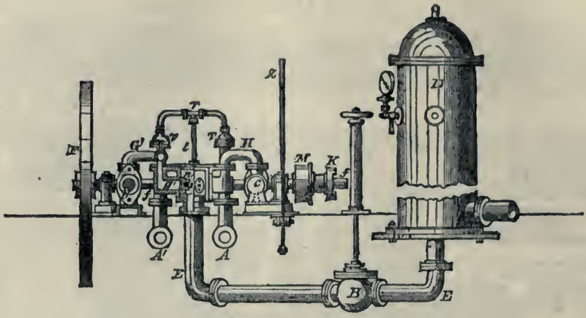




1196

the stops referred to, and passes through a tubular valve-rod; the valve is D-shaped; the pressure-port and exhaust-ports are shown; together with the relief-valve. The engine under its working pressure of about 500 lbs. per inch, runs with great regularity.

1197



1198

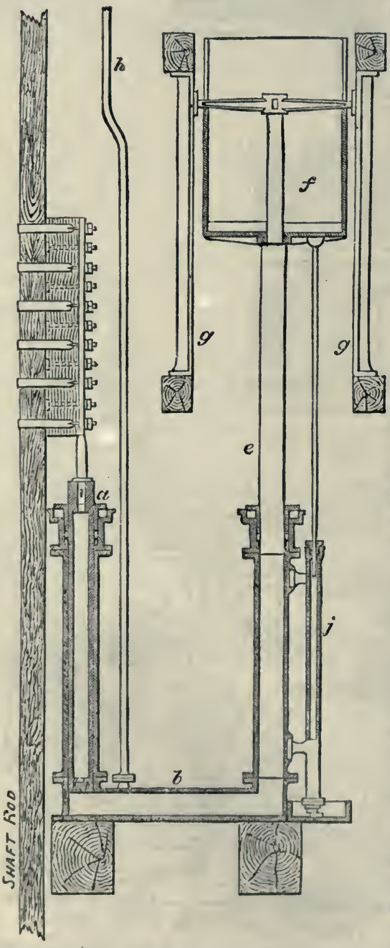


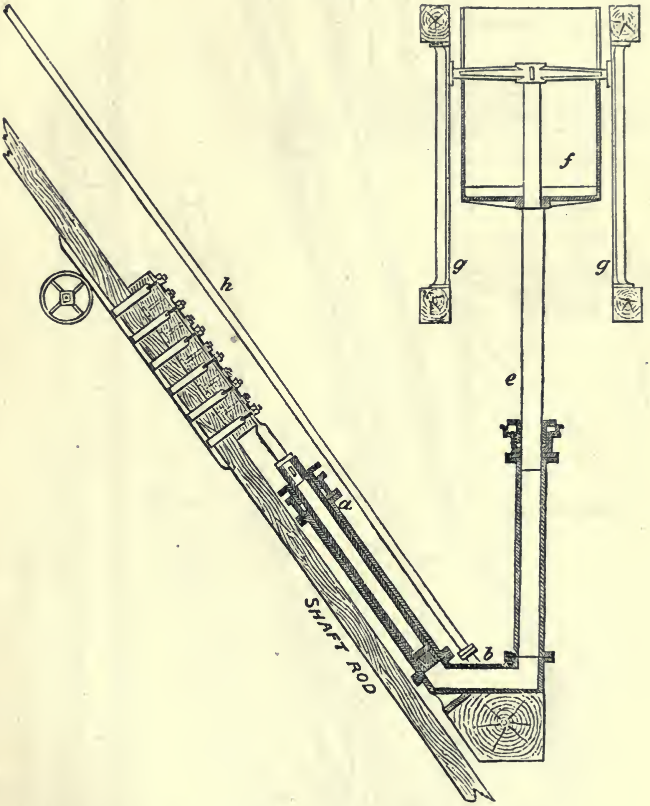
Fig. 1195 exhibits a rotary engine applied to winding, pumping, and ventilating purposes. In its general arrangement it includes an air-vessel, four ram-cases, and two winding-drums, a wheel fitted with crank-pin for pumping, and a fan. *Fig.* 1195, plan; *fig.* 1196, elevation on line *a*, *b*, of plan. *Fig.* 1197, cross-elevation of engine and air-vessel. A, A′, outlet-pipes from ram-cases; B, inlet-valve; D, air-vessel; E, inlet-pipe; F, fan driving-wheel, fitted on main shaft; G, H, outlet-pipes, connecting valve-boxes with ram-cases; K, K′, clutch-box; M, spur-pinion; N, N′, spur-wheel, with pin for attaching pump-rod; O, O′, excentric valve-rods; Q, shaft for driving winding-drum; R, spur-pinion; S, drum; I, spur-wheel on drum-shaft; *a*, *c*, ram-cases in section, *a*, *c*, in plan; *b*, rams; *d*, *d′*, fork crank-levers; *e*, slide-valves; *f*, pipes from cylinder; *g*, passage to cylinders; *m*, *m′*, excentrics; *p*, lever for shifting the clutch; *w*, brake-strap; *z*, brake-lever.

Hydraulic Bar.—In its simplest form the hydraulic bar consists of a main of pipes charged with water, with a plunger or piston at each end; the movement of one plunger equally affecting the movement of the other through the medium of the water stored within the main. Early in 1867 West and Darlington commenced to apply the hydraulic bar to the working of pumps and balancing of pump-rods. *Fig.* 1198 represents the counterbalancing apparatus in connection with a mining pump-rod when working in a vertical direction. *a*, plunger attached to main-rod; *b*, pipe connecting the second ram-case; *e*, plunger, with weight-box *f*; *g*, guides for weight-box; *h*, pipe communicating with cistern, for supplying such water as may be necessary to make up leakage; *j*, small supply-plunger, to be attached to the apparatus when the pipe, *h*, cannot be advantageously introduced.

The communication between the faces of the two plungers is entirely free; and hence, if the acting-ram, *a*, be raised, the balance-plunger, *e*, will fall and counterbalance the rods to the extent of its weight, less the trifling amount of friction incident to the movement.

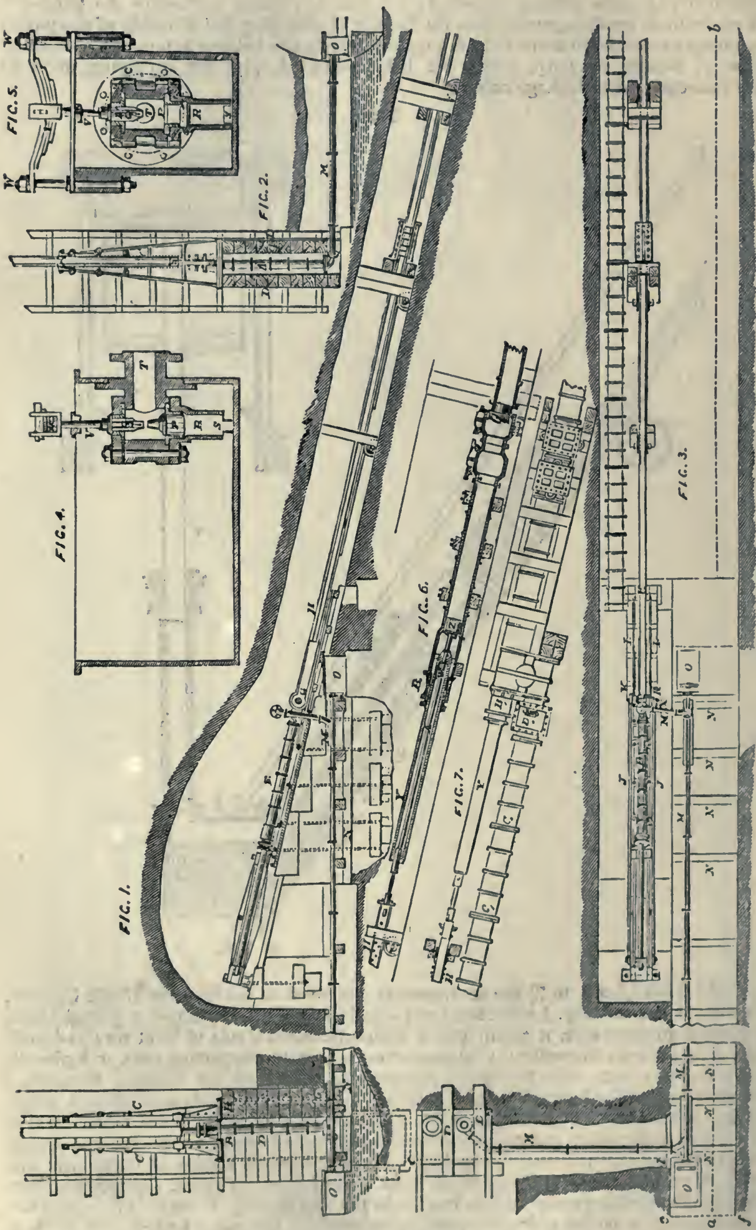
The details of this counterpoise arrangement (*fig.* 1199) are, in most respects, identical with those already described; but this *fig.*, which represents the pump-rod in an inclined position, exemplifies the facility of changing the direction of the power. *a*, plunger attached to main-rod; *b*, pipe connecting the balance ram-case; *e*, balance-ram; *f*, balance-box; *g g*, guides for balance-box: *h*, pipe for supplying water to the ram-cases when leakage occurs.

1199



In *fig.* 1200 (*figs.* 1 to 7) the arrangement employed at the Von der Heydt Colliery, Prussia, is shown. *Fig.* 1 side elevation: C guides for vertical plunger, D plunger-case, E inclined plunger-case, H pump rod, M hydraulic main, N sole of level, O valve-boxes. *Fig.* 2 transverse elevation: A plunger-case, D bearers supporting case, M hydraulic main, O valve-box. *Fig.* 3 plan: B plunger-case, D bearers for inclined plungers, J forming part of the hydraulic main, N bottom of level, O valve-boxes. *Fig.* 4 longitudinal section of valve-box: O.S. inlet, R pipe, P ordinary mitre valve for supplying main with water when necessary, *r* entrance to hydraulic main, G valve for discharging water from main, Y valve-stud, *i* spring. *Fig.* 5 transverse section of valve-box: S.R. inlet; P valve seating, T entrance to the main, G ejection valve, Y stud, *i* spring, W adjusting nuts for giving greater or less tension to the spring. *Fig.* 6 section of plunger and bucket pump: A bucket rod passing through plunger, Y plunger, Z bucket. *Fig.* 7 elevation of plunger pump valve-boxes and rising main: Y plunger-case, B stuffing box, C water main, D valve-box, H pump-rod. The motive plunger in this case is D, *fig.* 1. This plunger by means of the water contained within the main forces the plunger E upwards. This plunger in turn descends, or performs its downstroke in strict relation with the ascent of the forcing plunger. In these apparatus, *fig.* 1 to *fig.* 7, it is evi-

1200



dent that the reciprocating movements are unaffected by the position of the cylinders and that these may be placed either vertically or at any angle best suited to the special exigencies of the situation. The main of pipes may also run in an angular direction or through shafts and levels. In counterbalancing pump-rods the weight-box bears directly upon the line of pumping motion without occasioning any side strain. The transfer of power to any reasonable distance whether at surface, or underground, may also be effected at a loss in friction incomparably less than would arise from any other mode of transmission, whilst the pipes for the retention of the water may be carried into the remotest heading without causing any inconvenience. By one or other of the arrangements winzes may be drained below the deepest level, and the ground readily divided either for stopping or exploratory purposes.

The hydraulic bar apparatus for changing vertical into oblique motion consists, as heretofore, of two ram-cases coupled together; the motive ram alternating the pumping ram. In *fig.* 1201, *a* is the motive ram, fixed in vertical shaft; *b*, pumping ram, fixed in an inclined shaft; *c*, self-acting valve-arrangement for supplying water when necessary.

1201

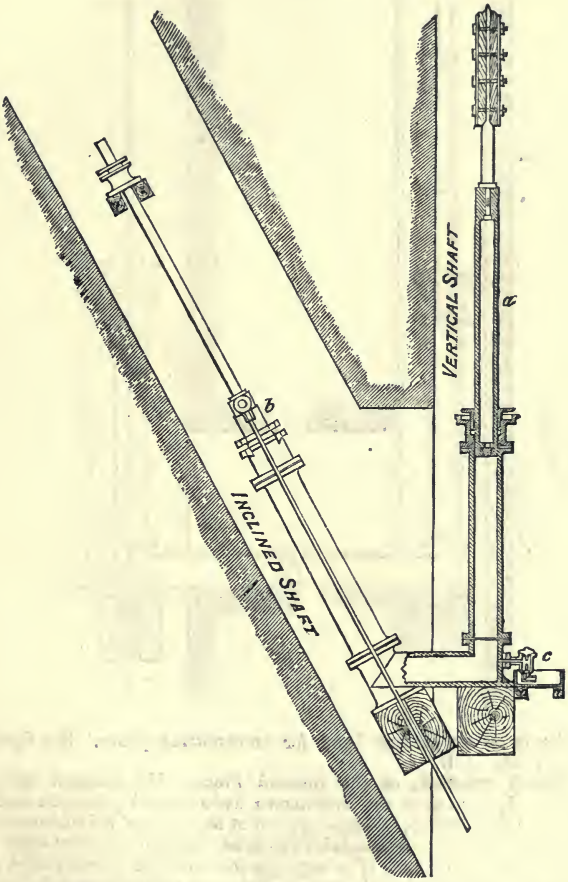
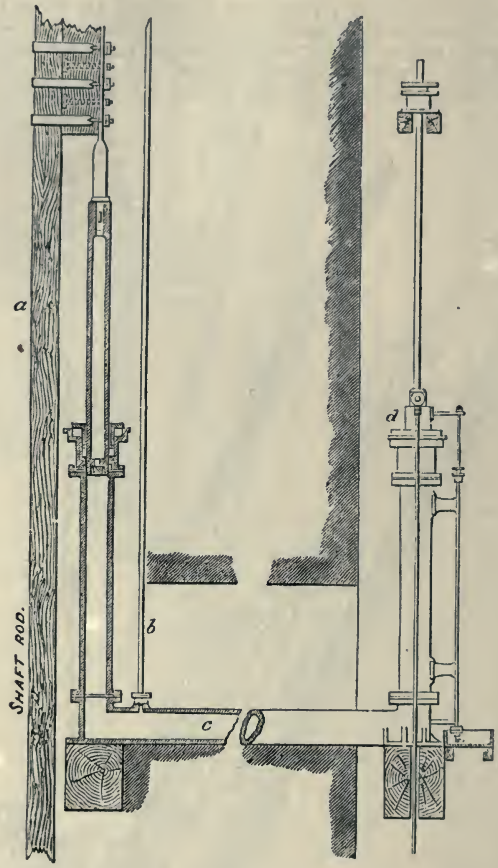


Fig. 1202, p. 868, shows a method in operation at Wheal Phœnix, in Cornwall, for transferring power from the main pump rod to a distant winze underground: *a*, main rod; *b*, supply pipe; *c*, water main; *d*, pumping rod fitted with side rods.

The Hydraulic Circuit.—In 1867, Jordan and Darlington designed an arrangement which they designated an hydraulic circuit. This apparatus consists of two or more force-pumps or plunger cases fitted with plungers. Motion is communicated to the force-pumps or plungers by any suitable machine fixed in a convenient situation. To each plunger-case is attached a small apparatus for drawing and discharging water under adjustable conditions. A main or run of pipes, the hydraulic circuit, commences from one of the plunger-cases; and when the power is to be transferred through drift-ways, the pipes are carried down the shaft through the levels to several points where power is required and returned by the same or a second shaft to the second ram-case,

1202



forming a circuit or an endless band for transmitting power. See Specification, A.D. 1867, No. 3386.—J. D.

HYDRAULIC PRESS, or the *Bramah Press.* Mr. Bramah took out his patent in 1796. It rests upon the well-known hydrostatical principle, that when a mass of fluid is in equilibrium, pressure applied at any part of it is transmitted over its whole mass, and each particle sustains the same pressure as every other particle. In its simplest form, it consists of a large piston moving in a water-tight cylinder, the bottom of which is filled with water, which also communicates by tubes filled with water, with the bottom of a cylinder of a small forcing pump. The water in this last is submitted to any pressure we may wish to apply, and that being transmitted to the large piston, lifts it up, moving along with it whatever may be connected with it. The apparent gain of power is just in proportion to the difference of areas of the sections of the pump, and of the cylinder. If the one, for example, have a radius of only one-fourth of an inch, and the others one of ten inches, the area, being in the proportion of the squares of the linear dimensions, will be as 1 to 1,600; and the apparent gain will be exactly proportional to this difference.

HYDRIODIC ACID (*Acide hydriodique,* Fr.; *Hydriodsäure,* Ger.) is an acid formed by the combination of 127 parts of iodine with 1 part of hydrogen by weight, and by measure equal volumes of iodine-vapour and hydrogen combined without condensation. It is obtained pure and in the gaseous state by introducing into a glass tube, closed at one end, a little iodine, then a small quantity of roughly-powdered glass moistened with water, upon this a few small fragments of phosphorus, and lastly more glass; this order, iodine, glass, phosphorus, glass, is repeated until the tube is two-thirds filled. A cork and narrow bent tube are then fitted and gentle heat applied, when the hydriodic acid is liberated, and may be collected in dry bottles by the displacement of air. Another process is to place in a small retort 10 parts of iodide of potassium with 5 of water, add 20 parts of iodine, then drop in cautiously 1 part of phosphorus cut into small pieces, and apply a gentle heat; hydriodic acid will be formed abundantly, and may be collected as before stated. The following equation expresses the reaction:—

$$2KI + 5I + P + 8HO \text{ yield } 2KO,HO,PO^5 + 7HI.$$

$$\mathbf{2KI + 5I^2 + 2P + 8H^2O = 2K^2HPO^4 + 14HI.}$$

Hydriodic acid greatly resembles hydrochloric acid; it is colourless, and highly acid, it fumes in the air, and is very soluble in water. Its density is 4·4, and under strong pressure it condenses to a yellowish liquid, which solidifies at 60° Fahr.

Hydriodic acid in solution is much more easily prepared by suspending iodine in water, and passing a stream of washed hydrosulphuric acid through it until the colour disappears; it is then heated to expel the hydrosulphuric acid, then allowed to rest, when it may be decanted from the precipitate of sulphur. The reaction consists simply in the displacement of the sulphur by the iodine, $HS + I = HI + S$.

This liquid may be evaporated until it acquires a density of 1·7, when it consists of $HI + 11HO$. It then distils at 262° Fahr. without decomposition. The solution cannot be long kept, it being decomposed by the oxygen of the air with the liberation of iodine, which imparts a dark colour to it. Chlorine decomposes it instantly, with liberation of the iodine.

The solution of hydriodic acid and of the iodides possess the power of dissolving a considerable quantity of iodine, forming a dark solution.—H.K.B.

HYDROBENZOIN. A compound produced by the action of nascent hydrogen on *benzoyl hydride—bitter almond oil.* See Benzole.

HYDROBROMIC ACID. See Bromine.

HYDRO-CARBONS. Compounds consisting of carbon and hydrogen only. See Carburetted Hydrogen: see also Watts's 'Dictionary of Chemistry.'

HYDROCHLORIC ACID, *Chlorhydric acid,* or *hydrogen chloride.* (*Acide chlorhydrique,* Fr.; *Salzsäure,* Ger.) *Sym.* HCl.; *at. weight,* 36·5. A compound of chlorine and hydrogen, which is a colourless gas, of a peculiar suffocating, pungent odour; it reddens vegetable blues, but possesses no bleaching properties. The solution of hydrochloric acid in water is the *muriatic acid* and *spirit of salt* of commerce; anciently *marine acid.*

Hydrochloric acid gas may be obtained by the direct union of its elements—hydrogen and chlorine. By exposure to sunlight, by passage of an electric spark, or by direct contact with flame, these two gases unite with explosive violence. 2 volumes of chlorine and 2 volumes of hydrogen combine to form 4 volumes of this acid. Its specific gravity is 1·247, air = 1·000.

By sealing up muriate of ammonia and sulphuric acid, apart, in a strong glass tube re-curved, and then causing them to act on each other, Sir H. Davy procured liquid muriatic acid. At 50° F. it condenses under a pressure of 40 atmospheres, to a liquid of spec. grav. 1·27.

Hydrochloric acid is best prepared by heating a mixture of 6 parts of chloride of sodium (*common salt*) and 10 parts of concentrated sulphuric acid previously diluted with 4 parts of water, in a capacious glass retort, connected with a set of Woolfe's bottles. This acid is extracted on a large scale from sea-salt, by the action of sulphuric acid at a moderate heat; but it was originally obtained from the salt by exposing a mixture of it and of common clay to ignition in an earthen retort. The acid gas which exhales is rapidly condensed by water. 100 cubic inches of water are capable of absorbing no less than 48,000 cubic inches of the acid gas, whereby the liquid acquires a specific gravity of 1·2109, and a volume of 142 cubic inches. This vast condensation of the gas is accompanied with a great production of heat; whence it becomes necessary to apply artificial refrigeration, especially if so strong an acid as the above is to be prepared. In general, the muriatic acid of commerce has a specific gravity varying from 1·15 to 1·20, and contains, for the most part, considerably less than 40 parts by weight of acid gas in the hundred. The above stronger acid contains 42·68 per cent. by weight; for since a cubic inch of water, which weighs 252·5 grains, has absorbed 480 cubic inches = 188 grains of gas; and 252·5 + 188 = 440·5; then 440·5 : 188 :: 100 : 42·68. In general a very good approximation may be found to the percentage of real muriatic acid, in any liquid sample, by multiplying the decimal figures of the specific gravity by 200. Thus, for example, at 1·162 we shall have by this rule, 0·162 × 200 = 32·4, for the quantity of gas in 100 parts of the liquid.

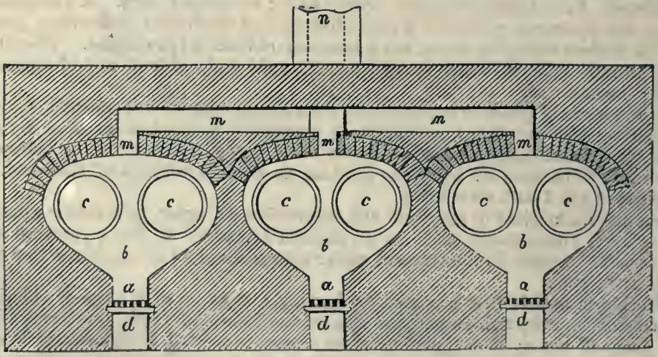
The preparation of this acid upon a commercial scale is frequently effected in this country by acting upon common salt in hemispherical iron pots, or in cast-iron cylinders, with concentrated sulphuric acid; taking 6 parts of the salt to 5 of the acid. The mouth of the pot may be covered with a slab of siliceous freestone, perforated with two holes of about two inches in diameter each, into the one of which the acid is poured by a funnel in successive portions, and into the other, a bent glass, or stoneware tube, is fixed, for conducting the disengaged muriatic gas into a series of large globes of bottle glass, one-third filled with water, and laid on a sloping sand-bed. A week is commonly employed for working off each pot; no heat being applied to it till the second day.

The decomposition of sea-salt by sulphuric acid was at one time carried on by some French manufacturers in large leaden pans, 10 feet long, 5 feet broad, and a foot deep, covered with sheets of lead, and luted. The disengaged acid gas was made to circulate in a conduit of glazed bricks, nearly 650 yards long, where it was condensed by a sheet of water exceedingly thin, which flowed slowly in the opposite direction of the gas down a slope of 1 in 200. At the end of this canal nearest the apparatus, the muriatic acid was as strong as possible, and pretty pure; but towards the other end, the water was hardly acidulous. The condensing part of this apparatus was therefore tolerably complete; but as the decomposition of the salt could not be finished in the leaden pans, the acid mixture had to be drawn out of them, in order to be completely decomposed in a reverberatory furnace; in this way nearly 50 per cent. of the muriatic acid was lost. And besides, the great quantity of gas given off during the emptying of the lead-chambers was apt to suffocate the workmen, or seriously injured their lungs, causing severe hæmoptysis.

The apparatus for condensing muriatic acid gas has been modified and changed, of late years, in many different ways.

The Bastringue Apparatus. At the end of a reverberatory furnace, a rectangular lead trough or pan, about 1 foot deep, of a width equal to that of the interior of the furnace, that is, about 5 feet wide and 6½ feet long, is encased in masonry, having its upper edges covered with cast-iron plates or fire tiles, and placed upon a level with the passage of the flame, as it escapes from the reverberatory. The arch which covers that pan forms a continuation of the roof of the reverberatory, and is of the same height. The flame which proceeds from the furnace containing the mixture of salt and sulphuric acid is made to escape between the vault and the surface of the iron plates or fire tiles, through a passage only 4 inches in height. When the burned air and vapours reach the extremity of the pan, they are reflected downwards, and made to return beneath the bottom of the pan, in a flue, which is afterwards divided so as to lead the smoke into two lateral flues, which terminate in the chimney. The pan is thus surrounded as it were with the heat and flame discharged from the reverberatory furnace. A door is opened near the end of the pan, for introducing the charge of sea-salt, amounting to 12 bags of 2 cwts. each, or 24 cwts. This door is then luted on as tightly as possible, and for every 100 parts of salt, 110 of sulphuric acid are poured in, of specific gravity 1·594, containing 57 per cent. of dry acid. This acid is introduced through a funnel inserted in the roof of the furnace. Decomposition ensues, muriatic acid gas mingled with steam is disengaged, and is conducted

1203

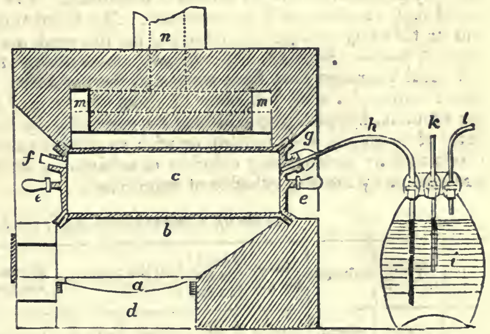


through 4 stone-ware tubes into the refrigerators, where it is finally condensed. These refrigerators consist of large stone-ware carboys, called *dame-jeannes* in France, to the number of 7 or 8 for each pipe, and arranged so that the neck of the one communicates with the body of the other; thus the gas must traverse the whole series, and gets in a good measure condensed by the water in them, before reaching the last.

When the operation is finished, the door opposite the pan is opened, and the residuum in it is discharged, in the form of a fluid magma, upon a square bed of bricks, exterior to the furnace. This paste speedily concretes on cooling, and is then broken into fragments and carried to the soda manufactory. The immense quantity of gas exhaled in discharging the pan, renders this part of the operation very painful to the workmen, and wasteful in reference to the production of muriatic acid. The difficulty of luting securely the cast-iron plates or fire tiles which cover the pan, the impossibility of completing the decomposition of the salt, since the residuum must be run off in a liquid state, finally, the damage sustained by the melting and corrosion of the lead, &c., are among the causes why no more than 80 or 90 parts of muriatic acid at 1·170 are collected, equivalent to 25 per cent. of real acid for every 100 of salt employed, instead of much more than double that quantity, which it may be made to yield by a well-conducted chemical process.

The *cylinder apparatus* is now much esteemed by many manufacturers. *Fig.* 1203 represents, in transverse section, a bench of iron cylinder retorts, as built up in a proper furnace for producing muriatic acid; and *fig.* 1204 a longitudinal section of one retort with one of its carboys of condensation. *a* is the grate; *b*, a fireplace, in which two iron cylinders, *c c*, are set alongside of each other. They are $5\frac{1}{2}$ feet long, 20 inches in diameter, about $\frac{1}{4}$ of an inch thick, and take 1·6 cwt. of salt for a charge; *d* is the ashpit; *e e* are cast-iron lids for closing both ends of the cylinders; *f* is a tube in the posterior lid, for pouring in the sulphuric acid; *g* is another tube, in the anterior lid, for the insertion of the bent pipe of hard glazed stone-ware *h*; *i* is a three-necked stone-ware carboy; *k* is a safety-tube; *l*, a tube of communication with the second carboy; *m m m m* are the flues leading to the chimney *n*.

1204



After the salt has been introduced, and the fire kindled, $83\frac{1}{4}$ per cent. of its weight of sulphuric acid, of sp. gr. 1·80, should be slowly poured into the cylinder through a lead funnel, with a siphon-formed pipe. The three-necked carboys may be either placed in a series for each retort, like a range of Woulfe's bottles, or all the carboys of the front range may be placed in communication with one another, while the last carboy at one end is joined to the first of the second range; and thus in succession. They must be half filled with cold water; and when convenient, those of the front row at least, should be plunged in an oblong trough of running water. The acid which condenses in the carboys of that row is apt to be somewhat contaminated with sulphuric acid, chloride of iron, or even sulphate of soda; but that in the second and third will be found to be pure. In this way 100 parts of sea-salt will yield 130 parts of muriatic acid, of sp. gr. 1·19; while the sulphate of soda in the retort will afford from 208 to 210 of that salt in crystals.

It is proper to heat all the parts of the cylinders equally, to insure the simultaneous decomposition of the salt, and to protect it from the acid; for the hotter the iron, and the stronger the acid, the less erosion ensues.

Some manufacturers, with the view of saving fuel by the construction of their furnaces, oppose to the flame as many obstacles as they can, and make it perform numerous circulations round the cylinders; but this system is bad, and does not even effect the desired economy, because the passages, being narrow, impair the draught, and become speedily choked up with the soot, which would be burned profitably in a freer space; the decomposition also, being unequally performed, is less perfect, and the cylinders are more injured. It is better to make the flame envelope at once the body of the cylinder; after which it may circulate beneath the vault, in order to give out a portion of its heat before it escapes at the chimney.

The fire should be briskly kindled, but lowered as soon as the distillation commences; and then continued moderate till the evolution of gas diminishes, when it must be heated somewhat strongly to finish the decomposition. The iron door is now removed, to extract the sulphate of soda, and to recommence another operation. This sulphate ought to be white and uniform, exhibiting in its fracture no undecomposed sea-salt.

In preparing hydrochloric acid from a mixture of common salt and sulphuric acid, the nature of the reaction varies with the proportions of raw materials employed. This is a point which demands the attention of the manufacturer. If two molecules of sulphuric acid be used with a single molecule of salt (or 98 parts by weight of acid to 78·5 of salt) the decomposition is completely at a moderate temperature, and bisulphate (acid sulphate) of soda is produced, whilst hydrochloric acid is evolved. But if *two* molecules of salt (or 117 parts by weight) be employed, with the same quantity of acid as before, the decomposition takes place in two stages, the final residue consisting wholly of neutral sulphate of soda; but in this case a much higher temperature is required to effect the decomposition. Hence the former method yields the hydrochloric acid with greater facility, and with less expenditure of fuel, whilst the latter process requires a higher temperature, but consumes only half the quantity of oil of vitriol.

Large quantities of hydrochloric acid are produced in the first stage of the manufacture of soda-ash. Formerly the acid-vapours were allowed to escape into the atmosphere, and caused great damage to the surrounding vegetation; but they are now carefully condensed in large towers or scrubbers. The weak solution of acid thus obtained may be afterwards concentrated. Mr. Clapham's process of obtaining a strong acid in this way consists in pumping up the weak acid into the condensing towers, where it becomes strengthened by fresh condensation of vapour.

Several processes have been suggested for obtaining hydrochloric acid without the use of sulphuric acid, but none of them can be said to be commercially successful. For example, hydrochloric acid may be generated by heating common salt with sulphate of magnesia, with pyrites, or with weathered sulphate of iron; the acid may also be obtained by decomposing chloride of calcium by the action of steam at a high temperature, or by heating chloride of magnesium.

Table of Hydrochloric Acid, by Dr. Ure.

Acid of 120 in 100	Specific gravity	Chlorine	Muriatic gas	Acid of 120 in 100	Specific gravity	Chlorine	Muriatic gas	Acid of 120 in 100	Specific gravity	Chlorine	Muriatic gas
100	1·2000	39·675	40·777	66	1·1328	26·186	26·913	32	1·0637	12·697	13·049
99	1·1982	39·278	40·369	65	1·1308	25·789	26·505	31	1·0617	12·300	12·641
98	1·1964	38·882	39·961	64	1·1287	25·392	26·098	30	1·0597	11·903	12·233
97	1·1946	38·485	39·554	63	1·1267	24·996	25·690	29	1·0577	11·506	11·825
96	1·1928	38·089	39·146	62	1·1247	24·599	25·282	28	1·0557	11·109	11·418
95	1·1910	37·692	38·738	61	1·1226	25·202	24·874	27	1·0537	10·712	11·010
94	1·1893	37·296	38·330	60	1·1206	23·805	24·466	26	1·0517	10·316	10·602
93	1·1875	36·900	37·923	59	1·1185	23·408	24·058	25	1·0497	9·919	10·194
92	1·1857	36·503	37·516	58	1·1164	23·012	23·050	24	1·0477	9·522	9·786
91	1·1846	36·107	37·108	57	1·1143	22·615	23·242	23	1·0457	9·125	9·879
90	1·1822	35·707	36·700	56	1·1123	22·218	22·834	22	1·0437	8·729	9·971
89	1·1802	35·310	36·292	55	1·1102	21·822	22·426	21	1·0417	8·332	8·563
88	1·1782	34·913	35·884	54	1·1082	21·425	22·019	20	1·0397	7·935	8·155
87	1·1762	34·517	35·476	53	1·1061	21·028	21·611	19	1·0377	7·538	7·747
86	1·1741	34·121	35·068	52	1·1041	20·632	21·203	18	1·0357	7·141	7·340
85	1·1721	33·724	34·660	51	1·1020	20·235	20·796	17	1·0337	6·745	7·932
84	1·1701	33·328	34·252	50	1·1000	19·837	20·388	16	1·0318	6·348	6·524
83	1·1681	32·931	33·845	49	1·0980	19·440	19·980	15	1·0298	5·951	6·116
82	1·1661	32·535	33·437	48	1·0960	19·044	19·572	14	1·0279	5·554	6·709
81	1·1641	32·136	33·029	47	1·0939	18·647	19·165	13	1·0259	5·158	5·301
80	1·1620	31·746	32·621	46	1·0919	18·250	18·757	12	1·0239	4·762	5·893
79	1·1599	31·343	32·213	45	1·0899	17·854	18·359	11	1·0220	4·365	4·486
78	1·1578	30·946	31·805	44	1·0879	17·457	17·941	10	1·0200	3·968	4·078
77	1·1557	30·550	31·398	43	1·0859	17·060	17·534	9	1·0180	3·571	4·670
76	1·1536	30·153	30·990	42	1·0838	16·664	17·126	8	1·0160	3·174	3·262
75	1·1515	29·757	30·582	41	1·0818	16·267	16·718	7	1·0140	2·778	3·854
74	1·1494	29·361	30·174	40	1·0798	15·870	16·310	6	1·0120	2·381	3·447
73	1·1473	28·964	39·767	39	1·0778	15·474	15·902	5	1·0100	1·984	2·039
72	1·1452	28·567	29·359	38	1·0758	15·077	15·494	4	1·0080	1·588	2·631
71	1·1431	28·171	28·951	37	1·0738	14·680	15·087	3	1·0060	1·191	1·224
70	1·1410	27·772	28·544	36	1·0718	14·284	14·679	2	1·0040	0·795	1·816
69	1·1389	27·376	28·136	35	1·0697	13·887	14·271	1	1·0020	0·397	1·408
68	1·1369	26·979	27·728	34	1·0677	13·490	13·863				
67	1·1349	26·583	27·321	33	1·0657	13·094	13·456				

The muriatic acid of commerce has usually a yellowish tinge, due to the presence of chloride of iron; but when chemically pure, it is colourless. It fumes strongly in the air, emitting a corrosive vapour of a peculiar smell. The characteristic test of muriatic acid in the most dilute state, is nitrate of silver, which causes a curdy precipitate of chloride of silver.

Liquid muriatic acid has a very sour corrosive taste, a pungent suffocating smell, and acts very powerfully upon a vast number of mineral, vegetable, and animal substances. It is largely employed in the manufacture of chlorine for preparing bleaching powder and other purposes; it is also used in the preparation of chloride of zinc and other metallic chlorides used in the arts; it is employed in the generation of carbonic acid gas from carbonate of lime; and it is a constituent of certain freezing mixtures. In combination with nitric acid, it forms the *aqua regia* of the alchemists, so called from its property of dissolving gold. See SODA MANUFACTURE.

HYDROCYANIC ACID. Syn. *Cyanhydric acid, Prussic acid.* C^2NH (**CNH**). This highly important acid is regarded by all chemists as being formed on the exact type of the ordinary inorganic hydracids, such as the hydrochloric or hydriodic. The compound radical analogous to chlorine, which is contained in it, has received the name of *cyanogen*, and possesses the formula C^2N (**CN**). That this body is precisely analogous in its relations to the simple salt-radicals is rendered certain by numerous facts. It combines directly with metals to form compounds; it possesses the same vapour-volume, and unites with hydrogen to form a hydracid, which in its turn decomposes the metallic oxides with formation of water. Thus we have, with metallic oxides and hydrochloric acid (M standing for a metal), $MO + HCl = MCl + HO$, and with hydrocyanic and metallic oxides (Cy standing for cyanogen), $MO + HCy = MCy + HO$. Two volumes of chlorine and two of hydrogen yield four volumes of hydrochloric acid gas, and two volumes of cyanogen with two of hydrogen yield four volumes of hydrocyanic acid. The density of the vapour of hydrocyanic acid is consequently 0·9476, the theoretical number being 0·9342. Its density in the fluid state is 0·6967, at a temperature of 64°·4. It boils at 80° F. at ordinary pressures.

Hydrocyanic acid is never prepared in the anhydrous state, except as a curiosity or for the purpose of scientific investigation. In fact, it cannot be long preserved of great strength; a somewhat complex decomposition invariably takes place in it, with production of brown adhesive matters containing cyanide of ammonium, and also a substance by some considered to be an acid, and known as the azulmic. Paracyanogen is probably formed at the same time. The constitution of azulmic acid is by no means well known, and even its very existence, as a definite chemical substance, is doubtful. It is singular that the presence of a mineral acid greatly retards the decomposition of prussic acid, especially if it be dilute; the pharmacopœian acid conquently may be preserved of uniform strength, in well-filled and closely-stoppered bottles, for almost any length of time. The deadly nature of prussic acid unhappily causes it to be only too frequently resorted to by the despairing or the murderer. Fortunately, however, in spite of its volatility, the chemist possesses excellent means for its detection.

Preparation.—1. Hydrated acid. As prussic acid is largely employed in medicine, but in a very dilute form, it is usual to prepare it and dilute until of the proper degree of strength. The following process for preparing it will be found to give a satisfactory result, and, moreover, it may be performed on any quantity of materials. The apparatus for the purpose will vary with the scale on which the experiment is to be made. If on a few ounces, glass retorts and flasks answer well, if good condensation is ensured, by means of a Liebig's condenser well supplied with very cold water. If a large quantity of prussic acid is to be made, such as several gallons, the apparatus should consist of a stoneware still, with head adjusted by grinding. The head should be capable of adjustment with a stoneware adapter to a worm of the same material enclosed in a tub of water. The joints are to be luted with a mixture of one handfull of almond meal and five handfulls of linseed meal, worked with water to the consistence of putty. A solution of rough chloride of calcium in water is to be made and placed in a large iron pot, with a cover so contrived as to permit the still to drop in up to the flange. 10 parts of yellow prussiate of potash are then to be bruised in a mortar and mixed with dilute sulphuric acid prepared by adding 6 parts of sulphuric acid (density 1·850) to 42 of water. The head being luted on, a fire is to be kindled in the furnace under the iron pot, and the chloride of calcium bath is to be kept boiling constantly until 36 parts of acid have distilled over. The beak of the still should be placed in the funnel which conducts the acid to the Winchester quart bottles which are to contain the product, and a piece of wet bladder is to be stretched over the funnel to prevent evaporation of the acid into the laboratory. The worm used for the purpose must be ascertained to be perfectly clean, and, if prussic acid is to be frequently made, should be kept specially for that operation. To each Winchester quart of the acid distilling over, one drop of sulphuric acid may be added to insure its keeping. But the acid thus prepared generally keeps for a long time even without this precaution, owing probably to small traces of the sulphuric acid being carried over during the distillation.

It is quite impossible to conduct the operation so as to yield a product of uniform strength; it is absolutely necessary, therefore, to determine the percentage of real hydrocyanic acid, and dilute it to the required degree. It fortunately happens that 1 grain of hydrocyanic acid yields almost exactly 5 grains of cyanide of silver; for one equivalent of acid = 27 produces 1 equivalent of cyanide of silver = 134; so that 27 : 134 :: 1 : 4·96. The acid produced will have, probably, to be reduced to one of two standards; namely, the so-called Scheele's strength, containing 5 per cent. of acid, or the P.L., containing 2 per cent.; 100 grains of the former should, consequently, yield 25 grains, and 100 of the P.L. 10 grains of cyanide of silver. In either case the calculation becomes obvious.

2. The anhydrous acid. Several processes for conducting this dangerous operation are known; the following is, perhaps, the most generally convenient. A large glass retort is so arranged that its neck is directed upwards at an angle of about 45°; a cork fitted to the aperture in the neck connects a glass tube with a bottle containing a little chloride of calcium. From the latter vessel another tube proceeds to a U-tube containing fragments of chloride of calcium, and from the latter a third, conducting the dehydrated vapour of prussic acid to an upright glass tube contained in a mixture of ice and salt. Into the retort is placed a mixture of 10 parts of yellow prussiate of potash, 7 of oil of vitriol, and 14 of water. The retort is to be heated with a charcoal fire, and the temperature of the bottle and U-tube, containing the chloride of calcium, is not to be allowed to fall below 90°, in order to prevent condensation of the anhydrous prussic acid taking place anywhere except in the tube contained in the freezing mixture. The vapour of anhydrous prussic acid is so dangerous that the greatest precaution must be taken to prevent inhaling the smallest portion.

Detection of prussic acid.—When prussic acid exists in moderate quantity in a solution it may be detected by first adding a few drops of potash, then a mixture of protosulphate and persulphate of iron, and finally a little hydrochloric acid; a bright blue precipitate indicates the presence of the acid. A much more delicate test, and one that is applicable when, from the dilution of the solution, the salts of iron are no longer capable of acting, is by the conversion of the prussic acid into sulphocyanide of ammonium. For this purpose the prussic acid is to be warmed on a watch-glass with a drop of sulphide of ammonium, until the solution has become colourless. The addition of a trace of a solution of a persalt of iron will show, by the formation of a blood-red colour, the presence of the acid sought. A very neat mode of applying this test is to place one drop of sulphide of ammonium on a watch-glass inverted over another containing the suspected fluid. On leaving the apparatus in a warm place, arranged in this manner, for a short time, the upper glass will be found to contain sulphocyanide of ammonium, which, after drying, will be in a state well adapted for showing the reaction with a persalt of iron.—C.G.W.

HYDRODYNAMICS. The mechanical science which treats of the motion of fluids. This science has, of course, most important bearings on the pumping-engines, water-wheels, &c., employed to facilitate the operation of the miner. It is not, however, possible to embrace this, which belongs to mechanical engineering, in this work. See HYDRAULIC MACHINERY, FOR MINES.

HYDRO-EXTRACTOR. A name sometimes given to the machines employed for expelling the water from woven goods. See DESICCATION.

HYDROFLUORIC ACID. It was observed by Schwankhardt, in 1670, that fluor spar and oil of vitriol would eat into glass. Scheele, in 1771, determined that this peculiar property was due to the liberation of an acid from the fluor spar.

Hydrofluoric acid is best obtained by placing finely-powdered fluor spar in a leaden retort, and twice its weight of highly-concentrated oil of vitriol. By a gentle heat the gas is distilled over, which must be collected in a leaden tube, in which, by means of a freezing mixture, it may be condensed into a liquid. If a solution of this acid in water is required, the extremity of the tube from the retort is carried into water.

Hydrofluoric acid attacks glass with great readiness, by acting on its silica.

Glass upon which any design is to be etched, is covered with an etching-wax, and the design made in the usual manner; this is placed over a leaden vessel, in which is a mixture of fluor spar and oil of vitriol; a gentle heat being applied, hydrofluoric acid escapes, and immediately attacks the glass. See FLUORINE.

HYDROGEN. (*Hydrogène*, Fr.; *Wasserstoff*, Ger.) A permanently gaseous elementary body, the lightest of all known substances, its specific gravity being ·0693; 100 cubic inches weighing, under ordinary pressure and temperature, only 2·14 grains. It is therefore nearly 14·5 times lighter than atmospheric air.

From its extreme lightness it was formerly used for filling balloons, but it has been superseded for that purpose by ordinary coal-gas, which can be obtained at a much cheaper rate; the difference of buoyant power being compensated by increasing considerably the size of the balloon. It is itself inflammable, but will not support combustion. In burning it combines with oxygen, forming water, which contains $\frac{1}{9}$th of its weight of hydrogen.

It is generally prepared by the action of dilute sulphuric acid on zinc, although there are many other processes which furnish it; as the decomposition of steam by iron fillings with the aid of heat, the decomposition of water by electricity, &c.

In the act of combining with oxygen, as when burnt in the oxyhydrogen blowpipe, the greatest possible heat is obtained; a piece of stout platinum wire being fused when placed in the flame, which cannot be affected by the greatest heat of our furnaces.

Hydrogen is often used in the process of soldering metals; it which case it is requisite to bring the two surfaces of the metal together in a perfectly metallic state at a high temperature. Hydrogen effects this completely; by its combustion it supplies the heat, and by entering into combination with the oxygen of the air, prevents the formation of oxides, which are so easily formed at the temperature required for the melting of the metals, and which, when present, prevent the union of the surfaces. See Autogenous Soldering.

Hydrogen is often used also for the reduction of metals from their different combinations; the reduction is effected by passing a current of hydrogen over the compounds heated to redness.

HYDROGEN, PHOSPHORETTED, or *Phosphamine.* A compound of hydrogen and phosphorus, PH^3. It is spontaneously inflammable if it escapes into the air.

HYDROGEN, SULPHURETTED. See Sulphuretted Hydrogen.

HYDROMETER. An instrument for ascertaining the specific gravities of liquids. Baumé's hydrometer, which is much used in France, and other countries of the continent of Europe, when plunged in pure water at the temperature of 58° Fahr., marks 0 upon its scale; in a solution containing 15 per cent. of common salt (chloride of sodium), and 85 of water by weight, it marks 15°; so that each degree is meant to indicate a density corresponding to one per cent. of that salt. See Alcoholmeter.

HYDROPHANE. A variety of opal which readily imbibes water, and when immersed it becomes transparent, though opaque when dry. It is found in Hungary and in Ireland, near the Giant's Causeway, and at Crosreagh, Ballywillin.

HYDROSTATIC BALANCE. HYDROSTATIC PRESS. A balance or a press constructed in obedience to the law that *In a quantity of fluid submitted to compression, the whole mass is equally affected, and similarly in all directions.* The subject belongs to Practical Engineering.

HYDROSTATICS. The science which treats of the equilibrium of fluids, and of the pressure exerted by them.

In the engineering arrangements by which water is supplied to towns, hydrostatics becomes of the utmost importance. The highest possible level is obtained for the reservoir; and from this a series of pipes is arranged through all the streets and houses. The tendency of the water is to rise to its original level, and hence all the pipes are filled with water, and in all such as are below the level of the water in the reservoir a pressure upward is exerted equal to the height of the reservoir above that point; and if a hole is pierced in the pipe, the water jets out with a force equal to this pressure. In the highest houses, the water perhaps only finds its level, and flows out without pressure quickly. See Hydraulic Crane; Hydraulic Machinery, for Mines.

HYDROSULPHURETS or *Hydrosulphides.* Chemical compounds of bases with sulphuretted hydrogen, or hydrosulphuric acid.

HYDROXYL. A radical containing HO^2 ($\mathbf{HO}$). Great prominence has been given to it in recent chemical theories. *Peroxide of hydrogen*, or *oxygenated water*, may be regarded as free hydroxyl, since it contains the molecule, or two atoms, of hydroxyl $2HO^2$ ($\mathbf{H^2O^2}$).

HYGROMETER (*ὑγρός, moist, μέτρον, measure*), is an instrument which measures the amount or degree of moisture in the atmosphere.

Water, both liquid and solid, always tends to assume the gaseous form, and in so doing exerts an elastic force, increasing as the temperature rises, but in a higher ratio, and in order that such increasing force may be exerted when water is confined in a given space, it is necessary that a larger and larger quantity of water should become vapour; if the weight of water be not increased, its elastic force will rise with its temperature, but in a much less ratio. For aqueous vapour, like any other gas, tends to expand by $\frac{1}{491}$th part of its volume at 32° Fahr. for every degree of increased temperature. The terms *saturated* and of *maximum elastic force* are applied to aqueous vapour, when any reduction of temperature or increase of pressure causes some of the vapour to be condensed. The temperature of saturated vapour is said to be at the dew-point. Thus, aqueous vapour of 60° Fahr. and of an elastic force of 518 inches is saturated, and 60° is its dew-point. These remarks apply to aqueous vapour mixed with air; differing only in vapour spreading less rapidly in a space filled with air than in a vacuous space. Air is said to be saturated with moisture when the aqueous vapour it contains is of maximum elastic force, the temperature of the air is then called its dew-point.

Daniell's hygrometer was the first accurate instrument invented of the kind: it consists of a small glass siphon, at each end of which is a small glass bulb about 1½ inch in diameter, a small but delicate thermometer is placed in the longer leg, as much ether is poured into the lower bulb, which is of black glass, as will half cover the enclosed thermometer bulb; before sealing the tube the ether is boiled to drive out all the air; the instrument is completed by covering the upper bulb with muslin. It is placed on a small brass stand, on which is placed another thermometer, whose readings show the air-temperature, at the time the siphon shows the dew-point. To make an observation, all the ether in the tube is collected into the lower bulb, and from a tube or bottle a few drops of ether are poured on the muslin of the upper bulb, its evaporation condenses the vapour within, fresh vapour flows along the bent tube from the lower bulb, gradually the temperature is reduced, until the dew-point of the surrounding air is reached, immediately a film of condensed vapour from the air surrounds the black glass bulb like a ring, at the level of the ether within it, and if the thermometer be read directly, almost the true temperature of the dew-point can be obtained, while the exterior thermometer will be that of the surrounding air. The expenditure of ether is an objection to this instrument, while its portability is a great recommendation.

Subsequently, several other hygrometers were devised, but none that can compare with Regnault's Condenser Hygrometer, which is a perfect instrument of its kind. It consists of a very thin and brightly-polished silver thimble, 45 mm. high and 20 mm. in diameter, fitted to a glass tube, which is again fixed by a small lateral tube, and a metallic tube, to a stand; the upper end of the glass tube is closed by a cork bearing a thin glass tube descending nearly to the bottom of the silver thimble, and a very delicate thermometer, the pear-shaped bulb of which is in the centre of the thimble; an exactly similar thermometer, similarly placed within a glass tube and silver thimble, is mounted on the other side of the stand, but the cork is not penetrated by any glass tube. To make an observation, as much good ether as will more than a third fill the thimble is poured into the lesser tube of those first described; the cork is then fitted air-tight and the instrument is put in connection, by means of a caoutchouc tube, with a common aspirator. Water flowing from the aspirator, air is drawn through the tube, and bubbling up through the ether, causes a sufficiently rapid evaporation. After a minute or two dew will be formed on the polished surface of the thimble, the thermometer should be instantly read, and the stream from the aspirator stopped, another reading should be taken on the instant of the evaporation of the dew; within a few minutes the process of collecting and evaporating the dew may be repeated many times, and the mean of repeated readings will give a very exact point. The other thermometer will give the surrounding temperature. The costliness of this instrument has prevented the general use it deserves. Instrument-makers have rendered it less costly by omitting the second thermometer and its appendages, and substituting a tube of black glass for the silver thimble. For ordinary use a common test-tube, with about 1½ inch depth of ether, in which is inserted a delicate tube-thermometer, and a glass tube may be used successfully by blowing through the tube, which should be of considerable length to reduce the temperature. Professor Connell has invented an hygrometer, where an exhausting syringe is used to lower the temperature.

A more important instrument than either of the above mentioned is the psychrometer, or wet and dry bulb hygrometer. While with the others the constant repetition of an *experiment* is necessary, this reduces it simply to the reading of an *observation.* It consists of two delicate thermometers, one recording the ordinary temperature of the air, the bulb of the other is covered with muslin, round the neck a lampwick is twisted, conducting to a cistern of rain or distilled water, the best form of which is a short small-necked glass bottle. The thermometers should be exactly similar, and placed at about from 2 to 4 inches apart, and parallel with each other, mounted on metal scales.

When the air is completely saturated, or in that condition when it will take up no more moisture, the readings of the two will be the same, but as the atmosphere becomes drier, evaporation becomes more rapid and the mercury in the wet bulb will fall more or less degrees below the ordinary temperature. Evaporation will proceed from the wet bulb even below the freezing point, but the readings should then be taken with great care, as the differences will always be small. The reading of the wet bulb will give the temperature of evaporation, and from that and the temperature of the ordinary air has to be deduced the dew-point.

HYMENÆA COURBARIL. A tree growing in South America, from which the resin *anime* exudes. See ANIME.

HYOSCYAMINE. A crystalline alkaloïd obtained from the Henbane (*Hyoscyamus niger*). It is also found in the thorn-apple (*Datura Stramonium*), and is therefore sometimes called *Daturine.*

HYPERSTHENE. A foliated mineral resembling diallage, having a pearly or metallic lustre on the cleavage planes. It is a silicate of protoxide of iron and magnesia; found at St. Paul's Island, Labrador, and elsewhere.

HYPERSTHENITE, or *Hypersthene Rock.* A rock resembling gabbro, composed of labrador-felspar and hypersthene.

HYPOCHLORIC ACID. ClO^4 ($\mathbf{Cl^2O^4}$) *At. wt.* 67·5. When finely-powdered chlorate of potash is gradually mixed into a paste with strong sulphuric acid, and heated in a bath of alcohol and water, a yellow gas is disengaged, which is this hypochloric acid, or the *peroxide of chlorine.* Although of much interest as a chemical compound, it has no use in the arts. See Watts's 'Dictionary of Chemistry.'

HYPOCHLOROUS ACID. ClO ($\mathbf{Cl^2O}$) *At. wt.* 43·5. This acid is best obtained by diffusing red oxide of mercury finely divided through twelve times its weight of water, which is introduced into a bottle containing chlorine, and agitated until the gas is absorbed. An oxychloride of mercury is formed, which is removed by subsidence. The weak fluid obtained is put into a flask, and heated in a water-bath, when the evolved gas is collected in a smaller portion of water, which becomes a pure solution of hypochlorous acid.

The salts are termed hypochlorites. See CHLORINE and BLEACHING.

HYPOSULPHATES. Saline compounds formed by the union of hyposulphuric acid with bases.

HYPOSULPHITES. Saline compounds formed by the union of hyposulphurous acid with bases.

Hyposulphate of Soda. The salts of the hyposulphuric acid are obtained from the hyposulphate of manganese, which is itself thus prepared: finely-divided binoxide of manganese is suspended in water, artificially cooled, and a stream of sulphurous acid passed through it. The binoxide gives up half its oxygen, becoming protoxide, which unites with the hyposulphuric acid which is formed, producing the soluble hyposulphate of manganese, which is separated from the excess of binoxide by filtration.

The following equation represents the reaction:—

$$MnO^2 + 2SO^2 = MnO,S^2O^5.$$

If the temperature were allowed to rise, sulphuric acid would be formed, and not hyposulphuric:—

$$MnO^2 + SO^2 = MnO,SO^3.$$

The hyposulphuric acid, unlike the hyposulphurous acid, may be obtained in the free state, and its solution permits even of being evaporated *in vacuo*, until it acquires the density of 1·347; but if carried further, it is decomposed into sulphuric and sulphurous acids.

The acid is obtained in the free state by adding baryta water to the hyposulphate of manganese; the soluble hyposulphate of baryta, filtered from the oxide of manganese, and precipitated exactly by the cautious addition of sulphuric acid, and filtered from the precipitate of sulphate of baryta, yields the pure solution of the acid, which may be evaporated *in vacuo*, as above stated.

It has no odour, but a very sour taste.

The hyposulphate of soda may be made directly from the manganese salt or from the free acid.

All the hyposulphates are soluble; they have not as yet met with any commercial application.

Hyposulphite of Soda. This salt, now so extensively used for photographic purposes, was first introduced by Sir J. Herschel. It may easily be prepared by the following process: viz. by transmitting through a solution of sulphide of sodium (prepared by fusing together in a covered crucible equal weights of carbonate of soda, and flowers of sulphur), a stream of sulphurous acid until it ceases to be absorbed; the liquid is then filtered and evaporated, when the hyposulphite of soda, $NaO,S^2O^2 + 5HO$ ($\mathbf{Na^2O,S^2O^2 + 5H^2O}$) crystallises out.

Another and perhaps better process consists in digesting a solution of sulphite of soda on flowers of sulphur. The sulphur gradually dissolves, forming a colourless solution, which yields on evaporation crystals of hyposulphite of soda; the reaction being shown by the following equation:—

$$NaO,SO^2 + S = NaO,S^2O^2 \quad (\mathbf{Na^2O,SO^2 + S = Na^2O,S^2O^2}).$$

The baryta salt may be obtained in small brilliant crystals, by mixing dilute solutions of chloride of barium and hyposulphite of soda.

The hyposulphurous acid is incapable of existing in the free state, for almost immediately on the addition of an acid to the solution of its salts, it is decomposed into sulphurous acid, with liberation of sulphur. ($S^2O^2 = SO^2 + S$).

The soluble hyposulphites have the power, in a marked degree, of dissolving certain salts of silver, as the chloride, iodide, &c., which are insoluble in water; forming with them soluble salts, whose solutions possess an intensely sweet taste, although the solutions of the hyposulphites alone possess a disagreeable bitter taste.

From the above reaction arises the principal value of the hyposulphite of soda, which is used by the photographer to dissolve off from the photograph, after the action of the light on it, all the undecomposed silver salt, thus preventing the further action of the light on the picture.

A double hyposulphite of soda and gold is used for gilding the daguerreotype plate, and for colouring the positive proof obtained in photographic printing. This double salt may be obtained in a state of purity, by mixing concentrated solutions of 1 part of chloride of gold, and 3 parts of hyposulphite of soda; by the addition of alcohol it is precipitated; the precipitate must be re-dissolved in a small quantity of water, and again precipitated by alcohol.

HYSON. A green tea. See Tea.

HYSTATITE. A variety of titaniferous iron from Arendal in Norway.

I

IBEX. An animal of the goat-kind, the hair of which is esteemed for some kinds of manufacture. Two species occur in Europe: the common ibex (*Capra Ibex*), inhabiting the Alps, and *C. Pyrenaicus*, found in the Pyrenees: whilst other species are found in Asia and in Africa. The wool of the *skyn*, or ibex of Little Thibet, has been used in manufacturing certain fabrics.

ICE. Water begins to solidify or to become ice at 32° F. See Freezing.

ICE-HOUSE. (*Glacière*, Fr.; *Eishaus*, Ger.) For the uses of common life, in these climates, the most economical and convenient means of refrigeration in hot weather may be procured by laying up a store of ice in winter, in such circumstances as will preserve it solid during summer.

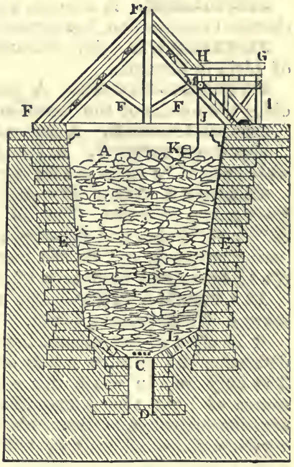
An ice-house should not be regarded as an object of mere luxury; in the southern countries of Europe it is considered among people in easy circumstances as an indispensable appendage to a country mansion. During the dog days, especially at those periods, and in those districts where the *sirocco* blows, a lassitude and torpor of mind and body supervene, with indigestion or total loss of appetite, and sometimes dysenteries, which are obviously occasioned by the excess of heat, and are to be prevented or counteracted chiefly by the use of cold beverages. By giving tone to the stomach, iced drinks immediately restore the functions of the nervous and muscular systems when they are languid; while they enable persons in health to endure without much inconvenience an atmosphere so close and sultry as would be intolerable without this remedy. Ice-houses, moreover, afford to country gentlemen a great advantage in enabling them to preserve their fish, butcher's meat, dead poultry, and game, which would otherwise, in particular states of the weather, immediately spoil. Considering at how little expense and trouble an ice-house can be constructed, it is surprising that any respectable habitation in the country should not have one attached to it. The simplest and most scientific form is a double cone, that is, two cones joined base to base; the one being of stones or brick-work, sunk under ground, with its apex at the bottom, into which the ice is rammed; the other being a conical roof of carpentry, covered with thatch, and pointed at top. The entrance should be placed always on the north side; it should consist of a corridor or porch with double doors, and be screened from the sunbeams by a small shrubbery. Such are the principles upon which an ice-house should be formed; but they will be better understood by the following explanation and figure.

A dry and sandy soil if possible should be selected; and here a cavity is to be dug, about 16 feet in diameter, terminating below like the point of a sugar-loaf. Its ordinary depth for a family may be about 24 feet; but the larger its dimensions are, the longer will it preserve the ice, provided it be filled. In digging, the workman should slope the ground progressively towards the axis of the cone, to prevent the earth falling in. This conical slope should be faced with brick or stone work about one foot thick, and jointed with Roman cement, so as to be air- and water-tight. A well is to be excavated, at the bottom 2 feet wide and 4 deep, covered at top with an iron grating for supporting the ice, and letting the water drain away.

The upper cone may likewise be built of brick-work, and covered with thatch; such a roof would prove the most durable. This is the construction shown in *fig.* 1205. Whatever kind of roof be preferred, there must be left in it an oblong passage into the interior. This porch should face the north, and be at least 8 feet long by 2½ feet wide; and perfectly closed by a well-fitted door at each end. All round the bottom of this conical cover, a gutter should be placed to carry off the rain to a distance from the ice-house, and prevent the circumjacent ground from getting soaked with moisture.

Fig. 1205 shows the section of a well-constructed ice-house, Under the ice-chamber A the ice is rammed into the space B. C is the grate of the drain-sink D. The portion E E is built in brick or stone; the base L of the ice-chamber slopes inwards towards the centre at C. The upper part of the brick-work E E is a little way below the level of the ground. The wooden framework, F F F F, forms the roof, and is covered with thick thatch. G H is the wooden work of the door I. At K the bucket is seen for lifting up a charge of ice, by means of the cord J passing over the pulley M, which enables the servant to raise it easily.

1205



The ice-house should have no window to admit light, but be, so to speak, hermetically sealed in every point, except at its cesspool, which may terminate in a water-trap to prevent circulation of air.

A clear day should be selected for charging the ice-house; but before beginning to fill, a quantity of long dry straw should be laid on the bottom crosswise; and as the ice is progressively introduced, straw is to be spread against the conical sides, to prevent the ice from coming into contact with the brick or stone-work. The more firmly compacted the ice is, the better does it keep; with which view it should be broken into pieces with mallets before being thrown in. No layers of straw should be stratified among the ice, for they would make its body porous. Some persons recommend to pour in a little water with the successive layers of ice, in order to fill up its small crevices and convert the whole into one mass.

Over the top layer a thick bed of straw should be spread, which is to be covered with boards surmounted with heavy stones, to close up the interstices in the straw. The inner and outer doors should never be opened at once; but the one should always be shut before the other is opened.

Dry snow well rammed keeps equally well with hard ice, if care be taken to leave no cavities in the mass, and to secure its compactness by sprinkling a little water upon the successive charges.

To facilitate the extraction of the ice, a ladder is set up against its sloping wall at one side of the door, and left there during the season.

Ice *imported* in 1871:—

	Tons	£	Tons	£
From Norway . .	95,448	82,865	139,321	128,196
Other countries .	508	398	100	55
	95,956	83,263	139,421	128,251

ICE-MANUFACTURE. Siebe's, Harrison's, and Carré's machines for making ice are described at page 488. See FREEZING.

ICE-PLANT. The *Mesembryanthemum crystallinum* is so called in allusion to the appearance of the surface of the leaves, which are studded with small watery vesicles. The ashes of the plant yield soda.

ICE-SPAR. A transparent glassy felspar, referred partly to sanidine and partly to anorthite.

ICELAND MOSS (*Lichen d'Islande*, Fr.; *Isländische Flechte*, Ger.) is a lichen, the *Cetraria Islandica*, which contains a substance soluble in hot water, but forming a jelly when it cools, styled *lichenine* by M. Guérin. This moss is called in the Pharmacopœia *Lichen Islandicus.* It appears to have derived its name from the circumstance that the Icelanders first discovered its medicinal qualities. Lichenine is prepared by extracting first of all from the plant a bitter colouring matter, by digesting 1 lb. of it in 16 lbs. of cold water containing 1 ounce of pearlash; then draining the lichen, edulcorating with cold water, and boiling it in 9 lbs. of boiling water, till 3 lbs. be evaporated. The jelly which forms, upon cooling the filtered solution, is dark coloured, but, being dried and redissolved in hot water, it becomes clear and colourless. Lichenine consists of 39·33 carbon, 7·24 hydrogen, and 55·43 oxygen. The mucilage of Iceland moss is preferred in Germany to common paste for dressing the warp of webs in the loom, because it remains soft, from its hygrometric quality. It is also mixed with the pulp, for sizing paper in the vat. For several curious compounds obtained from Iceland moss, see Watts's 'Dictionary of Chemistry.'

ICELAND SPAR. Crystallised carbonate of lime, of which the most beautiful specimens are brought from Iceland. These are remarkable for their double refraction; and hence this crystal is sometimes called *doubly-refracting spar.*

IDOCRASE. A mineral known also as *Vesuvian*, closely resembling garnet in chemical composition, but crystallising in the pyramidal system.

IDRIALINE. A hydrocarbon occurring with cinnabar in the quicksilver mines of Idria in Carniola.

IDWALE-STONE. A peculiar Welsh hone-stone. It is obtained from the older slate-rocks of the Snowdon district.

IGLESIASITE. A carbonate of lead and zinc, from Sardinia.

ILIXANTHINE. A substance derived from the leaves of the common holly, which might be employed for dyeing yellow.

ILLOOPA OIL. The produce of the *Bassia longifolia*, one of the most useful trees grown in India. The oil might be denominated a butter, as it is solid from 82° to 84° Fahr., and liquefies at 90° to 95° Fahr. It is used in India for illuminating purposes, and for the manufacture of soap. Samples of this oil were sent to the International Exhibition of 1862, by the Singapore Local Committee.

ILLUMINATION. The means of determining the relative values of various sources of illuminating power.

It is often of the utmost importance that we should be enabled, with facility, to determine the relative values of the light which we obtain from artificial sources. The only way in which this can be effected, is by comparing with some standard source of light the illuminating sources employed. Dr. Ure, who was on several occasions called on to direct his attention to inquiries of this nature, instituted many very ingenious and exact experiments; to some of these it appears important that we should direct especial attention. Of the original paper on the cost of illumination, many parts are now obsolete; but, as much of it is still of considerable practical value, the following selections have been made, all such being distinguished by Dr. Ure's name. After many experiments to determine a standard, Dr. Ure says:—

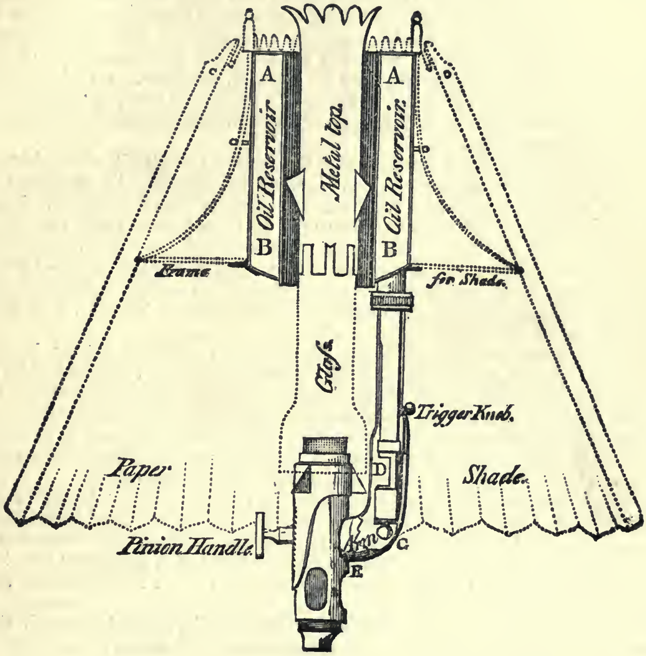
'After comparing lights of many kinds, I find every reason to conclude that a large wax candle, of three to the pound, either long or short, that is, either 12 or 15 inches in length, as manufactured by one of the great wax-chandlers in London, and furnished with a wick containing 27 or 28 threads of the best Turkey cotton, is capable of furnishing a most uniform, or nearly invariable standard of illumination. It affords one-tenth of the light emitted by one of the Argand lamps of the Trinity House, and one-eleventh of the light of my mechanical lamp, when each lamp is made to burn with its maximum flame, short of smoking.'

Dr. Ure, however, for many of his determinations employed the French mechanical lamp, known as Carcel's lamp; and in connection with this the following remarks occur:—

'Mr. Samuel Parker, long advantageously known to the public for his sinumbral and pneumatic fountain-lamps, as well as other inventions subservient to domestic comfort, having obtained a patent for a new lamp, in which the oil is heated by a very simple contrivance, in the cistern, to any desired degree, before arriving at the wick. I instituted an extensive series of experiments to determine its value in the production of light, and consumption of oil, compared to the value of other lamps, as well as candles in these respects.'

In *fig.* 1206, A, A, B, B, is a section of the cylinder which constitutes the cistern; the oil being contained between the inner and outer cylinders, and receiving heat from the flame of the lamp which passes up through the inner cylinder, and is reverberated more or less against its sides by the top of the metal chimney being notched and bent back. D is a slide-valve, which is opened to allow the oil to descend to the wick, and is shut when the cistern is to be separated from the pipe of supply, at E, for the purpose of recharging it with oil. The flame is modified, not by raising or lowering the wick, as in common lamps, but by raising or lowering the bell-mouthed glass chimney, which rests at its bottom on three points, and is moved by means of the rack-work mechanism F. The concentric cylindric space A, A, B, B, contains a pint imperial, and should be made entirely full before lighting the lamp; so as to leave no air in the cistern, which, by its expansion with the heat, would inevitably cause an overflow of the oil.

1206



The following arrangement was adopted in these experiments for determining the relative illumination of the different lights. Having trimmed, with every precaution, my French mechanical lamp, and charged it with pure sperm-oil, I placed it upon an oblong table, at a distance of 10 feet from a wall, on which a white sheet of paper was stuck. One of Mr. Parker's hot-oil lamps, charged with a quantity of the same oil, was placed upon the same table; and each being made to burn with its maximum brilliancy, short of smoking, the relative illumination of the two lamps was determined by the well-known method of the comparison of shadows; a wire a few inches long, and of the thickness of a crow-quill, being found suitable for enabling the eye to estimate very nicely the shade of the intercepted light. It was observed in numerous trials, both by my own eyes and those of others, that when one of the lamps was shifted half an inch nearer to or further from the paper screen, it caused a perceptible difference in the tint of the shadow. Professor Wheatstone kindly enabled me to verify the precision of the above method of shadows, by employing, in some of the experiments a photometer of his own invention, in which the relative brightness of the two lights was determined by the relative brightness of the opposite sides of a revolving silvered ball, illuminated by them.

1. The mechanical lamp was furnished with a glass chimney 1·5 inch in diameter at the base, and 1·2 at top; the wide bottom part was 1·8 inch long, and the narrow upper part 8 inches. When placed at a distance of 10 feet from the wall, its light there may be estimated as the square of this number, or 100. In the first series of experiments, when burning with its maximum flame, with occasional flickerings of smoke, it emitted a light equal to that of 11 wax candles, and consumed 912 grains of oil per hour. The sperm-oil was quite pure, having a specific gravity of 0·874

compared with water at 1000. In a subsequent series of experiments, when its light was less flickering, and equal only to that of 10 wax candles, it consumed only 815 grains, or 0·1164 of a pound per hour. If we multiply this number into the price of the oil (8*s.* per gallon) per pound, 11*d.*, the product 1·2084*d.* will represent the relative cost of this illumination, estimated at 100.

2. The hot-oil lamp burns with a much steadier flame than the mechanical, which must be ascribed in no small degree to the rounded slope of the bell-mouthed glass chimney, whereby the air is brought progressively closer and closer into contact with the outer surface of the flame, without being furiously dashed against it, as it is by the rectangular shoulder of the common contracted chimney. When charged with sperm-oil, and made to burn with its maximum flame, this lamp required to be placed one foot further from the screen than the mechanical lamp, in order that its shadow should have the same depth of tint. Hence, its relative illumination was, in that case, as the square of 11 to the square of 10; or as 121 to 100. Yet its consumption of oil was only 696 grains, or somewhat less than 0·1 of a lb. per hour. Had its light been reduced to 100, it would have consumed only 576 grains per hour, or ·082 of a lb. If we multiply this number by 11*d.*, the product 0·902*d.* will represent the relative cost of 100 of this illumination.

3. The hot-oil lamp being charged with the southern whale-oil, of specific gravity 0·926, at 2*s.* 6*d.* per gallon, or 3¾*d.* per lb., when burning with its maximum flame, required to be placed 9 feet and 1 inch from the screen to drop the same tint of shadow upon it as the flames of the other two lamps did at 10 and 11 feet with the sperm-oil. The square of 9 feet and 1 inch = 82 is the relative illumination of the hot-oil lamp with the southern whale-oil. It consumed 780 grains, or 0·111 of a pound per hour; but had it given 100 of light it would have consumed 911 grains, or 0·130 of a pound, which number being multiplied by its price 3¾*d.*, the product 0·4875*d.* will represent the relative cost of 100 of this light.

4. A hot-oil lamp charged with olive-oil of specific gravity 0·914, at 5*s.* 6*d.* per gallon, or 7½*d.* per lb. when burning with its maximum flame, required to be placed at 9 feet 6 inches, to obtain the standard tint of shadow upon the screen. It consumed 760 grains per hour. The square of 9½ feet is 90½, which is the relative intensity of the light of this lamp. Had it emitted a light = 100, it would have consumed 840 grains, or 0·12 of a pound per hour—which number multiplied by the price per pound, gives the produce 0·9*d.* as the relative cost of 100 of this light.

5. A hot-oil lamp charged with Price and Co.'s cocoa-nut oil (oleine), of specific gravity 0·925, at 4*s.* 6*d.* per gallon, or 5¾*d.* per lb. had to be placed 9 feet from the screen, and consumed 1,035 grains per hour. Had its light been 100 instead of 81 (9^2), the consumption would have been 1,277 grains, or 0·182 of a pound per hour! which number multiplied by its price per pound, the product 1·031*d.* will represent the cost of 100 of this illumination.

6. In comparing the common French annular lamp in general use with the mechanical lamp, it was found to give about one-half the light, and to consume two-thirds of the oil of the mechanical lamp.

7. Wax candles from some of the most eminent wax-chandlers of the metropolis were next subjected to experiment; and it is very remarkable that, whether they were threes, fours, or sixes in the pound, each afforded very nearly the same quantity of light, for each required to be placed at a distance of 3 feet from the screen to afford a shadow of the same tint as that dropped from the mechanical lamp, estimated at 100. The consumption of a genuine wax candle, in still air, is, upon an average of many experiments, 125 grains per hour, but as it affords only $\frac{1}{11}$th of the light of the mechanical lamp, 11 times 125 = 1,375 grains, or 0·1064 of a pound, is the quantity that would need to be consumed to produce a light equal to that of the said lamp. If we multiply that number by the price of the candles per lb. = 30*d.* the product = 5·892*d.* is the cost of 100 of illumination by wax. A wax candle, three in the pound (short), is one inch in diameter, 12 inches in length, and contains 27 or 28 threads, each about $\frac{1}{10}$th of an inch in diameter. But the quality of the wick depends upon the capillarity of the cotton fibrils, which is said to be the greatest in the Turkey cotton, and hence the wicks for the best wax candles are always made with cotton yarn imported from the Levant. A wax candle, three in the pound (long), is ⅞ths of an inch in diameter, 15 inches long, and has 26 threads in its wick. A wax candle, six to the pound, is 9 inches long, ⅘ths of an inch in diameter, and has 22 threads in its wick. The light of this candle may be reckoned to be, at most, about $\frac{1}{11}$th less than that of the threes in the pound. A well-made short three burns with surprising regularity in still air, being at the rate of an inch in an hour and a half, so that the whole candle will last 18 hours. A long three will last as long, and a six about 9½ hours. Sp. gr. of wax = 0·960.

8. A spermaceti candle, three in the pound, is $\frac{9}{10}$ths of an inch in diameter, 15 inches long, and has a plaited wick, instead of the parallel threads of a wax candle. The

same candles, four in the pound, are $\frac{8}{10}$ths of an inch in diameter, and 13½ inches long. Each gives very nearly the same quantity of light as the corresponding wax candles: viz. $\frac{1}{11}$th of the light of the above mechanical lamp, and consumes 142 grains per hour. Multiplying the last number by 11, the product, 1,562 grains = 0·223 of a pound, would be the consumption of spermaceti requisite to give 100 of illumination. Multiplying the last number by 24*d.*, the price of the candles per pound, the product, 5·352*d.* is the relative cost of 100 of this illumination.

9. *Stearic acid* candles, commonly called German wax, consume 168·5 grains, or 0·024 of a pound per hour, when emitting the same light as the standard wax candle. Multiplying the latter number by 11, and by 16*d.* (the price of the candles per lb.), the product 4·224*d.* will represent the relative cost of 100 of this illumination.

10. Tallow candles: moulds, short threes, 1 inch in diameter, and 12½ in length; ditto long threes, $\frac{9}{10}$ths of an inch in diameter, and 15 in length; ditto, long fours, $\frac{8}{10}$ths of an inch in diameter, and 13¾ in length. Each of these candles burns with a most uncertain light, which varies from $\frac{1}{12}$th to $\frac{1}{16}$th of the light of the mechanical lamp—the average may be taken at $\frac{1}{14}$th. The three consume each 144 grains, or 0·2 of a pound, per hour; which number, multiplied by 14, and by 9*d.* (the price per pound), gives the product 2·52*d.* for the relative cost of 100 of this illumination.

11. *Palmer's* spreading wick candles. Distance from the screen 3 feet 4 inches, with a shadow equal to the standard. Consumption of tallow per hour 232·5 grains, or 0·0332 of a pound. The square of 3 feet 4 inches = 11·09 is the relative illumination of this candle = 11·09 : 0·0332 :: 100 : 0·3 × 10*d.* = 3*d.* is the relative cost of this illumination.

12. Cocoa-nut stearine candles consumed each 168 grains per hour, and emitted a light equal to $\frac{1}{16}$th of the standard flame. Multiplying 168 by 16, the product 30·88 grains, or 0·441 of a lb., is the quantity which would be consumed per hour to afford a light equal to 100. And 0·441 multiplied by 10*d.*, the price per lb., gives the product 4·441*d.* as the cost of 100 of this illumination per hour.

13. A gas Argand London lamp, of 12 holes in a circle of ¾ of an inch in diameter, with a flame 3 inches long, afforded a light = 78½ compared to the mechanical lamp: and estimating the light of the said mechanical lamp as before at 100, that of the hot-oil lamp is 121, and that of the above gas-flame 78·57, or in round numbers 80, *and the common French lamp in general use* 50.

Collecting the preceding results, we shall have the following tabular view of the cost per hour of an illumination equal to that of the mechanical lamp, reckoned 100, or that of eleven wax candles, three to the pound.

Table of Cost per Hour of One Hundred of Illumination.

		Pence		Pence
1.	Parker's hot-oil lamp, with southern whale oil	0·4875	or about	½*d.*
2.	Mechanical or Carcel lamp, with sperm-oil	1·2804	„	1¼
3.	Parker's hot-oil lamp, with sperm-oil	0·902	„	1
4.	Ditto ditto common olive-oil	1·900	„	1
5.	Ditto ditto cocoa-nut oleine or oil	1·031	„	1
6.	French lamp in general use, with sperm-oil	1·7072	„	1¾
7.	Wax candles	5·822	„	6
8.	Spermaceti candles	5·352	„	5¼
9.	German wax (Stearic acid) ditto	4·224	„	4¼
10.	Palmer's spreading wick candles	2·800	„	2¾
11.	Tallow (mould) candles	2·520	„	2½
12.	Cocoa-nut stearine of Price and Co.	4·41	„	4½

The following Table contains, according to Péclet, the illuminating powers of different candles, and their consumption of material in an hour; the light emitted by a *Carcel* Argand lamp, consuming 42 grammes (= 42 × 15½ grains) in an hour, being called 100:—

	Intensity of light	Consumption per hour
Tallow candles, 6 in lb.	10·66	8·51
Stearine, or pressed tallow, 8 in lb.	8·74	7·51
„ „ 5 in lb.	7·50	7·42
Wax candles, 5 in lb.	13·61	8·71
Spermaceti, 5 in lb.	14·40	8·92
Stearic acid, commonly called stearine, 5 in lb.	14·40	9·33

The subjoined Table shows the economical ratios of the candles, where the second column gives the quantity of material in grammes which is requisite to produce as much light as the Carcel lamp:—

	Quality of material	Price per kilogramme	Cost of light per hour
Tallow candle, 6 per lb. . .	70·35	1 f. 40 c.	9·8 c.
,, ,, 8 per lb. . .	85·92	1 f. 40 c.	12·0 c.
Pressed tallow, 5 per lb. .	98·93	2 f. 40 c.	23·7 c.
Wax candle, 5 per lb. . .	64·04	7 f. 60 c.	48·6 c.
Spermaceti ditto, 5 per lb. .	61·94	7 f. 60 c.	47·8 c.
Stearine, 5 per lb. . . .	65·24	6 f.	37·1 c.

These results may be compared with mine given above. A kilogramme, or 1,000 grammes = 15,440 grains = 2¼ lbs. avoirdupois.'—*Ure.*

The rule observed in the determination of these questions of illuminating power, is, according to the laws of optics, that the sum of the impinging rays from any source, is inversely as the square of the distance from their source.

'The numerical estimation of the degrees of intensity of light constitutes that branch of Optics which is termed PHOTOMETRY.

'If light be a material emanation, a somewhat scattered in minute particles in all directions, it is obvious that the same quantity which is diffused over the surface of a sphere concentric with the luminous points, if it continue its course, will successively be diffused over larger and larger concentric spherical surfaces; and then its intensity, or the number of rays which fall on a given space, in each will be inversely as the whole surfaces over which it is diffused; that is, inversely as the square of their radii, or of their distances from the source of light. . . . . Let a candle be placed behind an opaque screen, full of small equal and similar holes; the light will shine through these, and be intercepted in all other parts, forming a pyramidical bundle of rays, having the candle in the common vertex. If a sheet of white paper be placed behind this, it will be seen dotted over with small luminous specks, disposed exactly as the holes in the screen. Suppose the holes so small, their number so great, and the eye so distant from the paper that it cannot distinguish the individual specks, it will still receive a general impression of brightness; the paper will appear illuminated, and present a mottled appearance, which, however, will grow more uniform as the holes are smaller and closer, and the eye more distant, and if extremely so, the paper will appear uniformly bright. Now if every alternate hole be stopped, the paper will manifestly receive only half the light, and will therefore be only half as much illuminated; and *cæteris paribus* the degree of illumination is proportional to the number of holes in the screen, or to the number of equally-illuminated specks on the surface; *i.e.* if the speck be infinitely diminished in size, and infinitely increased in number to the number of rays which fall on it from the original source of light.' (*Herschel.*) Reasoning thus, Sir John Herschel proceeds and establishes the following definitions:—

The real intrinsic brightness of a luminous object is the intensity of the light of each physical point in its surface.

The apparent intrinsic brightness of any object or luminary is the degree of illumination of its image or picture at the bottom of the eye.

The absolute light of a luminary is the sum of the areas of its elementary portions, each multiplied by its own intrinsic brightness.

The apparent light of an object is the total quantity of light which enters our eyes from it, however distributed on the retina.

Various instruments, called *photometers*, have been devised to measure the illuminating power of any body; these are, all of them, more or less defective, and the results which we obtain with the best of them are merely comparative with each other.

Bonguer's Photometer consists of two surfaces of white paper, of exactly equal size and reflective power, cut from the same piece in contact; these are illuminated, the one by the light whose illuminating power is to be measured; and the other by a light whose intensity can be varied at pleasure by an increase of distance, and can therefore be exactly estimated. The variable light is to be removed or approached, till the two surfaces are judged to be equally bright, when the distances of the luminaries being measured, or otherwise allowed for, the measure required is ascertained.

Rumford's Photometer.—Before a screen of white paper, in a darkened room, is placed a blackened cylindrical stick, and the two lights to be compared are so placed that two shadows are thrown upon the screen side by side, with an interval between them about equal in breadth to either shadow. The brighter flame must then be removed, or the feebler brought nearer to the screen, till the two shadows appear of equal intensity, when their distances from the lights must be measured, and their total illuminating powers will be in the direct ratio of the squares of the distances.

Ritchie's Photometer consists of a rectangular box, about an inch and a half or two inches square, open at two ends. It is blackened within to absorb the extraneous light. Within, inclined at angles of 45° to its axis, are placed two rectangular pieces of plain looking-glass, cut from one and the same rectangular strip; these are fastened so as to meet in the middle of a narrow slit, about an inch long, and an eighth of an inch broad, which is covered with a slip of fine tissue or oiled paper, and a blackened card prevents the reflected images from mingling. If we would compare two lights, they must be placed at such a distance from each other, and from the instrument between them, that the light from every part of each shall fall on the reflector next it, and be reflected to the corresponding portion of the paper. The instrument is then to be moved nearer to the one or the other, till the paper on either side of the division appears equally illuminated. When the lights are thus exactly equalised, it is clear that the total illuminating powers of the luminaries are directly as the squares of their distances from the middle of the instrument.

Wheatstone's Photometer is a small sphere with a reflecting surface, which being placed between the two lights, each light is seen on it by the spectator, the two being reflected from different points of the sphere's surface. By an ingenious but simple mechanical contrivance, a rapid looped motion is communicated to the ball, and by the principle of the *persistence of impressions*, the spectator immediately sees two looped curves of different brightnesses. The brighter light is removed until these curves seem of the same brightness, and the intensities of the luminous points are then as the squares of the distances.

Bunsen's Photometer consists of a sheet of cream-coloured letter-paper, rendered transparent over a portion of the surface by a mixture of spermaceti and rectified naphtha, which is solid at common temperatures, but becomes liquid on the application of a very gentle heat. The mixture is liquefied and painted over the paper with a brush, leaving a round disc of the size of half-a-crown in the centre uncovered. When a light is placed on one side of the paper a dark spot is observed on the uncovered portion. When another light is placed on the other side of the paper, the spot is still distinctly visible, if the distance of the light is such that the reflected portion from the paper be either of greater or of less intensity than that transmitted. When the paper is so situated between the two flames that the transmitted and reflected light are of the same intensity, the uncovered spot is no longer visible.

It will be evident from these descriptions that it is possible only, by any of these contrivances, to compare one light with another; there is not any arrangement by which we are enabled to express absolutely the illuminating power. Upon the principle of comparison, and comparison only, the following Tables have been constructed by the relative experimentalists. The observations of Péclet have been already given. The following comparative view of wax and stearine candles manufactured in Berlin, which have been deduced from the observations of Schubarth, is of much value:—

Kind of candles, and whence obtained		Relative intensity of light	Consumption in one hour, in grammes	Relative illuminating power
Common wax candles, of Tannhäuser	4's	103·5	7·877	85·20
	6's	91·0	7·176	83·20
	8's	100·0	6·562	100·0
Wax candles, of Walker . .	4's	132·7	9·398	92·66
	6's	120·3	8·082	97·69
	8's	113·1	7·132	104·1
Stearine candles, of Motard .	4's	117·4	9·427	81·74
	6's	111·8	9·383	78·23
	8's	121·0	7·877	100·7
Stearine candles, of Magnet and Oehmichen	4's	139·5	10·63	86·11
	6's	132·7	9·398	92·66
	8's	125·0	8·506	96·54
Stearine candles, from the same makers	6's	116·1	8·871	85·86
	8's	146·0	8·886	108·0
Candles made from palm-oil .	4's	124·5	9·880	82·67
	6's	115·3	9·178	82·56
	8's	167·5	8·813	113·70

These results show us that the mean illuminating power of wax and stearine candles is nearly the same.

The illuminating power of gases and of gas-burners will be found in the article Coal Gas.

ILMENITE. A variety of titaniferous iron ore, taking its name from one of its localities—the Ilmen Mountains in Siberia.

ILVAITE. A name frequently applied to the silicate of iron, known otherwise as *lievrite* and *yenite.* The term Ilvaite is derived from Ilva, the classical name of Elba—one of the localities of this mineral.

IMMORTELLES. Everlasting flowers, chiefly species of *Gnaphalium* and other Composite plants.

IMPERMEABLE is the epithet given to any kind of textile fabric rendered water-proof by one or other of the following substances:—

1. Linseed-oil, to which a drying quality has been communicated by boiling with litharge or sugar of lead, &c.

2. The same oil holding in solution a little caoutchouc.

3. A varnish made by dissolving caoutchouc in rectified petroleum or naphtha, applied between two surfaces of cloth, as described under Macintosh's patent. See Caoutchouc.

4. Vegetable or mineral pitch, applied hot with a brush, as in making tarpauling for covering goods in ships.

5. A solution of soap worked into cloth, and decomposed in it by the action of a solution of alum; whence results a mixture of acid, fats, and alumina, which insinuates itself among all the woolly filaments, fills their interstices, and prevents the passage of water.

6. A solution of glue or isinglass, introduced into a stuff, and then acted upon by a clear infusion of galls, whereby the fibres get impregnated with an insoluble, impermeable, pulverulent leather.

7. Plaster work is rendered impermeable by mixing artificial or natural asphaltum with it.

IMPORTS AND EXPORTS. Memorandum by the Inspector-General of Imports and Exports as to the method adopted for ascertaining the *real value* of the imports into the United Kingdom, issued by the Statistical Department of the Board of Trade in April 1864.

The *real value* of the imports into the United Kingdom—a term repeatedly employed in this work—as shown in the Statistical Accounts published under the authority of the Government, is ascertained as follows:—

1. In the case of certain articles—of those, namely, in regard to which the tariff prescribes that their value (either with or without a specification of quantity) shall be stated in the entry inwards at the Custom House—it rests on the declaration of the importers.

If the officer of Customs to whom such declaration of value is rendered should see reason to question its correctness, he is entitled to require further evidence on the point, or he may satisfy his doubts by an examination of the goods.

The articles of which the value is ascertained by this method, however, are but few compared with the whole number of those included in the Statistical Registry, and they are generally of minor importance.

2. In the case of the more numerous and more considerable articles which are entered at the Custom House by quantity alone, the value exhibited in the Statistical Record is obtained by means of a process of computation which combines the quantity with the average prices of the several commodities.

The average prices thus employed are supplied to the Inspector-General of Imports and Exports, in part by some of the leading merchants and brokers of the city of London, who willingly aid an operation so obviously serviceable to the public; in part by three gentlemen, who have special facilities for watching the course of the markets, and who receive a fixed remuneration from the Treasury for collecting such prices in the ports of London, Liverpool, and Hull, respectively.

In striking the average price for each article, regard is had to the specific distinctions under which it is exhibited in the tariff—these distinctions being of necessity observed also in the Statistical Registry—and not being in every instance identical with those which are commonly recognised in mercantile transactions.

As the same article, in many cases, varies widely in its market value, according to the country of which it is the produce, separate prices, applicable to the importations from the different countries, are in such cases required.

The rules which are required to be kept in view in fixing the average prices will appear more distinctly on reference to the annexed copy of an explanatory note which was addressed to the merchants and brokers from whom assistance was sought at the time when the registry of *real value* was first established.

When the prices obtained from different sources are found to disagree, such disagreement, unless it be referable to some known cause, is made the subject of a careful investigation before the average is finally adjusted.

The average price of an article being fixed for a particular month for the ports of London and Liverpool separately—and, in the case of certain descriptions of merchandise, for the port of Hull also—the quantity imported into each of the ports is computed at the price belonging to it, and the mean value thus ascertained of the importations into the two or the three ports, is adopted as the general rate of valuation for the importations into the kingdom at large.

The value attached to the importations of each article for the entire year is the sum of the values affixed to the importations of each successive month.

The following Table shows the manner in which the 'real value' of imports is computed in the office of the Inspector-General of Imports and Exports:—

Yellow Muscovado and Brown Clayed Sugar imported from Bengal in 1861.

Months	Imported into London			Imported into Liverpool			Imported into London and Liverpool jointly		Average price of the imports into London and Liverpool adopted for the United Kingdom	Quantities imported into the United Kingdom.	Computed real value
	Rate per cwt.	Quantity	Value	Rate per cwt.	Quantity	Value					
	s. d.	cwt.[1]	s.	s. d.	cwt.[1]	s.	cwt.[1]	s.	s. d.	cwts. qrs. lbs.	£
January .	27 2	0	0	27 8	8	221	8	221	27 8	8,097 0 24	11,201
February .	27 2	5	146	27 6	3	82	8	218	27 3	8,386 1 4	11,426
March . .	27 8	2	55	27 0	4	108	6	163	27 2	6,133 2 10	8,357
April . .	28 2	4	113	27 0	6	162	10	275	27 6	9,565 2 15	13,153
May . . .	29 8	10	297	26 3	11	289	21	586	27 11	20,986 0 20	29,293
June . .	29 8	1	30	25 9	4	103	5	133	26 6	4,568 2 9	6,053
July . .	30 2	4	121	25 9	0	..	4	121	30 2	3,982 2 15	6,007
August . .	30 2	11	332	25 9	18	463	29	795	27 5	28,476 1 3	39,036
September	30 8	17	521	26 0	16	416	33	937	28 4	33,002 0 5	46,753
October .	31 2	26	810	26 0	21	546	47	1,356	28 10	46,559 2 26	63,124
November.	30 8	38	1,165	25 6	7	179	45	1,344	29 10	45,466 0 1	67,820
December .	29 8	47	1,394	25 0	20	500	67	1,894	28 3	66,342 0 12	97,708
							Total . . .			281,566 1 4	399,931

Average Price of the Year, 28*s.* 5*d.* per cwt.

[1] Hundredweights in Thousands.

Linseed imported from the Russian Ports on the Black Sea in 1861.

Months	Imported into London			Imported into Hull			Imported into London and Hull jointly		Average price of the imports into London and Hull, adopted for the United Kingdom	Quantities imported into the United Kingdom	Computed real value
	Rate per cwt.	Quantity	Value	Rate per cwt.	Quantity	Value					
	s. d.	qrs.[1]	s. d.	s. d.	qrs.[1]	s. d.	qrs.[1]	s. d.	s. d.	qrs.	£
January .	56 0	..	..	55 0	..	..	..	..	55 6	6,629	18,395
February .	50 0	2	100 0	50 0	17	850 0	19	950 0	50 0	21,563	53,907
March .	51 0	..	..	47 6	31	1,472 6	31	1,472 6	47 6	56,061	133,145
April . . .	50 6	1	50 6	47 6	19	902 6	20	953 0	47 6	29,324	69,645
May . . .	51 6	2	103 0	47 6	2	95 0	4	198 0	49 6	6,880	17,028
June . . .	51 6	..	..	47 6	1	47 6	1	47 6	47 6	1,526	3,624
July . .	52 9	..	..	47 6	..	..	..	..	50 1	3,576	8,940
August . .	55 8	..	..	50 0	6	300 0	6	300 0	50 0	10,059	25,148
September	57 6	2	115 0	52 6	13	682 6	15	797 6	53 2	29,449	78,040
October .	59 6	5	297 6	55 0	21	1,155 0	26	1,452 6	55 10	36,048	100,634
November .	60 6	2	121 0	55 0	14	770 0	16	891 0	55 8	35,897	99,913
December	61 0	20	1,220 0	55 0	20	1,100 0	40	2,320 0	58 0	54,490	158,021
							Total			291,502	766,440

Average Price of the year, 52*s.* 7*d.* per quarter.

[1] Quarters in Thousands.

IMPREST. A paper printed in the report on the public accounts, gives an authoritative definition of this technical term, so unintelligible to many persons. The word 'imprest' is generally used in opposition to the term 'final payment.' A final payment is a payment made in final discharge of an obligation of the government to the public creditor; as, for instance, the payment of a bill for stores supplied to the government, or the payment of a salary to a government clerk. An 'imprest' means an advance of public money, to enable the person to whom it may be made to carry on some public service; and the person to whom the advance is made is called the 'imprest accountant.'

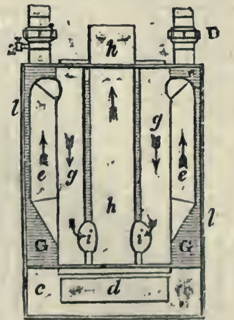
INCOMBUSTIBLE CLOTH is a tissue of the fibrous mineral called amianthus or asbestos. Cotton and linen cloth may be best rendered incapable of burning with flame by being imbued with a solution of sal-ammoniac or of alum.

INCUBATION, ARTIFICIAL. The Egyptians have from time immemorial been accustomed to hatch eggs by artificial warmth, without the aid of hens, in peculiar stoves, called *Mammals*. M. de Réaumur published in France, about a century ago, some ingenious observations upon this subject; but M. Bonnemain was the first person who studied with due attention all the circumstances of artificial incubation, and mounted the process successfully upon the commercial scale. So far back as 1777 he communicated to the Academy of Sciences an interesting fact, which he had noticed, upon the mechanism employed by chicks to break their shells; and for some time prior to the French Revolution he furnished the Parisian market with excellent poultry at a period of the year when the farmers had ceased to supply it. His establishment was ruined at that disastrous era, and no other has ever since been constructed or conducted with similar care. His apparatus derives peculiar interest from the fact that it was founded upon the principle of the circulation of hot water, by the intestine motions of its particles, in a returning series of connected pipes; a subject afterwards illustrated in the experimental researches of Count Rumford. It has of late years been introduced as a *novelty* into this country, and applied to warm the apartments of many public and private buildings. The following details will prove that the theory and practice of hot-water circulation were as perfectly understood by M. Bonnemain fifty years ago as they are at the present day. They were then publicly exhibited at his residence in Paris, and were afterwards communicated to the world at large in the interesting article of the *Encyclopédie Technologique*, intitled *Incubation Artificielle*, under the head of *Régulateur de Température*.

The apparatus of M. Bonnemain consisted: 1, of a boiler and pipes for the circulation of water; 2, of a regulator calculated to maintain an equable temperature; 3, of a stove-apartment, heated constantly to the degree best fitted for incubation, which he called the *hatching* pitch. He attached to one side a *poussinière* or chick-room, for cherishing the chickens during a few days after incubation.

The boiler is represented in vertical section and ground plan, in *figs.* 1207 and 1208. It is composed of a double cylinder of copper or cast iron *l*, *l*, having a grate *b* (see plan), an ashpit at *d* (section). The water occupies the shaded space c, c. *h*, *g*, *g*, *e*, *e*, are five vertical flues for conducting the burnt air and smoke, which first rise in the two exterior flues *e*, *e*, then descend in the two adjoining flues *g*, *g*, and finally remount through the passages *i*, *i*, in the central flue *h*. During this upward and downward circulation, as shown by the arrows in the section, the products of combustion are made to impart nearly the whole of their heat to the water by which they are surrounded. At the commencement, some burning paper or wood shavings are inserted at the orifice

1207



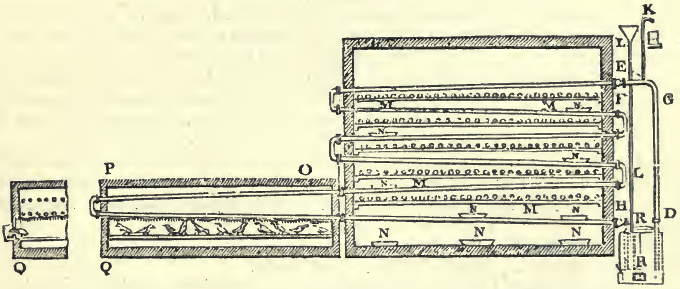
1208

m, to establish a draught in this circuitous chimney. The air is admitted into the ashpit at the side, in regulated quantities, through a small square door, moveable round a rod which runs horizontally along its middle line. This swing valve is acted upon by an expanding bar (see HEAT-REGULATOR), which opens it more or less, according to the temperature of the stove apartment in which the eggs are placed.

D is the upper orifice of the boiler, by which the hotter and consequently lighter particles of the water continually ascend, and are replaced by the cooled particles, which enter the boiler near its bottom, as shown in *fig.* 1209 at R. Into further details relative to the boiler it is needless to enter; for though its form, as designed by M. Bonnemain, is excellent and most economical of heat for a charcoal-fire, it would not suit one of pit-coal, on account of the obstruction to the pipes which would soon be caused by its soot.

In *fig.* 1209 the boiler is shown at R, with the rod which regulates the air-door of the ashpit. D is a stopcock for modifying the opening by which the hotter particles of water ascend; G is the water-pipe of communication, having the heating pipe of distribution attached between E F, which thence passes backwards and forwards with a very slight slope from the horizontal direction, till it reaches the *poussinière* O P Q. It traverses this apartment, and returns by N N to the orifice of the boiler H, where it turns vertically downwards, and descends to nearly the bottom of the boiler, discharging at that point the cooled and therefore denser particles of water to replace those which continually issue upwards at D. L R is a tube surmounted with a funnel for keeping the range of pipes always full of water; and K is a siphon orifice for permitting the escape of the disengaged air, which would otherwise be apt to occupy partially the pipes and obstruct the aqueous circulation.

1209



The faster the water gets cooled in the serpentine tubes, the quicker its circulation will be, because the difference of density between the water at the top and bottom of the boiler, which is the sole cause of its movement, will be greater. N represents small saucers filled with water, to supply the requisite moisture to the heated air, and to place the eggs, arranged along the trays M M, in an atmosphere analogous to that under the body of the hen.

When we wish to hatch eggs with this apparatus, the fire is to be kindled in the boiler, and as soon as the temperature has risen to about 100° F., the eggs are introduced; but only one-twentieth of the whole number intended, upon the first day: next day a like number is laid upon the trays, and thus in succession for twenty days, so that upon the twenty-first day the eggs first placed may be hatched for the most part, and we may obtain daily afterwards an equal number of chicks. In this way regularity of care is established in the rearing of them.

During the first days of incubation, natural as well as artificial, a small portion of the water contained in the egg evaporates by the heat, through the shell, and is replaced by a like quantity of air, which is afterwards useful for the respiration of the animal. If the warm atmosphere surrounding the eggs were very dry, such a portion of the aqueous part of the eggs would evaporate through the pores of the shells as would endanger the future life of the chick *in ovo*. The transpiration from the body of the hen, as she sits upon her eggs, counteracts this desiccation in general; yet in very dry weather many hatching eggs fail from that cause, unless they be placed in moist decomposing straw. The water-saucers N N are therefore essential to success in artificial incubation.

After the chickens are hatched, they are transferred into the nursery, O Q, on the front side of which there is a small grated trough filled with millet seed. Small divisions are made between the broods of successive days, to enable the superintendent to vary their feeding with their age.

In order to supply an establishment of the common kind, where 100 eggs are to be hatched daily, a dozen of hens would be needed, and 150 eggs must be placed under them, as only two-thirds in general succeed. At this rate, 4,300 mothers would be required to sit. Now supposing we should collect ten times as many hens, or 43,000, we should not be able to command the above number of chickens, as there is seldom a tenth part of hens in a brooding state. Besides, there would be in this case no fewer than 720 hens every day coming out with a fresh brood of chickens, which would require a regiment of superintendents.

Artificial Incubation by means of Hot Mineral Waters.—This curious process is described very briefly in a letter by M. D'Arcet. The following are extracts from his letter:—

'In June 1825, I obtained chickens and pigeons at Vichy, by artificial incubation, effected through the means of the thermal waters of that place. In 1827 I went to the baths of Chaudes-Aigues, principally for the purpose of doing the same thing there. Finding the proprietor a zealous man, I succeeded in making a useful application of this source of heat to the production of poultry.

'The advantage of this process may be comprehended, when it is known that the invalids who arrive at Vichy, for instance in the month of May, find chickens only the size of quails; whereas, by this means, they may be readily supplied six months old.

'The good which may be done by establishing artificial incubation in places where hot springs exist, is *incalculable*; it may be introduced into these establishments without at all interfering with the medical treatment of patients, since the hatching would go on in winter, at a time when the baths for other purposes are out of use.

'There is no other trouble required in breeding chickens, by means of hot baths, than to break the eggs at the proper time; for, when the apartments are closed, the whole of the interior will readily acquire a sufficiently elevated and very constant temperature.'

INDIA-RUBBER. See Caoutchouc.

INDIAN CORN. The *Zea Mays.* See Maize.

INDIAN FIRE. A pyrotechnic composition, sometimes used for signal-lights. It is composed of 7 parts of sulphur, 2 of realgar, and 24 of nitre.

INDIAN HEMP. A narcotic resinous substance obtained from *Cannabis Indica.* See Hemp.

INDIAN INK, or *China Ink.* A very beautiful black pigment, the best varieties of which are obtained from China. It is composed of a very fine black, cemented together with some kind of animal gelatine. See Ink.

INDIAN MATTING. Mats made in India from the reed *Papyrus corymbosus.*

INDIAN MILLET. The *Panicum miliaceum,* a grain cultivated in the East Indies.

INDIAN RED. A mineral substance from the Persian Gulf, which reaches us in a state of a dark red coarse powder: a silicate of iron and alumina, containing lime and magnesia. The same name is given to a pigment artificially prepared, which is essentially a sesquioxide of iron.

INDIAN TEAK. A hard wood used for ship-building, yielded by the *Tectona grandis.*

INDIAN YELLOW. This is a peculiar precipitate obtained from the urine of the cow, and, according to some authorities, of the camel, after the animal has been eating decayed and yellow mango leaves—the *Mangistana mangifer.* It appears to be composed of magnesia with a yellow body which may be prepared pure by boiling the mass with water, to which small quantities of muriatic acid are added, until the whole dissolves, and then filtering. On cooling, the liquor deposits the colouring matter in brilliant yellow scales, termed *purreic acid.* See Watts's 'Dictionary of Chemistry.'

INDIANITE. An Indian variety of anorthite, or lime-felspar.

INDICAN. A colourless substance existing in woad, and probably in other plants yielding indigo. Indigo-blue may be prepared from indican by treating it with sulphuric or hydrochloric acid. See Indigo.

INDICOLITE. A name applied to the blue varieties of tourmaline.

INDIGO. This invaluable dye-stuff consists essentially of a blue colouring matter, to which the name of *Indigo-blue* has been applied. This colouring matter occurs in the leaves of several species of plants, which, though few in number, belong to very different genera and orders. The only native European plant which is known with certainty to yield it is the *Isatis tinctoria,* or common woad. It has also been supposed to occur in the following plants, all of which are natives of Europe, viz.:—*Astragalus glycyphyllos, Centaurea Cyanus, Chelidonium majus, Cicer arictinum, Colutea arborescens, Coronilla Emerus, Galega officinalis, Hedysarum Onobrychis, Inula Helenium, Iris Germanica, Lotus corniculatus, Medicago sativa, Mercurialis perennis, Polygonum aviculare, Polygonum Fagopyrum, Rhinanthus Crista-galli, Sambucus nigra, Sambucus*

Ebulus, *Scabiosa succisa*, and *Vaccinium Myrtillus.* According to the investigations of Giobert and others, however, none of these plants afford any indigo-blue, though several of them, such as the *Mercurialis perennis*, contain a blue colouring matter of a peculiar nature. The indigo-bearing plants growing in tropical countries furnish far more indigo-blue than the *Isatis tinctoria.* Such are the various species of *Indigofera*, natives of the East and West Indies, the *Nerium tinctorium* and *Calanthe veratrifolia* of Hindostan, the *Asclepias tinctoria* and *Marsdenia tinctoria* of Sumatra, the *Polygonum tinctorium*, the *Isatis indigotica*, the *Justicia tinctoria*, and the *Bletia Tankervilleæ*, of China, and the *Amorpha fruticosa* of Carolina. Most of these plants belong to the natural order *Leguminosæ.* The others belong respectively to the orders *Cruciferæ*, *Apocyneæ*, *Asclepiadeæ*, *Polygoneæ*, *Acanthaceæ*, and *Orchideæ.* Indigo-blue has sometimes been observed to form in the milk of cows, especially such as have been fed exclusively on saintfoin. It has also been found by Prout, Hassall, and others in the urine of individuals suffering from various diseases; and Schunck has shown that the urine of men and animals, even when in a perfectly healthy state, may be made to yield indigo-blue in small quantities by treatment with strong acids. Hence it appears that this colouring matter may be obtained from a variety of sources, though it is nowhere found in great abundance.

The use of woad for the purpose of dyeing blue seems to have been known in Europe from the earliest times. We are told by Cæsar that the Britons stained their bodies blue with woad, in order to give themselves a more formidable appearance in battle; and Pliny informs us that their women, before entering on certain sacred rites, which were performed in a state of nudity, employed the same means of colouring their bodies, whereby they acquired the appearance of negroes. During the middle ages the cultivation of woad was carried on very extensively in several countries of Europe, especially in Thuringia in Germany, in the province of Languedoc in France, and in the neighbourhood of Rieti in Italy. The leaves of the plant were ground into a pulp, and then submitted to a long process of fermentation, by which means they were converted into a mass of a dark colour which was moulded into balls for the use of the dyer. (See WOAD.) No attempt to extract the blue colouring matter from the plant seems, however, to have been made before the commencement of the present century.

Whether indigo in its present form was known to the ancients has been doubted. Pliny and Dioscorides refer to a pigment called *Indicum*, which seems to have been of a blue colour, though there is little doubt that the article to which the name *Indicum nigrum* was applied was identical with our Indian ink. Of indicum Pliny says that it comes from India and is obtained from the slime adhering to reeds; that it is black when rubbed, but of a fine mixture of purple and blue when dissolved; and that there is another kind which is found swimming on the dye-vessels where purple is dyed, this being the scum of the purple-fish. He adds that those who adulterate indicum dye pigeons' dung or chalk with woad, but that the genuine substance may be known by heating it, when it gives a beautiful purple vapour and emits a smell like that of the sea, and for this reason it has been supposed to be obtained from the rocks. It can hardly be doubted that in this passage indigo is referred to, and that the second kind of indicum mentioned by Pliny consisted probably of the scum of indigo-blue found floating on the surface of the liquor in which the dyeing was performed. It seems, however, that at that time the colouring matter was not so completely separated from the other vegetable matters of the plant as at the present day, since pigeons' dung coloured with woad would bear very little resemblance to our present indigo, but would be a fair imitation of the preparation usually made from woad. It is probable, therefore, that at that period the process of manufacturing indigo was a very rude one, and consisted merely in the separation of a portion of the vegetable from the remainder. Even at the present day the natives of some countries, where the arts have not attained any high degree of development, produce an article from indigo-bearing plants which serves the purpose of dyeing blue, though not much resembling indigo in appearance. In Sumatra, for instance, as Marsden informs us, the natives do not manufacture indigo into a solid substance, but leave the stalks and branches for some days in water to soak and macerate, then boil it, and work with their hands some *chunam* (quicklime) among it, with leaves of the *pacoo saba* (a species of fern) for fixing the colour, after which they drain it off and use it in the liquid state. On the west coast of Africa the leaves of the indigo-plant are moulded into balls, which are then dried in the sun and stored up until they are wanted. These balls, which have a slight blue tint, may be preserved a long time, and be transported to great distances. When they are to be used for dyeing they are broken and reduced to a fine powder. This powder is then mixed with water to which the ashes of a certain plant are added, and the liquid is boiled in large earthenware vessels of a conical form, when it assumes a deep blue colour, and is then ready for dyeing the fabrics which are plunged into it.

The article known as indigo in the middle ages must have been very similar to the indigo of the present day; for though Marco Polo had described the manner in which the substance was produced from the plant, it was for a long time considered as a mineral; and even in the letters patent obtained, in 1705, by the proprietors of mines in the principality of Halberstadt, it was classed among minerals on account of which works were suffered to be erected.

Indigo seems to have been first extensively used in Europe by the Jewish dyers, who introduced it into the dye-houses of Italy. It was not, however, imported in any large quantities until the discovery of the passage round the Cape of Good Hope. At the beginning of the 17th century, the Dutch commenced carrying on an extensive trade with the East, and indigo was one of the articles which they imported in large quantities into European countries. Its use was found to be attended with so many advantages, that the employment of woad for the same purpose was gradually abandoned. The colour produced by it was more brilliant and far cheaper than the blue from woad. On the other hand, it was asserted that the goods dyed with indigo faded rapidly, and that the vitriol and other corrosive substances used along with it caused them, after some time, to rot. At the same time the exportation of large sums of money in payment for indigo, and the rapid decline in the cultivation of woad, which had previously furnished occupation to great numbers of people in various countries of Europe, and had been the source of great wealth to individuals, caused so much alarm, that the most stringent measures were adopted in order to prevent the use of indigo in dyeing. A decree of the Germanic Diet held at Frankfort, in 1577, prohibited, under the severest penalties, the newly-invented, pernicious, deceitful, eating and corrosive dye, called the *devil's dye*, for which vitriol and other cheaper materials were used instead of woad. This prohibition was renewed in 1594 and 1603. In the year 1650, the Elector of Saxony prohibited the sale and importation into his dominions of all fabrics dyed with other materials in the place of woad. This was followed by an Imperial mandate issued from Ratisbon, in the year 1654, forbidding the importation and the use by dyers of indigo and other injurious substances, and threatening with punishment and the confiscation of their goods all persons who should offer for sale any cloth dyed with forbidden and deceitful dyes, instead of with the permanent colour of woad. The people of Nuremberg even went so far as to compel their dyers by law annually to take oath, not to employ indigo, and this was continued down to a very recent period, though it was well known that its use was indispensable to them. In France, the use of indigo was forbidden in 1598, in consequence of an urgent representation by the states of the province of Languedoc, and this prohibition was afterwards repeated several times. But in the well-known edict of 1669, in which Colbert separated the fine from the common dyers, it was stated that indigo should be used without woad; and 1737, dyers were left at liberty to use indigo alone, or to employ a mixture of indigo and woad. In England the use of indigo was also forbidden, and by an act passed in the reign of Elizabeth, searchers were authorised to burn both it and logwood in every dye-house where they could be found. This act remained in force for nearly a century.

It has been doubted whether the plant which is employed in America for the manufacture of indigo is a native of that continent, or whether it was introduced by the Spaniards. It was remarked by the first voyagers on the new continent that the natives coloured their bodies and dyed their stuffs by means of indigenous plants which resembled the indigo-plant of Asia. Fernando Columbus, in the life of his father, says, that this plant grew in a wild state in the West India Islands, and that it was cultivated for the purpose of obtaining from it a blue pigment. Hernades mentions it among the native plants of Mexico, and says, that the Americans used it for dyeing their hair black. He adds, that they made from it a pigment, which they named *mohuitli* and *tleuohuitli*, the same as the *cæruleum* of the Latins, and he describes also the method of prepairing it. Nevertheless, it appears that the *Indigofera tinctoria* and *Anil* were really introduced into America by the Spaniards, and were the plants employed by them for the manufacture of indigo in Mexico, Guatemala, and St. Domingo, though some of the varieties produced by the influence of the climate and soil differ very widely in appearance from the parent stock. The manufacture of indigo was at one time carried on extensively in Central America and the West India Islands, and these countries formerly supplied the chief portion of the article consumed in Europe. The indigo of Guatemala at the same time surpassed all others in quality. In consequence, however, of the political disturbances in America, and the great improvements which have been effected in the manufacture of indigo by the zeal and perseverance of our countrymen in the East, its production in America has diminished very much; and at the present day, the indigo consumed in Europe is derived chiefly from India, and more especially from Bengal, Oude, and Madras. The remainder is imported from Java, Manilla, the Mauritius, and Senegal in the eastern hemisphere, and from Caraccas, Brazil, and Guatemala in the western. The East Indian and Brazilian indigo comes packed in chests; the Guatemala in ox-hides, called *serons.* Its quality depends upon the species of the plant, its ripeness, the soil and climate of its growth, and the mode of manufacture.

The plants which are cultivated in the East Indies, are the *Indigofera tinctoria, Anil, disperma,* and *pseudo-tinctoria.* The districts of Kishenagar, Jessore, and Moorshedabad, in Bengal, ranging from 88° to 90° east lat. and 22¾° to 24° north long., produce the finest indigo. That from the districts about Burdwan and Benares is of a coarser or harsher grain. Tyroot, in lat. 26°, yields a tolerably good article. The portion of Bengal most propitious to the cultivation of indigo, lies between the river Hoogly and the main stream of the Ganges. The ground having been ploughed in October, November, or beginning of December, the seed of the indigo plant is sown in the last half of March or beginning of April, while the soil being neither too hot nor too dry, is most propitious to its germination. A light mould answers best; and sunshine, with occasional light showers, are most favourable to its growth. From twenty-four to thirty pounds of seeds are required for sowing an acre of land. The plants grow rapidly, and will bear to be cut for the first time at the beginning of July, nay, in some districts, so early as the middle of June. The indications of maturity are the bursting forth of the flower-buds, and the expansion of the blossoms; at which period the plant contains most colouring matter. Another indication is taken from the leaves; which, if they break across, when doubled flat, denote a state of maturity. But this character is somewhat fallacious, and depends upon the poverty or richness of the soil. When much rain falls, the plants grow too rapidly, and do not sufficiently elaborate the blue pigment. Bright sunshine is most advantageous to its production. The first cropping of the plant is best; after two months a second is made; but at the present day, planters never undertake a third or fourth.

Two methods are pursued to extract the indigo from the plant: the first effects it by fermentation of the fresh leaves and stems; the second, by maceration of the dried leaves.

1. *From the recent leaves.*—In the indigo-factories of Bengal, there are two large stone-built cisterns, the bottom of the first being nearly upon a level with the top of the second, in order to allow the liquid contents to be run out of the one into the other. The uppermost is called the fermenting vat, or the steeper; its area is 20 feet square, and its depth three feet; the lowermost, called the beater or beating vat, is as broad as the other, but one-third longer. The cuttings of the plant, as they come from the field, are stratified in the steeper, until this is filled to within 5 or 6 inches from its brim. In order that the plant, during its fermentation, may not swell and rise out of the vat, beams of wood and twigs of bamboo are braced tightly over the surface of the plants, after which water is pumped upon them until it stands about 3 or 4 inches from the edge of the vessel. An active fermentation speedily commences, which is completed within 14 or 15 hours, a little longer or shorter, according to the temperature of the air, the prevailing winds, the quality of the water, and the ripeness of the plants. Nine or ten hours after the immersion of the plant, the condition of the vat must be examined; frothy bubbles are then seen rising like little pyramids, at first of a white colour, but soon becoming greyish-blue, and then deep purplish-red. The fermentation is at this time violent, the fluid being in constant commotion, and apparently boiling, innumerable bubbles mount to the surface, and a dense copper-coloured scum covers the whole. As long as the liquor is agitated, the fermentation must not be disturbed; but when it becomes more tranquil, the liquor is to be drawn off into the lower cistern. It is of the utmost consequence not to push the fermentation too far, because the quality of the whole indigo is thereby deteriorated; but rather to cut it short, in which case there is, indeed, a loss of weight, but the article is better. The liquor possesses now a glistening yellow colour, which, when the indigo precipitates changes to green. The average temperature of the liquor is commonly 85° Fahr.; its specific gravity at the surface is 1·0015; and at the bottom 1·003.

As soon as the liquor has been run into the lower cistern, ten men are set to work to beat it with oars or shovels 4 feet long, called *busquets.* Paddle-wheels have also been employed for the same purpose. Meanwhile two other labourers clear away the compressing beams and bamboos from the surface of the upper vat, remove the exhausted blue, set it to dry for fuel, clean out the vessel, and stratify fresh plants in it. The fermented plant appears still green, but it has lost three fourths of its bulk in the process, or from 12 to 14 per cent. of its weight, chiefly water and extractive matter.

The liquor in the lower vat must be strongly beaten for an hour and a half, when the indigo begins to agglomerate in flocks, and to precipitate. This is the moment for judging whether any error has been committed in the fementation; which must be corrected by the operation of beating. If the fermentation has been arrested too soon, much froth rises in the beating, which must be allayed with a little oil, and then a reddish tinge appears. If large round granulations are formed, the beating is continued, in order to see if they will grow smaller. If they become as small as fine sand, and if the water clears up, the indigo is allowed quietly to subside. Should the vat have been over-fermented, a thick fat-looking crust covers the liquor, which does not disappear by the introduction of a flask of oil. In such a case the beating must be moderated, and when the granulations become round, and begin to subside, and the liquor clears up, the beating must be discontinued. When the fermentation has been excessive, the froth or scum diffuses itself spontaneously into separate minute particles, that move about the surface of the liquor. On the other hand, a rightly-fermented vat is easy to work; the froth, though abundant, vanishing whenever the granulations make their appearance. The colour of the liquor, when drawn out of the steeper into the beater, is bright green; but as soon as the agglomeration of the indigo commences, it assumes the colour of Madeira wine; and speedily afterwards, in the course of beating, a small round grain is formed, which falls down and leaves the water transparent, when all the turbidity and froth vanish.

The object of the beating is threefold: first, it tends to disengage a great quantity of carbonic acid present in the fermented liquor; secondly, to give the newly-developed indigo its requisite dose of oxygen by the most extensive exposure of its particles to the atmosphere; thirdly, to agglomerate the indigo in distinct flocks or granulations. In order to hasten the precipitation, lime-water is occasionally added to the fermented liquor in the progress of beating; but those who manufacture the superior qualities of indigo, avoid the use of lime, as it has a tendency to make the indigo hard and red. In one side of the beating vessel a beam is fixed upright, in which three or more holes are pierced a few inches in diameter. These are closed with plugs during the beating, but, two or three hours afterwards, as the indigo subsides, the upper plug is withdrawn to run off the supernatant liquor, and then the lower plugs in succession. The state of this liquor affords, on being examined, an indication of the success of both the processes. When the whole liquor has run off, a labourer enters the vat, sweeps all the precipitate into one corner, and empties the thinner part into a spout which leads into a cistern, 20 feet long, 3 feet wide, and 3 feet deep. When all this liquor is once collected, it is pumped through a bag which retains the impurities into a boiler, placed at the side of the cistern and heated to ebullition. The froth soon subsides, leaving an oily-looking film upon the liquor. The indigo is by this process not only freed from the yellow extractive matter, but its density and the intensity of its colour are increased. From the boiler the mixture is run, after two or three hours, into a general receiver, called the *dripping vat* or table, which, for a factory of twelve pairs of preparation vats, is 20 feet long, 10 feet wide, and 3 feet deep, having a false bottom, 2 feet under the top edge. The cistern stands in a basin of masonry (made water-tight with *chunam* hydraulic cement), the bottom of which slopes to one end, in order to facilitate the drainage. A thick woollen web is stretched along the bottom of the inner vessel to act as a filter; but a piece of cotton cloth is generally preferred to wool, as the hairs which are detached from the latter injure the quality of the indigo. As long as the liquor passes through turbid, it is pumped back into the receiver. Whenever it runs clear, the receiver is covered with another piece of cloth to exclude the dust, and allowed to drain at its leisure. Next morning the drained magma is put into a strong bag and squeezed in a press. The indigo is then carefully taken out of the bag, and cut with brass wire into cubical pieces, measuring about 3 inches each way, which are dried in an airy house upon shelves of wicker work. During the drying, a whitish efflorescence appears upon the pieces, which must be carefully removed with a brush. In some places, particularly on the coast of Coromandel, the dried indigo lumps are allowed to effloresce in a cask for some time, and when they become hard they are wiped and packed for exportation.

From some experiments it would appear that the gas disengaged during the middle period of the fermentation is composed in 100 parts of 27·5 carbonic acid, 5·8 oxygen, and 66·7 nitrogen; and towards its conclusion, of 40·5 carbonic acid, 4·5 oxygen, and 55·0 nitrogen. Carburetted hydrogen does not seem to be disengaged. That the liquor in the beating vat absorbs oxygen from the air in proportion as the indigo becomes flocculent and granular, has been ascertained by experiment, as well as that sunshine accelerates the separation of the indigo-blue. Out of 1,000 parts of the fermented liquor of specific gravity 1·003, the blue precipitate may constitute 0·75 of a part. Such a proportion upon the great scale is, however, above the average, which is not more than 0·5. When lime-water is added, an extractive matter is thrown down, which amounts to from 20 to 47 parts in 1,000 of the liquor. It has a dark brown tint, a viscid appearance, an unpleasant smell, and a bitter taste. It becomes moist in damp air, and dissolves in water without decomposition. It is precipitated by lime, alkalis, infusion of galls, and acetate of lead. All indigo contains a little lime derived from the plant, even though none has been used in its preparation.

2. *Indigo from dried leaves.*—The ripe plant being cropped, is to be dried in sunshine from 9 o'clock in the morning till 4 in the afternoon, during two days, and threshed to separate the stems from the leaves, which are then stored up in magazines until a sufficient quantity is collected for manufacturing operations. The newly-dried leaves must be free from spots, and friable between the fingers. When kept dry, the leaves undergo, in the course of four weeks, a material change, their beautiful green tint turning into a pale bluish-grey, previous to which the leaves afford no indigo by maceration in water, but subsequently a large quantity. Afterwards the product becomes less considerable.

According to some manufacturers, the plants should be cut down in dry weather, an hour or two before sunset, carried off the field in bundles, and immediately spread upon a dry floor. Next morning the reaping is resumed for an hour and a half, before the sun acts too powerfully upon vegetation, and the plants are treated in the same way. Both cuttings become sufficiently dry by 3 o'clock in the afternoon, so as to permit the leaves to be separated from the stems by threshing. They are now thoroughly dried in the sunshine, then coarsely bruised, or sometimes ground to powder in a mill, and packed up for the operations of manufacture.

The following process is pursued to extract indigo from the dried leaves. They are infused in the steeping vat with six times their bulk of water, and allowed to macerate for two hours with continual stirring till all the floating leaves sink. The fine green liquor is then drawn off into the beating vat, for if it stood longer in the steeper, some of the indigo would settle among the leaves and be lost. Hot water, as employed by some manufacturers, is not necessary. The process with dry leaves possesses this advantage, that a provision of the plant may be made at the most suitable times, independently of the vicissitudes of the weather, and the indigo may be uniformly made; and moreover, the fermentation of the fresh leaves, often capricious in its course, is superseded by a much shorter period of simple maceration.

We are indebted to Dr. Roxburgh, for a description of the method employed for manufacturing indigo from the *Nerium tinctorium* or *Wrightia tinctoria.* (Vide 'Transactions of the Society of Arts,' vol. xxviii.) This plant, which attains the size of a small tree, is found on the lower regions of the mountainous tract near Rajamundry, and also on hills in the neighbourhood of Salem and Pondicherry, and grows in a sterile as well as rich soil. The leaves begin to appear in March and April, and at the end of April have attained their full size, when they are ready for gathering. At the end of August they begin to assume a yellowish rusty colour and soon fall off. The leaves yield no indigo until the plant is several years old, but the best leaves for making indigo are obtained from low bushy plants. They improve when kept for a day or two, but when they begin to wither, they yield but a small portion of very bad indigo, and when quite dry only a dirty brown fecula. In this they differ from the leaves of the common indigo-plant, which may be dried before extraction without loss of colour. They also differ from the latter in not yielding their colour to cold water. With cold water only a hard, black, flinty substance is obtained, not blue indigo. It is therefore necessary to employ hot water, which extracts the colour very readily. The leaves having been collected, are on the ensuing day thrown into copper scalding vessels, which are then filled with cold water to within 2 or 3 inches of the top. Hard water containing a large quantity of bicarbonate of lime is better adapted for the purpose than rain-water. The fire is then lighted and maintained rather briskly until the liquor acquires a deep green colour. The leaves then begin to assume a yellowish colour, the heat of the liquor being about 150° to 160° Fahr. The fire is then removed, and the liquor run off into the beating vat. Here it is agitated from 5 to 20 minutes. It is then mixed with about $\frac{1}{70}$th to $\frac{1}{100}$th part of lime-water, which produces a speedy granulation. After the indigo has subsided, the supernatant liquid appears of a clear Madeira wine colour. The quantity of indigo obtained, amounts to 1 lb. from 250 lbs. of green leaves; but it varies according to the season and the state of the weather. In August and September, the produce is only one-half or two-thirds of what it is in May and June, and even that is diminished if the weather is wet, or the leaves are treated immediately after being gathered. The scalding requires about three hours, and the agitation and precipitation the same time. The indigo is improved by treating it with a little sulphuric acid. The only fault it has is, that it breaks into small pieces, unless it has been dried slowly in the shade protected from the sun.

In the southern provinces of China a species of *Indigofera* is extensively cultivated for the sake of the dye which it affords. In the northern provinces two other plants are employed by the inhabitants for the same purpose. Mr. Fortune, the well-known Chinese traveller, to whom we owe the description of these plants and of the process of manufacturing indigo from them, states that one of them is grown in the neighbourhood of Shanghae, and he has given it the name of *Isatis indigotica*. The other, which is a species of *Justicia*, is largely cultivated in the hilly country near Ningpo, or rather in the valleys among the hills. It seems to be easily cultivated; it grows most luxuriantly, and is no doubt very productive. Having evidently been introduced from a more southern latitude, it is not hardy in the province of Chekiang any more than cotton is about Shanghae; but nevertheless it succeeds admirably as a summer crop. It is planted at the end of April or beginning of May, after the spring frosts are over, and it is cleared from the ground in October. During this period it attains a height of a foot or a foot and a half, becomes very bushy, and is densely covered with large green leaves. It is cut before any flowers are formed. The plants are grown, not from seed but from cuttings. These cuttings consist simply of a portion of the stems of the previous year, which after being stripped of their leaves are tied into bundles, each containing upwards of 1,000, and kept during the winter in a dry shed or outhouse, where after being firmly packed together they are banked round with dry loam, and covered with straw or litter so as to protect them from the frost. During the winter months the cuttings remain green and plump, and although no leaves are produced a few roots are generally found to be formed, or in the act of forming, when the winter has passed and the season for planting has come round. In this state they are taken to the fields and planted. The weather during the planting season is generally showery, as this happens about the change of the monsoon when the air is charged with moisture. A few days of this warm showery weather is sufficient to establish the new crop, which now goes on growing with luxuriance and requires little attention during the summer, indeed none except keeping the land free from weeds. In the country where this dye is manufactured there are numerous pits or tanks on the edges of the fields. They are usually circular in form, and have a diameter of about 11 feet and a depth of 2 feet. About 400 catties[1] of stems and leaves are thrown into a tank of this size, which is then filled to the brim with clear water. In five days the plant is partially decomposed, and the water has become yellowish-green in colour. At this period the whole of the stems and leaves are removed from the tank with a flat-headed broom made of bamboo-twigs. When every particle has been removed, the workmen employed give the water a circular and rapid motion with the brooms just noticed, which is continued for some time. During this part of the operation another man has employed himself in mixing about thirty catties of lime with water, which water has been taken out of the tank for the purpose. This is now thrown into the tank, and the rapid circular motion of the water is kept up for a few minutes longer. When the lime and water have been well mixed in this way the circular motion is allowed to cease. Four men now station themselves round the tank and commence beating the water with bamboo rakes made for the purpose. The beating process is a very gentle one. As it goes on, the water gradually changes from a greenish hue to a dingy yellow, while the froth becomes of a beautiful bright blue. During this process the head workman takes a pailful of the liquid out of the tank and beats it rapidly with his hand. Under this operation it changes colour at once, and its value is judged of by the hue it presents. The beating process generally lasts for about half an hour. At the end of this time the whole of the surface of the liquid is covered with a thick coating of froth of the most brilliant colours, in which blue predominates, especially near the edges. At this stage, it being desirable to incorporate the froth with the liquid below it, it is only necessary to throw a small quantity of cabbage-oil on the surface of the froth. The workmen then stir and beat it gently with their flat brooms for a second or two, and the whole instantly disappears. The liquid, which is now darker in colour, is allowed to repose for some hours, until the colouring matter has sunk to the lower stratum, when about two-thirds of the liquid is drawn off and thrown away. The remaining third part is then drawn into a small square tank on a lower level, which is thatched over with straw, and here it remains for three or four days. By this time the colouring matter has separated itself from the water, which is now entirely drained off, the dye occupying three or four inches of the bottom in the form of a thick paste and of a beautiful blue colour. In this state it is packed in baskets, and exposed for sale in all the country towns in this part of China. Like the Shanghae indigo, made from *Isatis indigotica*, it is called '*Tien-ching*' by the Chinese.—*Gardeners' Chronicle and Agricultural Gazette*, April 8, 1854.

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[1] A Chinese catty is equal to 1⅓ lb.

The cultivation of indigo in Central America has fallen off very much of late years. Nicaragua formerly exported annually about 5,000 bales of 150 lbs. each. At present the export probably does not exceed 1,000 or 2,000 bales. Under the government of Spain, the state of San Salvador produced from 8,000 to 10,000 bales annually. A piece of ground equal to two acres generally produces from 100 to 120 lbs. at a cost of not far from 30 to 40 dollars.

There is an indigenous biennial plant, abounding in many parts of Central America, which produces indigo of a very superior quality, but gives less than half the weight which is afforded by the cultivated species. The *Indigofera disperma* is the species employed in cultivation. It attains its highest perfection in the richest soils. It will grow, however, upon almost any soil, and is very little affected by drought or by superabundant rains. In planting it, the ground is perfectly cleared, usually burnt over, and divided with an implement resembling a hoe into little trenches, 2 or 3 inches in depth, and 12 or 14 apart, at the bottom of which the seeds are strewn by hand, and lightly covered with earth. A bushel of seed answers for 4 or 5 acres of land. In Nicaragua it is usually planted towards the close of the dry season in April or May, and attains its perfection for the purpose of manufacture in from two and a half to three months. During this time it requires to be carefully weeded, to prevent any mixture of herbs, which would injure the quality of the indigo. When it becomes covered with a kind of greenish farina, it is in a fit state to be cut. This is done with knives at a little distance above the root, so as to leave some of the branches, called in the West Indies 'ratoons,' for a second growth, which is also in readiness to be cut, in from six to eight weeks after. The crop of the first year is usually small, that of the second is esteemed the best, although that of the third is hardly inferior. It is said that some fields have been gathered for ten consecutive years without being re-sown, the fallen seed obviating the necessity of new plantings.

After the plant is cut, it is bound in little bundles, carried to the vat, and placed in layers in the upper or larger one called the steeper (*mojadora*). This vat holds from 1,000 to 10,000 gallons, according to the requirements of the estate. Boards loaded with weights are then placed upon the plants, and enough water let on to cover the whole, which is now left to steep or ferment. The rapidity of this process depends much upon the state of the weather and the condition of the plant. Sometimes it is accomplished in 6 or 8 hours, but generally requires from 15 to 20. The proper length of time is determined by the colour of the saturated water; but the great secret is to check the fermentation at the proper point, for upon this, in a great degree, depends the quality of the product. Without disturbing the plant, the water is now drawn off by cocks into the lower vat or 'beater' (*golpeadoro*), where it is strongly and incessantly beaten, in the smaller estates with paddles by hand, in the larger by wheels turned by horse- or water-power. This is continued until it changes from the green colour, which it at first displays, to a blue, and until the colouring matter, or flocculæ, shows a disposition to curdle or subside. This is sometimes hastened by the infusion of certain herbs. It is then allowed to settle, and the water is carefully drawn off. The pulp granulates, at which time it resembles a fine soft clay; after which it is put into bags to drain, and then spread on cloths in the sun to dry. When properly dried it is carefully selected according to its quality, and packed in hide cases, 150 lbs. each, called *serons*. The quality has not less than 9 gradations, the best being of the highest figure. From 6 to 9 are called *flores*, and are the best; from 3 to 6 *cortes*; from 1 to 3, inclusive, *corbes*. The two poorer qualities do not pay expenses. A *mansana* of 100 yards square produces on an average about one ceroon at each cutting. After the plant has passed through the vat, it is required by law that it shall be dried and burnt; because in decomposing it generates by the million an annoying insect called the 'indigo fly.'

Burmese Indigo.—The political agent at the Court of Mandalay furnishes an interesting report on the cultivation of indigo in the territories of the King of Burmah. The manufacture of indigo in Upper Burmah on any scale, we are told, appears to have been first commenced in the year 1860, when His Majesty the King of Ava procured Bengal workmen from Calcutta, and had a factory erected in the city of Ameerapoora, under the superintendence of some Armenian gentlemen who had had experience in the indigo-factories in India. Subsequently four other factories were established: one at Shayet-Khan, of five vats, a short distance above Mandalay; one to the north-east of the Mandalay hill, of three vats; one about 12 miles to the west of Sagine, of ten vats; and one, on a small scale inside the Palace, in one of His Majesty's gardens. The agricultural subjects of His Majesty's within the capital and its suburbs are required to allot a third share of their land for the purpose of sowing indigo, wherever the land is found to be suitable within the vicinity of the factory; and in consideration of this, the land-tax is remitted on the remaining two-thirds of the land; but the cultivators have to give the out-turn of the indigo crop to His Majesty, and receive no renumeration for their labour, the seed only being supplied. The King obtains a yearly supply of the seed from Bengal, and has indigo-plantations of his own, which are set apart exclusively for this purpose. Indigo made from the Burmese plant, indigenous to the country, is found not to be equal to the Bengal indigo. The land upon which the seed is sown is ploughed in the same manner as that for wheat or grain cultivation, but not until the monsoon season is over; the seeds are then scattered about as in other grain cultivation, and in the course of a few weeks shoot up, and before four months have elapsed the young plants rise to the height of about 2½ feet, when they are cut down, tied up in bundles, and carted off to the nearest factory. The late Crown Prince sent several Burmese youths to Bengal some years ago to study the manufacture of indigo. They returned at the latter end of the year 1868, and are now engaged in superintending the plantations and manufacture of the dye. Chinese merchants of Mandalay export indigo to the Shan States and China. The average annual out-turn is about 8,000 viss, which is sold on His Majesty's account at the rate of 400 rupees for 100 viss or 4½ maunds. There is no prohibition as to the cultivation of the plant or manufacture of the dye.

The following account of the manufacture of indigo on the Senegal is taken from Perottet's 'Art de l'Indigotier':—

The land destined to the cultivation of the plant ought to be perfectly level and free from undulations, so as to prevent the seed from being washed into the hollows or lower parts by the heavy rains so frequent in the tropics. Soils of a greyish colour abounding in clay are not adapted for the purpose, as they are too compact and cold. Sandy soils of a whitish colour must also be avoided. Light soils, abounding in humus or vegetable remains, and having a colour between grey and dark brown, are to be preferred to all others. The soil should, at all events, not be one very retentive of moisture. The quantity of indigo obtained from the same weight of plant may vary, according to the soil, from 4 lbs. to 10 lbs., and the quality also varies in a corresponding degree. The extent of ground which is required for the production of indigo on a large scale is so great that the use of manure becomes almost impossible. Nevertheless, the employment of the refuse of the plant, after the extraction of the indigo, as a manure on fresh plantations is found to be attended with very beneficial results. The ground, if new, must be turned up by means of a plough or hoe, to the depth of at least 10 or 12 inches, three times successively, at intervals of 3 months, before the sowing takes place. The sowing must only be undertaken in fine weather, never during heavy rain. The seed employed should be perfectly ripe, and, if possible, not more than one year old. It is to be left in the seed-vessels in which it is contained until the time when it is wanted. The latter are then put into a wooden mortar and reduced to fragments, and the seed is separated by winnowing from the dust, *débris*, &c., with which it is mixed. The sowing is to be effected broad-cast, and as evenly as possible. It should take place, if possible, just before the approach of rain, in which case the use of a harrow is not required, as the rain generally has the effect of completely levelling the ground and covering up the seed with soil. The *Indigofera tinctoria*, and its varieties *macrocarpa* and *emarginata*, being a plant with numerous crowded branches, it is not necessary in sowing it, to take more than from 6 to 7½ kilogrs. of seed to 1 arpent of ground; but the *Indigofera Anil*, being more sparingly branched, and therefore taking up less room, requires to be more thickly sown. At about 10 or 12 days after sowing, when the young indigoferæ have attained a height of about 81 to 108 millimeters, the ground must be carefully weeded, and this operation must be repeated as soon as the weeds have again made their appearance and commenced to interfere with the growth of the crop. When the season is favourable, 3 months are generally sufficient to enable the plants to attain the degree of development necessary for the production of indigo. At the period when inflorescence commences, the plant is far richer in colouring matter than at any other. As soon, therefore, as there are any indications of flowering, and when the lower leaves, in the axils of which the flowers appear, begin to acquire a yellowish tint, and when pressed in the hands produce a slight crackling noise, no time must be lost in cutting down the plant. This is effected by means of good knives or sickles, and as near the ground as possible. The stems, after being cut, are tied together into bundles or sheaves, and carried to the manufactory. Since the colouring principle of the indigoferæ is extremely susceptible of change by the action of destructive agencies, it is necessary to use the utmost despatch in gathering the crop, and to have the manufactory of such a size in proportion to the plantation, that no time may be lost in working up the material as soon as gathered. The plants must on no account be cut when they are moistened either with rain or dew, because in this case they acquire a blackish tint in consequence of the friction to which they are exposed in cutting them and taking them to the manufactory, this tint being a sign of the disappearance of the colouring matter. Besides this, it has been observed that during the continuance of rain, the indigo-producing principle diminishes very considerably, and sometimes even disappears entirely, so that, if cut during or immediately after rain, the plants yield little or no indigo. The indigo-plant is subject to the attack of a green caterpillar, which sometimes appears in such quantities as to destroy the whole crop. No certain and easy means of destroying this pest is known. It has been recommended to pass wooden rollers over the ground, before the plants have attained any great size, so as to crush the caterpillars without injuring the plants, and this plan has been attended with partial success.

In order to obtain good results in the manufacture of indigo, it is necessary that the plants should be of the same age, of the same species, and from the same field. The *Indigofera Anil* begins to ferment several hours sooner than the *I. tinctoria*, so that if a mixture of both be taken, the produce from either one or the other will be lost, and the indigo obtained will also be of a bad quality. The plants should, as soon as possible after being gathered, be placed in the steeping-vat, which is a vessel built of bricks, and well lined with cement, from 3½ to 8 meters in length, of the same width, and about 1 meter deep. In this vessel the plants are arranged in successive layers, the lower layers being slightly inclined towards one end, in order to facilitate the subsequent running-off of the liquor. The vessel being full, a number of poles of fir-wood are laid lengthways over the plants, at a distance of 162 mill. from one another. Three beams are then laid crosswise over the poles, their ends being well secured by passing them through slits which are cut in the upright posts at the sides of the cistern, and then fixing them by means of iron pins, passing through holes in the posts. By this means the plants are prevented from rising above the surface of the liquor during the process of maceration. The vat is now filled with water from an adjacent cistern, in which it has been allowed to stand for 24 hours for the purpose of allowing all foreign matters contained in it to be deposited. After standing in contact with the leaves for about 6 hours, a change usually begins to manifest itself in the liquor, which must therefore, from that time forward, be carefully watched. As soon as this liquor begins to acquire a green colour, and when a little of it, on being kept for a short time in the mouth, leaves a slight impression of harshness (*âpreté*) on the tongue and the palate, it is a sign that the maceration is complete, and that the liquor should be drawn off without delay. If this be not done, the colour of the liquor changes from green to brown, a new species of fermentation commences, accompanied by the formation of acetic acid, and the plant begins to yield substances of a mucilaginous nature, which contaminate the indigo, and completely spoil its quality. It is therefore of the greatest importance to ascertain exactly when the maceration of the plant is complete. The following are the chief indications of this point having been attained:—1. When the water which was at first clear begins to become muddy, and acquires a slight greenish tinge. 2. When bubbles of a greenish colour rise to the surface here and there. 3. When towards the edge of the vat some mucilage, or a kind of greyish scum, commences to be formed. 4. When a very slight purple pellicle is observed on the surface of the liquor, especially near the corners of the vat. 5. When the liquor begins to exhale a slight but not disagreeable odour of herbs. When the fermentation has proceeded too far, the following phenomena present themselves:—1. A considerable quantity of large bubbles of air are disengaged, which burst at the surface, forming a layer of greyish mucilage. 2. The surface of the liquor becomes covered with a copper-coloured pellicle. 3. A heaving of the liquor in the vat is observed, giving rise to the disengagement of large greenish bubbles, which communicate a brownish colour to the water. 4. The liquor acquires a fetid smell, a strongly acid taste, and a soapy appearance. These phenomena manifest themselves when the weather is hot, after the fermentation has continued about 12 or 14 hours. It then becomes impossible to obtain indigo of good quality, the only product being a black matter resembling wax.

The liquor is now run off from the steeping-vat into the beater, which is a cistern of about the same dimensions as the former, but situated at a rather lower level. Here it is subjected to the beating process, the object of which is to expose the reduced indigo to the oxygen of the atmosphere, as well as to promote the disengagement of the carbonic acid gas with which the liquid is charged, and which prevents the precipitation of the indigo. The beating is performed by men, who, provided with paddles, agitate the liquid rapidly, so as to bring every part of it successively into contact with the air. It is of importance that this process should be broken off at the right moment, for if it be continued too long, the grain formed at first will redissolve and be lost. And if, on the other hand, it be arrested before the proper time has arrived, a portion of the indigo will remain unprecipitated. In order to ascertain in what state the liquor is, a little of it must be poured into a drinking glass and mixed with an equal volume of clear water. If there is formed round the circumference of the glass a line of a bluish-green colour, the beating must be continued; but if, on the contrary, the liquid appears of a uniform brown colour, and if on adding to it a few drops of clear lime-water with the finger the indigo precipitates immediately in grains, the process must be arrested. The beating usually occupies from an hour and a half to two hours. The liquid is now to be well mixed with about $\frac{1}{10}$th of its volume of clear lime-water, and allowed to rest until the indigo has quite settled. By opening successively the plugs which are placed at different heights in the side of the vessel, the clear liquor is then drawn off in separate portions and permitted to run away, care being taken that none of the indigo is allowed to be carried away with the water. By means of an opening situated near the bottom of the beating vat the indigo mixed with water is then run off, and flowing through a canal is received on a cloth strainer or filter. This filter rests on a round or four-cornered vessel, the top of which is on a level with the surface of the ground, and which is called the *diablotin.* When the liquid has run through the filter, the indigo which remains behind in a state of paste is mixed up again with water, and the mixture is poured on a canvas filter and allowed to run immediately into the boiler. The refuse matter, consisting of leaves of the plant, &c., remains on the canvas, while the indigo suspended in water runs through. The boiler is a vessel with sides of masonry, and a bottom consisting of a copper plate which rests on iron bars, and is well cemented to the sides. Underneath the copper plate is the fire-place. The top must be covered with a wooden lid, consisting of two flaps which are fixed to hinges at the sides and meet together over the top. At the moment when the mixture of indigo and water is introduced into the boiler, the latter must already be about one third full of hot water, the mixture being sufficient almost to fill it entirely. The heat is now raised gradually to the boiling-point, and the boiling is continued for about two hours. In order to prevent the indigo from adhering to the bottom and sides of the boiler, the liquor must be kept continually stirred with a wooden rake. The object of the boiling is to drive away all the carbonic acid that may still be present in the liquor, to remove the soluble extractive matters which would render the indigo dull and impure, to prevent the fermentation or putrefaction of the indigo which would otherwise take place, and lastly, to facilitate the subsequent processes of filtering and pressing. The fire having been removed, the liquor is allowed to stand for some time, and as soon as the indigo has settled, the supernatant liquid is drawn off by means of taps fixed in one of the sides of the boiler. The lowest tap is then opened, and the indigo is run off with the water and received on a filter, consisting of blue Guinea cloth stretched on a frame. The first portions of liquid which run through are usually coloured with indigo, and must therefore be caught in a suitable vessel and poured on the filter again. As soon as the liquid has percolated, the indigo, which is now a compact paste, is removed from the filter by means of a wooden ladle and put into a press, which consists of a wooden box pierced with holes. The press having been lined with cloth, the indigo is put in, the cloth is folded round it as evenly as possible, a wooden lid is dropped on the cloth, and the mass is submitted to pressure by means of a screw, until no more liquid runs through at the bottom, which takes place as soon as the indigo has been reduced to about a third of its original volume. The press is then opened, the indigo is taken out of the cloth, laid on a table and divided by means of a knife into pieces of a cubical shape. These cubes are then taken to the drying shed, where they are placed on trellises covered with matting or very thin cloth, so as to admit of the free passage of air. Care must be taken not to dry them too rapidly, otherwise the cakes would crack and split into fragments, which are then of little commercial value, and it is therefore necessary to protect them from currents of dry air by covering them with canvas or Guinea cloth. During the drying process, which occupies from 8 to 10 days, the cakes should be turned several times. They are then closely packed in boxes, each box holding about 25 kilogrammes. The boxes should be lined with paper.

It may be remarked, that when the indigo is of good quality, the volume of the paste diminishes very little when subjected to pressure. If the process of filtering takes up much time and the pressing is attended with difficulty, it may be anticipated that the indigo will turn out of bad quality. This may proceed from the plant having been overgrown, or from the maceration or the beating process having been continued too long, or from the employment of too large a quantity of lime-water. The difficulty experienced in pressing the indigo paste, and which is often so great as to cause the cloth in which it is enveloped to break, is caused by the presence of a mucilaginous or viscous substance mixed with the indigo, which may be removed by treating the paste again with boiling water, and repeating the operations of filtering and pressing.

In regard to the state in which indigo exists in the plants from which it is derived, and the nature of the process by which it is obtained, various opinions have been entertained by chemists. Berthollet in his work on dyeing says, 'that the three parts of the process employed have each a different object. In the first a fermentation is excited, in which the action of the atmospheric air does not intervene, since an inflammable gas is evolved. There probably results from it some change in the composition of the colouring particles themselves; but especially the separation or destruction of a yellowish substance, which gave to the indigo a greenish tint, and rendered it susceptible of undergoing the chemical action of other substances. This species of fermentation passes into a destructive putrefaction, because the indigo has a composition analogous to that of animal substances. Hitherto the colouring particles have preserved their liquidity. In the second operation, the action of the air is brought into play, which, by combining with the colouring particles, deprives them of their solubility, and gives them the blue colour. The beating serves, at the same time, to dissipate the carbonic acid which is formed in the first operation, and which by its action presents an obstacle to the combination of the oxygen. The separation of this acid is promoted by the addition of lime; but if an excess be introduced, it counteracts the free combination of the oxygen. The third part of the process has for its objects—the deposition of the colouring matter, become insoluble by combination with oxygen, its separation from foreign substances, and its desiccation, which gives it more or less hardness, whence its appearance varies.' De Cossigny was of opinion that volatile alkali was the agent by which the colouring matter was extracted from the plant and held in solution until volatilised by the agitation process. Roxburgh concluded from his experiments, 'that the indigo plants contain only the base of the colour, which is naturally green; that much carbonic acid is disengaged during its extrication from the leaves; that the carbonic acid is the agent whereby it is probably extracted and kept dissolved; that ammonia is not formed during the process; that the use of the alkalis employed is to destroy the attraction between the base and the carbonic acid; and that the vegetable base being thereby set at liberty, combines with some colouring principle from the atmosphere, forming therewith a coloured insoluble fecula, which falls to the bottom and constitutes indigo.'

Chevreul, who was the first chemist of any eminence to examine the indigo-bearing plants and their constituents, inferred from his analyses of the *Isatis tinctoria* and the *Indigofera Anil*, that these plants contain indigo in the white or reduced state, in the same state in which it exists in the indigo-vat; that in this state it is held in solution by the vegetable juices, and that when the solution is removed from the plant, it is converted, by the action of the atmospheric oxygen, into indigo-blue. Giobert, from an examination of the *Isatis tinctoria*, drew the following conclusions:—1. Indigo-blue does not pre-exist in the plant, but is formed during the operations by means of which we believe it to be extracted. 2. There exists in a small number of plants a peculiar principle, different from all the known proximate constituents of plants, and which has the property of being convertible into indigo; this principle may be called *indigogene*. 3. This principle differs from indigo in containing an excess of carbon, of which it loses a portion, in passing into the state of indigo-blue, by the action of a small quantity of oxygen which it takes up. 4. The loss of this portion of carbon must be attributed to its undergoing combustion, and being converted into carbonic acid. 5. It differs in its properties from common indigo in being colourless and soluble in water, and by its greater combustibility, which causes it to undergo spontaneous combustion at the ordinary temperature of the atmosphere. 6. Its combustibility is enhanced by heat and by combination with alkalis, especially lime; it is diminished by the action of all acids, even carbonic acid. About the year 1839, the *Polygonum tinctorium*, an indigo-bearing plant indigenous to China, became the subject of a series of investigations by several French chemists, chiefly with a view to ascertain whether this plant, if grown in France, could be advantageously employed in the preparation of a dyeing material as a substitute for foreign indigo. Baudrimont and Pelletier, after an examination of this plant, arrived at the conclusion that the indigo is contained in it as reduced indigo, in the same state as it is in woad, according to Chevreul. Robiquet, Colin, Turpin, and Joly, on the other hand, expressed a very decided conviction that indigo-blue pre-exists in the plant, but not in a free state; that it is combined with some organic substance or substances, which render it soluble in water, ether and alcohol; and that the operation of potent agencies is requisite in order to destroy this combination and set the indigo at liberty. The explanation of Chevreul, proceeding from an authority of such eminence, and being the simplest, has been adopted by most chemists. Nevertheless, there are objections to it which render it inadmissible. Reduced indigo is a body which is only soluble in alkalis, and cannot, therefore, be contained as such in the juice of indigo-plants, which is mostly acid. As it also takes up oxygen with the greatest avidity, and is converted into indigo-blue, it is difficult to conceive how the whole of it can be preserved in a colourless state in the cells of plants, in which it must occasionally come in contact with the oxygen eliminated by the vegetable organism. If these plants contained reduced indigo, the juice ought, moreover, to turn blue the moment it became exposed to the atmosphere, which is not always the case. The necessity for a long process of fermentation in order to obtain the colouring matter would also not be very apparent, the mere contact with oxygen being, it might be supposed, all that was necessary for the purpose. The facility with which the indigo-blue is destroyed if the process of fermentation is carried too far, is also inconsistent with the supposition that it is contained in plants either as such, or in a de-oxidised state, since indigo-blue is a body not easily decomposed, except by very powerful agents.

In order to throw some light on this subject, an investigation was undertaken by Schunck into the state in which indigo-blue exists in the *Isatis tinctoria*, or common woad, which is the only plant indigenous to Europe that yields any considerable quantity of the colouring matter. Schunck succeeded in obtaining from that plant a substance of very peculiar properties, to which he gave the name of *Indican*. This substance has the appearance of a yellow or light brown transparent syrup. It has a bitter taste. It is very easily soluble in water, alcohol, and ether; its solutions are yellow, and have an acid reaction. Its compounds with bases are yellow. When its watery solution is mixed with a strong acid, such as muriatic or sulphuric acid, no change takes place at first, but on leaving the solution to stand, or on heating it, it becomes blue and opalescent, then acquires a purple colour, and at length deposits a quantity of purplish-blue flocks, which are quite insoluble in water. These flocks consist for the most part of indigo-blue, but they contain also a red colouring matter and several brown substances of a resinous nature. The supernatant liquid contains a peculiar kind of sugar, and on being distilled, yields carbonic, formic, and acetic acids. Hence it follows that the plant does not contain indigo-blue ready formed either in the blue or colourless state, that the latter exists in the vegetable juice in a state of combination with sugar, forming a compound of that peculiar class known to chemists as *glucosides*. This compound is readily dissolved by water, and the indigo-blue may then be liberated and precipitated from the solution by means of acids, and probably also by other agents, but the simultaneous action of oxygen is not necessary during the process of decomposition, which the compound undergoes in yielding indigo-blue. Now if, as seems probable, the various species of indigofera contain indican or some similar substance, the phenomena which took place during the process of manufacturing indigo may easily be explained. During the steeping process the indican is dissolved, and, in consequence of the fermentation which then takes place in the liquor, it is decomposed into indigo-blue and sugar. The former would then be precipitated; but since ammonia is, according to most authors, evolved at the same time, the indigo-blue is, by the simultaneous action of the alkali and the sugar, or other organic matters contained in the liquid, reduced and dissolved, forming a true indigo vat, from which the colouring matter is afterwards precipitated by the combined action of the atmospheric oxygen and the lime, during the beating process. According to Schunck, two distinct periods may be observed in the decomposition of indican. During the first period, indigo-blue is the chief product of decomposition; during the second, the red and brown resinous matters make their appearance with very little indigo-blue. The formation of carbonic, acetic, and formic acids is, according to Schunck, dependent on that of the brown resinous matters. It would appear, therefore, that the copious disengagement of carbonic acid, as well as the acid taste, attributed to acetic acid, sometimes observed during the manufacture of indigo, are phenomena which indicate the formation, not of indigo-blue, but of other substances, which may prove very injurious to the quality of the indigo. These substances being soluble in alkalis, but insoluble in water, are precipitated, as soon as the liquid loses the alkaline reaction which it possesses at the commencement, and becomes acid. Though indigo-blue is a body of very stable character, not easily decomposed when once formed, except by potent agencies, still the assertion of Perottet and others, that 'nothing is more fugitive, and more liable to be acted on by destructive agencies, than the colouring principle of the indigoferæ,' will be easily understood when the following facts, mentioned by Schunck, are taken into consideration. If a watery solution of indican, this indigo-producing body, be boiled for some time, it then yields by decomposition, not a trace of indigo-blue, but only indigo-red; and if it be boiled with the addition of alkalis, it then gives neither indigo-blue nor indigo-red, but only the brown resinous matters before mentioned. The mere action of alkalis is, therefore, sufficient to cause the molecules, which would otherwise have gone to form indigo-blue, to arrange themselves in a totally different manner, and yield products which bear very little resemblance to it. It is evident, therefore, that one of the chief objects to be kept in view by the manufacturer of indigo, is the proper regulation of the process of fermentation, so as to prevent the formation of the other products, which take the place of indigo-blue, and are formed at its expense.

The indigo of commerce occurs in pieces, which are sometimes cubical, sometimes of an irregular form. These pieces are firm and dry, and are easily broken, the fracture being dull and earthy. It is sometimes lighter, sometimes *apparently* heavier than water, this difference depending on its being more or less free from foreign impurities, as well as upon the treatment of its paste in the boiling, pressing, and drying operations. Its colour is blue of different shades; as light blue, purplish-blue, coppery-blue, and blackish-blue. On being rubbed with the nail, or a smooth hard body, it assumes the lustre and hue of copper. It is usually a homogeneous mass, but it occasionally contains grains of sand or other foreign bodies, and sometimes presents inequalities of colour. It is frequently full of small cavities, which proceeds from the drying process having been conducted too rapidly, and it is also covered at times with a whitish matter consisting of mould. It varies very much in consistency, being sometimes dry, hard, and compact, whilst sometimes it is easily broken into thin flat pieces. Indigo is devoid of smell and taste. When applied to the tongue, however, it adheres slightly, in consequence of the property which it possesses of rapidly absorbing moisture, a property which is often had recourse to in order to ascertain its quality. When thrown on red-hot coals it yields vapours of a deep purple colour, which, when condensed on cold bodies, give shining needles having a coppery lustre. It is insoluble in water, cold alcohol, ether, muriatic acid, dilute sulphuric acid, cold, ethereal, and fat oils; but boiling alcohol and oils dissolve a little of it, which they deposit on cooling. Creosote has the property of dissolving indigo.

Indigo varies very much in quality, but it requires much discrimination in order to judge fairly of the quality of any sample from mere inspection and application of the tests usually employed by dealers. A cake of indigo being broken, and the nail or the edge of a shilling being passed with a tolerable degree of pressure over the fractured part, a fine coppery streak will be produced if the indigo is good. If the indigo furrows up on each side of the nail, it is weak and bad, and if the coppery streak be not very bright it is not considered good. When a piece of indigo is broken the fracture should be held up to the sun, and, if it has not been well strained from the dross, particles of sand will be seen glistening in the sun-light. The outside or coat should also be as free from sand as possible. When the squares are broken in the chests the indigo fetches a low price, and if it is very much crushed it is only bought by the consumers for immediate use. The methods employed for ascertaining the true amount of colouring matter in any sample of indigo will be described below.

Indigo is generally classified according to the various countries from which it is obtained. The principal kinds are the following:—Bengal, Oude, Madras, Manilla, Java, Egyptian, Guatemala, Caraccas, and Mexican.

At the present day the finest qualities of indigo are obtained from Bengal, the produce of that country having now taken the place in public estimation which was once occupied by that of the Spanish colonies. The export of indigo from Bengal, which in 1853 amounted to 120,000 maunds (of 74 lbs. 10 oz.) would require for its culture about 1,025,000 acres, and an annual expenditure of 1,300,000*l*. Of this extent of land about 550,000 acres is believed to be included in the Lower Provinces, and consists chiefly of alluvial lands rescued from the rivers. The best qualities of Bengal indigo are manufactured in the Jessore and Kishenaghaur districts, but each district produces a quality peculiar to itself, and differences of a less striking character may be perceived in the produce of different factories. The Bengal indigo, when packed in chests, consists of four principal qualities, viz., the blue, purple, violet, and copper. But these kinds, by passing over into one another, produce a number of intermediate varieties, such as purply-blue, blue and violet, purply-violet, &c. The various qualifications would, therefore, be distinguished as follow:—1. Blue. 2. Blue and violet. 3. Purple. 4. Purple and violet. 5. Violet. 6. Violet and copper. 7. Copper. The leading London brokers, however, classify Bengal indigo into the following grades: fine blue, fine purple and violet, fine red and violet, good purple and violet, middling violet, middling defective, consuming fine, middling and good, ordinary, ordinary and lean trash. The finest qualities of Bengal indigo present the following characteristics. They consist of cubical pieces, are light, brittle, of a clean fracture, soft to the touch, of a fine bright blue colour, porous, and adhering to the tongue. The lower qualities have a duller colour, assume more and more of a reddish tinge, are heavier, more compact, and less easily broken.

The indigo from the upper provinces of India comes chiefly from Tyroot, Oude, and Benares. It is inferior to Bengal indigo.

Of Madras indigo there are two kinds, viz.:—1. Dry leaf, made from dry stacked leaves. 2. Kurpah, which is manufactured from the wet leaf in the same way as Bengal indigo. The latter has only come into use since 1830. Both are of inferior quality to Bengal indigo.

The Manilla indigos present the marks of the rushes upon which they have been dried. The pieces are either cubical, or flat and square, or of irregular shape. The quality is very unequal. Java indigo occurs in flat, square, or lozenge-shaped masses, the quality approaching that of Bengal. Both these kinds are consumed chiefly on the continent of Europe.

Guatemala indigo is imported into this country in serons or hide wrappers, each containing about 150 lbs. nett. It occurs in small irregular pieces, which are more or less brittle, compact, lighter than water, and of a bright blue colour with an occasional tinge of violet. There are three kinds of Guatemala indigo, viz.: 1. Flores, which is the best, and approaches in quality that of the finer Bengal indigos; 2. Sobres; and 3. Cortes, which is the lowest in quality, being heavy, difficult to break, and of a coppery-red colour. Of the first kind very little now reaches the market. The indigo of Caraccas is, generally speaking, inferior to that of Guatemala.

The manufacture of indigo was formerly carried on in St. Domingo, but has for some time been entirely abandoned.

The indigo of commerce, even when not adulterated, is a mixture of different substances. When it is heated in a state of fine powder to 212° F. it loses from 5 to 10 per cent. in weight, the loss consisting of water. When the dry powder is heated in a crucible, a great part of it burns away, and there is left at last a greyish ash, consisting of the carbonates and phosphates of lime and magnesia, sulphate of lime, alumina, oxide of iron, clay, and sand. These matters are partly derived from the plant, partly from the lime and the impurities of the water employed in the manufacture. The quantity of inorganic matter contained in ordinary indigo varies very much. In the better qualities it amounts on an average to about 10 per cent. of the weight; whilst in the inferior qualities, especially of Madras indigo, it often rises to between 30 and 40 per cent. The organic portion of the indigo, or that which is dissipated when indigo is heated, also consists of several different substances.

By treating indigo with various solvents, Berzelius obtained, besides indigo-blue, the true colouring matter of indigo, three other bodies, viz. *indigo-gluten*, *indigo-brown*, and *indigo-red*, which seem to be contained in various proportions in all kinds of indigo. Indigo-gluten is obtained by treating indigo with dilute sulphuric, muriatic, or acetic acid, and then with boiling water. It is left on evaporation of its solutions as a yellow transparent extract, which is soluble in spirits of wine, and easily soluble in water, more difficultly in acid liquids. Its taste is like that of extract of meat. It yields by dry distillation much ammonia and a fetid oil, and behaves in most respects like vegetable gluten. On treating the indigo, after being freed from the indigo-gluten, with hot strong caustic lye, the indigo-brown together with a little indigo-blue dissolves, forming a dark brown, almost black solution, from which the indigo-brown after filtration from the portion insoluble in alkali is precipitated by means of acid. After being purified, indigo-brown has the appearance of a dark brown transparent resin, which is almost tasteless and quite neutral. By dry distillation it affords ammonia and empyreumatic oil. It is decomposed by nitric acid and chlorine. It combines both with acid and bases. Its compounds with alkalis are dark brown, and easily soluble in water. The compound with baryta is not easily soluble in water, and that with lime is insoluble. By boiling the alkaline compounds with lime in excess the indigo-brown may be separated and rendered insoluble. The green substance obtained by Chevreul from indigo seems to have been a compound of indigo-brown with ammonia containing a little indigo-blue, either in a state of combination or mechanically intermingled. Indigo-brown seems to bear a great resemblance in many of its properties to the brown resinous substances obtained by Schunck in the decomposition of indican with acids. From its constant occurrence in all kinds of indigo, it may be inferred that it is not a mere accidental impurity, but stands in some unknown relation to indigo-blue. As long, however, as its origin and composition are unknown, this must remain a mere supposition. After the removal of the indigo-gluten and indigo-brown, the indigo is exhausted with boiling alcohol of specific gravity 0·83. A dark red solution is obtained, which is filtered and distilled, when the indigo-red contained in it is deposited as a blackish-brown powder, which is quite insoluble both in water and in alkaline liquids. Indigo-red, according to Berzelius, is amorphous, but by distillation *in vacuo* yields a white crystalline sublimate, as well as unchanged indigo-red. Concentrated sulphuric acid dissolves it, forming a dark yellow solution, which deposits nothing on being mixed with water; the diluted solution is rendered colourless by wool, which at the same time acquires a dirty yellowish-brown or red colour. The description given by Berzelius leaves it doubtful whether the indigo-red obtained by him from indigo was a pure unmixed substance. From the leaves of the indigoferæ, as well as from those of the *Isatis tinctoria*, a substance may, according to Schunck, be extracted which has received from him the name of *indirubine*, but which seems to be merely indigo-red in a state of purity. This substance has, according to Schunck, the following properties: it crystallises in small silky needles of a brownish-purple colour, which when rubbed with a hard body show a slight bronze-like lustre. When carefully heated it may be entirely volatilised, yielding a yellowish-red vapour, which condenses in the form of long plum-coloured needles, having a slight metallic lustre. It dissolves in concentrated sulphuric acid, forming a solution of a beautiful purple colour, which when diluted with water yields no deposit and then imparts a fine purple colour to cotton, wool, and silk. It is insoluble in water, but dissolves in boiling alcohol with a splendid purple colour. It is insoluble in alkalis, but dissolves when exposed to the combined action of alkalis and reducing agents, just as indigo-blue does, forming a solution from which it is again precipitated on exposure to the oxygen of the atmosphere. This solution dyes cotton purple. In most of its properties this body bears a striking resemblance to indigo-blue, and the composition of the two is identical.

It has been doubted whether these various substances or impurities with which indigo-blue is associated produce any effect in the dyeing process on cotton. In a memoir by Schwarzenberg, to which a prize was awarded by the Société Industrielle de Mulhouse, the author arrives at the conclusion that neither indigo-gluten, indigo-brown, nor indigo-red gives rise to any appreciable effect when added to an indigo vat prepared with pure indigo-blue. Nevertheless differences are observable in dyeing with different kinds of indigo, which can only be explained on the supposition that something besides indigo-blue takes part in the process. In the ordinary blue vat, made with copperas and lime, any effect which might be produced in dyeing by the indigo-brown is neutralised by the lime, which forms with it an insoluble compound. Indigo-red, however, dissolves, as mentioned above, in contact with alkalis and reducing agents, and the solution imparts a purple colour to cotton. In the ordinary indigo vat its presence may be detected by precipitating a portion of the liquor, and treating the precipitate with boiling alcohol, which then usually acquires a red colour. It is possible, therefore, that a small part of the effect produced in dyeing with indigo may be due to indigo-red.

That portion of the indigo which remains after treatment with acid, alkali, and alcohol consists essentially of indigo-blue, the true colouring matter of indigo, mixed, however, with sand, earthy particles, and other impurities. In order to purify it, the residue, while still moist, is to be mixed with lime, the quantity of which must amount to twice the weight of the crude indigo, and which has been previously slaked with water. The mixture is then put into a bottle capable of holding about 150 times its volume of water, and the bottle is filled up with boiling water and shaken. A quantity of finely-powdered protosulphate of iron, amounting to ⅔rds of the weight of the lime is then added, the bottle is closed with a stopper, well shaken, and left to stand for several hours in a warm place. The mass gradually becomes green, and the indigo-blue is then converted by the precipitated protoxide of iron into reduced indigo, which dissolves in the excess of lime, forming a deep yellow solution. This solution when clear is poured off from the deposit into a vessel containing a sufficient quantity of dilute muriatic acid to supersaturate the whole of the lime. The reduced indigo which is precipitated in greyish-white flocks, is agitated with water until it has become blue, and the regenerated indigo-blue is collected on a filter and washed with water, in order to remove the chloride of calcium and excess of muriatic acid. The following method of obtaining pure indigo blue has been recommended by Fritzsche: 4 ozs. of crude indigo and the same weight of grape-sugar are put into a bottle capable of holding 12 lbs. of water; a solution of 6 ozs. of concentrated caustic soda-lye in alcohol is then added, after which the bottle is filled with hot spirits of wine of 75 per cent., and the whole is left to itself for some time. The liquid becomes at first wine-red, then yellow, and on being filtered and left exposed to the air, deposits the indigo-blue in small crystalline scales, which are to be filtered off and washed at first with alcohol, and then with water.

Pure indigo-blue has the following properties:—Its colour is dark blue inclining to purple. When rubbed with a hard body it assumes a bright coppery lustre. It has neither taste nor smell, possesses neither acid nor basic properties, and belongs, as regards its chemical affinities, to the class of indifferent substances. Its specific gravity is 1·50. When heated in the open air it melts, boils, and burns with a smoky flame, leaving a carbonaceous residue. But when it is heated in a vessel partially closed, or *in vacuo*, it begins to evolve at a temperature of about 550° F. a violet-coloured vapour, which condenses on the colder parts of the apparatus in the form of long crystalline needles, which are blue by transmitted light, but exhibit by reflected light a beautiful coppery lustre. These needles are unchanged indigo-blue. A great portion of the indigo-blue is however decomposed during the heating process. Indigo-blue is insoluble in water, alkalis, and dilute acids. Boiling alcohol and boiling oil of turpentine dissolve a minute quantity of it, and deposit it again on cooling. Fixed oils also dissolve a little of it at a heat exceeding that of boiling water, yielding blue solutions, the colour of which, when the heat is further increased, changes, according to Mr. Crum, first to crimson and then to orange. By the action of dilute nitric and chromic acids indigo-blue is decomposed and converted into *isatine*, a body soluble in water and crystallising in red needles. Chlorine also decomposes indigo-blue, changing it into *chlorisatine*, a substance having properties very similar to those of isatine. Both isatine and chlorisatine afford with different reagents a great number of products of decomposition, none of which have, however, as yet found any application in the arts. By the long-continued action of boiling nitric acid indigo-blue is converted, first into *indigotic acid*, a white crystalline acid, and then into *nitropicric acid*, which is yellow and crystallised. The latter is sometimes employed for imparting a yellow colour to silk and wool, but it is generally prepared from cheaper materials than indigo-blue. The action of concentrated sulphuric acid on indigo-blue is very remarkable. When the acid is poured on the pure substance and gently heated it acquires in the first instance a green colour, which changes after some time to blue. No gas of any kind is evolved. When however crude indigo is employed, there is a perceptible disengagement of sulphurous acid, resulting from the action of the sulphuric acid on the impurities of the indigo, such as the indigo-gluten, &c. On adding water, a solution of a beautiful deep blue colour is obtained. The filtered liquid contains a peculiar acid, to which the names of *indigo-sulphuric, sulphindigotic, sulphindylic*, or *cæruleo-sulphuric acid* have been applied.

This acid is a so-called *double acid.* It contains indigo-blue and sulphuric acid, but in such a peculiar state of combination, that neither of the two constituents can be detected by ordinary re-agents, nor again eliminated as such from the compound. It combines with bases, without either of the two constituents separating. The compounds are called *indigo-sulphates*, and are, like the acid, of a dark blue colour. When the solution of indigo-blue in concentrated sulphuric acid is diluted with water, there is usually formed a small quantity of a dark-blue flocculent precipitate, which is the *phenicine* of Mr. Crum, or the *indigo-purple* of Berzelius. It is a compound of indigo-blue with sulphuric acid, containing less of the latter than indigo-sulphuric acid. It is always formed when the quantity of sulphuric acid employed is not more than eight times that of the indigo-blue, or when the action of the acid on the latter has continued for only a short time. By heating it with an excess of acid it is changed into indigo-sulphuric acid. Though soluble in concentrated sulphuric acid, it is insoluble in the dilute acid, and hence is precipitated on the addition of water. On filtering and washing, however, it begins to dissolve, as soon as the free sulphuric acid has been removed, and may then be completely dissolved by pure water. The solution has a blue colour just like that of indigo-sulphuric acid. Its compounds with bases have a blue colour with a purplish tinge. The blue acid liquid filtered from the indigo-purple on being supersaturated with carbonate of potash or soda, deposits a dark blue powder, which consists of the indigo-sulphate of potash or soda. These compounds are insoluble in water containing a large quantity of neutral salts, and are therefore precipitated when the excess of sulphuric acid is neutralised by carbonate of potash or soda. As soon, however, as the sulphate of potash or soda has been removed by washing, the indigo-sulphate may be dissolved in pure water, yielding a dark-blue solution. The indigo-sulphates of the alkalis may also be prepared by steeping wool, previously well cleaned, into the solution in sulphuric acid. The wool takes up the colour, becoming of a dark blue colour, and after having been well washed with water, in order to remove the excess of acid as well as the impurities which are always present in the solution when crude indigo has been employed, is treated with carbonate of potash, soda, or ammonia, which separate the acid from the wool, and produce blue solutions containing the salts of the respective bases. The indigo-sulphates of the earths and metallic oxides, which are mostly insoluble blue powders, may be obtained from the alkaline salts by double decomposition. By an excess of caustic alkali, indigo-sulphuric acid is immediately decomposed, giving a yellow solution, from which it is impossible to obtain the acid again. By means of reducing agents, such as sulphuretted hydrogen, nascent hydrogen, protosalts of tin and iron, &c., indigo-sulphuric acid is decolorised, but the colour is restored by the oxygen of the atmosphere. Indigo-sulphuric acid, in a free state or in combination with alkalis, is employed in the arts for the purpose of imparting a blue colour to silk and wool. It has very little affinity for cotton fibre, but is nevertheless employed occasionally for blueing white cotton-yarn and other bleached goods.

By treatment with strong boiling caustic potash- or soda-lye, indigo-blue is gradually decomposed and converted into a colourless crystallised acid, *anthranilic acid.* By weak solutions of caustic alkalis it is not in the least affected. If, however, it be subjected to the combined action of an alkali or alkaline earth and some body having a strong affinity for oxygen, such as protoxide of iron and tin, sulphur, sulphurous or phosphorous acid, or organic matters, such as grape-sugar, &c., it disappears by degrees, yielding a yellow solution, containing in the place of indigo-blue another substance, which has been called *indigo-white*, *indigogene*, or *reduced indigo.* When an excess of some acid is added to the yellow solution, the indigo-white is precipitated in white or greyish-white flocks, which on filtration and exposure to the atmosphere rapidly become blue, and are re-converted into indigo-blue. Indigo-white is insoluble in water, but slightly soluble in alcohol. It is soluble in caustic alkalis, lime- and baryta-water. The solutions on exposure to oxygen become covered with a pellicle of regenerated indigo-blue. With an excess of lime it gives an insoluble compound. Its compounds with alumina and metallic oxides, which are insoluble in water, may be obtained by double decomposition. Salts of oxide of copper, when added to its solutions in alkali, convert it immediately into indigo-blue, the oxide of copper being reduced to suboxide. Indigo-blue is also converted into indigo-white, when it is exposed to the action of fermenting or putrefying substances, in the presence of water. Here the decomposing organic matter is the reducing agent, and ammonia, which is usually formed during the process of putrefaction, is the solvent of the indigo-white. If a piece of cotton, wool, or silk be dipped into an alkaline solution of indigo-white, and then exposed to the atmosphere, it acquires a blue colour, which may be made deeper by repeated dippings, and subsequent exposure. It is on this property of indigo-white that the dyeing with indigo depends.

The true chemical formula of indigo-blue, which was first discovered by Mr. Crum, is $C^{16}H^{5}NO^{2}$; and 100 parts contain therefore by calculation 73·28 carbon, 3·81 hydrogen, 10·68 nitrogen, and 12·23 oxygen. The formula of indigo-white is $C^{16}H^{6}NO^{2}$, and it differs therefore from indigo-blue by containing 1 atom more of hydrogen, which is taken up during the so-called reduction of the latter, and lost again by oxidation during its reconversion into indigo-blue.

Since the value of indigo depends entirely on the quantity of indigo-blue which it contains, it is of great importance to ascertain the exact amount of the latter in any given sample of the article. Before commencing the determination of the indigo-blue, a weighed portion of the indigo ought to be heated for some hours at 212° F., and then weighed again. The loss in weight which takes place represents the amount of water contained in the sample. A weighed quantity of the dried indigo is then to be heated over the flame of a lamp until all the organic matter has been burnt away. By weighing the residue which is left the amount of ash or inorganic matter is ascertained. In order, in the next place, to determine the amount of indigo-blue, several methods have been devised by various chemists, none of which however yield very accurate results. Of these methods the following are the principal ones:

1. A weighed quantity of finely-pounded indigo is rubbed with water in a porcelain mortar. An equal weight of pure lime is then slaked with water, and the hydrate is well mixed with the indigo. The mixture is then poured into a stoppered bottle of known capacity, and the mortar is well rinsed with water, which is added to the rest. The bottle is now heated in a water-bath for several hours, and a quantity of finely-pounded sulphate of iron is added; the bottle is then filled up with water, the stopper is inserted, and after the contents have been well shaken the whole is allowed to repose for some hours, until the indigo has become reduced and the sediment has sunk to the bottom. A portion of the clear liquor is then drawn off with a siphon, and the quantity of liquid having been accurately measured, it is mixed with an excess of muriatic acid, and the precipitate, after having been oxidised, is collected on a weighed filter and well washed with water. Lastly, the filter with the indigo-blue is dried at 212° F. and weighed, and the weight of the filter having been subtracted from that of the whole, the weight of the indigo-blue is ascertained. Supposing now that the whole quantity of liquid had been 200 measures, that 50 measures had been drawn off yielding 10 grains of indigo-blue, then the sample contained on the whole 40 grains of the latter. For 60 grains of indigo it is necessary to take from 1 lb. to 2 lbs. of water.

According to Mr. John Dale of Manchester, who has had great experience in the valuation of indigo for practical purposes, this method, though rather long and tedious, still gives more accurate results than any other. The quantity of indigo-blue indicated by it is generally below the actual quantity contained in the sample. According to Berzelius, this loss arises from the lime forming an insoluble compound with a portion of the reduced indigo-blue. Mr. Dale, however, is of opinion, that even when every precaution has been taken, a certain loss, proceeding from some hitherto unascertained cause, cannot be avoided. When, for instance, pure indigo-blue is treated with lime and copperas in the manner just described, the quantity which is again obtained by precipitation from any portion of the liquid is always less than what it should be by calculation, even when no excess of lime has been employed.

2. The second method of determining the indigo-blue is performed as follows:— About 15 or 20 grains of pure indigo-blue, obtained by precipitation from an indigo

vat, and the same quantity of the indigo to be tested, which must be previously ground to a fine powder, are weighed off, and each of them is treated with about 12 times its weight of concentrated sulphuric acid in a flask or porcelain basin. After being heated at a temperature of 120° to 140° F. for about 24 hours, and occasionally well agitated, the two liquids are mixed with water, so that the volume of the two shall be exactly equal. Two equal measures of a weak solution of hypochlorite of lime are then taken, and to the first is added a quantity of the solution of pure indigo. The chlorine liberated by the excess of sulphuric acid in the solution destroys the blue colour of the indigo-sulphuric acid. More of the solution must be added until the liquid begins to acquire a greenish tinge, and the number of measures necessary for the purpose is noted. The same experiment is then made with the solution of crude indigo. The quantity of indigo-blue in the latter is of course in inverse ratio to the number of measures which are requisite in order to take up the whole of the chlorine which is liberated. If, for example, the same quantity of hypochlorite of lime decolourises 167 measures of the solution of pure indigo-blue and 204 measures of the solution of crude indigo, then the quantity of indigo-blue contained in 100 parts of the latter is given by the following proportion:—$204 : 167 :: 100 : x = 81{\cdot}8$.

A number of samples of indigo may be tested in this manner at the same time. Care must be taken to prepare a fresh solution of indigo-blue for every series of trials, since this solution undergoes a change on standing, which renders it quite inapplicable as a standard of comparison. It is necessary also to pay great attention at the moment when the greenish colour indicating an excess of the sulphate of indigo begins to appear, for it will often be found that this colour disappears after standing a few minutes, and a fresh quantity of the blue solution must then be added cautiously, until the greenish tinge becomes permanent, even after standing for some time. Modifications of this process have been introduced by various chemists by the use of permanganate of potash, chlorate of potash, or bichromate of potash, in the place of hypochlorite of lime; but as the principle on which the process depends is in each case identical and the *modus operandi* is almost the same, it will be unnecessary to enter into any minute description of these modifications. The whole method is, however, open to serious objections, and the results which it affords cannot at all be depended on. In the first place, it is difficult to institute a strict comparison between the different shades of colour resulting from the decomposition of the sulphate of indigo in different cases, since the pure green tinge observed when an excess of the pure sulphate has been added to the decomposing agent, gives place to a dirty olive or brownish-green, when a solution of crude indigo is employed, in consequence of the impurities contained in the latter. Secondly, it is almost impossible to avoid the formation of a certain quantity of sulphurous acid during the action of concentrated sulphuric acid on crude indigo. This sulphurous acid during the following operation becomes oxidised before the blue sulphate is destroyed, and hence the percentage of indigo-blue is apparently raised. In employing this method, it is common to find more than 80 per cent. of indigo-blue in a good sample of indigo, whereas the best qualities seldom contain above 60 per cent., and average qualities between 40 and 50 per cent. This method may show a percentage of 70 indigo-blue, when the method first described indicates between 50 and 60.

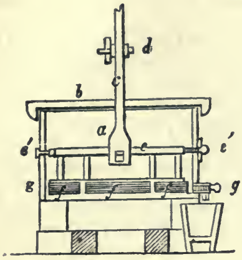
3. The third method of estimating the indigo-blue is performed in the following manner:—Equal weights of the samples to be tested are treated with equal quantities of concentrated sulphuric acid in the manner above described, and the solutions are then diluted with water and introduced into graduated glass cylinders, water being added to each until they all exhibit exactly the same shade of colour. The richer the sample is in indigo-blue, the greater will be the quantity of water necessary for this purpose, the number of measures of water required in each case indicating the relative amount. The great objection to this method consists in the circumstance, that the different kinds of indigo do not give the same shade of blue when their solutions in sulphuric acid are diluted with water, some exhibiting a pure blue colour, others a blue with a greenish, or purplish tinge. It therefore becomes difficult to institute an exact comparison between them.

Employment of Indigo in Dyeing.—As indigo-blue is insoluble in water, and as it can penetrate the fibres of wool, cotton, silk, and flax only when in a state of solution, the dyer must study to bring it into this condition in the most complete and economical manner. This is effected either by exposing it to the concurrent action of alkalis and of bodies which have an affinity for oxygen superior to its own, such as certain metals and metallic oxides, or by mixing it with fermenting matters, or finally, by dissolving it in a strong acid, such as the sulphuric. The first method is that which is employed in the

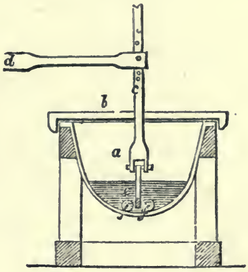
Copperas or Common blue Vat.—Before being used the indigo must be broken into small pieces, the size of nuts, moistened with hot water, and then left for a day; after which it is reduced to a soft paste in a mill. The indigo-mill is represented in *figs.* 1210 and 1211.

a, is a four-sided iron cistern, 2 feet 11 inches long, 19 inches broad, and 18 inches deep, cylindrical or rounded in the bottom, and resting upon gudgeons in a wooden frame. It has an iron lid *b*, consisting of two leaves, between which the rod *c* moves to and fro, receiving a vibratory motion from the crank *d*. By this construction, a frame *e*, which is made fast in the cistern by two points *e′ e′*, is caused to vibrate, and to impart its swing movement to six iron rollers *f*, *f*, *f*, four inches in diameter, three being on each side of the frame, which triturate the indigo mixed with water into a fine paste. This mill is capable of grinding 1 cwt. of indigo at a time. Whenever the paste is uniformly ground, it is drawn off by the stopcock *g*, which had been previously filled up by a screwed plug, in order to prevent any of the indigo from lodging in the orifice of the cock, and thereby escaping the action of the rollers.

1210



1211



Mills of other forms are also used occasionally. One of these consists of a hemispherical iron vessel open at the top, in which a stone of corresponding shape is fixed, so as to leave a small space between it and the sides and bottom of the vessel, in which the indigo undergoes the necessary trituration with water, the motion being produced by means of a vertical shaft fixed to the centre of the stone.

The other ingredients necessary for setting the vat are copperas or protosulphate of iron, newly slaked quicklime, and water. Various proportions of these ingredients are employed, as for instance, 1 part by weight of indigo (dry), 3 parts of copperas, and 4 of lime; or 1 of indigo, 2½ of copperas, and 3 of lime; or 8 of indigo, 14 of copperas, and 20 of lime; or 1 of indigo, ¾ of copperas, and 1 of lime. The sulphate of iron should be as free as possible from the red oxide of iron, as well as from sulphate of copper, which would re-oxidise the reduced indigo-blue. The vat having been filled with water to near the top, the materials are introduced, and the whole after being well stirred several times is left to stand for about twelve hours. The chemical action which takes place is very simple. The protoxide of iron which is set at liberty by the lime reduces the indigo-blue, and the indigo-white is then dissolved by the excess of lime, forming a solution, which, on being examined in a glass, appears perfectly transparent and of a pure yellow colour, and becomes covered wherever it comes into contact with the air, with a copper-coloured pellicle of regenerated indigo-blue. The sediment at the bottom of the vat consists of sulphate of lime, peroxide of iron, and the insoluble impurities of the indigo, such as indigo-brown in combination with lime, as well as sand, clay, &c. If an excess of lime is present, a little reduced indigo-blue will also be found in the sediment in combination with lime.

The copperas vat is employed in dyeing cotton, linen, and silk. For cotton goods no other kind of vat is used at the present day. The dyeing process itself is very simple. The vat having been allowed to settle, the goods are plunged into the clear liquor, and after being gently moved about in it for some time are taken out, allowed to drain, and exposed to the action of the atmosphere. Whilst in the liquid the fabric attracts a portion of the reduced indigo-blue. On now removing it from the liquid it appears green, but soon becomes blue on exposure to the air in consequence of the oxidation of the reduced indigo-blue. On again plunging it into the vat, the deoxidising action of the latter does not again remove the indigo-blue which has been deposited within and around the vegetable or animal fibre, but on the contrary, a fresh portion of reduced indigo-blue is attracted, which on removal from the liquid is again oxidised like the first, and the colour thus becomes a shade darker. By repeating this process several times, the requisite depth of colour is attained. This effect cannot in any case be produced by one immersion in the vat, however strong it may be. The beauty of the colour is increased by finally passing the goods through diluted sulphuric or muriatic acid, which removes the adhering lime and oxide of iron. After being used for some time, the vat should be refreshed or fed with copperas and lime, upon which occasion the sediment must first be stirred up, and then allowed to settle again, so as to leave the liquor clear. The indigo-blue, however, is in course of time gradually removed, and by degrees the vat becomes capable of dying only pale shades of blue. When the colour produced by it is only very faint, it is no longer worth while using it, and the contents are then thrown away. In dying cotton with indigo, it seems to be essential that the reduced indigo-blue should be in combination with lime. If potash or soda be used in its stead it is impossible to obtain dark shades of blue.

When cotton piece goods are to be dyed of a uniform blue, they are not submitted to any preparatory process of bleaching or washing, Indeed, the size contained in unbleached goods seems rather to facilitate than to impede the dyeing process. In dying these goods a peculiar roller apparatus is employed. When certain portions of the fabric are to retain their white colour a different plan is adopted. The pieces having been bleached, those portions which are to remain white are printed with so-called *resists.* These resists consist essentially of some salt of copper, mixed with an appropriate thickening material. The copper salt acts by oxidising the reduced indigo-blue at the surface, and thus rendering it insoluble before it can enter the interior of the vegetable fibre, since it is only when deposited within the fibre itself that the colouring matter becomes durably fixed. The pieces are now stretched upon square dipping frames, made of wood or of iron, furnished with sharp hooks or points of attachment. These frames are supended by cords over a pulley, and thus immersed and lifted out alternately at proper intervals. In dyeing, a set of 10 vats is used, the first vat containing 5 or 6 lbs. of indigo, and the quality increasing gradually up to 80 lbs. in the last vat. The pieces are dipped for 7½ minutes in the first vat, then taken out and exposed to the air for the same length of time, then dipped in the second vat, and so on to the last. After passing through the last vat, a small bit of the calico is dried, in order to see whether the colour is sufficiently dark. If it is not, the whole series must be dipped once more in the same vat in which the last dipping was performed. When the bottom of the vat is raked up so as to have more lime in suspension, the vat becomes what the dyer calls *hard*, that is to say, the oxide of copper of the resist is precipitated in a compact state, and consequently acts with more efficiency. But when the vat has been at rest for some time, and there is little lime in suspension, then it is called *soft.* When it is in this state, the oxide of copper is thrown down in a bulky form, and when the pieces are afterwards agitated in the liquor, in order to detach the oxide of iron which always floats about in the vat, and attaches itself to the fabric, and which, if left adhering, would cause light stains, technically called *grounding* ; then the oxide of copper is also detached, and the indigo penetrates to those parts which are to remain white. When cotton yarn is dyed in the copperas vat, the latter is generally heated by means of steam-pipes passing through the liquor, the object being to give to the colour the peculiar gloss or lustre, which is required in this class of goods. No preparatory process is required, except simply steeping in hot water. In dyeing, wooden pins are put through the hanks, their ends resting on supports passing over the top of the vat, and the yarn is then slowly turned over, one half being in the liquor, the other half over the pins. It is then taken out, wrung, exposed to the air, and again dipped, this operation being repeated until the requisite shade is obtained.

The methods employed for producing the colours called *China blue* and *pencil blue* on calico have been described under Calico-Printing.

The *urine vat* is prepared by digestion of the ground indigo into warmed stale urine, which first deoxidises the indigo-blue, and then dissolves it by means of its ammonia. Madder and alum are likewise added, the latter being of use to moderate the fermentation. This vat was employed more commonly formerly than at present, for the purpose of dyeing woollen and linen goods.

Woad Vat.—In former times, woad was the only material known to the dyers of Europe for producing the blue colour of indigo. For this purpose it was previously submitted to a peculiar process of fermentation, and the product was named *pastel* in France. For most purposes indigo has taken the place of woad in the dye-house, and for cotton goods it is now used alone. In the dyeing of woollen goods, however, the use of woad has been retained to the present day, for the purpose rather of exciting fermentation and thus reducing the indigo which is employed at the same time, than of imparting any colour to the material to be dyed. Indeed, the woad used by woollen dyers in this country contains no trace of colouring matter. Various substances, such as rhubarb-leaves, turnip-tops, weld, and other vegetable matters, have accordingly been tried, but without success, since the fermentation is more steadily maintained by means of woad than by any other material. Pastel, which does contain a little blue-colouring matter, is preferred to woad by many of the French dyers. The materials employed in the ordinary woad or pastel vat, in addition to woad and indigo, are madder, bran, and lime. In the so-called *Indian* or *potash vat*, madder, bran, and carbonate of potash are used: in the *German vat*, bran, carbonate of soda, and quicklime without woad. The chemical action which takes place in the woad vat is not difficult to understand. The nitrogenous matters of the woad begin, when the temperature is raised, to enter into a state of fermentation, which is kept up by means of the sugar, starch, extractive matter, &c., of the madder and bran. In consequence of the fermentation, the indigo-blue becomes reduced, and is then dissolved by the lime, thus rendering the liquid fit for dyeing. Great care is necessary in order to prevent the process of fermentation from passing into one of putrefaction, which if allowed to proceed would lead to the entire destruction of the indigo-blue in the liquor. If any tendency to do so is observed, it is arrested by the addition of lime, which combines with the acetic, lactic, and other organic acids that commence to form when putrefaction sets in. On the other hand, an excess of lime must also be avoided, since the reduced indigo-blue is thereby rendered insoluble, and unfit to combine with the material.

The following account of the method of dyeing woollen goods with indigo, as carried on at present in Yorkshire, may suffice to give a general idea of the process:—

The dye-vats employed are circular, having a diameter of 6 feet 6 inches, and a depth of 7 feet, and are made of cast iron $\frac{5}{8}$ths of an inch in thickness. They are surrounded by brickwork, a space of 3 inches in width being left between the brickwork and the iron, for the purpose of admitting steam, by means of which the vats are heated. The interior surface of the brickwork is well cemented. In setting a vat the following materials are used:—5 cwts. of woad, 30 lbs. of indigo, 56 lbs. of bran, 7 lbs. of madder, and 10 quarts of lime. The woad supplied to the Yorkshire dyers is prepared and grown in Lincolnshire. It is in the form of a thick brownish-yellow paste, having a strong ammoniacal smell. The indigo is ground with water in the usual manner. The madder acts in promoting fermentation, but it also serves to give a reddish tinge to the colour. The lime is prepared by putting quicklime into a basket, then dipping it in water for an instant, lifting it out again, and then passing it through a sieve, by which means it is reduced to a fine powder, called by the dyers *ware*. The vat is first filled with water, which is heated to 140° Fahr., after which the materials are put in, and the whole is well stirred until the woad is dissolved or diffused, and it is then left to stand undisturbed over night. At 6 o'clock the next morning the liquor is again stirred up, and 5 quarts more lime are added. At 10 o'clock, 5 pints of lime are again thrown in, and at 12 o'clock the heat is raised to 120° Fahr., which temperature must be kept up until 3 o'clock, when another quart of lime is introduced. The vat is now ready for dyeing. When the process of fermentation is proceeding in a regular manner, the liquid, though muddy from insoluble vegetable matter in suspension, is of a yellow or olive-yellow colour; its surface is covered with a blue froth or a copper-coloured pellicle, and it exhales a peculiar ammoniacal odour; at the bottom of the vat there is a mass of undissolved matter, of a dirty yellow colour. If there is an excess of lime present, the liquor has a dark green colour, and is covered with a greyish film, and when agitated, the bubbles which are formed agglomerate on the surface, and are not easily broken. Cloth dyed in a liquor of this kind loses its colour on being washed. This state of the vat is remedied by the addition of bran, and is of no serious consequence. When, on the other hand, there is a deficiency of lime, or in other words, when the fermentation is too active, the liquor acquires first a drab, then a clay-like colour; when agitated, the bubbles which form on its surface burst easily, and when stirred up from the bottom with a rake it effervesces slightly, or *frets* as the dyers say. If the fermentation be not checked at this stage, putrefaction soon sets in, the liquid begins to exhale a fetid odour, and when stirred evolves large quantities of gas, which burn with a blue flame on the application of a light. The indigo is now totally destroyed, and the contents of the vat may be thrown away. No further addition of woad is required after the introduction of the quality taken in first setting the vat, the fermentation being kept up by adding daily about 4 lbs. of bran, together with 1 quart or 3 pints of lime. Indigo is also added daily for about 3 or 4 months. The vat is then used for the purpose of dyeing light shades, until the indigo contained in it is quite exhausted, and its contents are then thrown away.

Woollen cloth before being dyed is boiled in water for 1 hour, then passed immediately into cold water. If it be suffered to lie in heaps immediately after being boiled, it undergoes some change, which renders it afterwards incapable of taking up colour in the vat. When a purple bloom is required on the cloth, it is dyed with cudbear to a light purple shade before being dipped. In dyeing, the cloth is placed on a network of rope attached to an iron ring, which is suspended by four iron chains at a depth of about 3 feet beneath the surface of the liquor. The cloth is stirred about in the liquor by means of hooks for about 20 or 30 minutes. It is then taken out and well wrung. It now appears green, but on being unfolded and exposed to the air rapidly becomes blue. When the vat contains an excess of lime the cloth has a dark green colour when taken out. It is then passed through hot water and dipped again, if a darker shade is required. When woollen flocks are to be dyed, they are placed in a net made of cord, which is suspended by hooks at the side of the vat. They are then transferred to a stronger net and wrung out by several men. In dyeing flocks a more active fermentation of the vat is required than with cloth.

The process of dyeing by means of sulphate of indigo is quite different from indigo dyeing in the vat. This process was discovered by Barth, at Grossenhayn in Saxony, about the year 1740, and the colour produced by it is hence called *Saxon blue.* The method of purifying sulphate of indigo, by immersing wool in the solution of crude indigo in oil of vitriol, previously diluted with water, has been described above. The process of making sulphate of indigo or *extract of indigo*, as it is called, as now practised on the large scale, is as follows:—1 lb. of indigo is mixed with from 8 to 9 lbs. of oil of vitriol, and the mixture is left to stand for some hours in a room, the temperature of which is 90° Fahr. It is then diluted with water, and filtered through paper. There is left on the filter a dirty olive-coloured residue, which is used for some purposes by woollen dyers. By now adding common salt to the liquid, a blue precipitate of sulphate of indigo is produced, which is collected on a filter, and washed with a solution of salt in order to remove the excess of acid. No neutralisation with alkali is required when this plan is pursued. The blue produced on wool and silk by means of sulphate of indigo is very fugitive, and is now seldom required, its place having been in a great measure taken by the blue from prussiate of potash. The chief use of sulphate of indigo is for dyeing compound colours, such as green, olive, grey, &c.—E.S.

On a new Method of Dyeing and Printing by means of Indigo.—By reason of its insolubility, alike in neutral and in alkaline solvents, the colouring matter of indigo cannot be fixed upon any textile fibre until it has been reduced, *i.e.*, converted into *white indigo*, which is soluble in alkalis and solutions of the alkaline earths. The energetic reducing properties of hydrosulphite of soda, and its almost instantaneous action upon indigo, which it converts into white indigo, in presence of an alkaline solution even at ordinary temperatures, have induced Messrs. Schutzenberger and Lalande to examine the practical employment of this salt in the various applications of indigo in the arts of dyeing and printing.

The indigo vats most generally used in modern times are the sulphate of iron (green copperas) vat for vegetable fibres, and the fermenting vat for wool-dyeing. The main defect of the copperas vat is the presence of a bulky sediment of oxide of iron and of sulphate of lime, which requires to subside before the clear portion of the liquid can be used for dyeing. The fermentation vat is difficult to work, and is subject to accidents, or morbid changes, which sometimes in the course of a few hours involve the entire loss of the indigo which they contain. (Such accidents are not unfrequently due to the malice of some workman, and are, of course, a kind of rattening.) The hydrosulphite vat, which the authors propose in lieu of the present methods, both for animal and vegetable fibres, is 'set' as follows:—Bisulphite of soda, marking 30° to 35° Baumé (1·26 to 1·30 specific gravity), is put in a covered cask filled up to the surface with coils of sheet zinc, or granulated zinc. This arrangement serves to increase the points of contact between the liquid and the metal. After standing for about an hour, the liquid is drawn off into milk of lime, which precipitates the salts of zinc. The whole is well stirred, and the clear liquid is separated either by filtration and pressure or by decantation, water having been previously added. During all these operations air should be as far as possible excluded. If the hydrosulphite of soda thus obtained is mixed with ground indigo, and the amounts of lime or soda needful to dissolve the reduced indigo, we immediately obtain a yellowish solution, which contains no insoluble matter except the earthy matters present in the indigo. By this process 1 kilogramme of indigo may be reduced and dissolved in such a concentrated state that the liquid does not exceed 10 to 15 litres. In dyeing the beck is filled with water—a suitable amount of reduced indigo added, and the operation is performed in the cold for cotton and at a hand-heat for wool. The dye-liquid being clear for its entire depth, the dyeing process can be conducted without loss of time. The excess of hydrosulphite present constantly reduces the scum of oxidised indigo which forms on the surface of the bath, and successive quantities of the concentrated solution of indigo are added from time to time as they are required. By means of this facility of keeping the vat at any degree of strength required, any shade may be produced with the least possible time and trouble. As regards cotton-dyeing the new process is distinguished for its ease and rapidity. In wool-dyeing all risk of spoiling the indigo is avoided. Shades are produced at once brighter and more solid than with the old vats, and it is easy to obtain upon wool bright blue bottoms such as were formerly producible only by means of the sulphate of indigo, and which were, of course, much more fugitive.

In printing with indigo, the process hitherto followed has been to use white indigo, or indigotate of tin obtained by precipitating a tin vat with hydrochloric acid or by adding to the clear portion of a copperas vat a mixture of hydrochloric acid and salt of tin. This precipitate is thickened with gum, and printed upon the calico. It is then fixed by treatment with milk of lime. The goods are then successively passed through bleaching-liquor, sulphuric acid, and a soap-bath. The process is at once difficult, delicate, and expensive. It is only by constant and anxious attention that running and injuries to the accuracy of the design are avoided during the treatment with lime-water, and only a very small fraction of the indigo is actually deposited upon the fibre. The numerous attempts hitherto made to replace the above-described process with some other means of fixing indigo have not proved successful. We need only mention as instances, China blue, pencil blue, and printing with a concentrated indigo-vat in an atmosphere of coal-gas in order to exclude atmospheric oxygen. The new method, as tested by the authors upon a manufacturing scale, consists mainly in printing with an alkaline solution of dissolved indigo suitably concentrated and thickened, the colour containing, moreover, a large excess of hydrosulphite of soda. The presence of this salt keeps the indigo-blue constantly in a perfectly-reduced state, which would otherwise become oxidised. It thus supersedes in a much more convenient manner the use of coal-gas. The printing can be carried on in common air with ordinary machines. Oxidation is so little perceived that after an hour of working the colour remains reduced to yellow. On the other hand, by printing on dissolved indigo, immediate fixation is secured as the colouring matter is almost entirely utilised. Experience shows that with shades of equal depth, solid blues are obtained at an expenditure of from 50 to 60 per cent. less indigo than with the old process. The shades obtained are more beautiful and solid, and the design comes out more distinct and better defined. The new blue not needing to be fixed by any subsequent process after printing, can be applied simultaneously with the majority of other colours, such as aniline-black, garancine colours, whether obtained by dyeing or steaming, catechu, chrome colours, albumen colours, &c. Novel styles can be thus originated, which could scarcely be executed by any other process. The new colour is obtained by thickening with gum, or any other suitable substance, an alkaline solution of white indigo sufficiently concentrated, and adding to the mixture a sufficient quantity of hydrosulphite of soda. After printing, the indigo is oxidised by hanging up the pieces for twelve to fourteen hours. They are finally washed and soaped.

Our *Imports* of indigo in 1871 and 1872 were as follows:—

Places	1871		1872	
	Quantities	Value	Quantities	Value
	cwts.	£	cwts.	£
From Germany	405	12,914	...	...
,, France	2,393	75,558	...	...
,, Egypt	7,608	148,800	3,077	61,400
,, India (French Possessions)	1,586	37,275	252	6,013
,, Philippine Islands . .	1,080	25,182	1,947	30,616
,, United States of America .	600	16,394	253	7,372
,, Mexico	....	...	777	19,949
,, Central America . .	13,799	322,587	12,901	305,316
,, New Granada (the United States of Colombia) .	4,165	118,448	4,532	104,752
,, British Possessions, South Africa	419	15,780	...	...
,, British India:				
Bombay and Scinde .	395	8,397	1,694	26,499
Madras . . .	29,486	715,304	19,413	508,042
Bengal and Burmah .	42,707	1,391,602	41,002	1,370,591
,, Straits Settlements . .	...	...	259	7,497
,, Other countries . .	1,664	49,003	1,213	34,300
Total . .	106,307	2,937,224	87,320	2,482,347

INDIGO-BROWN. A brown substance of uncertain composition obtained from commercial indigo.

INDIGO-COPPER. The native protosulphide of copper, known also as *Covelline.*

INDIGO-GREEN. A green substance obtained from indigo by adding potash to an alcoholic solution of an alkaline hyposulph-indigotate.

INDIGO-PURPLE. Finely-powdered indigo is added to twenty times it weight of acid sulphate of soda in a state of fusion, and the mixture is heated and stirred till a sample colours water violet. The paste thus produced is then intimately mixed with 70 or 80 times its weight of water, and the colouring matter is precipitated by common salt and washed with saline water. After drying it forms a mass of interlaced silky crystals having a coppery lustre.

INDIGO-RED. A red substance found in commercial indigo. For particulars relative to this and other indigo colours, consult Watts's 'Dictionary of Chemistry,' and the authorities there quoted.

INDISINE. See Aniline-Violet.

INDIUM. This metal was discovered in 1863, by Professors Reich and Richter, who detected it, by the aid of spectrum analysis, in the zinc-blende of Freiberg in Saxony. The spectrum of salts of indium is characterised by two indigo-blue lines, one very bright, and the other fainter. Indium is a soft, malleable, lead-grey metal, of specific gravity 7·2. The atomic weight is believed to be 74. The metal is readily soluble in hydrochloric acid, forming a deliquescent chloride of indium. The salts of indium have hitherto been but imperfectly studied, and none of them have yet found any application in the arts.

INGRAIN. Wools, &c., are said to be dyed *ingrain* when they are subjected to that process before manufacture.

INK. (*Encre,* Fr.; *Tinte,* Ger.)

Writing Ink may be and is prepared in many different ways; but it is essentially a tanno-gallate of iron.

Nut-galls, sulphate of iron, and gum are the only substances truly useful in the preparation of ordinary ink; the other things, often added, merely modify the shade and considerably diminish the cost to the manufacturer upon the great scale. Many of these inks contain little gallic acid or tannin, and are therefore of inferior quality. To make 12 gallons of ink, we may take 12 pounds of nut-galls, 5 pounds of green sulphate of iron, 5 pounds of gum Senegal, 12 gallons of water. The bruised nut-galls are to be put into a cylindrical copper, of a depth equal to its diameter, and boiled during three hours, with three-fourths of the above quantity of water, taking care to add fresh water to replace what is lost by evaporation. The decoction is to be emptied into a tub, allowed to settle, and the clear liquid being drawn off, the lees are to be drained. The gum is to be dissolved in a small quantity of hot water, and the mucilage thus formed, being filtered, is added to the clear decoction. The sulphate of iron must likewise be separately dissolved, and well mixed with the above. The colour darkens by degrees, in consequence of the peroxidation of the iron, on exposing the ink to the action of the air. But ink affords a more durable writing when used in the pale state, because its particles are then finer and penetrate the paper more intimately. When ink consists chiefly of tannate of peroxide of iron, however black, it is merely superficial, and is easily erased or effaced. Therefore, whenever the liquid made by the above recipe has acquired a moderately deep tint, it should be drawn off clear into bottles and well corked up. Some ink-makers allow it to mould a little in the casks before bottling, and suppose that it will thereby be not so liable to become mouldy in the bottles.

From the comparatively high price of gall-nuts, sumach, logwood, and even oak bark are too frequently substituted, to a considerable degree, in the manufacture of ink; but always injuriously.

The ink made by the recipe given above, is much more rich and powerful than many of the inks commonly sold. To bring to their standard a half more water may safely be added, or even twenty gallons of tolerable ink may be made from that weight of materials.

Sumach and logwood admit of only about one half of the copperas that galls will take to bring out the maximum amount of black dye.

Lewis, who made exact experiments on inks, assigned the proportion of three parts of galls to one of sulphate of iron, which, with average galls, will answer very well; but good galls will admit of more copperas.

Red Ink.—This ink may be made by infusing for three or four days in weak vinegar, Brazil wool chipped into small pieces; the infusion may then be boiled upon the wood for an hour, strained and thickened slightly with gum arabic and sugar. A little alum improves the colour. A decoction of cochineal with a little water of ammonia, forms a more beautiful red ink, but it is fugitive. An extemporaneous red ink of the same kind may be made by dissolving carmine in weak water of ammonia, and adding a little mucilage.

Blue Ink.—Mr. Stephens's patent blue ink is made by dissolving Prussian blue in a solution of oxalic acid. The blue should be washed in dilute muriatic acid. M. Harnung has given the following as the best formula for blue ink:—

Mix 4 parts of perchloride of iron in solution with 750 parts of water, then add 4 parts of cyanide of potassium dissolved in a little water; collect the precipitate formed, wash it with several additions of water, allow it to drain until it weighs about 200 parts; add to this one part of oxalic acid, and promote solution of the cyanide by shaking the bottle containing the mixture. The addition of gum and sugar is useless, and even appears to exercise a prejudicial effect on the beauty of the ink. It may be kept without any addition for a long time.

Gold and Silver Inks are prepared by grinding upon a porphyry slab, with a muller, gold or silver leaves, with white honey, until they are reduced to the finest possible state of division. The honey is thoroughly washed from the powdered metals, and these are mixed up with gum-water.

Indelible Ink.—A very good ink, capable of resisting chlorine, oxalic acid, and ablution with a hair-pencil or sponge, may be made by mixing some of the ink made by the preceding prescription, with a little genuine China ink. It writes well. Many other formulæ have been given for indelible inks, but they are all inferior in simplicity and usefulness to the one now prescribed. Solution of nitrate of silver thickened with gum, and written with upon linen or cotton cloth, previously imbued with a solution of soda, and dried, is the ordinary permanent ink of the shops. Before the cloths are washed the writing should be exposed to the sunbeam, or to bright daylight, which blackens and fixes the oxide of silver. It is easily discharged by chlorine and ammonia.

A good permanent ink may be made by mixing a strong solution of chloride of platinum with a little potash, sugar, and gum to thicken. The writing made therewith should be passed over with a hot smoothing iron to fix it.

Another indelible ink may be prepared by adding lamp-black and indigo to a solution of the gluten of wheat in acetic acid. This ink is of a beautiful black colour, at the same time cheap, and cannot be removed by water, chlorine, or dilute acids. M. Herberger gives the following directions for its preparation:—Wheat gluten is carefully freed from the starch, and then dissolved in a little weak acetic acid; the liquid is now mixed with so much rain-water that the solution has about the strength of wine vinegar, that is, neutralises $\frac{1}{16}$th of its weight of carbonate of soda. 10 grains of the best lamp-black and 2 grains of indigo are mixed with 4 ounces of the solution of gluten, and a little oil of cloves added. This ink may be employed for marking linen, as it does not resist mechanical force.

Indelible ink of Dr. Traill is essentially the same as above.

French indelible ink is made of Indian ink diffused through dilute muriatic acid for writing with quills, and through weak potash-lye for writing with steel pens.

Marking Ink.—The inks used for marking linen generally consist of a solution of nitrate of silver, coloured with sap-green, Indian ink, or some other colouring agent, and thickened with gum. Under the combined influence of light and the organic matter, the salt of silver is decomposed, and a black stain is produced. This is indelible when washed with soap and water, but may be removed by a solution of cyanide of potassium.

A cheap indelible marking-ink, which resists the action of chlorine, and is employed by bleachers to mark their goods, is prepared by dissolving coal-tar in naphtha.

Ink-powders are occasionally used, but consist merely of the common constituents of ink in a dry state. A black ink of this kind may be prepared by mixing 4 parts of powdered gall-nuts with 2 parts of green copperas and 1 part of gum arabic. This mixture may be conveniently carried in the form of a powder, and may be prepared for use by simply dissolving it in water.

China or *Indian Ink.*—Proust says that lamp-black purified by potash-lye, when mixed with a solution of glue and dried, formed an ink which was preferred by artists to that of China. M. Merimée, in his interesting treatise entitled *De la Peinture à l'Huile*, says, that the Chinese do not use glue in the fabrication of their ink; but that they add vegetable juices, which render it more brilliant and more indelible upon paper. When the best lamp-black is levigated with the purest gelatine or solution of glue, it forms, no doubt, ink of a good colour, but wants the shining fracture, and is not so permanent on paper as good China ink, and it stiffens in cold weather into a tremulous jelly. Glue may be deprived of the gelatinising property by boiling it for a long time, or subjecting it to a high heat in a Papin's digester; but as ammonia is apt to be generated in this way, M. Merimée recommends starch-gum, made by sulphuric acid, to be used in preference to glue. He gives, however, the following directions for preparing this ink with glue. Into a solution of glue he pours a concentrated solution of gall-nuts, which occasions an elastic resinous-looking precipitate. He washes this matter with hot water, and dissolves it in a spare solution of clarified glue. He filters anew, and concentrates it to the proper degree for being incorporated with the purified lamp-black. The astringent principle in vegetables does not precipitate gelatine when its acid is saturated, as is done by boiling the nut-galls with lime-water or magnesia. The first mode of making the ink is to be preferred. The lamp-black is said to be made in China, by collecting the smoke of the oil of sesame. A little camphor (about 2 per cent.) has been detected in the ink of China, and is supposed to improve it. Infusion of galls renders the ink permanent on paper.

Printing Ink.—This is essentially a combination of lamp-black—finely-divided carbon—with oil. Mr. Underwood, in a communication made by him to the Society of Arts, well defines the necessary qualifications of a good ink:—

1. It must distribute freely and easily, and work sharp and clean.

2. It must not have too much tenacity for the type, but have a much greater affinity for the paper, and so come off freely upon it.

3. It must dry almost immediately on the paper, and not dry at all on the type or rollers: this is a great desideratum, especially for newspapers.

4. It should be literally proof against the effects of time and chemical reagents, and never change colour.

Great attention must be paid to the quality of the linseed-oil employed, and even the character of seed from which the oil is obtained should not be neglected.

The linseed-oil is clarified from the fatty matters, and the pure oil is boiled with great care at a carefully-regulated temperature; and, during the boiling, the best pale yellow soap is added to give it consistency, and the required dryers are also now mixed with it. The best black is that obtained from the smoke of naphtha, the combustion being carefully regulated. This black is ground up carefully with the drying oil, which has assumed the character of a varnish, and the ink is complete.

INKING-ROLLER. See Printing.

INOSITE. A variety of glucose, or grape-sugar, occurring in the muscles of the heart and of certain other organs. It is also found in the kidney-bean, whence it is sometimes termed *phaseomannite.*

INSTANTANEOUS MATCHES. See Matches.

INULIN. A substance similar in its properties to starch, discovered by Rose in 1804. It has been obtained from elecampane root, potato and dahlia tubers, from dandelion roots, and many other similar plants. See Watts's 'Dictionary of Chemistry.'

INVERTED SUGAR. A peculiar kind of sugar, formed by the prolonged boiling of ordinary cane-sugar with water.

IODIC MERCURY. See Mercury.

IODIDES. Compounds of iodine with metals or radicals. The more important are described under the respective metals, as iodide of potassium, under Potassium.

IODINE (*Iod*, Fr.; *Jod*, Ger.) is one of the elementary substances; it was accidentally discovered in 1812 by M. Courtois, a manufacturer of saltpetre at Paris. He found that, in the manufacture of soda from the ashes of seaweeds, the metallic vessels in which the processes were conducted became much corroded; and in searching for the cause of the corrosion, he discovered this now important substance. It was first described by Clement in 1813, but was afterwards more fully investigated by Davy and Gay-Lussac.

Gay-Lussac and Clement at first regarded hydriodic acid as hydrochloric acid, until Sir H. Davy suggested the idea of its being a new and peculiar acid, and iodine as a substance analogous in its chemical relations to chlorine.

It was named iodine from the Greek word ἰώδης, violet-coloured, on account of the colour of its vapour.

Iodine exists in many mineral waters, in combination with potassium and sodium.

In the mineral kingdom, iodine has been found in one or two rare ores, as in a mineral brought from Mexico, in which it existed in combination with silver, and also in one from Silesia in combination with zinc. See Iodite.

It exists also in very small quantities in sea-water, from which it is extracted by many seaweeds, which act therefore as concentrators of iodine; these seaweeds, when dried and ignited, yield an ash, technically called *kelp*, from which all the soda of commerce was previously obtained, but the chief value of the kelp now is on account of the iodine which it yields. The following is the process most generally adopted for the extraction of the iodine from the seaweeds:—

The sun-dried seaweed is incinerated in shallow excavations at a *low* temperature, for, if the temperature was allowed to rise too high, a considerable quantity of iodide of sodium would be lost by volatilisation. The half-fused ash or kelp which remains is broken into fragments, and treated with boiling water, which dissolves about one half of the ash.

The liquid thus obtained is evaporated, when, on cooling, the more crystallisable salts separate, viz., sulphate and carbonate of soda, with some chloride of potassium. The mother-liquor still contains the iodide of sodium, sulphide of sodium, and some carbonate of soda. This liquor is then mixed with about one-eighth of its bulk of sulphuric acid, and allowed to stand for twenty-four hours; carbonic and sulphurous acid, and sulphuretted hydrogen gases escape, a fresh quantity of sulphate of soda crystallising out, mixed with a precipitate of sulphur.

The supernatant acid liquor is then transferred to a leaden still, to which is adapted a double tubulated leaden head luted on with pipe-clay; it is then heated to 140° Fahr., when binoxide of manganese is added.

The temperature may be gently raised to 212° Fahr., but not higher, as some chlorine would come over, and combine with some of the iodine, forming chloride of iodine.

This iodine is condensed in spherical glass condensers, each having two mouths opposite to each other, and inserted the one into the other, the end one being fitted to the neck of the leaden head.

The iodine is purified by resublimation.

The following formula represents the reaction:—

Iodide of Sodium		Oxide of Manganese		Sulphuric Acid		Sulphate of Soda		Sulphate of Manganese		Iodine		Water
NaI	+	MnO^2	+	$2HSO^4$	=	$NaSO^4$	+	$MnSO^4$	+	I	+	$2HO$.
$\mathbf{2NaI}$	+	$\mathbf{MnO^2}$	+	$\mathbf{2H^2SO^4}$	=	$\mathbf{Na^2SO^4}$	+	$\mathbf{MnSO^4}$	+	$\mathbf{I^2}$	+	$\mathbf{2H^2O}$.

The British iodine is largely manufactured at Glasgow, from the kelp of the west coast of Ireland and the western islands of Scotland.

In Mr. E. C. C. Stanford's method of preparing kelp, the dried and compressed seaweed, instead of being burnt in the open air, is distilled in retorts with superheated steam, and thus all loss of iodine is prevented.

The methods of preparing iodine from the mother-liquor of the kelp have been variously modified. Thus, the use of oxide of manganese may be dispensed with; or chlorine of gas may be transmitted through the mother-liquor; or the liquor may be distilled with chloride of iron.

Another source of commercial iodine is to be found in Chili saltpetre, or native nitrate of soda. This salt in its raw state always contains iodine, though in only very small proportion. This iodine may be extracted from the mother-liquor left in the process of refining the salt, by treating the liquor with sulphurous or with nitrous acid.

Iodine is a crystallisable solid, its primary form being a rhombic octohedron. It is however usually met with in micaceous, soft, friable scales, having a greyish-black colour, a metallic lustre, and an acrid hot taste. Even at ordinary temperatures, and more especially when moist, it is sensibly volatile, emitting an odour like that of chlorine, only much weaker.

At 225° F. it fuses, and at 347° F. boils, and is converted into a magnificent violet vapour. It may nevertheless be distilled, in the presence of steam, at a temperature of 212°, as is seen in the process of manufacture.

Iodine, in the solid state, has a specific gravity of 4·947, the specific gravity of the vapour being, according to Dumas, 8·716. Iodine is only very slightly soluble in water, it requiring 7,000 parts of water to dissolve it; even then it imparts a yellow colour to the solution, and is used in that state as a test for starch, with which it forms a beautiful blue compound, which is, however, destroyed by heat.

Alcohol and ether dissolve it more readily; but the most powerful solvents of iodine are the solutions of the iodides. Iodine stains the skin, and most organic substances, of a brown colour; it attacks the metals rapidly; iron or zinc being readily dissolved by it if placed in water with it, an iodide of the metal being formed.

All the compounds of iodine with the metals and with hydrogen are decomposed by chlorine, and even by bromine, iodine being set free. Advantage is taken of this fact in detecting the presence of iodine. If the iodine exists in combination with a metal, or as hydriodic acid, its solution will not form the characteristic intense blue compound with starch, but on the addition of a little chlorine, or solution of bleaching powder, the iodine is set free and forms the blue compound with the starch. If, however, the iodine exists as iodic acid, it will not act upon starch until reduced by some reducing agent, as sulphurous acid. In using the chlorine care must be taken not to use too much, as it would unite with the iodine and prevent it acting on the starch.

Iodine is used to a considerable extent in medicine; particularly for glandular swellings, and goître. It is also much used in photography, and in the preparation of certain coal-tar colours. The chemical symbol for iodine is I; its atomic weight 126·88; and the combining volume of its vapour 2.

The price of iodine has suffered recently (1873–4) some remarkable fluctuations.

Messrs. Evans, Lescher, and Evans, in their monthly Drug-market Report for February, state that, in consequence of the makers having failed to carry out the combination which has hitherto kept up the price, iodine has suddenly, though not unexpectedly, fallen more than 50 per cent. in value, and in like manner iodide of potassium has equally declined. The immediate result of the fall is an immense demand from all quarters, everyone having let their stocks run out, greater than can be supplied at the moment. The decline has been followed immediately by a slight advance, which has now been considerably further augmented.

IODITE, or **IODYRITE.** A native iodide of silver, consisting of iodine 53·109 and silver 46·380. It is found at Guadalajara in Spain, at Albarradon near Mazapil in Zacatecas (Mexico), and at Delirio mines near Chañarcillo in Chili. See Silver.

IOLITE. A name applied to the mineral otherwise known as *cordierite* or *dichroite*, in allusion to the violet colour which it frequently presents. See Dichroite.

IPECACUANHA. The root of the *Cephaëlis Ipecacuanha*, valued in medicine as an expectorant, emetic, purgative, and sedative. It owes its active principle to an alkaloïd called *emetina*. The cultivation of the ipecacuanha plant has recently been introduced into India.

IRIDIUM. A rare white metal, found in connection with platinum and osmium. Smithson Tennant in 1804 discovered that certain black scales which remained after native platinum was dissolved in nitro-muriatic acid, was an alloy of two metals, iridium and osmium. For a full account of the methods of separating this native alloy from platinum, and of separating iridium and osmium from each other, consult Watts's 'Dictionary of Chemistry.' The native alloy on account of its hardness is used to point metallic pens. See Iridosmine.

IRIDIUM OXIDE. A substance is so known in the Russian mint. It consists, according to Deville, of:—volatile substances (and oxygen), 28·0; soluble salts, 12·0; platinum, 3·8; rhodium, 1·8; palladium, 0·4; copper, 0·6; iron, 0·7; iridium and loss, 52·7 = 100·0.

IRIDOSMINE. A native alloy of iridium and osmium found with native platinum.

IRISH DIAMONDS. A name sometimes applied to rock-crystal found in Ireland. It is occasionally cut and polished by the jeweller, and mounted in bog-oak.

IRISH GREEN. An architect's name for the green serpentinous marble of Connemara in Western Galway.

IRISH MOSS. A term applied to the seaweed, otherwise known as Carrageen moss (*Chondrus crispus*). It is used in the preparation of bandoline, and of a jelly for invalids. See Algæ.

IRON (*Fer*, Fr.; *Eisen*, Ger.) is a metal of a bluish-grey colour, and a dull fibrous fracture, but it is capable of acquiring a brilliant surface by polishing. Its specific gravity is 7·78. It is the most tenacious of metals, and the hardest of all those which are malleable and ductile. It is singularly susceptible of the magnetic property, but in its pure state soon loses it. When rubbed it has a slight smell, and it imparts to the tongue a peculiar astringent taste, called chalybeate. In a moist atmosphere iron speedily oxidises, and becomes covered with a brown coating called rust.

Every person knows the manifold uses of this truly precious metal. It is capable of being cast in moulds of any form; of being drawn out into wires of any desired strength or fineness; of being extended into plates or sheets; of being bent in every direction; of being sharpened, hardened, and softened at pleasure. Iron accommodates itself to all our wants, our desires, and even our caprices; it is equally serviceable to the arts, the sciences, to agriculture, and war; the same ore furnishes the sword, the ploughshare, the scythe, the pruning hook, the needle, the graver, the spring of a watch or of a carriage, the chisel, the chain, the anchor, the compass, the cannon, and the bomb. Iron in the state of peroxide, and in several chemical combinations, enters largely into our Pharmacopœias, this metal having been long a favourite medicine.

This metal has been found in a native state; but it is obtained by a metallurgical process from certain ores of iron, which are scattered over the crust of the globe with a beneficent profusion proportioned to the utility of the metal. They are found under every latitude, and every zone; in every mineral formation, and are disseminated in every soil.

The minerals containing iron as an essential constituent, and in considerable quantity, are very numerous, as the metal is found in the native state, forming very complicated mixtures with other elements, in masses of mainly extra-terrestial origin, and combined with arsenic, and sulphur, in various proportions in the different varieties of copper-iron- and arsenical-pyrites, and also with oxygen forming different oxides, which in their turn unite with water and with carbonic acid, forming the hydrates and carbonates of iron; these being the only minerals available for metallurgical treatment under ordinary circumstances. The silicates, sulphates, and phosphates of iron are also of great importance, in studying the production, of the ores of iron proper and in influencing their qualities for the smelter, but the interest is only an indirect one.

It is thought advisable in this place to describe only such native productions of iron as are of some such economic value, reserving for notice under their mineralogical names such as are merely interesting as minerals.

Useful Iron Ores.—See Iron Ores in its alphabetical place for the rare varieties.

Native Iron.—This species, which is very rare, occurs in small grains and plates, or massive and disseminated. It is malleable and ductile, more so than ordinary malleable iron, and ranges in specific gravity between 7 and 7·8. It contains carbon, and occasionally some other metal, but *not nickel.* A specimen from Gross Kamsdorf, in Thuringia, analysed by Klaproth, yielded 92·5 iron, 6 lead, and 1·5 copper: its structure was foilated and its texture crystalline. Native iron was found by Schreiber, in a vein at Oulle, near Allemont in Dauphiné. A specimen containing 91·8 iron and 7·0 carbon (*Shepard*), was observed at Canaan in Connecticut, in a vein, two inches broad, lying in mica slate; another specimen was found in sandstone at Penn Yan, in New York. *John* states that it is mixed with the platinum grains from South America, and more recently M. Molnar has affirmed that he has found native iron in the gold sands at Oláhpian. Mossier has found volcanic iron in lava at Graveneire in Auvergne; it had a steel-grey or silver-white colour, foilated texture, and hackly fracture; and Dr. Andrews states that he detected native iron in grains in the basaltic rock from the Giant's Causeway. These instances would seem to prove the actual existence of native iron, which was for a long time disputed.

Native Meteoric Iron.—This species is distinguished from the last by containing *nickel* and sometimes *cobalt.* It is very malleable, often cellular, but sometimes compact, and in parallel plates which pass into rhomboids or octohedrons. When polished and etched with acids, it exhibits linear and angular markings, or *Widmanstatt's* figures, as they have been termed, and from which an impression may be printed on paper. A great number of undoubted meteorites have been described and analysed. The following Table from Nicol's 'Manual of Mineralogy' exhibits the composition of some of the most remarkable:—

	Iron	Nickel	Cobalt	Copper	Manganese	Magnesium	Sulphur	Chlorine	Insol. matter	Total
1	93·78	3·81	0·21	...	...	...	...	...	2·20	100
2	88·04	10·73	0·46	0·07[1]	0·13	0·05	trace	...	0·48	100
3	88·23	8·52	0·76	...	trace	0·28	trace	...	2·21	100
4	89·78	8·89	0·67	...	...	...	...	...	...	99·34
5	85·61	12·27	0·89	...	...	...	...	...	...	98·77
6	90·88	8·45	0·67	0·002	...	...	...	...	...	100
7	66·56	24·71	...	...	3·24[2]	...	4·00	1·48	...	99·99
8	90·24	9·76	...	...	...	...	...	...	...	100
9	83·57	12·67	...	...	...	...	...	0·91[3]	...	99·54
10	92·58	5·71	...	trace[4]	...	...	...	...	1·40	99·69
11	81·8	11·9	1·0	...	0·2	...	5·1	...	...	100

[1] With tin+0·04 carbon.
[2] With chromium.
[3] +2·30 sulphide of iron.
[4] With arsenic.

The insoluble matter in the above contains in 100 parts:—

In No.	Iron	Nickel	Phosphorus	Silica	Carbon	Magnesium	Total
1	65·99	15·01	14·02	2·04	1·42	...	98·4
2	48·67	18·33	18·47	...	...	9·66	95·13
3	68·11	17·72	14·17	...	...	...	100·0
10	44·1	24·50	11·4	? 10·0	...	...	90·0

The above analyses are of:—1. A mass of 103 lbs. weight, which fell at Bohumilitz, in Bohemia, in 1829. 2. A mass weighing 1,600 lbs., found in 1748, near Krasnojarsk, on the Yenisei. 3. The so-called 'Verwünschte Burggraf,' from Elbogen in Bohemia, which weighed 191 lbs. 4. A mass of 71 Vienna pounds weight, which fell at Hraschina, near Agram, in Croatia, on May 26, 1751. 5. A mass in the Haarlem Museum, found in 1793, on the plain between the Great Fish River and Graf Reynet, in the Cape Colony, originally weighing 300 lbs. 6. Found at Lenarto, in Hungary, original weight 194 lbs. 7. From Clairborne in Alabama. 8. From Petosi.

9. Is a more recent analysis of the same. 10. From Lockport in North America. 11. From Bitburg, near Trèves, which weighed above 3,300 lbs.

According to *Shepard* ('Silliman's American Journal'), the fall of meteoric stones is confined principally to two zones. The one, belonging to America, lies between 33° and 44° N. lat., and is about 25° in length. Its direction is more or less from N.E. to S.W., following the general line of the Atlantic coast. Of all the occurrences of this phenomenon during the last 50 years, 92·8 per cent. have taken place within these limits, and mostly in the neighbourhood of the sea. The zone of the eastern continent, with the exception that it extends 10° further to the north, is bounded by the same degrees of latitude, and follows a similar north-east direction; but it has more than twice the length of the American zone. Of the observed falls of aërolites, 90·9 per cent. occurred within this area, and were also concentrated in that half of the zone which extends along the Atlantic.

Amongst the remarkable masses of meteoric iron the following must be named:—that found by Don Rubin de Celis, in Tucuman in South America in 1783, weighing 300 cwts.; that discovered in 1784 on the Riacho de Bendego in Brazil, estimated to measure 32 cubic feet, and to weigh 17,300 lbs.; and that on the Red River in Louisiana, weighing above 3,000 lbs., and presenting distinct octahedral crystals.

The Swedish expedition to Greenland discovered some enormous masses of meteoric iron in 1870, and in 1871 it brought back twenty specimens, amongst which were two of enormous size; the largest, weighing more than 49,000 Swedish pounds, or about 21 tons English, with a maximum sectional area of 42 square feet, is now placed in the hall of the Royal Academy of Stockholm; whilst, as a compliment to Denmark, on whose territory they were found, the second largest, weighing 20,000 lbs., or about 9 tons, has been presented to the museum of Copenhagen. Chemical analyses of these remarkable masses have proved them to contain nearly 5 per cent. of nickel, with from 1 to 2 per cent. of carbon, and to be quite identical with many aërolites of known meteoric origin. These masses were discovered lying loose on the shore, but immediately resting upon basaltic rocks, in which they appear to have been originally imbedded. Professor Nordenskjöld and several others familiar with meteoric irons consider these masses to be meteorites. See Aërolites.

Franklinite.—This ore of iron usually crystallises in octahedra, but is also found massive. According to Rammelsberg, it consists of iron 45·16, manganese 9·38, zinc 20·30, oxygen 25·16. It is said to occur in amorphous masses at Altenberg, near Aix-la-Chapelle, but it is found abundantly at Hamburgh, New Jersey, where it occurs in a metamorphic Silurian limestone with red oxide of zinc and garnet. It is also found at Stirling Hill in the same locality, where it is associated with *Willemite* in a large vein, in which cavities occasionally contain crystals from 1 to 4 inches diameter. The attempts to use this ore have not been very successful. Dana says it is ground up and used for a dark paint, and some of it has been smelted for iron, to which the zinc is thought to give tenacity. The zinc has also been separated and the residues smelted for spiegeleisen. See Franklinite.

Magnetite, *Magnetic Iron Ore*, *Native Loadstone*, or *Octahedral Iron Ore.*—This very rich and valuable ore occurs especially in igneous or metamorphic rocks, either in distinct crystals, or, as in many basalts, disseminated through the mass, when it frequently imparts magnetic properties to the rocks, especially to greenstone, serpentine and basalt. It also forms beds in gneiss, in chlorite-, mica-, hornblende-, and clay-slates, in marble, greenstone, and other rocks, but seldom appears in veins. The largest known masses occur in the northern parts of the globe, in Scandinavia, Lapland, Siberia, and North America. Less extensive masses occur in the Hartz, in Saxony, Bohemia, Silesia, and Styria; and in Southern Europe, in Elba and Spain. Magnetite is the most important ore of iron in Norway, Sweden, and Russia. The Dannemora mines in Sweden, wrought in an open quarry 150 feet broad, and 500 feet deep, furnish the fine Oeregrund iron, largely imported into England for the manufacture of steel. Some highly magnetic varieties, especially from Siberia and the Hartz, form natural magnets, possessing distinct polarity. Others become polar only after contact with magnets of sufficient power. Magnetic iron ore is found in rather considerable masses not far from Haytor on Dartmoor, and near the village of Brent, at the southern extremity of Dartmoor. It is also found in Cornwall, in the vicinity of the Indian Queens; near Penryn, Ponsanooth, and a few other localities. Magnetic iron ore fuses with extreme difficulty; it is not acted upon by nitric acid, but when powdered is soluble in hydrochloric; its specific gravity varies from 4·24 to 5·4. The chemical formula of pure magnetite is FeO,Fe^2O^3, corresponding to 31·03 of protoxide, and 68·77 of peroxide of iron, or of 72·40 iron, and 27·60 oxygen, which agrees closely with the analyses of Berzelius, Kobell, and Karsten.

Analyses I. and II. are of magnetic iron ore from Cornwall by Noad; III. of Dannemora magnetite by Ward:—

	I.	II.	III.
Water	2·50	3·20	0·11
Protoxide of iron . .	20·00	13·00	27·55
Peroxide of iron . .	44·40	66·50	58·93
Protoxide of manganese .	0·16	0·56	0·10
Alumina	5·20	3·60	0·29
Lime	0·60	0·56	0·38
Magnesia	1·00	1·52	0·61
Sulphuric acid . . .	0·04	0·04	0·10
Phosphoric acid . . .	0·50	0·57	trace
Insoluble residue . .	24·20	9·40	12·54
Total . .	99·60	98·95	100·61
Metallic iron . . .	46·8	57·56	61·16

Hæmatite; Specular Iron; Fer oligiste; Micaceous Iron Ore.—This ore has a metallic lustre; colour, iron black to steel grey, but often tarnished; the light transmitted through the thin edges of its crystals appears of a beautiful red colour. Its powder is always of a well-marked brown-red hue, passing into cherry red, which distinguishes it from the black oxide ore; its fracture is conchoidal or uneven; it is brittle, and its specific gravity is 5·2. Its chemical composition is Fe^2O^3, or 70·03 iron, and 29·97 oxygen; in the reducing flame of the blowpipe, it becomes black and magnetic.

Specular iron includes specimens of a perfect metallic lustre. The specular variety occurs chiefly in crystalline rocks in large beds or veins. The mines of the island of Elba, celebrated from antiquity, still furnish the finest crystals, which occur in druses of the massive variety, along with pyrites and quartz; fine crystals are likewise produced from St. Gotthard, Framont, in the Vosges mountains, the Hartz, Altenberg in Sweden, and from Katharinenburg in the Ural.

Micaceous iron ore is that variety of hæmatite which has a distinctly micaceous character. Beautiful specimens of the micaceous variety occur at Zorge and other parts of the Hartz. At Hennock, not far from Haytor on Dartmoor, a very large lode of the micaceous ore exists; it is also found near Tavistock in Devonshire, at Huel Owles tin mine, and Botallack tin and copper mine at St. Just in Cornwall, and in Wales, Cumberland, and Perthshire. It also occurs in volcanic rocks, as in Auvergne, on Vesuvius, Ætna, and the Lipari Islands, especially Stromboli, where some fine crystals, three inches broad and four long, have been procured.

Hæmatite is a term more strictly applied to the red varieties of the specular iron ores, on account of the red colour of its powder, from ἁιμα, blood. The red hæmatites are those which have a distinctly red colour when scratched, or which yield a red streak. One variety is known as *fibrous red iron.* If soft and earthy, it is called *red ochre*; a peculiar variety of this kind is found near Rotherham in Yorkshire, and is known as *raddle.* It is used for polishing lenses in Sheffield, and largely employed for marking sheep. The *red chalk* used for drawing is a variety of the same kind.

Red hæmatite.—This ore is found in the greatest abundance in the mountain or carboniferous limestone formations. The most abundant deposits in this country are those of Lancashire and Cumberland.

The hæmatite of Whitehaven occurs in the carboniferous limestones near the outcrop or surface-edge of the slaty rocks upon which that formation rests. The greater part of the excavations from which it is extracted are subterraneous, and so extensive is often the mass of iron ore in which the workings are carried on, that it is difficult in such situations to obtain a clear idea of the nature of this important deposit. (*Warington Smyth.*)

The following are the quantities of red hæmatite produced since 1868:—

	1868	1869	1870	1871	1872
Lancashire:	tons	tons	tons	tons	tons
Barrow-in-Furness	767,625	784,507	871,938	931,048	909,077
Cumberland:					
Hodbarrow . .	201,380	198,705	174,943	207,146	211,771
Whitehaven . .	725,248	848,974	1,014,143	976,874	954,505
Total . .	1,694,253	1,932,186	2,061,024	2,115,068	2,075,353

The price, which was about 11*s.* or 13*s.* a ton in 1865, varies now (1873) from 30*s.* to 36*s.* per ton, owing to the great demand for hæmatite pig-iron for Bessemer-steel making.

In addition to the above, it is thought desirable, as showing the very large quantities of ore which are raised from these hæmatite mines, to give the detailed produce for a single year, 1872:—

Lancashire.

No.	District or mine	Quantities		Value		
		tons	cwts.	£	*s.*	*d.*
1	Askham	5,718	0	7,000	0	0
2	Crossgate	28,793	0	35,991	5	0
3	Dalton Mine	27,693	0	34,616	5	0
4	Dunnerdale	2,105	13	1,453	1	0
5	Elliscales	18,749	0	23,436	5	0
6	Goldmine	Nil.		...		
7	Highfield	15,784	0	19,680	0	0
8	Lindale Moor	4,407	0	5,508	15	0
9	Lindale Cote Eure Pits	42,679	0	52,848	15	0
10	Lindale Moor and Gilbrow and Whitriggs	158,341	0	197,926	5	0
11	Longlands	352	0	343	0	0
12	Martin	28,605	0	35,759	5	0
13	Moot Hall	1,500	0	1,875	0	0
14	Monsell	24,174	0	30,220	0	0
15	Newton	6,300	0	7,875	0	0
16	Park	262,305	0	327,881	5	0
17	Parkhouse	26,191	0	32,738	15	0
18	Pennington	2,421	0	3,026	0	0
19	Plumpton	4,307	0	5,383	15	0
20	Roanhead and Askham	170,769	0	213,461	5	0
21	Stainton and Bolton Heads	1,770	0	2,212	10	0
22	Stank	6,052	0	7,565	0	0
23	Thwaite Feart	1,761	0	2,289	6	0
24	Urswick	322	19	390	2	7
25	Whitriggs	10,965	0	13,706	5	0
	Sundry other mines	55,013	0	...		
	Total of Lancashire iron ore	909,079	12	1,118,186	19	7

Cumberland.

No.	District or mine	Quantities		Value		
		tons	cwts.	£	*s.*	*d.*
1	Bigrigg and Cleator Moor	73,913	0	92,391	0	0
2	Birks	10,773	0	13,466	5	0
3	Cleator	69,183	0	86,478	15	0
4	Cropfield	63,068	0	78,835	0	0
5	Cropgill	36,370	0	45,562	10	0
6	Eskdale	3,000	0	3,750	0	0
7	Eskett	26,760	0	33,450	0	0
8	James and John	8,520	0	10,650	0	0
9	James's Mine and New Pit	9,055	18	11.319	0	0
10	Fronington Parks	4,559	1	4,559	1	0
11	High House	20,090	17	25,112	0	0
12	Hodbarrow	211,771	0	264,713	15	0
13	Kelton and Knockmurton	14,435	0	18,044	0	0
14	Montreal	241,048	0	301,310	0	0
15	Salter and Eskatt Park	103,000	0	128,750	0	0
16	Waterblear	500	0	500	0	0
17	Winder (1.)	540	0	675	0	0
18	Winder (2.)	3,938	0	4,922	10	0
19	Woodend	16,928	1	16,928	1	0
	Sundries	37,053	0	...		
	Total of Cumberland iron ore	954,505	9	1,178,416	17	0

The following analyses of some carefully-selected samples of the hæmatite of the carboniferous limestone are by Messrs. Dick and Spiller. (*Memoirs of the Geological Survey of Great Britain. The Iron Ores of Great Britain.* Part I.)

	Cleator Moor	Cleator Moor	Ulverstone	Lindall Moor, near Ulverstone
Peroxide of iron	95·16	90·36	86·50	94·23
Protoxide of manganese	0·24	0·10	0·21	0·23
Alumina	...	0·37	...	0·51
Lime	0·07	0·71	2·77	0·05
Magnesia	...	0·06	1·46	trace
Phosphoric acid	trace	trace	trace	trace
Sulphuric acid	trace	trace	0·11	0·09
Bisulphide of iron	trace	0·06	...	0·03
Water, hygroscopic	...	...	...	0·39
„ combined	...	...	...	0·17
Insoluble residue	5·68	8·54	6·55	5·18
Carbonic acid	...	...	2·96	...
Total	101·15	100·20	100·56	100·88
Metallic iron	66·6	63·25	60·55	65·96

The carboniferous limestones of Derbyshire and Somersetshire also contain veins and deposits of hæmatite, though of a quality not equal to those of Lancashire; the same ore is also met with in the Devonian series of Devon, West Somerset, and Cornwall. See HÆMATITE.

Brown Hematite.—Under this term are included the following minerals:—

1. Turgite, of the composition $2Fe^2O^3+HO$ with 5·6 per cent. of water.
2. Göthite „ Fe^2O^3+HO „ 10·1 „
3. Limonite „ $2Fe^2O^3+3HO$ „ 14·4 „

Of these minerals, the first also known as *hydro-hæmatite*, resembles the ordinary red hæmatite, giving a bright red streak, but decrepitates when heated. It has hitherto been considered to be of rare occurrence; but latterly it has been generally recognised that the red ore of Bilbao is to a considerable extent of this composition, and probably all hydrated ores giving a red as distinguished from a brown streak may be referred here. Göthite is a finely-crystallised mineral, which has been found at Restormel in Cornwall in great abundance; other varieties are known as *Lepidocrocite* and *Stilpnosiderite.*

Limonite includes all the massive and earthy varieties. The so-called *hydrate of iron* is a calcareous brown hæmatite, occurring at the base of the Cheadle coal-field in North Staffordshire. It is highly esteemed in South Staffordshire for making special classes of pig-iron.

Brown hæmatites being in all cases produced by the alteration of other ores, their quality is in great part determined by the composition of the mineral from which they have been derived. Substantially they may be referred to the action of atmospheric air and water upon two minerals—namely, carbonate of protoxide of iron, and iron pyrites—and in a lesser degree they may be formed from magnetite or silicates containing protoxide of iron. Beds of clay ironstone (argillaceous carbonate) are usually altered at the surface into an earthy brown hæmatite, and lodes of spathic carbonate are at times changed to considerable depths into a similar substance, which change in composition is often not attended with any alteration of form, but the mass becomes spongy in the interior, giving a free passage to the reducing gases in the furnace, which renders them easily reducible; a change that is further accelerated by the fissuring produced by the expulsion of the confined water on heating. The great brown iron ore lodes of Bilbao, which occur in cretaceous limestones, are supposed to be likely to produce spathic ores when worked to greater depths.

The change of iron pyrites into brown iron ore is familiar to all miners under the term of gozzan, where the pyritic contents of lodes have been changed to a red rusty mass, which is taken as an indication of the presence of the sulphides of the more valuable metals in depth. These gozzans are not workable as iron ores, mainly from the presence of quartz, and sulphides and arsenides of other metals. A very good ore derived from the alteration of iron pyrites is shipped in considerable quantities from Santander, and masses of the original mineral may be found unchanged in the centre of some of the larger masses.

When the original carbonate contains manganese, the derived brown ore will generally be associated with pyrolusite or other highly-oxidised manganese ores, forming an intimate mixture suitable for simultaneous reduction, with the production of a highly manganesiferous pig-iron. Such ores are common in the Siegen districts of Rhenish Prussia, and in the neighbourhood of Carthagena in Spain, from which latter locality they are largely exported to England, Belgium, and other parts of Europe.

The largest developments of this class of ore in England are in the lower secondary strata, where it is found at different horizons in the oolitic rocks all through the midland counties, from Wiltshire to Lincolnshire; the most important localities being in Northamptonshire. As a rule these are of a low quality, containing not more than 35 per cent. of iron, with a considerable quantity of sand, and a high proportion of phosphorus; but from the low cost at which they can be raised, being got in open quarry workings, they are in great demand for mixing with the higher class but more expensive ores of Wales and South Staffordshire, besides being largely smelted on the spot.

In addition to the ordinary atmospheric action, the production of brown iron ores is largely due to organic agency in the so-called bog- and lake-ores, which are produced by the action of minute vegetable organisms (*diatoms*), on iron in solution in stagnating waters. These ores are generally very impure, containing large quantities of sand and a good deal of phosphorus; bog-ore is usually found in irregular concretions, forming at times connected beds, but more generally they are detached in swampy and forest-ground at a short distance below the surface. The lake-ores which are found in Sweden and Finland are entirely of organic origin; they form small granular or disc-like concretions, which are dredged up from the beds of lakes during the winter. The formation goes on continuously, so that, after clearing the ground, a fresh deposit of workable thickness is re-formed in about twenty years. The varying nature of ores of this class will be seen from the following analyses:—

Analyses of Brown Iron Ores from various sources.

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.
Peroxide of iron	90·05	89·76	59·05	52·83	52·86	67.59	62·59	27·93	25·50
Protoxide of iron	...	...	...	...	...	...	...	5·08	...
„ manganese	0·08	0·04	0·09	0·81	0·51	1·45	8·52	...	...
Lime	0·06	0·49	0·25	14·61	7·46	0·47	...	0·91	0·02
Alumina	...	0·63	...	...	7·39	4·18	...	34·47	57·40
Magnesia	0·20	0·40	0·28	5·70	0·68	0·23	...	0·62	...
Carbonic acid	...	...	...	18·14	...	...	...	...	...
Phosphoric acid	0·09	0·13	0·06	0·32	1·26	0·18	1·50	...	...
Sulphuric acid	...	...	0·09	0·28	0·06	...	trace	...	...
Silica	...	...	34·40	...	13·16	7·81	11·37	9·87	2·80
Water	9·22	7·05	6·38	4·75	11·37	17·81	16·02	19·36	11·00
Organic matter	...	...	...	1·30	...				
Insoluble residue	1·07	2·57	...	0·04	...	...	...	...	...
Metallic iron	63·04	62·86	41·34	36·98	37·00	47·32	43·82	...	...

I. Black brush ore; II. Smith ore—Forest of Dean. III. Llantrissant ore. IV. Froghall calcareous ore, or 'Hydrate of iron.' V. Northampton ore, from the inferior oolite, Wellingborough. VI. Lake ore, from Platen, Wermland, Sweden. VII. Bog iron ore, from Lingen, in East Friesland. VIII. Belfast aluminous ore, containing in addition 3·51 of titanic acid. IX. Bauxite, from Baux, in the south of France, with 3·10 of titanic acid.

A special class of brown iron ores has of late become of considerable importance. These are the aluminous ores, consisting essentially of mixtures of hydrated peroxide of iron and alumina. The proportion of iron varies considerably, but they are valued chiefly for the alumina, on account of its fluxing power, being used to prevent the reduction of silica and the formation of extra siliciferous iron when smelting hæmatite containing quartz. These ores are known as 'Belfast aluminous ores,' from their occurrence in the county of Antrim; and by the mineralogical name of Bauxite, from the locality in the south of France where it was first discovered. A yet more aluminous variety is obtained in Carniola. The Irish ore occurs in a thin irregular bed of concretionary pisolitic structure, interstratified in the great mass of basalt covering the whole of the county of Antrim north of Belfast.

Passing east from Slievananee, the iron-beds are worked from the face of the basaltic escarpment overhanging Milltown, Red Bay, at the entrance of Glenariff Glen. The beds dip west about 5°, and are about 200 feet above the upper limit of the White Limestone. Further to the east the iron-band has been traced to near Garron Point. Two miles to the west of Carnlough the ferruginous series is seen at a height of 600 feet above the sea-level, dipping at an angle of about 40° E. magnetic. The matrix of the pisolitic ore, 22 inches in thickness, is of a bright vermilion-red colour, becoming browner as it passes downward; it then passes into a friable yellowish ochre, 4½ feet thick, which, in its turn, graduates into a blue lithomarge 35 feet thick. Overlying the pisolitic ore is a semi-prismatic basalt, the columns of which are perpendicular, and consequently include with the underlying strata an angle of 50°.

Other outcrops are worked at Ballyvaddy and Tully, near Glenarm, and at Anteville, Kilwaughter, and Shane's Hill, near Larne.

The following Table of analyses of the pisolite ores of Antrim is from Messrs. Tate and Holden's paper, published in the 'Quarterly Journal of the Geological Society':—

Names of mines	Kilwaughter	Tully	Red Bay	Red Bay	Slievananee	Slievananee
Peroxide of iron	45·00	45·50	59·40	77·22	71·00	81·50
Protoxide of iron	...	...	...	...	18·00	...
Oxide of manganese	trace	trace	...	...	trace	2·57
Titanic acid	36·44	2·00	...	trace	...	trace
Vanadic acid		...				
Alumina, soluble in acids		3·00	2·80	...	...	4·20
„ insoluble		32·50				
Silica, insoluble		3·50	10·40	20·65	9·00	8·50
Silica, soluble		0·50				
Magnesia	2·44	...	...	...	...	...
Lime	0·56	0·35	...	...	...	·93
Water of combination	18·00	12·65	8·40	2·13	...	1·96
Percentage of metallic iron	31·50	31·85	41·58	54·05	63·70	65·20
Analyst	J. Cameron	J. Cameron	Dr. Apjohn	J. Cameron	J. Cameron	Prof. Hodges

Lithomarge is an aluminous mineral found in Ireland, with the Antrim ore.

	I. Basalt	II. Basalt	III. Lithomarge	IV. Ochre	V. Bole
Silica	39·72	53·70	49·75	56·40	30·88
Alumina	14·32	25·41	29·88	3·46	20·76
Peroxide of iron	27·87	8·95	6·61	24·14	26·16
Lime	4·15	4·55	0·43	0·90	2·60
Magnesia	4·00	...	1·47	...	...
Sulphide of iron	...	trace	...	...	...
Soda	9·94	...	...	...	...
Potash		...	6·35	15·10	...
Water		4·30	4·48	...	19·60

I. Slieve Gallion; Dr. Apjohn. II. Antrim; Professor Hodges. III. Lithomarge; Germany. IV. Drumrankin, near Ballymena; Dr. Apjohn. V. Bole, Germany.

'There can be no doubt that the lithomarge and bole alternating with compact basalts are but decomposed basalts. The passage from basalt to lithomarge and bole can be traced in all cases; not unfrequently large masses of basalt are to be seen in the midst of the lithomarge, the concentric layers presenting all the varieties of texture and colour between the hard and black basalt of the interior and the purple or yellowish argillaceous masses in which the basalt appears to be imbedded. Again, the boles often contain cavities filled with the ordinary zeolites of the amygdaloid basalts.

'Observations in the field and the preceding comparative analyses go far to prove that the bole and lithomarge are the resultants of aqueous action in combination with acidulated gases, which, dissolving out certain mineral substances, has effected the decomposition of the basalts, especially of the more felspathic ones.'—*Tate and Holden.*

The following is a series of analyses of Forest of Dean ores, by Dr. Noad:—

	I.	II.	III.	IV.	V.
Water . . .	3·16	5·80	2·90	2·11	7·70
Carb. lime . .	27·00	25·50	39·60	14·10	18·40
„ magnesia .	15·00	18·30	25·00	17·10	18·80
Oxide manganese .	...	...	...	...	0·20
Peroxide of iron .	40·80	38·10	29·00	59·70	36·62
Alumina . . .	6·00	3·60	...	1·89	...
Sulphuric acid . .	traces	traces	traces	traces	traces
Phosphoric acid .	traces	traces	traces	0·20	0·30
Insoluble residue .	8·84	8·70	3·50	5·10	18·00
	100·80	100·00	100·00	100·26	100·02

This brown iron ore is also found at Alston Moor and Weardale, Durham, but is only used to a limited extent on account of its association with lead and zinc. It occurs at Llantrissant, near Cardiff; in many parts of Devon, especially at Smallacombe, near Newton Abbot; and at Sharkam Point, near Brixham. It has also been recently found at Poltimore, near South Molton, in Devonshire, much of it containing considerable quantities of manganese. In Cornwall the brown hæmatite is worked at Restormel, near Lostwithiel; at several places around St. Austell; in Constantine; and other parts.

Some of the brown hæmatites contain a large percentage of manganese. Their general composition is illustrated in the following analyses (*Dr. Noad*):—

	I.	II.	III.	IV.
Water	12·85	12·80	12·40	13·20
Oxide of manganese . . .	3·08	9·60	8·80	11·20
Lime	...	...	...	...
Magnesia	1·72	1·10	1·20	1·08
Alumina	1·20	0·92	1·20	1·04
Peroxide of iron . . .	68·57	68·45	67·77	66·98
Sulphuric acid	0·11	0·11	0·10	0·096
Phosphoric acid	1·01	1·02	1·12	1·054
Insoluble residue	12·00	9·50	8·80	11·200
	100·54	101·20	99·79	100·85

The brown iron ores of the secondary formations have of late years assumed considerable importance. In the Lias, the Oolite, and in the Lower Greensand formations, brown hæmatites (that is, hydrated oxides of iron), generally impure and sandy, are found. They range almost continuously from the northern parts of Wiltshire to the wolds of Yorkshire, passing through Oxfordshire, Northamptonshire, and Lincolnshire, appearing as an ochreous brown oolitic rock. The most important bed is that occurring in the lower part of the great oolite, from the neighbourhood of Banbury through Northamptonshire. The extent of the workings in Northamptonshire will be best judged of by the following details of the quantities of iron ore produced from the mines of *Northamptonshire* in 1872:—

No.	District or mine	Quantity		Value		
		tons	cwts.	£	s.	d.
1	Blisworth	83,514	0	31,317	15	0
2	Brixworth (Denby)	10,850	7	4,168	15	0
3	Castle Dykes (Stowe)	1,500	0	562	10	0
4	Cogenhoe	25,000	0	9,357	0	0
5	Duston, *Northampton*	63,703	0	23,889	0	0
6	Duston	87,019	0	32,632	0	0
7	Gayton	33,961	0	12,735	0	0
8	Wellingborough	149,953	3	56,232	0	0
9	Glendon	98,148	10	36,805	10	0
10	Finedon					
11	Burton					
12	Gayton	...		...		
13	Chapter Lands, *Irthlingboro'*	114,868	11	43,074	0	0
14	Islip, *Thrapstone*	35,700	0	13,387	10	0
15	Ditto					
16	Newbridge (*Twywell*)	70,000	0	26,250	0	0
17	East End, Wellingboro'	65,914	0	24,715	15	0
18	Woodford	73,502	0	27,563	5	0
19	Ringstead	43,498	15	16,311	15	0
20	Irchester	46,961	1	18,735	0	0
	Total of Northamptonshire	1,004,093	7	377,736	15	0

In some places the Northamptonshire ore appears to be the result of an alteration of an argillaceous carbonate, similar to the Cleveland ore.

The importance of the iron ores of Yorkshire (North Riding or Cleveland District) will be shown by the production of Cleveland ore in 1872.

No.	District or mine	Quantities		Value		
		tons	cwts.	£	s.	d.
1	Upleatham	588,031	0	1,056,862	0	0
2	Ditto (*Hob Hill*)	273,548	0			
3	Lofthouse	432,455	0			
4	Liverton	266,236	0			
5	Normanby	254,272	7			
6	Cliff (Brotton)	111,820	0			
7	Skelton (Guisbro')	166,419	9			
8	Port Mulgrave	141,525	0			
9	Belmont	181,068	8			
10	Spa or Margrave Park	35,933	19			
11	Spa Wood (Guisbro')	63,393	19			
12	Eskdale side	30,339	0			
13	Huntcliffe (*Brotton*)	180,473	6			
14	Brotton	392,783	12			
	While seventeen mines made returns to the inspector of mines of	2,156,650	0	806,219	0	0
	Total of Cleveland	4,974,950	0	1,863,081	0	0

The following are the quantities of brown hæmatite which have been produced since 1868:—

	1868	1869	1870	1871	1872
	Tons	Tons	Tons	Tons	Tons
Cornwall	8,310	4,619	11,214	21,947	48,199
Devonshire	11,105	6,399	10,193	14,124	29,361
Somersetshire	...	626	2,110	2,645	2,000
Gloucestershire (Forest of Dean)	160,722	165,250	168,254	199,111	180,271
Frampton Cotterell	6,566	6,773	15,249	8,487	9,201
Wiltshire	75,084	104,795	101,423	159,894	96,117
Northamptonshire	449,116	540,259	761,248	779,314	1,004,093

	1868	1869	1870	1871	1872
	Tons	Tons	Tons	Tons	Tons
Oxfordshire	...	10,167	38,803	28,330	63,536
Lincolnshire	205,699	253,024	248,329	290,673	318,802
Staffordshire (Churnet Valley) .	76,995	72,851	62,882	87,830	110,458
North Wales	500	62	100	...	4,730
South Wales	83,835	82,871	107,326	83,824	72,965
Isle of Man	220	1,291	...	...	...
Ireland	...	...	70,600	107,734	146,550

The Yorkshire ores occupying a somewhat uncertain position are placed with the *argillaceous carbonates*, p. 930.

The iron ores of Lincolnshire—which are placed by Mr. Judd in the greensand or lower cretaceous formation (the neocomian of D'Orbigny)—are thus described by him:—

'The existence in this district (the neighbourhood of Claxby) of fragments of iron-slag, calcined ore, and charcoal, associated with Roman pottery, indicates that these ores were known and worked at a very early period.

'The only ironstone in this district (between Claxby and Nettleton) which is now sufficiently rich to repay the working, is a rock almost entirely made up of small and beautifully-polished oolitic grains of hydrated peroxide of iron. The earthy material, full of large concretionary masses of ironstone, which was at first thought to be equally valuable, is found to yield so small an average percentage of iron, that it is not worked. The oolitic ironstone rock is crowded with fossils, the shells of the gigantic *Pecten cinctus* being especially abundant. It also frequently exhibits veins of beautifully-crystallised calcspar. The ore is thus an eminently calcareous one: it yields on analysis from 28 to 33 per cent. of metallic iron.

'The useful bed of ironstone averages 6 feet 6 inches in thickness. It is mined by means of adits driven into the face of the hill.'—*Quarterly Journal of the Geological Society*, 1870.

In 1872, 62,653 tons were raised at Claxby; while at Froddingham, near Brigg, 256,149 tons were produced.

Carbonate of iron; Sparry iron; Spathose iron; Spathic iron; Sphærosiderite; Spatheisenstein.—This important species has been divided into two varieties; spathose iron proper, and the compact carbonate, the clay-ironstone of the coal-formation. Sparry iron appears to range through nearly the same series of formations as the anhydrous hæmatites: it occurs in beds and masses often of immense extent, especially in Styria and Carinthia. In the Erzberg, near Eisenerz in Styria, it rests on gneiss, and is wrought in an open quarry. The Stahlberg and Momel, near Schmalkald, the vicinity of Siegen, and Müsen in Westphalia, show similar extensive masses; whilst in Anhalt and the Hartz it forms large veins in greywacke or in Devonian limestone. Other very extensive deposits of this ore are found in the Pyrenees, and the Basque provinces of Spain, as near Bilbao; and at Pacho near Bogotà in New Granada. Most of these localities yield fine crystals; and these also occur in metallic veins at Joachimsthal in Bohemia, Freiberg in Saxony, Clausthal in the Hartz, Beeralston in Devonshire, Alston Moor in Cumberland, and in many of the mines of Cornwall, where the rare hexagonal prisms have been found. In England the crystalline carbonate of iron occurs in the Devonians of South Somersetshire and North Devon. It exists in numerous lodes upon Exmoor, although they have been but partially worked. On the Brendon and Eisen hills there have been mines for several years, those mines producing in 1872, 27,913 tons. At Perranzabuloe in Cornwall an immense deposit of spathose iron exists, and is now (1874) being worked to a considerable extent, a railway having been constructed to carry the ore to the southern ports. It is also found in the carboniferous limestones of Northumberland and Durham, especially in Weardale, which district produced in 1872, 97,953 tons.

The specific gravity of sparry carbonate of iron varies from 3·00 to 3·67. Its primitive form is, like that of carbonate of lime, an obtuse rhombohedron. Without changing this form, its crystals are susceptible of containing variable quantities of carbonate of lime, till it passes wholly into this mineral. When heated before the blowpipe, it turns brown without melting, and becomes attractable by the magnet after being slightly heated in the flame of a candle. Even by a short exposure to the air after its extraction from the mine, it also assumes the same brown tint, but without acquiring the magnetic quality; after long exposure to the air it becomes wholly converted into hydrated hæmatite.

The variations in composition of this important mineral are shown in the following analyses:—

	Steinheim, Hanau	Rancié, Pyrenees	Müsen, Siegen	Ehrenfriedersdorf	*Henry*, Somersetshire	*Noad*, Somersetshire
Protoxide of iron .	63·75	53·50	43·59	36·81	37·33	52·56
Sesquioxide of iron .	...	...	...	...	8·52	...
Protoxide of manganese	0·75	6·50	17·87	25·31	12·65	4·82
Magnesia . . .	0·25	0·70	0·08	...	4·52	2·41
Lime	traces	...	0·24	...	traces	1·25
Carbonic acid . .	34·00	39·20	38·22	38·35	35·80	38·68
	98·75	99·90	100·00	100·47	98·82	99·72

Spathic ores vary very much in appearance according to the amount of manganese present; the richest, such as those of Siegen, are coarsely crystalline with curved cleavage faces of a pearly lustre; while the Styrian, which contains but little manganese, although otherwise very pure, is of a dull granular fracture. The Cornish ore from Perran is also very dull and unlike the crystalline mineral.

Coal-measure iron stones.—The compact carbonate of iron has no relation externally with the sparry variety. It comprehends most of the clay-ironstones, particularly those which occur in flattened spheroidal masses of various sizes among the coal-measures. The colour of this ore is often a yellowish brown, reddish grey, or a dirty brick-red. Its fracture is close grained, it is easily scratched, and gives a yellowish brown or grey powder. It adheres to the tongue, has an odour slightly argillaceous when breathed upon; blackens at the blowpipe without melting, and becomes attractable by the magnet after calcination. The ironstones of the coal-formation admit of a natural division into two great classes, viz. the *argillaceous*, and the *blackband* or *carbonaceous*. The earthy or lithoid carbonates occur in some regions in the upper limestone shales, and they extend upwards through the coal-measures proper towards their higher limits; they likewise occur in extensive beds in the Jurassic formation. particularly in North Yorkshire; near the upper limit of the Lias, or base of the oolites proper; and again higher, as nodules and perhaps as beds, in the middle oolites, or Oxford clays. They are also found extensively as courses of nodules in the Wealden series, and as beds in the Greensand. When these grey carbonates contain lime in abundance, and when clay is not largely present, they are sometimes changed by atmospheric influences into hydrated hæmatites; in Northamptonshire, for example, and widely in France. The only great coal-fields in Great Britain in which these ores do not occur in sufficient abundance to form the basis of a large production of iron, are those of Northumberland and Durham, and of Lancashire. The great importance of the argillaceous and blackband ironstones of our coal-fields is clearly shown by the fact, that they supply a very large proportion of the entire iron produced (*Blackwell*). They vary considerably in their percentage of iron, which is generally not more than 30 to 33 per cent., but occasionally ranges as high as 40 per cent. They are rarely used when they contain less than 25 per cent. The varying proportions of iron, silica, and alumina which they contain is shown in the subjoined analyses of the ore from different localities:—

	Berthier		
	Bressac	Aveyron	St. Etienne
	I.	II.	III.
Water	...	...	...
Carbonic acid	35·50	28·90	38·4
Protoxide of iron	35·00	54·20	41·8
„ manganese	0·30	1·10	4·1
Lime	...	0·30	0·2
Magnesia	1·60	0·90	0·3
Silica	26·50	12·80	12·3
Alumina	11·80	1·80	3·2
Peroxide of iron	...	...	...
Sulphuric acid Phosphoric acid } *not determined* .	...	...	...
	100·70	100·00	100·30

Scotch varieties	Dr. Colquhoun			
	IV.	V.	VI.	VII.
Carbonic acid	32·53	30·76	35·17	33·10
Protoxide of iron	35·22	38·80	53·03	47·33
,, manganese	...	0·07	...	0·13
Lime	8·62	5·30	3·33	2·00
Magnesia	5·19	6·70	1·77	2·20
Silica	9·56	10·87	1·40	6·63
Alumina	5·34	6·20	0·68	4·30
Peroxide of iron	1·16	0·33	0·23	0·33
Carbon	2·13	1·87	3·03	1·70
Sulphur	0·62	0·16	0·02	0·22
	100·37	101·00	98·61	97·94

Welsh varieties	Dr. Noad			
	Red vein	Red vein pin	Soap vein	Black pin
	VIII.	IX.	X.	XI.
Silica	8·31	15·40	9·54	12·00
Alumina (insoluble)	3·13	5·00	4·46	4·00
Carbonate of iron	73·79	57·99	77·34	71·70
Oxide of manganese	·92	·64	·53	1·42
Carbonate of lime	2·95	3·45	...	2·64
,, magnesia	3·80	8·58	·90	4·23
Alumina (soluble)	2·52	3·52	2·50	1·15
Phosphoric acid	·53	·75	·57	·48
Sulphuric acid	traces	traces	traces	traces
Bisulphide of iron	·17	·24	·19	traces
Potash	·48	·45	·53	·49
Organic matter and water	2·36	2·34	2·24	1·64
	98·96	98·36	98·80	99·74
Metallic iron	35·62	28·00	37·3	34·6

Cleveland ironstones	Mr. Crowder			
	Easton Nab (main seam)		Hutton Low Cross	
	XII.	XIII.	XIV.	XV.
Silica	11·95	7·65	16·55	15·65
Peroxide of iron	6·73	1·20	...	1·80
Protoxide of iron	39·05	43·35	37·41	35·75
Alumina	13·83	9·88	9·86	4·95
Lime	2·52	0·58	3·08	7·39
Magnesia	2·72	5·35	trace	2·98
Sulphur	trace	0·09	trace	trace
Phosphoric acid	1·02	3·87	0·67	5·05
Carbonic acid	16·38	22·36	26·32	23·47
Water	5·80	5·07	6·11	4·89
	100·00	100·00	100·00	100·00

Blackband, from the neighbourhood of Pontypool, South Wales	Dr. Noad	
	XVI.	XVII.
Carbonaceous matter	15·00	13·42
Carbonate of iron	61·00	64·44
,, magnesia	10·90	13·54
,, lime	13·20	8·60
	100·00	100·00
Iron per cent.	29·6	31·1

The coal-measure ironstones, for the five years ending 1872, were produced in these Islands as follow :—

Argillaceous Carbonate, including Blackband.

	1868	1869	1870	1871	1872
	tons	tons	tons	tons	tons
Somersetshire	4,525	3,146	3,036	2,673	1,000
Shropshire	278,541	318,483	337,627	415,972	408,425
Warwickshire	14,795	15,000	17,500	34,075	43,375
Staffordshire, North	709,796	600,000	847,252	975,250	361,603
Staffordshire, South	340,578	350,000	450,000	705,665	641,950
Derbyshire	368,440	352,072	384,865	492,973	307,183
Northumberland and Durham	125,000	129,500	125,000	203,948	197,953
Yorkshire :					
West Riding	785,629	230,905	307,717	407,997	466,305
Cleveland	2,785,307	3,094,677	4,072,888	4,581,901	4,974,950
North Wales	35,813	33,431	59,140	51,887	23,045
South Wales	628,855	622,130	452,729	884,890	1,174,629
Scotland	1,250,000	1,950,000	3,500,000	3,300,000	3,270,000
Ireland	27,169	48,804	9,768	...	30,000

Total Iron Ore produce of the United Kingdom in 1872.

Counties, &c.	Quantities		Value		
	tons	cwts.	£	s.	d.
Cornwall	48,199	19	27,033	11	8
Devonshire	29,361	0	15,524	2	0
Somersetshire	30,913	8	30,163	8	0
Gloucestershire	199,453	5	149,588	0	0
Wiltshire	96,117	10	36,168	0	0
Oxfordshire	63,536	0	47,652	0	0
Northamptonshire	1,004,093	7	377,736	15	0
Lincolnshire	318,802	0	79,675	0	0
Shropshire	408,425	0	153,669	0	0
Warwickshire	43,375	0	16,246	0	0
Staffordshire, North	361,603	0	216,961	0	0
Staffordshire, South	641,950	0	420,135	0	0
Derbyshire	307,183	0	184,308	8	0
Lancashire	852,064	12	1,063,186	19	0
Cumberland	917,452	0	1,141,416	17	0
Yorkshire North Riding	4,974,950	10	1,863,081	0	0
West Riding	466,305	0	174,864	0	0
Northumberland and Durham	97,953	13	36,730	0	0
North Wales	27,775	0	19,710	0	0
South Wales and Monmouthshire	1,247,594	0	744,465	12	0
Isle of Man	994	6	497	0	6
Scotland	3,270,000	0	817,500	0	0
Ireland	176,550	3	158,562	10	0
Total iron ore production of the United Kingdom	15,584,857	2	7,774,874	3	9

Titanate of iron ; Titanitic iron ; Ilmenite.—This variety occurs in various formations, as in the *miascite* of the Ilmen mountains ; in *talc*, with dolomite, at Gastein in Salzburg ; in the *zircon-syenite* at Egersund in Southern Norway ; and in *gneiss*, with magnetic iron ore, at Tvedestrand, and Krageroe, near Arendal ; and in enormous quantities in the Upper Laurentian or Labrador series of the lower St. Lawrence Valley, and Labrador in Canada, with hypersthene and rutile in Labradorite gneiss, the so-called *norite rock*. The sand produced from the waste of these rocks produces the titaniferous iron sands, which are treated in the American bloomary. Its chemical composition is a titantite of protoxide of iron and magnesia in variable proportions, with peroxide of iron or magnetite; its value as an iron ore depends upon the predominance of the latter components. Titaniferous ores, when not containing more than 8 per cent. of titanium, may be treated advantageously, as they yield good iron from the absence of sulphur and phosphorus; but with larger proportion of titanium they become too refractory, and require too much flux to be smelted alone, the proportion of fuel required being greatly increased.

History of Iron-Smelting.—There is abundance of evidence that iron was well known in the early ages, and was applied to various useful purposes. The earliest method of working the furnace where ores were smelted seems to have been by exposing them to the wind: the furnaces, perforated with holes, were built on eminences, and could only be worked when there was a strong breeze; the fire was regulated by opening and shutting the apertures. Mungo Park gives, in his 'Travels in Africa,' the following interesting account of an iron-smelting operation in Kamalia, at which he himself assisted: 'The ironstone was broken into pieces the size of a hen's egg; a bundle of dry wood was first put into the furnace, and covered with a considerable quantity of charcoal; over this was laid a stratum of ironstone, and then another of charcoal, and so on until the furnace was quite full. The furnace was a circular tower of clay, about 10 feet in height and 3 in diameter, surrounded in two places with withes, to prevent the clay from cracking and falling to pieces by the violence of the heat. Round the lower part, on a level with the ground, but not so low as the bottom of the furnace, which was somewhat concave, were made seven openings, into each of which were placed three tubes of clay, and the openings again plastered up in such a manner that no air could enter the furnace but through the tubes, by the opening and shutting of which the fire was regulated. The fire was applied through one of the tubes, and blown for some time with bellows made of goat's skin. The operation went on very slowly at first, and it was some hours before the flame appeared above the furnace; but after this it burnt with great violence all the first night, and the people who attended put in at times more charcoal. On the day following the fire was not so fierce, and on the second night some of the tubes were withdrawn, and the air allowed to have free access to the furnace; but the heat was still very great, and a bluish flame rose some feet above the top of the furnace. On the third day from the commencement of the operation all the tubes were taken out, the ends of many of them being vitrified with the heat, but the metal was not removed until some days afterwards, when the whole was perfectly cool; part of the furnace was then taken down, and the iron appeared in the form of a large irregular mass, with pieces of charcoal adhering to it. It was sonorous, and when any portion was broken off, the fracture exhibited a granulated appearance like broken steel.'

That the iron ores of Monmouthshire and Gloucestershire were extensively worked by the Romans during the period of their reign in Britain is certain, from the immense beds of iron cinders that have been discovered in the Forest of Dean; it is probable that Bath was the principal seat of their foundries; relics of their operations, in the form of cinders and coins, have likewise been discovered in Yorkshire and in other counties. During the reign of William the Conqueror, Gloucester was the city where the trade of forging iron was chiefly carried on, the Forest of Dean supplying the ores. It is uncertain when the art of casting was first discovered; cannon are supposed to have been first used in England by Edward III., who used them in his invasion of Scotland in 1327, at Cressy, and at the siege of Calais in 1346. These cannons were not, however, cast, but were constructed on the same principles as coopers construct their barrels; a number of iron bars, fitting as close as possible to each other, were arranged round a cylinder of wood, and were then bound together by strong iron hoops; the wood being driven out, there remained an iron pipe which formed the barrel. This mode was superseded by *casting* the cannon of bronze.

During the 14th and 15th centuries, iron and steel were imported into this country from Germany, Prussia, and other places, and also iron from Spain; but as several improvements in the manufacture has taken place in the course of this period in England, laws were made towards the conclusion of the 15th century, prohibiting the importation of any of the articles manufactured in this country in iron and steel. During the reign of Elizabeth, the consumption of charcoal by the iron furnaces was so great, that it was deemed necessary to enact laws to prohibit the erection of new furnaces, and to prevent the felling of timber for fuel; persons interested in the manufacture of iron were consequently compelled to turn their attention to the finding of some substitute for charcoal, and in the reign of James I. and Charles I. many attempts were made to smelt iron with pit-coal, but without success; the consequence was the entire abandonment of iron-making in many parts of the country, and a great decrease in the manufacture in others; so complete indeed was the failure of all the experiments made to substitute pit-coal for charcoal, that all attempts were abandoned till the early part of the next century, when pit-coal was first used (1713) by Mr. Abraham Darby in his furnace at Colebrook Dale; and in the 44th volume of the Philosophical Transactions, published in 1747, it is stated, that 'Mr. Ford, from iron and coal, both got in the same Dale (Colebrook), makes iron brittle or tough as he pleases, there being cannon thus cast so soft, as to bear turning like soft iron.' Notwithstanding, however, the establishment of the fact that iron ore could be smelted, and iron manufactured with pit-coal, and although great efforts were made, by increasing the column of blast by the substitution of steam-power for that of horses and human labour, there appears to have been a steady and progressive diminution in the quantity of iron produced in this country; and recourse was had to foreign markets, particularly to those of Sweden and Russia, for the necessary and increasing demand. Thus, the imports of iron between the years 1711 and 1776 were as follow:—

	Tons
1711 to 1718	15,642
1729 „ 1735	25,501
1750 „ 1755	34,072
1761 „ 1766	48,980

In 1740 there were only 59 blast-furnaces in work in England and Wales, the total make of which amounted to not more than 17,350 tons, being an average of 294 tons per annum for each furnace, a quantity very little exceeding that sometimes made in a *single week* in some of the furnaces in Wales at the present day.

The earliest contrivance for throwing a powerful and constant blast into the furnace was a forcing pump, worked by a water-wheel or by a steam-engine; and it appears that the first cylinders, at least of any magnitude, were erected at the celebrated Carron Iron Works in the year 1760 by Mr. John Smeaton. These cylinders were four feet six inches in diameter, exactly fitted with a piston, moved up and down by means of a water-wheel; in the bottom of the cylinder was a large valve, like that of a bellows, which rose as the piston was lifted up, and thus admitted the air into the cavity of the cylinder below. Immediately above the bottom was a tube which went to the furnace, and as it proceeded from the cylinder, was furnished with a valve opening outwards. Thus when the piston was drawn up, the valve in the bottom rose and admitted the air that way into the cylinder, while the lateral valve shut, and prevented any air from getting into it through the pipe. When the piston was thrust down, the valve in the bottom closed, while the air, being compressed in the cavity of the cylinder, was violently forced out through the lateral tube into the furnace. There were four of these large cylinders applied to blow the furnace, and so contrived, that the stroke of the pistons, being made alternately, produced an almost uninterrupted blast. A large column of air, of triple or quadruple density, was thus obtained, and effects equivalent to these great improvements followed. The same furnace that formerly yielded ten and twelve tons weekly, now sometimes produced forty tons in the same period, and on the average in one year 1,500 tons of metal (Scrivenor); and such was the impulse given to the trade by this unexpected success of a powerful blast with pit-coal, that in 1788 the manufacture of pig-iron in England, Wales and Scotland, amounted to 68,300 tons, being an increase of 50,950 tons on the quantity manufactured previous to the introduction of pit-coal.

A new era in the history of the iron manufacture may be considered to have been established in 1788–90, by the introduction of the double power-engine of James Watt, the regular and increased effects of which powerful machine was soon felt in most of the iron districts; the proprietors of furnaces greatly increased their make, and fresh capital was embarked in the trade; in the short period of eight years the manufacture of pig-iron was nearly double, being in the year 1796 (according to the return sent to the Chairman of the Committee of the House of Commons, on the subject of the coal trade, when Mr. Pitt had in contemplation to add to the revenue by a tax upon coal at the pit-mouth) 125,079 tons from 121 furnaces—104 English and Welsh, and 17 Scotch; the English and Welsh furnaces producing an average of 1,048 tons each per annum, and the Scotch furnaces 946 tons. In 1806, the number of furnaces in blast in Great Britain was 173, and the make 258,206 tons of pig-iron, being an increase in ten years of 133,127 tons per annum; of these 162 were coke-furnaces, the average produce of each of which had risen to 1,546 tons. In this year great excitement existed in the iron trade, in consequence of the proposal of Lord Henry Petty to levy, as a war-tax, a duty of 40*s.* per ton on pig-iron; he introduced a bill into the House of Commons having this object, and succeeded in carrying it, notwithstanding a powerful opposition, by a majority of ten members; the measure was however abandoned.

In France in 1801, the quantity of cast-iron produced amounted to 140,000 tons, from 550 blast-furnaces, of which only one (that of Creusot) was worked with coke. In 1809 a description of the English process of making iron was published by Order of Council, by M. de Bonnard (an engineer of mines); another engineer of mines (M. de Gallois), after having passed several months in England, established at St. Etienne the second blast-furnace in France, wherein the minerals were treated in the same manner as the English, and in which coke was employed; but the difficulties he had to encounter proved a bar to his success, and he is said to have died prematurely from the grief and trouble which the enterprise occasioned him (Scrivenor). The employment of pit-coal in the manufacture of iron received a very slow development in France, for in 1818 the quantity of cast iron made with coke was very small, and no wrought iron was prepared with pit-coal; in 1824 not more than 3,000 tons of cast iron were made with coke, but in 1828 it had risen to 17,000 tons. Though this did not amount to a tenth of the whole produce, nevertheless the quantity of bars made with pit-coal amounted in this year to 48,000 tons, being nearly one-third of the total manufacture of wrought iron.

Theory of Iron Smelting—The production of metallic iron from its ores is effected by exposing the ore at a suitable temperature to the action of a reducing gas, such as hydrogen, carburetted hydrogen, or carbonic oxide; the first of these is employed in the laboratory, but for practical purposes only the latter can be used. If the reduction is effected at a comparatively low heat such as a dull redness, the product is a dark grey powder which is stable if kept out of contact with the air, but which burns when shaken out into the air at ordinary temperatures, and still more brilliantly in oxygen, forming the so-called pyrophoric iron. This substance is only of interest as a pharmaceutical product (*Ferrum reductum*). The reduction by carbonic oxide is effected in all cases where the ore is exposed to the gases arising from the combustion of carbonaceous matter, whether the fuel be burnt separately, as in reverberatory gas or cementation furnaces, or in contact with ore, as in the various forms of blast-furnace. The simplest cases which can occur under these circumstances are represented by the following equations:—

I. With hydrogen as the reducing agent $Fe^2O^3 + 3H = 2Fe + 3HO$
II. „ carbonic oxide „ „ $Fe^2O^3 + 2CO = 2Fe + 2CO^2$

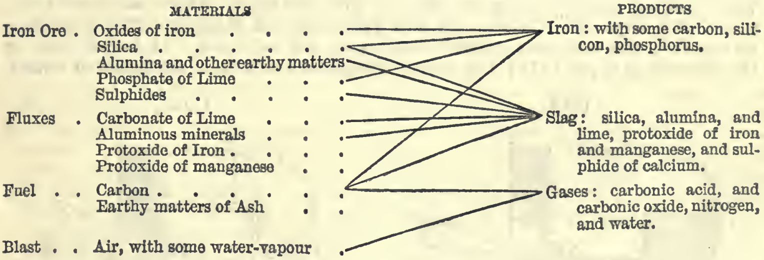
The products vary: in the first case, two equivalents of iron and three of water, and in the second two equivalents of carbonic acid to the same quantity of iron for each equivalent of peroxide of iron. Such a result cannot, however, be got on the large scale, from the fact that finely-divided metallic iron when exposed to a high temperature in contact with carbon either in the solid or gaseous form takes up a proportion of the latter substances, forming carbonised compounds, which are known as *malleable iron*, *steel*, and *cast iron*, according to the amount present. In the first case, the amount is very small, not exceeding a few thousandths of an unit per cent.; but the presence of carbon may be verified by the production of fetid hydrogen gas, owing to the presence of volatile hydrogen-carbons when even the finest and softest wrought iron is dissolved in an acid. Steel contains from about 0·10 to about 2 per cent. of carbon. When the proportion exceeds 2 per cent., and it may in some cases reach as high as 6 per cent., the product is known as cast iron.

In addition to carbon, iron is found on the large scale to contain other substances; the most important of these in modifying its physical properties are *silicon*, *phosphorus*, and *sulphur*. These are derived from the impurities of the ore; quartz, phosphate of lime, and some metallic sulphide, being almost invariably present in the minerals treated on the large scale, and a proportion of these substances is certain to be reduced if the conditions of temperature and exposure be favourable; silica, under the action of carbon in the presence of iron, being readily reducible in almost any proportion, according to the temperature; thus, at a very high heat as much as 22 per cent. of silicon may be combined with iron; practically, however, nothing like as much can be obtained; about 6 per cent. may be regarded as a maximum. When phosphate of lime is present in the ore under the ordinary condition of reduction in the blast-furnace, almost the whole of the phosphorus is obtained in the iron. Sulphur is obtained in like manner from metallic sulphides.

Of the alloys of iron with other metals there is only one of any practical importance, namely, that with the allied metal manganese, which may combine with it in all proportions up to about 30 per cent. Copper, when present in iron, even in minute quantity modifies its properties in a marked and prejudicial manner, but there is no proof of these two metals actually combining.

The earthy and foreign substances, besides modifying the quality of the iron, by their partial reduction play another and more important part in the economy of iron-smelting in procuring the so-called slag, cinder, or scoriæ, that is a fusible product usually more or less glassy, which is formed by the addition of appropriate solvents or fluxes, in order that the otherwise infusible earthy matters such as quartz, sand, clay, at present in the ore, and the ash of the fuel may be separated and removed from the reduced metal, which would otherwise be incapable of coalescing into a connected mass, whether by fusion or otherwise. These fluxes, according to the nature of the process, may be either lime, magnesia or other alkaline bases, alumina, or in some cases the oxides of iron or manganese. The heat required for this operation is very considerable, and requires a considerable consumption of fuel above that necessary for the reduction and fusion of the metal. A further and still larger source of expenditure of heat is due to the fact that when the carbonic acid produced in the reduction of the ore is exposed to carbon at a high temperature it is partially reduced with the production of carbonic oxide, which escapes, carrying a large proportion of the total heating power of the fuel, unless special arrangements are adopted for utilising it.

Practically, therefore, the reactions of iron-smelting may be expressed synoptically in the following manner:—



Production of malleable iron directly from the ore.—The simplest processes of iron-smelting are those in which malleable iron is produced directly from the ore. They are still practised to a considerable extent in India and other parts of the East, and were formerly universally employed in Europe, but now they have become almost extinct; the latest representatives being the Catalan and Corsican forges, and the *Stück-Öfen*, or lump-furnace, which is to be found in one or two places in eastern Europe. These processes consist essentially in the exposure of pure ore to the action of heat in small blast-furnaces, which may be either open hearth-fires, like a smith's forge, or have low shafts or stacks, a few feet high, in which the ore and fuel are charged alternately, the combustion being urged by a blast of air introduced through one or more nozzles below. The operation is continued until a lump of malleable iron is formed in the bottom of the furnace from the reduction of the ore, or a portion of the ore; the remainder being employed in fluxing the silica and other earthy matters both in the ore and the ash of the fuel. This is effected by a partial reduction of the ore from peroxide of iron—which is chemically indifferent to silica at a high temperature—to the state of protoxide, which combines readily with it; forming a fusible slag or cinder at the welding temperature of iron. The spongy and slightly-alloyed mass of iron so produced is then consolidated by hammering, which compacts it to a solid mass, the liquid cinder being expelled by the blows of the hammer. The same reaction takes place in all processes where no special fluxes are added for fluxing the silica, the flux being essentially silicates of protoxide of iron, infusible at comparatively low temperatures; and, under these conditions, only wrought iron can be produced, the ore not being kept in contact with carbon for a sufficiently long time to produce cast iron, except to a very small extent.

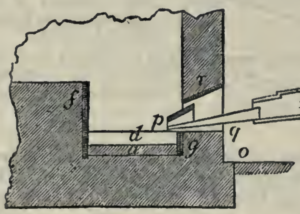
The following are the principal processes in which malleable iron is produced directly:—

1. The Catalan and Corsican forge.
2. The German and American bloomary fires.
3. The Stück-Öfen or lump-furnace.
4. The Chenot or retort-furnace.
5. The Siemens' direct-furnace.

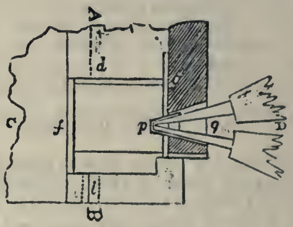
Of these the first and second are conducted in open fires, and differ only in details of manipulation; the former using the ore partly in the state of lumps, which are reduced, and partly in the state of fine dust or *greillade*, which principally goes into the slag; while in the latter the whole of the ore is powdered and clayed in alternate layers with the fuel. The *Stück-Öfen* is larger than the open fire, and the operation is continued for several hours; the lump of reduced iron being removed by breaking away the breast of the furnace, instead of pulling it out from the top. The common Indian method of making iron is conducted in a furnace of this class, but of very small dimensions; not more than 5 or 6 feet high, instead of 15 or 20 feet, as is used in Europe. In the Chenot and similar processes the reduction is effected in fire-clay retorts, with the production of spongy masses of iron; while in the last, or Siemens' process, which is of recent introduction, the ore is melted in a cylindrical vessel, with a refractory lining, and reduced by churning it up with carbonaceous matter; lime, or other fluxes, being previously introduced to combine with the silica, and prevent unnecessary loss of iron by scorification.

In the Catalan, or French method, the ore previously roasted in a kiln is afterwards strongly torrefied in the forge before the smelting begins; operations which follow in immediate succession. Ores treated in this way should be very fusible and very rich; such as black oxide of iron, hæmatites, and certain spathose iron ores. From 100 parts of ore, 50 of metallic iron have been procured, but the average product is 35. The furnaces employed are rectangular hearths, *figs.* 1212 and 1213, the water-blowing machine being employed to give the blast. There are three varieties of this forge: the Catalan, the Navarrese, and the Biscayan. The dimensions of the first, the one most generally employed, are as follow: 21 inches long, in the direction *p f*, *fig.* 1213; 18½ inches broad, at the bottom of the hearth or *creuset*, in the line A B; and 17 inches deep, *fig.* 1212, The tuyère, *q p*, is placed 9½ inches above the bottom, so that its axis is directed towards the opposite side, about 2 inches above the bottom. But it must be moveable, as its inclination needs to be changed, according to the stage of the operation, or the quantity of the ores. It is often raised or lowered with pellets of clay; and even with a graduated circle, for the workmen make a great mystery of this matter. The hearth is lined with a layer of *brasque* (loam and charcoal-dust worked together), and the ore, after being roasted, is sifted; the small powder being set aside to be used in the course of the operation. The ore is piled up on the side opposite to the blast in a sharp saddle ridge, and it occupies one-third of the furnace. In the remaining space of two-thirds the charcoal is put. To solidify the small ore on the hearth, it is covered with moist cinders mixed with clay.

1212



1213



The fire is urged with moderation during the first two hours, the workman being continually employed in pressing down more charcoal as the former supply burns away, so as to keep the space full, and prevent the ore from crumbling down. By a blast so tempered at the beginning the ore gets well calcined, and partially reduced in the way of cementation. But after two hours, the full force of the air is given; at which period the fusion ought to commence. It is easy to see whether the torrefaction be sufficiently advanced by the aspect of the flame, as well as of the ore, which becomes spongy or cavernous; and the workman now completes the fusion, by detaching the pieces of ore from the bottom, and placing them in front of the tuyère. When the fine siftings are afterwards thrown upon the top, they must be watered, to prevent their being blown away, and to keep them evenly spread over the whole surface of the light fuel. They increase the quantity of the products, and give a proper fusibility to the scoriæ. When the scoriæ are viscid, the quantity of siftings must be diminished; but if thin, they must be increased. The excess of slag is allowed to run off by the *chio* or floss-hole. The process lasts from five to six hours, after which the pasty mass is taken out, and placed under a hammer to be cut into lumps, which are afterwards forged into bars.

Each mass presents a mixed variety of iron and steel, in proportions which may be modified at pleasure; for, by using much of the siftings, and making the tuyère dip towards the sole of the hearth, iron is the chief product; but if the operation be conducted slowly, with a small quantity of siftings, and an upraised tuyère, the quantity of steel is more considerable. This primitive process is favourably spoken of by M. Brongniart. The weight of the lump of metal varies from 200 lbs. to 400 lbs. As the consumption of charcoal is very great, amounting in the Palatinate or Rheinkreis to seven times the weight of iron obtained (though in the Pyrenees it is only thrice), the Catalan forge can be profitably employed only where wood is exceedingly cheap and abundant.

In smelting and refining by a continuous operation, three different stages may be distinguished:—1. The roasting of the ore to expel the sulphur, which would be less easily separated afterwards. The roasting dissipates likewise the water, the carbonic acid, and any other volatile substances which the minerals may contain. 2. The deoxidisement and reduction to metal by exposure to charcoal or carburetted vapours. 3. The melting, agglutination, and refining of the metal to fit it for the heavy hammers where it gets nerve. There are several forges in which these three operations seem to be united in a single one, because, although still successive, they are practised at one single heating without interruption. In other forges, the processes are performed separately, or an interval elapses between each stage of the work. Three systems of this kind are known to exist:—1. The Corsican method; 2. The Catalan with wood charcoal; and, 3. The Catalan with coke.

The furnaces of Corsica are a kind of semicular basin, 18 inches in diameter, and 6 inches deep. These are excavated in an area, or a small elevation of masonry, 8 or 10 feet long by 5 or 6 broad, and covered in with a chimney. This area is quite similar to that of the ordinary hearths of our blast-furnaces.

The tuyère stands 5 or 6 inches above the basin, and has a slight inclination downwards. In Corsica, and the whole portion of Italy adjoining the Mediterranean shores, the iron ore is an oxide similar to the specular ore of the Isle of Elba. This ore contains a little water, some carbonic acid, and occasionally pyrites, but in small quantity. Before deoxidising the ore, it is requisite to expel the water and carbonic acid combined with the oxide, as well as the sulphur of the pyrites.

The operations of roasting, reduction, fusion, and agglutination are executed in the same furnace. These are indeed divided into two stages, but the one is a continuation of the other. In the first, the two primary operations are performed at once:—the reduction of a portion of the roasted ore is begun at the same time that a portion of the raw ore is roasted: these two substances are afterwards separated. In the second stage, the deoxidisement of the metal is continued, which had begun in the preceding stage; it is then melted and agglutinated, so as to form a ball to be submitted to the forge-hammer.

The roasted pieces are broken down to the size of nuts, to make the reduction of the metal easier. In executing the first step, the basin and area of the furnace must be lined with a *brasque* of charcoal-dust, 3, 4, or even 5 inches thick: over this *brasque* a mound is raised with lumps of charcoal, very hard, and 4 or 5 inches high. A semicircle is framed round the tuyère, the inner radius of which is 5 or 6 inches. This mass of charcoal is next surrounded with another pile of the roasted and broken ores, which must be covered with charcoal-dust. The whole is sustained with large blocks of the raw ore, which form externally a third wall.

These three piles of charcoal, with roasted and unroasted ore, are raised in three successive beds, each 7 inches thick: they are separated from each other by a layer of charcoal-dust of about an inch, which makes the whole 24 inches high. This is afterwards covered over with a thick coat of pounded charcoal.

The blocks of raw ore which compose the outward wall form a slope; the larger and stronger pieces at the bottom, and the smaller in the upper part. The large blocks are sunk very firmly into the charcoal-dust, to enable them better to resist the pressure from within.

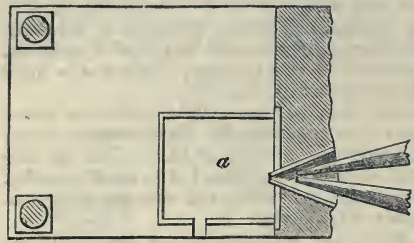
On the bottom of the semicircular well formed within the charcoal lumps, kindled pieces are thrown, and over these, pieces of black charcoal; after which the blast of a water-blowing machine (*trompe*) is given. The fire is kept up by constantly throwing charcoal into the central well. At the beginning of the operation it is thrust down with wooden rods, lest it should affect the building; but when the heat becomes too intense for the workmen to come so near the hearth, a long iron rake is employed for the purpose. At the end of about 3 hours, the two processes of roasting and reduction are commonly finished: then the raw ore no longer exhales any fumes, and the roasted ore, being softened, unites into lumps more or less coherent.

The workman now removes the blocks of roasted ore which form the outer casing, rolls them to the spot where they are to be broken into small pieces, and pulls down the *brasque* (small charcoal) which surrounds the mass of reduced ore.

The second operation is executed by cleaning the basin, removing the slags, covering the basin anew with 2 or 3 *brasques* (coats of pounded charcoal), and piling up to the right and the left two heaps of charcoal-dust. Into the interval between these conical piles two or three baskets of charcoal are cast, and on its top some cakes of the reduced crude metal being laid, the blast is resumed. The cakes, as they heat, undergo a sort of liquation, or sweating, by the action of the earthy glasses on the unreduced black oxide present. Very fusible slags flow down through the mass; and the iron, reduced and melted, passes finally through the coals, and falls into the slag basin below. To the first parcel of cakes others are added in succession. In proportion as the slags proceeding from these run down, and the melted iron falls to the bottom, the thin slag is run off by an upper overflow or *chio* hole, and the reduced iron kept by the heat in the pasty condition, remains in the basin: all its parts get agglutinated, forming a soft mass, which is removed by means of a hooked pole in order to be forged. Each lump or *bloom* of malleable iron requires 3 hours and a half for its production.

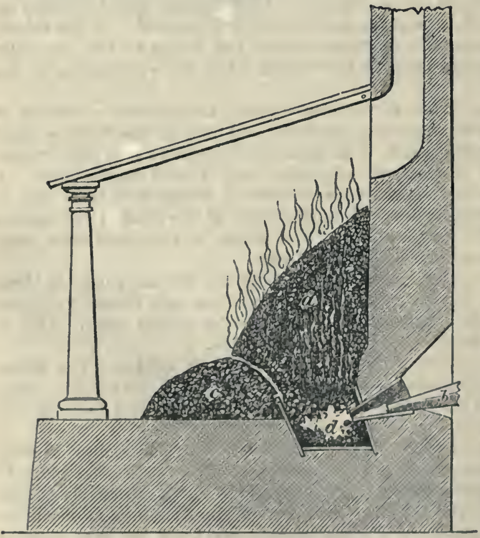
The iron obtained by this process is in general soft, very malleable, and but little steely. In Corsica four workmen are employed at one forge. The produce of their labour is only about 4 cwts. of iron from 10 cwts. of ore and 20 of charcoal, mingled with wood of beech and chestnut. Though their ore contains on an average 65 per cent. of iron, only about 40 parts are extracted; evincing a prodigious waste, which remains in the slags.

1214



The difference between the Corsican and the Catalonian methods consists in the latter roasting the ore at a distinct operation, and employing a second one in the reduction, agglutination, and refining of the metal. In the Catalonian forges, 100 pounds of iron are obtained from 300 pounds of ore and 310 pounds of charcoal; being a produce of only 33 per cent. It may be concluded that there is a notable loss, since the sparry iron ores, which are those principally smelted, contain on an average from 54 to 56 per cent. of iron. The same ores smelted in the ordinary blast-furnace produce about 45 per cent. of cast iron.

1215



In some parts of America, particularly in the States of Vermont and New Jersey, the *Catalan* forge was at one time employed for smelting the rich magnetic ores which there abound. The form of this fire (which is nearly uniform everywhere), and the manipulation with it in America, is thus described by Overman:—The whole is a level hearth of stone-work, from 6 to 8 feet square, *fig.* 1214, at the corner of which is the fireplace, *a*, from 24 to 30 inches square, and from 15 to 18, often 20, inches deep. Inside it is lined with cast-iron plates, the bottom plate being from 2 to 3 inches thick. *Fig.* 1215 represents a cross section through the fireplace and tuyère, commonly called tue iron; *d* represents the fireplace, which, as remarked above, is of various dimensions. The tuyère *b* is from 7 to 8 inches above the bottom, and more or less inclined according to circumstances. The blast is produced by wooden bellows of the common form, or more generally by square wooden cylinders, urged by water-wheels. The ore chiefly employed is the crystallised magnetic ore. This ore very readily falls to a coarse sand, and when roasted varies from the size of a pea to the finest grain. Sometimes the ore is employed without roasting. In the working of such fires much depends on the skill and experience of the workman. The result is subject to considerable variation, that is, whether economy of coal or that of ore is our object. Thus a modification is required in the construction either of the whole apparatus or in parts of it. The manipulation varies in many respects. One workman by inclining his tuyère to the bottom, saves coal at the expense of obtaining a poor yield. Another by carrying his tue iron more horizontally at the commencement, obtains a larger amount of iron, though at the sacrifice of coal. Good workmen pay great attention to the tuyère, and alter its dip according to the state of the operation. The general manipulation is as follows:—The hearth is lined with a good coating of charcoal-dust; and the fire-plate, or the plate opposite the blast, is lined with coarse ore, in case any is at our disposal. If no coarse ore is employed, the hearth is filled with coal, and the small ore piled against a dam of coal-dust opposite the tuyère, *a*. The blast is at first urged gently, and directed upon the ore, while the coal above the tuyère is kept cool. Four hundred pounds of ore are the common charge, two-thirds of which are thus smelted, and the remaining third, generally the finest ore, is held in reserve, to be thrown on the charcoal when the fire becomes too brisk. The charcoal is piled to the height of two, sometimes even three and four feet, according to the amount of ore to be smelted. When the blast has been applied for an hour and a half, or two hours, most of the iron is melted, and forms a pasty mass at the bottom of the hearth. The blast may now be urged more strongly, and if any pasty or spongy mass yet remains, it may be brought within the range of the blast and melted down. In a short time the iron is revived, and the scoriæ are permitted to flow through the tapping hole *c*, so that but a small quantity of cinder remains at the bottom. By means of iron bars, the lump of pasty iron is brought before the tuyère. If the iron is too pasty to be lifted, the tuyère is made to dip into the hearth; in this way the iron is raised from the bottom, directly before, or to a point above the tuyère, until it is welded into a coherent ball, twelve or fifteen inches in diameter. This ball is brought to the hammer or squeezer, and shingled into a bloom, which is either cut in pieces to be stretched by a hammer, or sent to the rolling mill to be formed into marketable bar iron. A mixture of fibrous iron, cast iron, and steel, is the result of the above process; the quality of the iron depends entirely on the quality of the ore, for there are no opportunities for the exercise of any skill to create improvements in the process—poor ores cannot be smelted at all. In Vermont, where the rich magnetic ores are employed, 4 tons of ore and 300 bushels of charcoal are required to produce 1 ton of blooms.

Although the old process of making iron directly from the ore has been completely abandoned in Germany, it is still employed to a considerable extent in the United States, where it was introduced early in the eighteenth century; and has latterly been employed in Canada for the treatment of the black magnetic and titaniferous sands of the Labrador. The following description of the process has been given by Dr. Sterry Hunt:—The hearth or furnace (also known as the bloomary fire, Jersey or Champlain forge) varies in length and breadth in different localities from 27 by 30 inches to 28 by 32 inches, and the depth from 20 to 25 inches above the tuyère, and from 8 to 14 inches below; the sides are made of cast-iron plates, and the bottom usually of beaten earth or cinders, but in the best-constructed hearths a hollow casting cooled by water is preferred. At East Middlebury in Vermont, the bottom plate is 4 inches thick, with a hollow space of 2 inches within it. The side plates, which are 1¼ inch thick, are slightly inclined inwards, and rest on ledges on the bottom plate. A water-box, measuring 12 by 8 inches, is let into the tuyère plate; and the water, after cooling the tuyère, passes through the bottom plate. The tuyère is placed 12 inches above the bottom at such an inclination that the blast may strike the middle of the hearth. It is of segmental form, measuring 1 inch in height by ¾ inch wide. In front of the furnace, at a height of 16 inches above the bottom, is placed a flat iron hearth 18 inches wide. The side plate beneath it is provided with a tap-hole for drawing off the cinders from time to time. The cast-iron plates used in the construction of these furnaces last for two years.

The blast employed has a pressure of from 1½ to 1¾ lb. to the square inch, and is heated by passing through a stove of the ordinary siphon-pipe pattern, placed in an upper chamber above the furnace, and heated by the waste flame. The temperature at East Middlebury is said to be from 280° to 320°. The use of hot blast is attended with a considerable saving both of time and fuel, 240 bushels of charcoal being sufficient to produce a ton of bloom with hot, while 300 are required with cold blast. The weight of the charcoal may be estimated at from 16 to 18 lbs. per bushel.

The working of the furnace is conducted in the following manner:—The fire having been made up and the furnace heaped with charcoal, the ore in coarsely-pulverised form is scattered at short intervals over the top of the burning fuel, and in its passage downwards is reduced to the metallic state, the grains agglomerating to an irregular mass or lump at the bottom, while the earthy matters form a liquid slag or cinder, which is drawn off from time to time through the openings in the front plate. Fresh ore and coal are continually added, until at the end of 2 or 3 hours a sufficiently large loup is formed. This is then lifted before the tuyère to get a good welding heat, and shingled to a bloom under the hammer, the reheating of which is usually effected in the same fire.

In the larger sized furnaces a loup of 300 lbs. is produced every 3 hours, making the produce per day of 24 hours, 2,400 lbs. of blooms; in some cases it is said 1,500 lbs., or even more, are produced in 12 hours.

The essential difference between the Catalan and the American forge consists in the method of charging. In the former the greater part of the charge of ore, in comparatively large lumps, is placed at the commencement of the operation on the sloping wall of the hearth opposite the tuyère, only the small ore, or *greillade*, being added subsequently. In the American or German method, on the contrary, the whole of the ore is reduced to a fine state of division, and is added by small proportions: a plan which dispenses with the charging of the furnace after each operation, and permits of a continuous system of working.

In order further to economise the waste heat, the plan is usually adopted in the Franche-Comté fire, of passing the flame and gases from two hearths into a chamber, which serves for the reheating of the blooms when it is required to draw them out into bars; a set of small blast-pipes, placed just above the forge, serves to heat a portion of air, which is led into the chamber to burn any carbonic oxide gas that may have escaped. The gases from the reheating chamber are afterwards employed to heat the principal blast of the forge in the usual manner.

At Ausable, in the State of New York, the ores employed are dressed so as to yield about 50 per cent. of iron—2 tons being required to make 1 ton of blooms; while at the New Russia forges, where a nearly pure magnetite is smelted, 3 tons of dressed ore are stated to yield 2 tons of blooms. The loss at this rate would not be more than 5½ per cent. on the theoretical contents of the ore: a result which could scarcely be obtained by any other method.

At Moisie in Quebec, where titaniferous black sand is treated, the results obtained are not so favourable, owing to the more refractory character of the ore. The tuyère is laid nearly horizontal, as it was found that the strong inclination used with coarser ores could not be advantageously used with the fine sands. A less dense blast is also used, the average working pressure being about 1 lb. to the square inch. Each hearth yields eight loups, or about 15 cwts. in the day of 24 hours; the consumption of charcoal being at the rate of 466 bushels to the ton of blooms. This charcoal is chiefly produced from small and light wood, such as spruce, fir, and birch, the weight being only 15 lbs. to the bushel, about 62½ cwts. being consumed to make a ton of iron.

This very unfavourable result is due to the imperfectly cleaned state in which the ore is smelted; the quartz, but more especially the titanic acid, using up a large portion of the protoxide of iron, in order to form a slag. The amount of titanic acid in the slags is in some cases as high as 34 per cent. and the iron from 40 to 52 per cent. By the use of magnetic machines for separating the ore before treating it in the furnace, it would be possible to remove the non-magnetic and more highly titaniferous part, which is practically worthless, leaving a comparatively pure magnetite, which could be more advantageously smelted.

The quality of the iron produced in the bloomary fire at Moisie is said to be very superior, as the result of experiments made upon it in England shows that it possesses a tensile strength equal, or superior, to that of the best Yorkshire iron, and works easily both cold and hot. This excellence is to be attributed to the almost perfect freedom of the magnetic sand from sulphur and phosphorus. A sample taken from a bloom when examined gave only ·0094 per cent. of sulphur and ·00184 per cent. of phosphorus, and no trace of titanium could be found.

The *Fourneaux à pièce* of the French, or *Stück-Öfen* of the Germans, resembles *fig.* 514, Copper. The tuyère (not shown there), having a dip towards the bottom of the hearth where the smelted matter collects. When the operation is finished, that is at least once in every 24 hours, one of the sides of the hearth must be demolished, to take out the pasty mass of iron, more or less pure. This furnace holds a middle place in the treatment of iron, between the Catalan forge and the cast-iron *Floss-Öfen*, or high blast-furnaces. The *Stück-Öfen* are from 10 to 15 feet high, and about 3 feet in diameter at the hearth. Most usually there is only one aperture for the tuyère and for working; with a small one for the escape of the slag; on which account, the bellows are removed to make way for the lifting out of the lump of metal, which is done through an opening left on a level with the sole, temporarily closed with bricks and potter's clay, while the furnace is in action.

This outlet being closed, and the furnace filled with charcoal, fire is kindled at the bottom. Whenever the whole is in combustion, the roasted ore is introduced at the top in alternate charges with charcoal, till the proper quantity has been introduced. The ore falls down; and whenever it comes opposite to the tuyère the slag begins to flow, and the iron drops down and collects at the bottom of the hearth into the mass or *Stück*; and in proportion as this mass increases, the *floss-hole* for the slag and the tuyère is raised higher. When the quantity of iron accumulated in the hearth is judged to be sufficient, the bellows are stopped, the scoriæ are raked off, the little brick wall is taken down, and the mass of iron is removed by rakes and tongs. This mass is then flattened under the hammer into a cake from 3 to 4 inches thick, and is cut into two lumps, which are submitted to a new operation; where it is treated in a peculiar refinery, lined with charcoal *brasque*, and exposed to a nearly horizontal blast. The above mass seized in the jaws of powerful tongs, is heated before the tuyère; a portion of the metal flows down to the bottom of the hearth, loses its carbon in a bath of rich slags or fused oxides, and forms thereby a mass of iron thoroughly refined. The portion that remains in the tongs furnishes steel, which is drawn out into bars.

This process is employed in Carniola for smelting a granular oxide of iron. The mass or *Stück* amounts to from 15 to 20 hundred-weight after each operation of 24 hours. Eight strong men are required to lift it out, and to carry it under a large hammer, where it is cut into pieces of about 1 cwt. each. These are afterwards refined, aud drawn into bars as above described. These furnaces are now almost generally abandoned on the Continent, in favour of *charcoal high* or *blast-furnaces.*

Chenot's Process.—As far back as 1823, M. Adrien Chenot introduced a process for preparing metallic iron, in a spongy form, direct from the ore by cementation in charcoal. The ore usually employed in this process is brown hæmatite, which, in the form of lumps, is mixed with wood-charcoal in more than sufficient quantity to effect its deoxidation. The furnace used for reduction consists of a cubic pedestal of masonry, surmounted by a truncated cone, and containing two rectangular chambers or retorts, which widen in the lower part to facilitate the descent of the reduced charge. Each retort is surrounded by a series of vertical flues, communicating below with the fireplaces and above with a large flue. The reduced iron is discharged from the retorts on to a special cooler, where oxidation is prevented. The daily charge of a furnace, working with a single retort, at Hautmont, consisted of about 1½ ton of calcined Sommorostro ore (containing 55 per cent. of iron), and about ½ ton of wood-charcoal. This charge would yield about 12 cwts. of iron-sponge, and about 2 cwts. of charcoal would be regained as the excess over the quantity needed for reduction. At the same time there is about 1 ton 6 cwts. of coal consumed as fuel. The reduction occupies three days, but as the freshly-formed sponge is allowed to remain three days in the cooler, the entire process occupies six days. When perfectly reduced, the iron sponge presents a bright grey colour, and is so soft that it may be readily sliced with a knife; it is easily ignited, and when set on fire burns until it is completely oxidised. The specific gravity is very variable, but the average is about 1·25.

In addition to the 'external' or 'indirect' method described above, Chenot's sponge may be obtained by an 'internal' or 'direct' method, in which the ore is reduced not by means of solid charcoal, but by a hot current of carbonic-oxide gas. The furnace in which this reduction is effected is similar to that used for the indirect process, excepting that the reducing chamber is connected with gas-furnaces for generating the carbonic oxide. A modification of Chenot's direct method, by M. Tourangin, has been used both in France, and near Bilbao, in Spain. The iron-sponges are balled up in a charcoal hearth. It should be remarked, that the raw material suited for Chenot's process should be a pure ore, such as hæmatite or spathose ore, porous in texture, and not fusible at the temperature at which the reduction is effected.

Gurlt's Process.—In 1857, Dr. Adolph Gurlt introduced a process for reducing iron-ores by means of gaseous fuel, maintaining that either cast-iron steel, or wrought-iron could be obtained according to the proportion of carbon in the reducing gases. It was said that the process effected a saving of about 50 per cent. of fuel, compared with that consumed in the blast-furnace. The reduction and cementation of the ore requires a current of reducing gases, which may be generated at a moderate temperature; but the fusion of the reduced iron must be effected at a higher temperature in a current of neutral gas, that is to say, neither reducing nor oxidising. Hence the process was resolved into two operations conducted in separate furnaces. The reduction was effected in a furnace with a shaft similar to that of an ordinary blast-furnace, and supplied with carbonic oxide from a gas-generator. The fusion was conducted in a closed hearth, connected with two gas-generators, and supplied with a blast through tuyères. Experiments made by Gurlt, in 1857, at the Rheinbach Hütte, near Bonn, decidedly failed, but the process was afterwards successfully worked, in a modified form, at Santa Aña de Bolueta, in Biscay. The ore used at Bolueta was

Sommorostro brown hæmatite, containing about 65 per cent. of iron. The gases were generated from oak- and beech-wood charcoal. The iron was obtained in spongy masses, having the form of the pieces of ore from which they were reduced. The sponge was protected from oxidation by cooling under charcoal-dust. Three charges were worked daily; these consisted in the aggregate of 72 cwts. of ore, with 18¾ cwts. of charcoal, and produced 26¾ cwts. of iron-sponge. Gurlt's fusion-furnace was not employed at Bolueta, but the sponges were welded in the Catalan forge. Every 100 lbs. of finished bar-iron represented a consumption of 285 lbs. of raw ore, and 174 lbs. of wood-charcoal. It is maintained that the loss of iron is compensated by the saving in fuel; hence the process has been recommended where fuel is dear, and a supply of pure and porous ores is readily accessible.

Siemens's processes for the direct production of malleable iron.—The production of wrought iron or steel directly from the ore has recently been brought prominently into notice by Mr. Siemens, who has adopted several methods based upon the use of his regenerative gas-furnace for this purpose. The following are some of the methods employed, as described by the inventor:—

A Method of producing spongy iron by means of a rotative furnace.—This furnace consisted of a long cylindrical tube of iron of about 8 feet diameter, mounted upon antifriction rollers; the brick lining of it was mounted with longitudinal passages for heating currents of air and gas, prior to their combustion at the one extremity of the rotary chamber. The flame produced passes thence to the opposite or chimney end, where a mixture of crushed ore and carbonaceous material was introduced. By the slow rotation of this furnace, the mixture advanced continually to the hotter end of the chamber, and was gradually reduced to spongy iron. This dropped through a passage constructed of refractory material on to the hearth of a steel melting furnace, where a bath of fluid pig-metal had been provided. The supply of reduced ore was continued till the carbon in the mixture was reduced to the minimum point before indicated. The rotation was then arrested to prevent further descent of reduced ore; spiegel was added, and the contents of the melting-furnace tapped into a ladle, and thence into ingots.

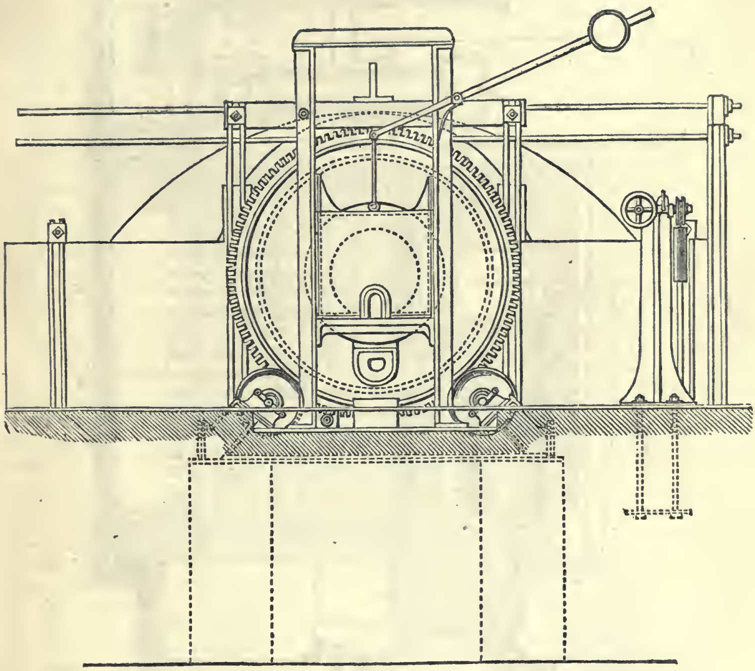
This rotary furnace was erected by Mr. Siemens at the Landore Works, in 1869, and it was so far successful, as the reduction of the ore was accomplished in a comparatively short time. A difficulty, however, presented itself, which led to its immediate abandonment; it was found that the spongy metal produced absorbed sulphur from the heating gases, and was rendered unfit for the production of steel; the spongy iron, moreover, upon its introduction into the steel melting furnace, floated upon the metallic bath without being readily absorbed into it, and was in great part reoxidised and converted into slag by the action of the flame in the furnace.

These experiments proved that the successful application of reduced ores could not be accomplished through their conversion into spongy metals, and fully explained the want of success which had attended the previous efforts of Clay, Chenot, Yates, and others to produce iron directly from the ore. On the other hand, Mr. Siemens observed that in melting iron ores no sulphur was absorbed from the flame; and it occurred to him that by melting ores mixed with fluxing materials in a furnace so arranged as to accomplish its fusion in a continuous manner and on a large scale, the fused ore might be acted upon by solid carbonaceous matter, so as to separate the metallic iron in a more compact form, while the earthy constituents of the ore would form a fusible slag with the fluxing material. Experiments proved that this reduction by precipitation of the iron could be accomplished only at an intense heat, exceeding the welding heat of iron, but that the iron so produced was almost chemically pure, although the ores and the fuel used might contain a very considerable percentage of sulphur and phosphorus.

The furnace used for carrying out this process of fusion and precipitation consists of a reverberatory gas-furnace, having two beds formed by the ore itself: on the upper bed a lake of fused ore is formed, which can be let off into the lower bed by piercing the intervening bank of unfused ore; the lower bed is divided into two compartments, each provided with a door, used alternately. The dense carbonaceous material, such as anthracite or hard coke, to be used for the precipitation of the iron in the lower bed, is reduced to a state of powder and mixed with about an equal weight of pulverulent ore. This mixture is spread over the bottom surface of the working bed, and the fluid ore is let in upon it. By stirring with a rabble it is transformed into a pasty and foaming mass, which in the course of from 40 to 50 minutes is shaped into a metallic ball in a bath of fluid cinder, which may be shingled in the usual manner and formed into bar-iron, or transferred to the pig-iron bath of a steel melting furnace, where it readily dissolves. The accomplishment of this process involves, however, a certain degree of manual labour and skill, as, if it be carelessly conducted, the yield of iron will be unsatisfactory. The analysis of the slags shows a variable percentage of iron, amounting rarely to less than 15 per cent., but reading occasionally up to 40 per cent.

A form of rotating furnace, represented in *fig.* 1217 in longitudinal section, and in an end elevation in *fig.* 1216, has been found to give very successful results in practice. It consists of a cylindrical chamber of wrought iron mounted upon friction-rollers, and capable of receiving motion at different speeds from pairs of spur-wheels driven by a steam-engine. The arrangements for forcing, which are those of the usual regenerative gas-furnace, are placed at one end of the cylinder, while the other is closed by a working door with a stopper-hole like that of an ordinary reverberatory furnace, as seen in *fig.* 1216. The slags are received into a waggon, which runs upon a railway, in a pit below the cylinder. The lining or fettling of the cylinder is formed of a bauxite or aluminous iron ore, which is ground up with a little graphite, and strongly heated. The iron of the ore is thus reduced to the metallic state; and the alumina, from the intense and long-continued heating, is converted into a dense substance resembling emery, which is capable of resisting abrasion by the materials of the charge, as well as being unaffected chemically.

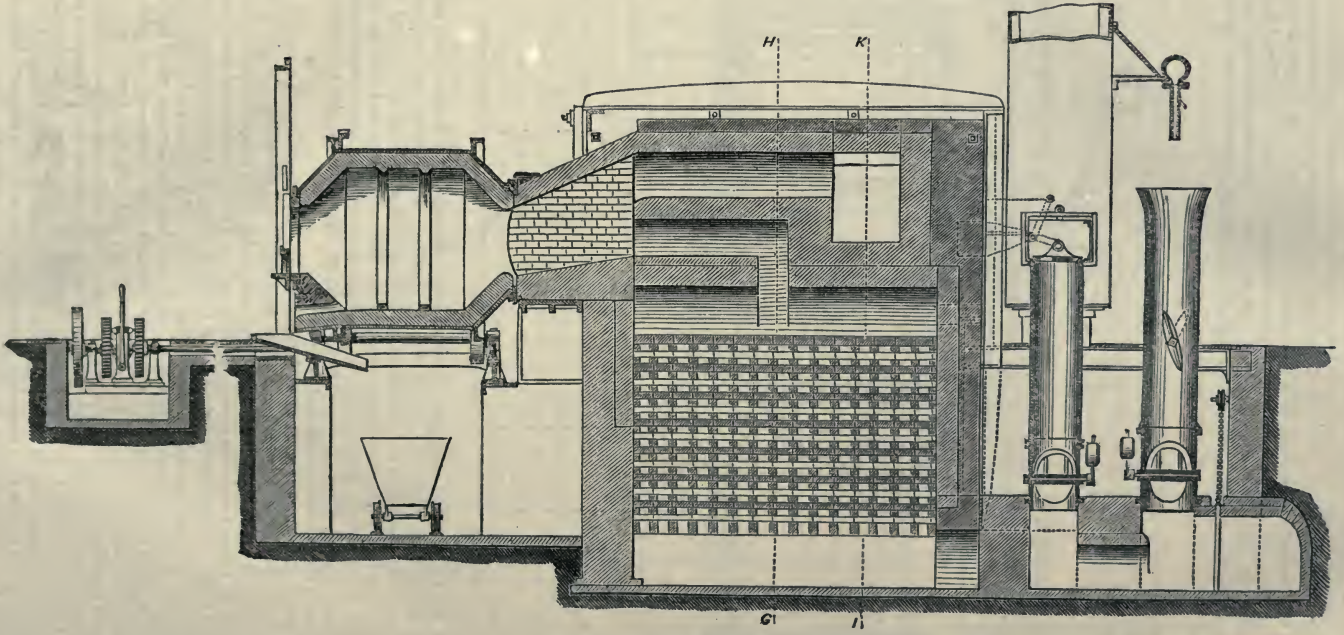
1216



The rotative furnace is worked as follows :—

The ore to be smelted is broken up into fragments, not exceeding the size of peas or beans; to it is added lime or other fluxing material in such proportion that the gangue contained in the ore and flux combines with only a little protoxide of iron into basic and fluid slag. If the ore is hæmatite, or contains silica, it is preferable to add alumina in the shape of aluminous iron ore; manganiferous iron ore may also be added with advantage. A charge of say 20 cwts. of ore is put into the furnace when fully heated while it is slowly revolving. In about 40 minutes this charge of ore and fluxing material will have been heated to a bright redness, and from this time from 5 cwts. to 6 cwts. of small coal of uniform size (not larger than nuts) are added to the charge, whilst the rotative velocity is increased in order to accelerate the mixture of coal and ore. A rapid reaction is the result; the peroxide of iron being reduced to magnetic oxide begins to fuse, and at the same time metallic iron is precipitated by each piece of carbon, while the fluxing materials form a fluid slag with the siliceous gangue of the ore. The slow rotative action is again resorted to, whereby the mass is turned over

1217



and over, presenting continually new surfaces to the heated lining and to the flame within the rotator.

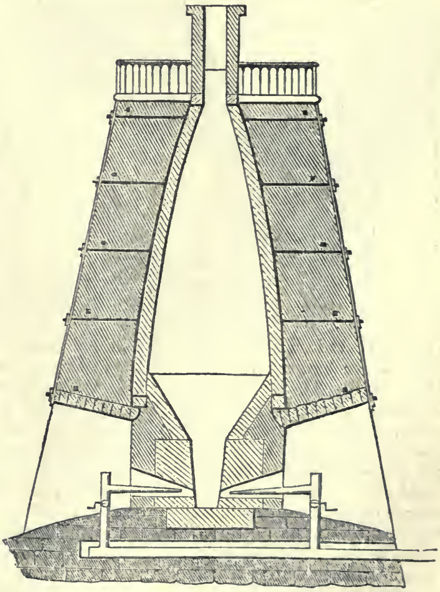
During the time of this reaction, carbonic oxide gas is evolved from the mixture of ore and carbon, and heated air only is introduced from the regenerator, to effect its combustion within the rotating chamber. The gas from the gas-producers is entirely, or almost entirely, shut off during this portion of the process. When the reduction of the iron ore is thus nearly completed, the rotator is stopped in the proper position for tapping off the fluid cinder; after this the quick speed is imparted to the rotator, whereby the loose masses of iron contained in it are rapidly collected into two or three metallic balls. These are taken out and shingled in the usual way of consolidating puddled balls; the furnace is tapped again, and is ready to receive another charge of ore. The time occupied in working one charge rarely exceeds two hours: and supposing that 10 cwts. of metallic iron is got out per charge, the apparatus is capable of turning out at least 5 tons of puddled bar per diem. If anthracite or hard coke is available for effecting the reduction of the ore, it should be crushed much finer than when coal or brown coal is used, the idea being that each particle of the reducing agent should be consumed during the period of chemical reduction. If wood is used, it must be charged, for the same reason, in still larger pieces.

It is feasible to push the operation within the rotator to the point of obtaining cast steel. If this is intended, the relative amount of carbonaceous matter is somewhat increased in the first instance, so that the ball if shingled, would be of the nature of puddled steel, or contain even more carbon mechanically enclosed.

It may however be asked, why the rotating furnace should admit of the complete combustion of carbon, whereas in the blast-furnace such complete combustion is, as is well known, not possible, because each atom of carbonic acid formed would immediately split up into two atoms of carbonic oxide by taking up another equivalent of carbon from the coke present? The following explanation will serve to elucidate this point:

In the rotative furnace streams of carbonic oxide are set up within the mass under reaction, and this carbonic oxide on reaching the surface meets the current of intensely-heated air proceeding from the regenerators, and completes with its perfect combustion within the free space of the chamber. The carbonic acid thus generated comes in no further contact with the carbon, consequently it cannot split up, but is drawn away unchanged into the chimney, while the evolved heat is taken up by the sides of the chamber, and transmitted by reverberation and conduction to the mixture of ore, fluxes, and coal.

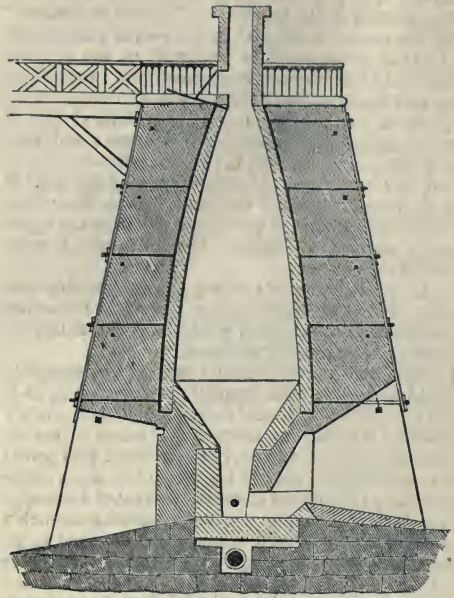
1218



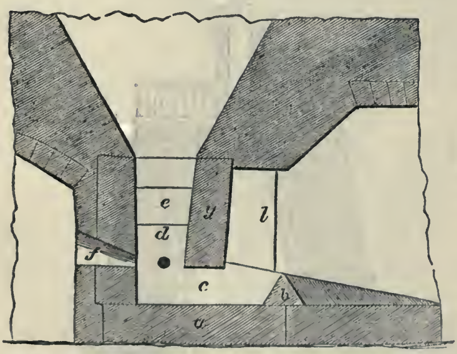
Charcoal Blast-Furnace.—The general form of the charcoal blast-furnace, as used in the United States, where this fuel is common, is shown in vertical section in *fig.* 1219, and in section through the tuyère arches in *fig.* 1218. The ores designed to be smelted in this furnace are hydrated oxides of iron, such as brown hæmatite, brown ironstone, pipe-ore, and bog-ores. The height is 35 feet; hearth from base to the boshes, 5 feet 6 inches; width at the bottom, 24 inches; and at top, 36 inches. The tuyères are 20 inches above the base. The boshes are 9 feet 6 inches in diameter, and measure from the top of the crucible 4 feet, which gives about 60° slope. The blast is conducted through sheet-iron or cast-iron pipes laid below the bottom stone into the tuyères. The top is furnished with a chimney, by which the blaze from the tunnel head is drawn off. Around the top is a fence of iron or wood. *Fig.* 1220 shows the method of preparing and arranging the hearthstones. *d* is the bottom stone, made of a fine close-grained sandstone, from 12 to 15 inches thick, at least 4 feet wide, and

6 feet long; it reaches underneath at least half of the dam-stone *b*. This bottom stone is well bedded in fire-clay, mixed with three-fourths sand. After the bottom stone is placed, the upper part of which must be three-fourths of an inch lower at the dam-stone than at the back, the two side stones, *c*, are laid embedded in fire-clay. These stones must be at least 6 feet and a half long, reaching from 18 inches behind the crucible to the middle of the dam-stone. Their form is most commonly square, that is, a prism of four equal sides; the transverse section of the grain must be in all cases placed towards the fire; the side stones are sometimes square, but often bevelled according to the slope of the hearth. Upon these stones the tuyère stones, *d*, are bedded; the latter suffer much from heat, and therefore ought to be of the best quality. They should be from 20 to 24 inches square, or even larger: the tuyère holes, *f*, a kind of taper arch, are cut out before the stones are bedded. These stones do not reach further than to the front or tymp-stone, *g*, and are therefore scarcely 4 feet long; the top stone *e*, is generally sufficiently high to raise at once the crucible to its destined height. After both sides are finished, the back stone *l* is put in, and then the tymp-stone, *g*; the space between the hearthstones and the rough wall of the furnace stack is filled and walled up with common brick or stones.

1219



1220



In starting a charcoal furnace, it is first thoroughly dried by burning a fire for several weeks in the interior, which has a temporary lining of bricks. The lower part of the furnace or the hearth is then filled gradually with charcoal, and when the fuel is well ignited, and the furnace half filled, ore may be charged in; but it is sometimes advisable to increase the draught by forming grates by laying across the tymp a short iron bar, as high up as the dam-stone, by resting upon this bar six or seven other bars or ringers, and by pushing their points against the back stone of the hearth. There is not much iron made during the first 24 hours; most of the ore is transformed into slag, and the iron which comes down gets cold on the bottom stone, where it is retained; the blast should not be urged too fast at first, but increased gradually, in order to avoid the serious evil arising from a cold hearth; if all goes on well, the hearth will be free from cold iron or clinkers in a week, the yield of iron will increase, and the burden may be increased likewise. The average charge of charcoal, which should be dry, coarse, and hard, is about 15 bushels. According to Overman's experience, the most favourable height for a charcoal furnace is 35 or 36 feet; if below this standard they consume too much fuel, if above they are troublesome to work; if it be desired to enlarge the capacity of a furnace, he thinks it better to increase the diameter of the boshes, or to curve the vertical section. There is much difference of opinion amongst managers of furnaces on the subject of the proper size for the throat of the furnace; the tendency of narrow throats would seem to be to consume more coal than wide ones, inasmuch as in Pennsylvania and throughout the whole west, where narrow tops are preferred, the consumption of charcoal per ton of iron is from 160 to 180 bushels, while in the State of New York, and further east, where the furnace throats are wider, the consumption is from 120 to 130 bushels. Another subject which demands the strictest attention is the regulation of the blast. A weak soft charcoal will not bear a much greater pressure than from half a pound to five-eighths of a pound to the square inch; strong coarse charcoal will bear from three-quarters of a pound to a pound; and again, it may be laid down as a rule, that the larger the throat in proportion to the boshes, the stronger ought to be the blast, and that a narrow top and wide boshes, while they permit a weaker blast, involve the loss of much fuel. In every case a careful roasting of the ores at charcoal furnaces will prove advantageous; this is the surest means of saving coal and blast, and of avoiding more annoyances in the working of the furnaces.

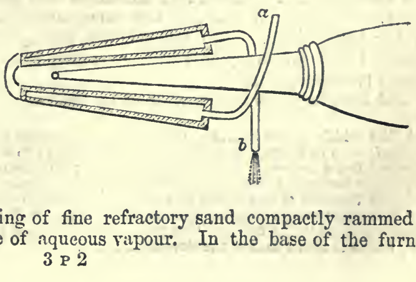
The above account represents the form of blast-furnace as constructed at the time of the former edition of this work. Other modifications have since been introduced mainly in the direction of increased size, and the avoidance of strongly-contracted slopes as sudden changes in dimensions.

English Process of Iron-making.—The 'Mineral Statistics' gives us the quantity of pig-iron produced in Great Britain in the year 1872, as follows:—

	Tons
Northumberland	38,766
Durham	760,172
Yorkshire, North Riding	1,122,114
Do. West Riding	148,636
Derbyshire	283,375
Lancashire	524,041
Cumberland	440,575
Shropshire	133,046
North Staffordshire	275,925
South Staffordshire and Worcestershire	673,470
Northamptonshire and Lincolnshire	96,413
Gloucestershire, Wilts, and Somerset	97,481
North Wales	54,698
South Wales	1,002,623
Scotland	1,090,000

Of the Blast-Furnace.—The blast-furnaces at present in use are of various sizes, being from 35 to 90 feet in height, and at the *boshes*, or widest part, from 12 to 30 feet. The internal form commonly adopted consists essentially of two frustums of cones meeting each other at their bases, at the point where the widest part or the top of the boshes is situated. From this point the furnace gradually contracts both upwards to its mouth, and downwards to the level of the tuyères below. The hearth, properly speaking, is that part of the furnace only which receives the fluid metal and cinder, as they fall below the level of the tuyères. It forms a short prolongation from that point of the lower inverted cone. From the boshes upward the width gradually decreases to the tunnel-head, which varies from 7 to 9 feet in diameter, according to the size of the furnace. The hearth is generally a cube, from 2½ to 3 feet square. The air is introduced by one, two, or three small apertures, called *tuyères*. When two tuyères are used, the orifices of their blow-pipes are about 3 inches in diameter, and the pressure of the blast is from 2½ to 3 lbs. on the square inch. To prevent the tuyères from being melted by the intense heat to which they are exposed, a stream of cold water is caused constantly to flow round their nozzles by an arrangement which will be immediately understood by an inspection of *fig.* 1221, which represents a section of a tuyère nozzle thus protected, the cold water entering the casing by the tube *a*, and the hot water running off by the tube *b*. The upper part of the furnace above the boshes is called the *cone* or *body*. It is formed by an interior lining of fire-brick, about 14 inches in thickness, between which and the exterior masonry is a casing of fine refractory sand compactly rammed in, air-holes being left for the escape of aqueous vapour. In the base of the furnace

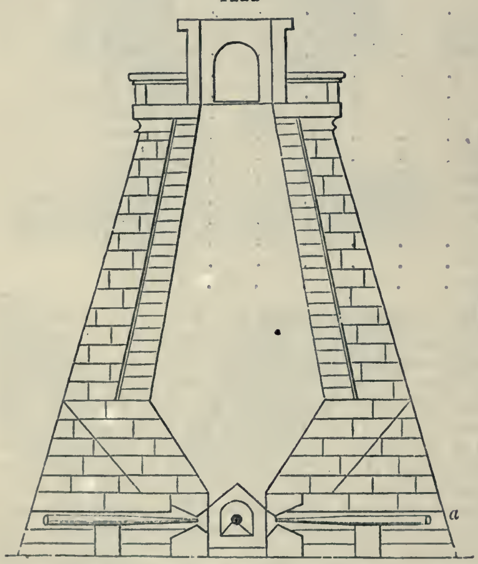
1221



four arches are left, the back and sides are called *tuyère houses*, the front is called the *cinder fall*; the bottom of the furnace is formed either of large blocks of coarse sandstone or of large fire-bricks. The materials are charged into the furnace through the tunnel-head, which is provided with one or more apertures for the purpose. The general form of a blast-furnace is shown in *fig.* 1222, and the following measurements represent the interior structure of two that worked well:—

	No. 1 feet	No. 2 feet
Height from the hearth to the throat or mouth . .	45	49
„ of the crucible or hearth	6½	6
„ of the boshes	8	7
„ of the cone	30½	36
„ of the chimney or mouth	8	12¾
Width of the bottom of the hearth[1]	2½	2
„ at its upper end	3	2⅔
„ of the boshes[2]	12⅔	13½
„ at one-third of the belly	12	11½
„ at two-thirds of ditto	8⅓	9½
„ at mouth	4½	3⅙
Inclination of the boshes[3]	59°	52°

1222



1223

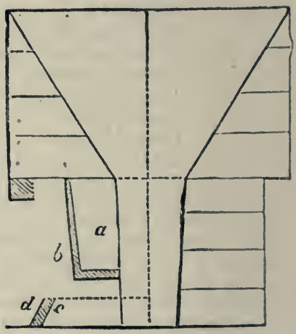


Fig. 1223 represents the hearth and boshes in a vertical side section. *a* is the tymp-stone, and *b* the tymp-plate, for confining the liquid metal in the hearth; the latter is wedged firmly into the side-walls of the hearth; *c* is the dam-stone, which occupies the whole breadth of the bottom of the hearth, excepting about 6 inches, which space, when the furnace is at work, is filled before every cast with a strong binding sand. This stone is faced outside by a cast-iron plate *d*, called the *dam*-plate, of considerable thickness and peculiar shape. The top of the dam-stone, or rather the notch of the dam-plate, lies from 4 to 8 inches under the level of the tuyère-hole. The space under the tymp-plate, for 5 or 6 inches down, is rammed full for every cast with a strong loamy earth or even fine clay, a process called tymp-stopping.

The blowing-machines employed in Staffordshire are generally cast-iron cylinders,

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[1] The width of the hearth differs greatly in the furnaces in different localities. In Scotland it varies from 6 to 8 feet; in the Welsh furnaces from 5 to 8 feet. When coke is used as fuel, Mr. Truran thinks 6 feet a sufficient width for all purposes; but with coal, with full-sized furnaces, 16 to 19 feet across the boshes, he thinks a 7-feet hearth to be more advantageous.

[2] The diameter of the boshes in some of the Welsh furnaces is as much as from 18 to 19 feet.

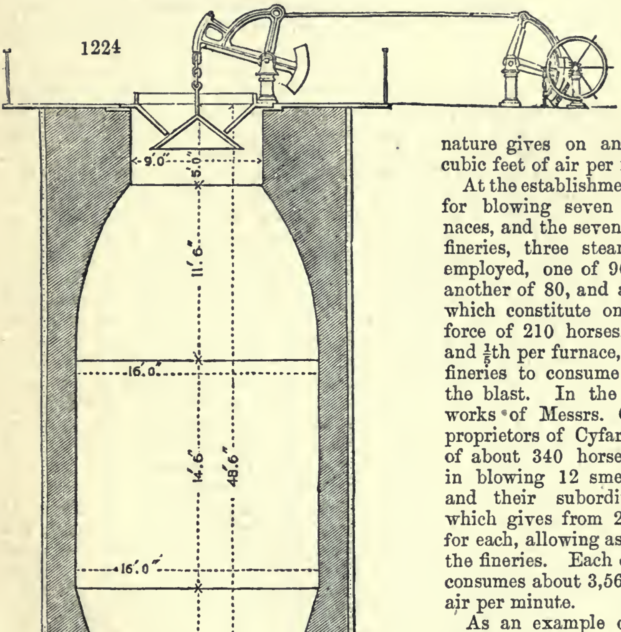
[3] The angle with which the boshes rise in different furnaces varies from 50° to 80°. Mr. Truran thinks that when the full smelting power of the furnace is desired, the angle should not be less than 70°, which is about that of the Scotch furnaces.

in which a metallic piston is exactly fitted as for a steam-engine, and made in the same way. Towards the top and bottom of the blowing-cylinders orifices are left covered with valves, which open inside when the vacuum is made with the cylinders, and afterwards shut by their own weight. Adjutages conduct into the iron globe or chest the air expelled by the piston, both in its ascent and descent, because these blowing-machines have always a double stroke.

The pressure of the air is made to vary through a very considerable range, according to the nature of the fuel and the season of the year; for as in summer the atmosphere is more rarefied, it must be expelled with a compensating force. The limits are from $1\frac{1}{2}$ to $3\frac{1}{2}$ lbs. on the inch, the average in Staffordshire being 3 lbs. The orifices, or nose-pipes, through which the air issues, also vary with the nature of the coke and the ore.

In a blast-apparatus employed at the Cyfartha works, moved by a 90-horse steam-power, the piston-rod of the blowing-cylinder is connected by a parallelogram mechanism with the other end of the working-beam of the steam-engine. The cylinder is 9 feet 4 inches in diameter, and 8 feet 4 inches high. The piston has a stroke 8 feet long, and it rises 13 times in the minute. By calculating the sum of the space percursed by the piston in a minute, and supposing that the volume of the air expelled is equal to only 96 per cent. of that sum, we find that 12,588 cubic feet of air are propelled every minute. Hence a horse-power applied to blowing-machines of this nature gives on an average 137 cubic feet of air per minute.

1224



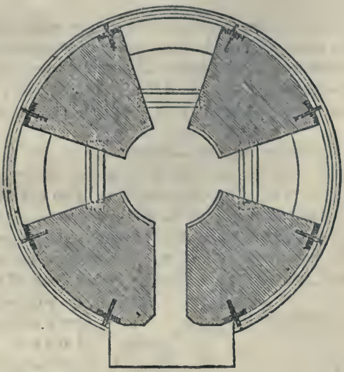
At the establishment of Cyfartha for blowing seven smelting furnaces, and the seven corresponding fineries, three steam-engines are employed, one of 90 horse-power, another of 80, and a third of 40, which constitute on the whole a force of 210 horses, or 26 horses and $\frac{1}{8}$th per furnace, supposing the fineries to consume one-eighth of the blast. In the whole of the works of Messrs. Crawshay, the proprietors of Cyfartha, the power of about 340 horses is expended in blowing 12 smelting furnaces and their subordinate fineries; which gives from 25 to 26 horses for each, allowing as before $\frac{1}{8}$th for the fineries. Each of the furnaces consumes about 3,567 cubic feet of air per minute.

As an example of the blowing power used in Cleveland, the blast-furnaces at Ayresome may be selected. They are four in number: each 18 feet high; 25 feet width of boshes; 15 feet broad at throat, with cup and cone; 10 feet 6 inches broad. The hearth is 8 feet diameter; 3 feet deep below tuyères, and 4 feet above them. There are 10 boilers for four furnaces, but only 8 are in use at a time. They are plain cylinders, 60 feet long, and $4\frac{1}{2}$ feet in diameter.

There are 3 blast-engines; but 2 only required to blow the four furnaces. They have 96-inch blast- and 40-inch steam-cylinders; the steam-pressure is 50 lbs., and the blast $4\frac{1}{4}$ lbs. in the engine house, equal to 4 lbs. at the tuyères.

One engine, blowing two furnaces making 750 tons of pig-iron per week, gives 11,500 cubic feet of blast per minute, at 30 strokes per minute; but when making 800 tons, 32 strokes are required.

1225



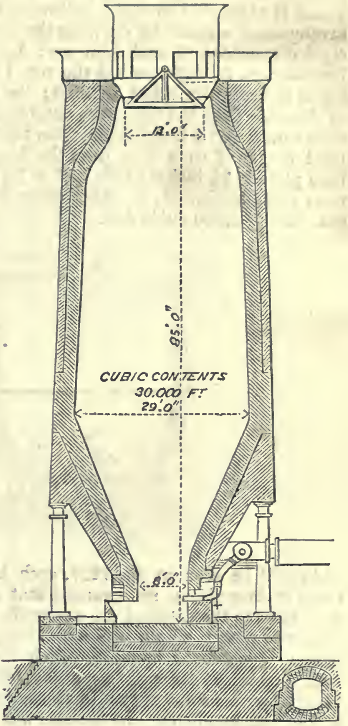
The form of the blast-furnace from the boshes to the throat is exhibited in *fig.* 1222 as a truncated cone, and such was formerly invariably the construction; of late years, however, considerable variations have been introduced. In Scotland the body of the furnace frequently is carried up cylindrical, or nearly so, for a considerable height, terminating with the usual truncated cone to the mouth; in other places a curved line is substituted for a straight one. The form adopted in some furnaces at Ebbw Vale and Blaina is shown in *fig.* 1224 in vertical section, and in *fig.* 1225 in horizontal section at the tuyère level.

The diameter of the throat or filling place is a subject of very great importance to the operations of the furnace. Most iron masters are, we believe, agreed as to the impolicy of the narrow tops formerly adopted; the waste of fuel in such furnaces, where the width of the throat scarcely averaged one-fourth of the diameter of the furnace, was very great, the average yield of coal to the ton of crude iron exceeding 6 tons; by enlarging the throat to one-third, the consumption of coal was reduced to 4 tons; and by continuing the enlargement to one-half, it was reduced to 2 tons. Mr. Truran states that, on reducing the diameter of the throat of a furnace at Dowlais from 9 feet to 6, the make of pig-iron weekly fell off from 97 tons to an irregular make of from 50 to 70 tons; and that while with the 9-feet throat the consumption of coal was 45 cwts. to the ton of iron, it rose with the 6-feet throat to 70, 80, and 90 cwts., the quality of the iron being exceedingly bad. On enlarging the throat to 9½ feet, the make, for a period of six months, averaged over 160 tons, with a good yield of coal and other materials. Mr. Truran appears to question the utility of reducing the diameter of the furnace at the top, which was only adopted in the first place from an erroneous impression that the furnace could be filled best through a contracted mouth; but it may be questioned whether this widening of the throat may not be carried too far, so as to disperse the heated gases too rapidly, and whether a diameter much greater than one-half of the largest dimensions of the furnace above the boshes can with utility be adopted. On this subject Mr. Kenyon Blackwell says:—

'If that part of the blast-furnace commencing at the point where it attains its greatest width were continued of the same wide dimensions upwards to its mouth, two objectionable results would ensue: first, the upper part of the furnace would be cooled by the too rapid dispersion of the ascending column of heated gases, and by the entire absence of the reverberating effect of the contracted mouth; and, secondly, the materials could not be equally spread from the filling-holes over so wide a surface. The diameter of the upper part of the furnace ought, therefore, to be such as will cause the materials thrown in at the filling-holes to distribute themselves equally in their descent over every part of the sectional area of the furnace, and will produce such a reverberation only of heat as shall be sufficient to expel the water and carbonic acid contained in the materials, without consuming any of the carbon of the fuel, which ought to remain intact until it reaches the lower regions of the furnace, where it is vaporised as carbonic oxide, and produces the reactions on which the reduction of the ore depends.'

An example of the largest and most improved modern type of blast-furnace as used in the Cleveland district is shown in *fig.* 1226, which represents one of the Newport furnaces at Middlesbrough in a vertical section. The foundation, up to the ground level, consists entirely of brickwork resting upon clay. From this point a circular base is carried to a height of 7 feet in solid brickwork, mainly of fire-brick, with a stone curb all round, on which the supporting columns rest. These columns are 18 feet 6 inches in height, averaging 2 feet 4 inches in diameter, with a thickness of metal of 2 inches. They serve to support the structure from the angle of the bosh upwards; the lower part being carried partly by the wrought-iron conical casing, and partly by the brickwork and stanchions which surround the hearth. The whole of the furnace from the tuyères upwards is cased with wrought-iron plates, those of the lower or conical part being $\frac{1}{2}$ inch thick, while those of the barrel vary from $\frac{7}{16}$ths of an inch below to $\frac{3}{8}$ths of an inch at the top. The interior of the furnace is lined throughout with fire-brick lumps 5 inches thick, and of dimensions varying with the internal diameter, no two courses being alike. The backing between the inner lining and the shell is of ordinary fire-brick. Up to a short distance above the tuyères every fire lump is chisel-dressed on both beds and joints, and the same is also the case with the hearth lumps, which consist of two courses set on an edge and breaking joint; the lower course being 18 inches deep and the upper one 3 feet. The following are the principal dimensions of the furnace:—Diameter of the hearth, 8 feet; depth at tuyères, 3 feet 6 inches; diameter at the bosh, 28 feet; diameter of the bell-opening, 13 feet; total height from the hearth to the platform, 83 feet; the cubical capacity is 30,085 cubic feet. There are four tuyères, each with a nozzle 6 inches in diameter, and the dam opening is 2 feet wide. The pig-beds are necessarily of large dimensions, being capable of holding 1,200 moulds for each furnace. The slag-boxes are eight in number, and large enough to contain upwards of 3 tons of slag each.

1226

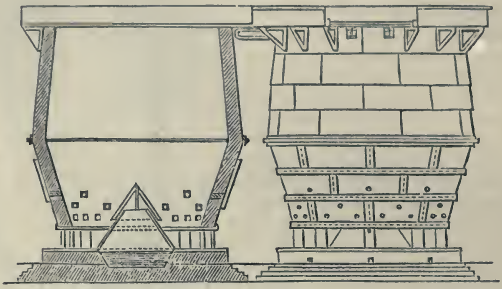


Calcination of the Ironstone.—This is effected either in kilns, or in the open air; the object being to separate carbonic acid, water, sulphur, and other substances volatile at a red heat. The operation is performed most effectually, and probably at the smallest cost, in kilns. The interior shape of the calcining-kilns differs in different works, but they may all be reduced to that of the common lime-kiln. A coal-fire is first lighted at the bottom of the kiln, and the ironstone is placed over and around, until the floor is covered with red-hot ore; a fresh layer of ironstone, with about 5 per cent. of coal, is then laid on, to the depth of 8 or 9 inches; and when this is red hot, a second layer is added, and so on gradually till the kiln is filled. By the time this is done, the lowermost layer is cold and fit to draw; so that the working of the kiln is a continuous operation. When the ore is calcined in the open air, a heap mingled with small coal (if necessary) is piled up over a stratum of larger pieces of coal, the heap being 5 or 6 feet high, by 15 or 20 feet broad. The fire is applied at the windward end, and, after it has burnt a certain way, the heap is prolonged at the other extremity, as far as the nature of the ground, or the convenience of work, requires. From the impossibility of regulating the draught, and from exposure to the weather, the calcination of ore cannot be so well performed in the open air as in kilns; and as to the relative cost of the two methods, Mr. Truran calculates that the quantity of coal per ton of ore is, in the kiln, one hundred-weight of small, and in the open air, two hundred-weights of small, and a half hundred-weight of large; and that while the cost of filling the kiln is barely a penny per ton, that of stacking the heaps on the open-air plan, and watching them during the period they are under fire, amounts to fourpence per ton. Against this must, however, be placed the cost of erecting the kiln, which according to the same authority amounts, for a kiln of a capacity equal to 70 tons of argillaceous ore, which will calcine 146 tons weekly, to 160*l*. The ironstone loses by calcining from 25 to 30 per cent. of its weight; it has undergone a remarkable change by the operation; in the raw state, it is a grey or light brown stony-looking substance, not attracted by the magnet; after calcination it has a dry feel, adheres strongly to the tongue, is cracked in all directions, is of a light reddish colour throughout, and acts powerfully on the magnet. It should be carried to the furnace as soon as possible, or if kept should be carefully protected from the rain.

The calcining kilns, *fig.* 1227, were erected at Middlesbrough, from the designs of

John Gjers. They were of a circular form, and have wrought-iron shells; but unlike ordinary kilns of this class, the shells are made of the same shape as the interior of the kilns, so that there is a uniform thickness of 15 inches of fire-brick lining in all parts. The shell and lining of each kiln rest upon an annular cast-iron entablature, which is supported by eight hollow cast-iron pillars cast on the base plate. By this arrangement a space for drawing the charge is left all round the bottom. The principal dimensions of each kiln are: Internal diameter at the bottom, 14 feet; at the largest part, 20 feet; and at the top, 18 feet. The height from the base plate to the top of the columns, 2 feet 3 inches; the thickness of the entablature, 4 inches. Height of the shell from the top of the entablature on which it rests to the level of the largest diameter, 9 feet 2 inches; and from that level to the top of the shell, 12 feet 2 inches; total height of each kiln, from the base plate to the top of the shell, 22 feet. The base plate is 2½ inches thick, and is 20 feet in diameter; it is cast in eight pieces, and rests upon brickwork, in which the air-passages are formed. The cubic contents of each kiln is 5,500 cubic feet.

1227

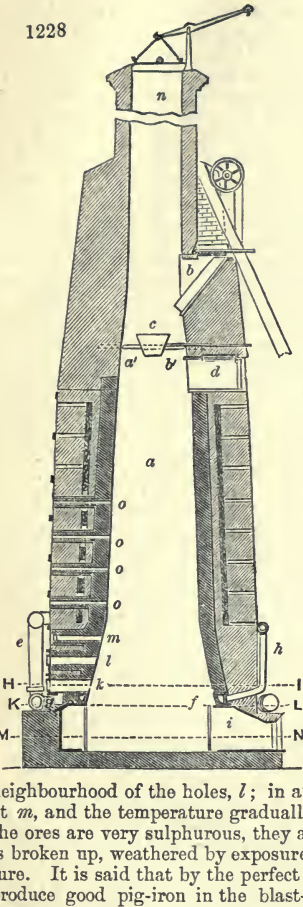


As will be seen in *fig.* 1227, each kiln is provided with a cast-iron central cone, made in two pieces, so arranged that an annular space is left between them. This cone spreads the calcined ore outwards towards the openings through which it can be withdrawn, and it also acts beneficially in assisting to break up any large scars or lumps partly fused together, which may happen to come down. The central cone might, as far as the mere spreading action is concerned, be made plain and in a single piece; but the form shown in the figure has been adopted by Gjers with a view of, in some cases, employing the annular space between the two cones for the admission of waste gas from the furnace. Where the quantity of furnace-gas is not sufficient to be applicable to this purpose, the double cones still furnish the means of giving a good air-supply to the kilns.

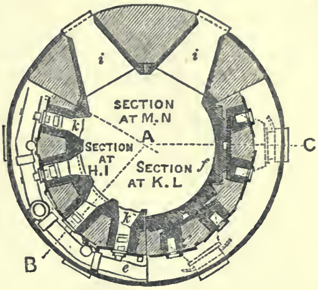
In the case of the particular kilns we are describing, the central cones are each 8 feet in diameter at the bottom, and 8 feet high, and the air is conducted to them through eight channels or flues formed in the brickwork at the base of each kiln. In addition to these passages, there are a number of holes, *fig.* 1127, for the supply of air formed in the outer shell. The kilns are placed at a distance of 25 feet apart from centre to centre, and each is surrounded at the top by a gallery formed of wrought-iron brackets covered with cast-iron plates. The galleries of four kilns are connected with each other at four points, the space between the kilns being bridged over with wrought-iron girders.

Westman's Calcining Kiln.—Kilns in which the waste gases of the blast-furnace are applied to the calcination of ores are extensively used in Sweden, and have thence been introduced into Russia and the United States. The improved form given to these kilns by Westman, in which the gases are burnt by introduction of a blast of air, is represented in the accompanying woodcuts. *Fig.* 1228 is a vertical section of the kiln, the right half being taken through the line A B, and the left half through A C in *fig.* 1229. *Fig.* 1229 shows horizontal sections at different heights along the lines M N, K L, and H I of *fig.* 1228. The shaft, *a*, is everywhere circular in horizontal section. The raw ore is introduced through the shoot, *b*, which when not in use is closed by a trap-door, and is delivered in the middle of the kiln through the moveable hopper, *c*. The opening, *d*, allows the throat, *a′ b′*, to be examined, and thus it may be seen whether the kiln is properly filled and the ore duly distributed, whilst it also allows the ore to be re-arranged when necessary. The gas is conveyed through the circular main, *e*, and passing through the channel, *g*, enters the furnace through the twelve passages, *k*; the supply of gas may be regulated by means of horizontal sliding valves. The air necessary for combustion is introduced through the tube, *h*, and enters the furnace through twenty-four openings in the hollow ring, *f*. The roasted charge is withdrawn through six passages, *i*, and air serving to oxidise the sulphur in the hot ore also gains access through these apertures. The openings, *l*, *m*, serve for introducing bars for working the ores when necessary; *o*, *o*, are sight-holes; and, *n*, is the chimney, furnished with a damper for regulating the draught.

1228



1229



The diameter of the shaft varies in different kilns from 6 to 10 feet, and the number of passages for withdrawing the roasted ore may vary from 5 to 10. The following figures have been given by Westman as representing the quantities of ore roasted in 24 hours with kilns of various sizes:—

With	5	passages for drawing the charge . .	22 to 30 tons.
,,	6	,, ,,	28 ,, 36 ,,
,,	8	,, ,,	35 ,, 48 ,,
,,	10	,, ,,	45 ,, 60 ,,

The temperature in Westman's kiln can be governed by regulating the admission of air and gas, and if necessary by addition of solid fuel. When the kiln is at a proper working temperature, it exhibits a red heat in the neighbourhood of the discharge passages, *i*; the ore sinters in front of the gas-openings, *k*; is in a pasty condition in the neighbourhood of the holes, *l*; in an almost pasty state, but having the edges sharp, at *m*, and the temperature gradually diminishes in the upper part of the furnace. If the ores are very sulphurous, they are roasted twice. After the first roasting the ore is broken up, weathered by exposure to the air, and again roasted at a higher temperature. It is said that by the perfect method of roasting in this kiln, it is possible to produce good pig-iron in the blast-furnace from Swedish ores containing too much sulphur to be otherwise smelted.

Flux.—The flux that is used in the blast-furnace is *limestone*, either in the state of carbonate as it comes from the quarry, or calcined in kilns, by which it is deprived of water and carbonic acid. The lowest bed of the coal-formation usually rests on limestone, and in the coal-formation itself are found not only the ore and its most appropriate fuel, but the pebbly grits which afford the blocks of refractory stone necessary for building those parts of an iron furnace that are required to endure the utmost extremity of heat, as well as those seams of refractory clay, of which the fire-bricks are composed, with which the middle and upper parts of the furnace are lined. In Styria where the spathic ores contain large quantities of protoxide bases, such as lime, magnesia and manganese, siliceous and aluminous fluxes are sometimes required in the form of quartzose schists and clay-slate. Very siliceous hæmatites are beneficially fluxed by the addition of coal-measure shale, in addition to the limestone, or preferably by the aluminous brown hæmatite found in the basalt of Antrim. Titaniferous iron ores also require the use of aluminous fluxes, such as Labrador felspar or even ordinary brick in addition to limestone.

The composition of the limestone to be used in smelting operations is of considerable importance; where calcareous ores are used, the presence of silicic acid in the limestone is advantageous; if clay ores are the main material from which iron is manufactured, a magnesian limestone is preferable, but an aluminous limestone should be used where siliceous ore predominates. Chemical analysis alone can determine to which class a particular limestone belongs, as there is often nothing in the external appearance by which a pure limestone may be distinguished from one containing 40 or 50 per cent. of foreign matter.

Carbonised pit-coal, or coke was, till within the last twenty-five years, the sole combustible used in the blast-furnace. Coal is coked either in the open air or in kilns. In the former, as practised in Staffordshire, the coal is distributed in circular heaps about 5 feet in diameter by 4 feet high, and the middle is occupied by a low brick chimney piled with loose bricks, to open or to leave interstices between them, especially near the ground. The larger lumps of coal are arranged round this chimney, and the smaller ones towards the circumference of the mass. When everything is adjusted a kindling of coals is introduced into the bottom of the brick chimney, and, to render the combustion slow, the whole is covered with a coat of coal dross, the chimney being loosely covered with a slab of any kind. Openings are occasionally made in the crust, and afterwards shut up, to quicken and retard the ignition at pleasure during its continuance of twenty-four hours. Whenever the carbonisation has reached the proper point for forming good coke the covering of coal dross is removed, and water is thrown on the heap to extinguish the combustion, a circumstance deemed useful to the quality of the coke. In this operation in Staffordshire coal loses the half of its weight, or two tons of coal produce one of coke.

In order to prepare larger quantities of coke at once, long ridges are often substituted for circular heaps, the length of which varies with circumstances and the consumption of coke; they sometimes extend to the length of 200 feet. On erecting one of these ridges a string is stretched along the coking station, in the direction of which large pieces of coal are placed slanting against each other, leaving a triangular space between them, so that a longitudinal channel (ignition passage) is formed, through which the string passes. In arranging the pieces it is necessary to pay attention to the natural stratification of the coals, which should be at right angles to the longitudinal direction of the ridge. Parallel with the first series of coals is placed a second, and then a third, and so on; but the pieces constantly diminish in size until the station measures 6 feet on both sides. Upon this substructure the heap is then made, without particular care in the arrangements, the largest pieces below and the smallest above, until it has reached a height of about 3 feet. To facilitate the ignition, stakes are rammed in at distances of 2 feet from each other, projecting above throughout the whole length of the ridge, which, when subsequently removed, leave vacant spaces for the introduction of burning coal. The ridge, being thus kindled at more than 100 distinct spots, soon breaks out into active combustion. As soon as the burner observes the thick smoke and flame cease at any one part, and a coating of ash making its appearance, he endeavours immediately to stop the progress of the fire by covering it with powdered coal-dust, repeating the operation until the whole ridge is covered, when it is left two or three days to cool; the covering on the side exposed to the wind should be thicker and increased in stormy weather. When the fire is nearly extinguished, which occurs in two or three days, the coke is drawn. This mode of coking is simple, but not very economical. The fire proceeding from the upper part of the ridge in a downward direction, towards the lower and interior parts, converts the coal in the upper strata into coke before that in the interior has acquired the temperature necessary for charring, and is still in want of a supply of air, which can only be furnished from without, and must not be excluded by a covering. During the time, therefore, that the inner parts of the heap are being converted into coke, the outer portions are being uselessly, though unavoidably consumed. For further details concerning coking, see the articles Coal and Coke.

The 'blowing-in' of a coal blast-furnace is an operation which requires much care and experience. A fire of wood is first lighted on the hearth; upon this is placed a quantity of coke, and when the whole is well ignited, the furnace is filled to the throat with regular charges of calcined ore, limestone, and coke, and the blast, which should at first be moderate, is turned on. At the works around Merthyr Tydvil, the first charges generally consist of 5 cwts. of calcined argillaceous ore and $1\frac{3}{4}$ cwt. limestone, to 4 cwts. of rich coke; this burden is kept on for about 10 days, it is then increased to 6 cwts. of calcined ore and $2\frac{1}{2}$ cwts. of limestone (*Truran*). The cinders usually make their appearance in about 12 hours after blowing; the metal follows in about 10 hours after, collecting in the hearth to the amount of 3 or $3\frac{1}{2}$ tons in 60 hours after blowing. If all goes on well about 22 tons of metal will be produced in the first week, 38 tons in the second, 55 in the third, and nearly 80 in the fourth; after 10 or 12 weeks the produce will average 110 tons. By forcing the furnace in its infancy a much greater produce of iron may be obtained, though to the injury of its subsequent working. Mr. Truran relates the following case in point. A furnace was blown in at the Abersychan works with such volumes of blast and rich burden of materials that a cast of several tons was obtained within 14 hours after applying blast. The first week's blowing produced 200 tons, at which rate it continued for two or three weeks, when it rapidly diminished, falling so low as 19 tons for one week's make. From this deplorable state it was made to produce 26 tons, and, after considerable delay, 100 tons; but with a large increase in the yield of materials over that at the other furnaces. When a furnace is first blown in it should be made to produce grey iron; but the tendency of forcing is to produce a white iron with a dark scouring cinder.

The quantity of air thrown into a blast-furnace in full work is enormous, exceeding in weight the totals of all the solid materials used in smelting. A furnace working on foundry iron of a capacity of 275 yards receives 5.390 cubic feet of air per minute, which amounts weekly to 1,695 tons; when working on white iron a larger volume of blast is employed, averaging 7,370 cubic feet per minute, or 2,318 tons per week.

The disorders to which blast-furnaces are liable have a tendency to produce white cast iron. The colour of the slag or scoriæ is the surest test of these derangements, as it indicates the quality of the products. If the furnace is yielding an iron proper for casting into moulds, the slag has an uniform vitrification and is slightly translucid. When the dose of ore is increased, the slag becomes opaque, dull, and of a greenish yellow tint, with blue enamelled zones. Lastly, when the furnace is producing white metal, the slags are more or less black and glossy. The scoriæ from a coke are much more loaded with lime than those from a charcoal blast-furnace. This excess of lime appears adapted to absorb and carry off the sulphur which would otherwise injure the quality of the iron. From numerous analyses Dr. Noad made of blast-furnace cinders, we select the following as illustrating their general composition under different conditions of the furnace:—

Analyses of Blast Furnace Cinders.

	I.	II.	III.	IV.	V.	VI.	VII.
Silica	40·20	38·49	41·12	40·50	49·40	40·56	42·96
Alumina	17·00	14·12	22·00	12·48	21·08	27·33	20·20
Lime	30·34	34·35	29·48	26·55	17·56	10·30	10·19
Magnesia	7·16	6·14	1·88	3·20	4·96	2·75	2·90
Protoxide of manganese .	traces	1·54	traces	11·20	1·04	2·00	1·53
Protoxide of iron . .	1·90	2·10	3·60	3·20	3·60	13·12	19·80
Potash	1·26	1·48	not determined	1·15	·87	1·90	1·10
Sulphuret of calcium .	1·70	1·16	1·09	2·20	1·49	·46	1·32
Loss	·43	·62	·83	·52		1·58	
	100·00	100·00	100·00	100·00	100·00	100·00	100·00

I. Mean of four analyses of grey iron cinders from a furnace at Blaina, South Wales. II. Mean of four analyses of grey iron cinders from an iron work in Staffordshire. III. Mean of four analyses of grey iron (cold blast) cinders from Pontypool, South Wales. IV. Mean of four analyses of green cinders from a furnace at Ebbw Vale, Monmouthshire, smelting spathose ore. V. Mean of four analyses of blast-furnace cinders from Sweden. VI. Mean of four analyses of white iron cinders from a furnace at Cwm Celyn Iron Works, Monmouthshire. VII. Mean of four analyses of white iron cinders from the same works, the furnace 'scouring.'

The following Table exhibits the 'yields' of materials per ton on the iron made in various works. During the month ending July 25, 1857, there were consumed in four furnaces at Ebbw Vale 1,354 tons 14 cwts. of coke; 1,792 tons of coal; 2,440 tons 19 cwts. of calcined mine; 1,818 tons of 10 cwts. red ore; 1,347 tons 6 cwts. of calcined cinders; and 1,226 tons 7 cwts. of burnt lime. The quantity of pig-iron made was 2,305 tons 7 cwts.:—

Yields of Materials per Ton of Iron.

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.
	cwts.	cwts.	cwts.	cwts.	cwts.	cwts.	cwts.	cwts.	cwts.
Calcined mine .	48	28	0	46	33	27	21	37½	49¼
Hæmatite . .	0	10	10	0	0	10	15¾	7¾	9½
Cinders . .	0	10	25	0	0	0	11½	11½	0
Coal . . .	50	42	36	coke 34	40	coke 34	34		
Limestone . .	17	14	16	16	5	15	13	4¼	18¼

I. Dowlais foundry iron. II. Dowlais forge iron. III. Dowlais inferior forge iron. IV. Hirwain foundry iron. V. Dundyvan, Scotland, foundry iron. VI. Pontypool cold blast-foundry iron. VII. Ebbw Vale forge iron. VIII. Cwm Celyn forge iron. IX. Coalbrook Vale foundry iron.

The 'cinders' mentioned in the foregoing Table are not those from the blast-furnace, but are derived from the cast iron during the processes of 'refining,' 'puddling,' &c., by which the cast iron is converted into wrought iron. These cinders are very rich in iron, which exists in them principally in the form of silicate of the protoxide. They often occur beautifully crystallised, particularly after they have been calcined: an operation which is always performed on them in well-conducted works, and which has for its object the removal of the sulphur and the peroxidation of a portion of the iron. These cinders, though very rich in iron, are always contaminated to a considerable extent with both sulphur and phosphorus, as might be expected, seeing that they are the results of operations which have for their objects the removal of the foreign matters contained in the pig-iron. The tendency of the former is to make the metal what is called 'hot short,' so that it cannot be worked while hot under the hammer; the tendency of the latter element is to make the iron 'cold short,' so that it breaks when an attempt is made to bend it when cold. The separation of sulphur is very perfectly effected by the calcination of the cinder, and it is interesting to trace the progress of its gradual elimination. In some parts of the heap (which often contains several thousand tons of cinder) large masses of prismatic crystals of pure sulphur may be found, but usually nearly the entire surface of the heap is covered with a thin layer of sulphate of iron, sometimes crystallised, but generally in various stages of decomposition; lower down in the heap, where the heat is greater, the sulphate of iron disappears, and in its place red oxide of iron, without a trace of sulphur, is found. In calcining a heap of cinders care is required not to allow the heat to rise too high, or immense masses will become melted together, involving the necessity of blasting, which entails much expense. After the heap has been burning for some months, streams of water are directed over the surface, by which much soluble sulphate of iron is removed. Unfortunately, the process of calcination does not remove any of the phosphoric acid, which necessitates a judicious employment of these cinders in the blast-furnace. Dr. Noad repeatedly submitted 'forge cinders' to analysis, and we give in the following Table the average results of his experiments:—

Analyses of Forge Cinders.

	I.	II.	III.	IV.	V.	VI.
Silica	6·000	6·67	32·000	15·300	12·300	12·800
Protoxide of iron . .	63·750	72·60	52·200	51·720	67·360	10·500
Peroxide of iron . .	11·420	6·30	5·000	19·980	2·850	70·000
Sulphuret of iron . .	5·766	4·56	1·953	5·396	5·600	·620
Oxide of manganese .	1·680	1·77	not determined	·960	not determined	1·140
Alumina . . .	2·400	2·22	9·600	1·300	5·600	·427
Lime	1·232	·12	traces	·420	traces	traces
Magnesia . . .	traces	traces	traces	traces	traces	traces
Phosphoric acid . .	7·268	5·36	·252	4·140	6·320	4·500
	99·516	99·60	101·105	99·216	100·030	99·987

I. Tap cinder from refined metal. II. Tap cinder from puddling furnace. III. Cinder from re-heating furnace. IV. Mixed cinder from the heap after a few days' burning. V. Cinder squeezed out of the puddled bar during the process of shingling. VI. Specimen from a large heap of thoroughly calcined cinder.

Hot-blast.—One of the greatest improvements ever made by simple means in any manufacture, is the employment of hot air instead of the ordinary cold air of the atmosphere, in supplying the blast of furnaces for smelting and founding iron. The discovery of the superior power of a hot over a cold blast in fusing refractory lumps of cast iron was accidentally observed by Mr. James Beaumont Neilson, engineer to the Glasgow Gas Works, about the year 1827, at a smith's forge in that city, and it was made the subject of a patent in the month of September in the following year. No particular construction of apparatus was described by the inventor by which the air was to be heated, and conveyed to the furnace; but it was merely stated that the air may be heated in a chamber or closed vessel, having a fire under it, or in a vessel connected in any convenient manner with the forge or furnace. From this vessel the air is to be forced by means of a bellows into the furnace. The quantity of surface which a heating furnace is required to have for a forge is about 1,260 cubic inches; for a cupola furnace, about 10,000 cubic inches. The vessel may be enclosed in brickwork, or fixed in any other manner that may be found desirable, the application of heated air in any way to furnaces or forges, for the purpose of working iron, being the subject claimed as constituting the invention.

Whenever a forced stream of air is employed for combustion, the resulting temperature must evidently be impaired by the coldness of the air injected upon the fuel. The heat developed in combustion is distributed into three portions: one is communicated to the remaining fuel; another is communicated to the nitrogen of the atmosphere and to the volatile products of combustion; and a third to the iron and fluxes, or other surrounding matter, to be afterwards dissipated by wider diffusion. This inevitable distribution takes place in such a way, that there is a nearly equal temperature over the whole extent of a fire-place, in which an equal degree of combustion exists.

We thus perceive that if the air and the coal be very cold, the portions of heat absorbed by them might be very considerable, and sufficient to prevent the resulting temperature from arising to a proper pitch; but if they were very hot they would absorb less caloric, and would leave more to elevate the common temperature. Let us suppose two furnaces charged with burning fuel, into one of which cold air is blown, and into the other hot air, in the same quantity. In the same time, nearly equal quantities of fuel will be consumed with a nearly equal production of heat; but notwithstanding this, there will not be the same degree of heat in the two furnaces, for the one which receives the hot air will be hotter by all the excess of heat in its air above that of the other, since the former air adds to the heat while the latter abstracts from it. Nor are we to imagine that by injecting a little more cold air into the one furnace, we can raise its temperature to that of the other. With more air indeed we should burn more coals in the same time, and we should produce a greater quantity of heat, but this heat being diffused proportionally among more considerable masses of matter, would not produce a greater temperature; we should have a larger space heated, but not a greater intensity of heat in the same space.

Thus, according to the physical principles of the production and distribution of heat, fires fed with hot air should, with the same fuel, rise to a higher pitch of temperature than fires fed with common cold air. This consequence is independent of the masses, being as true for a small stove which burns only an ounce of charcoal in a minute, as for a furnace which burns a hundred-weight; but the excess of temperature produced by hot air cannot be the same in small fires as in great, because the waste of heat is usually less the more fuel is burned.

This principle may be rendered still more evident by a numerical illustration. Let us take, for example, a blast-furnace, into which 600 cubic feet of air are blown per minute; suppose it to contain no ore but merely coal or coke, and that it has been burning long enough to have arrived at the equilibrium of temperature, and let us see what excess of temperature it would have if blown with air of 300° C. (572° F.), instead of being blown with air at 0° C.

600 cubic feet of air, under the mean temperature and pressure, weigh a little more than 45 lbs. avoirdupois; they contain 10·4 lbs. of oxygen, which would burn very nearly 4 lbs. of carbon, and disengage 16,000 times as much heat as would raise by one degree per cent. the temperature of 2 lbs. of water. These 16,000 portions of heat, produced every minute, will replace 16,000 other portions of heat, dissipated by the sides of the furnace, and employed in heating the gases which escape from its mouth. This must take place in order to establish the assumed equilibrium of caloric.

If the 45 lbs. of air be heated beforehand up to 300° C., they will contain about $\frac{1}{8}$th part of the heat of the 16,000 disengaged by the combustion, and there will be therefore in the same space $\frac{1}{8}$th of heat more, which will be ready to operate upon any bodies within its range, and to heat them $\frac{1}{8}$th more. Thus the blast of 300° C. gives a temperature which is $\frac{9}{8}$ths of the blast at zero C., or at even the ordinary atmospheric temperature; and as we may reckon at from 2,200° to 2,700° F. (from 1,200° to 1,500° C.), the temperature of blast-furnaces worked in the common way, we perceive that the hot-air blast produces an increase of temperature equal to from 270° to 360° F.

Now, in order to appreciate the immense effects which this excess of temperature may produce in metallurgic operations, we must consider that often only a few degrees more temperature are required to modify the state of a fusible body, or to determine the play of affinities dormant at lower degrees of heat. Water is solid at 1° under 32° F.; it is liquid at 1° above. Every fusible body has a determinate melting point, a very few degrees above which it is quite fluid, though it may be partly below it. The same observation applies to ordinary chemical affinities. Charcoal, for example, which reduces the greater part of metallic oxides, begins to do so only at a determinate pitch of temperature, under which it is inoperative, but a few degrees above it is in general lively and complete. It is unnecessary in this article to enter into any more details to show the influence of a few degrees of heat more or less in a furnace upon chemical operations, or merely upon physical changes of state.

Figs. 1230, 1231, exhibit the apparatus of a hot blast as mounted at the Codner Park works, belonging to William Jessop, Esq., in every requisite detail. The drawings from which the wood-cuts are faithfully copied were kindly furnished for this work by Mr. Joseph Glyn, F.R.S., the distinguished engineer of the Butterly Iron Works.

The smelting furnaces have now generally three tuyères, and three sets of air-heating furnaces. The figures show two sets built together; the third set being detached on account of peculiar local circumstances. The air enters the horizontal pipe A, in the ground plan, *fig.* 1230, on one side of the arched or siphon pipes, shown in upright section in *fig.* 1231, and passes through these pipes to the horizontal pipe B, on the other side; whence it proceeds to the blast-furnace. These siphon pipes are flattened laterally, their section being a parallelogram, to give more heating surface, and also more depth of pipe (in the vertical plane), so as to make it stronger, and less liable to bend by its own weight when softened by the red heat. This system of arched pipe apparatus is set in a kind of oven, from which the flue is taken out at the top of it; but it thence again descends before it reaches the chimney, entering it nearly at the level of the fire-grate (as with coal-gas retorts). By this contrivance the pipes are kept in a bath of ignited air, and not exposed to the corroding influence of a current of flame. The places and directions of these oven-flues are plainly marked in the drawing.

1230

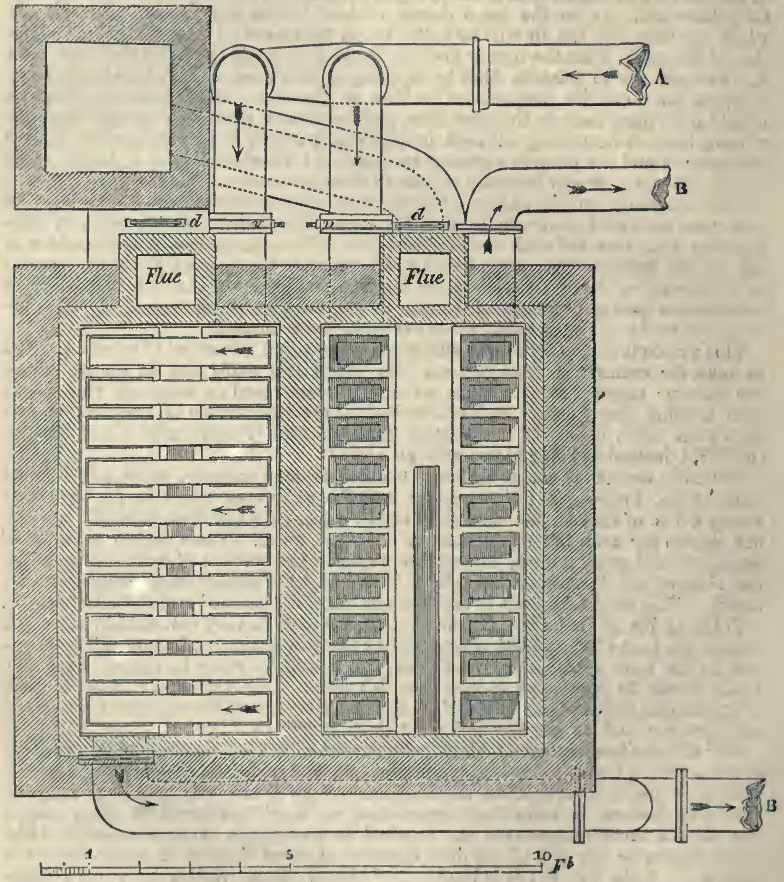


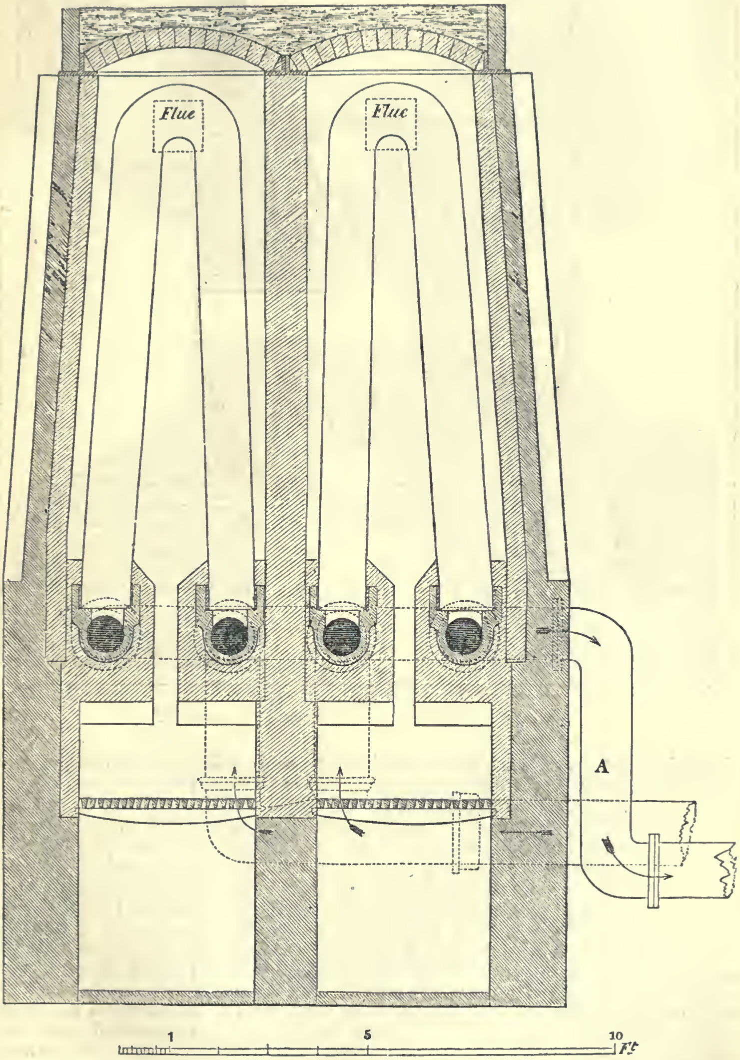
Fig. 1232 is a plan of the blast-furnace, drawn to a smaller scale than that of the preceding figures.

The three sets of hot-blast apparatus all communicate with one line of conducting pipes A, which leads to the furnace. Thus in case of repairs being required in one set, the other two may be kept in full activity, capable of supplying abundance of hot air to the blast, though of a somewhat lower temperature.

During a visit which Dr. Ure made to Mr. Jessop, at Butterly, he found this eminent and very ingenious ironmaster had made several improvements upon his hot-blast arrangements, whereby he prevented the alteration of form to which the arched pipes were subject at a high temperature, as also that he was about to employ five tuyères instead of three. For a drawing and explanation of his furnace-feeding apparatus, see SMELTING.

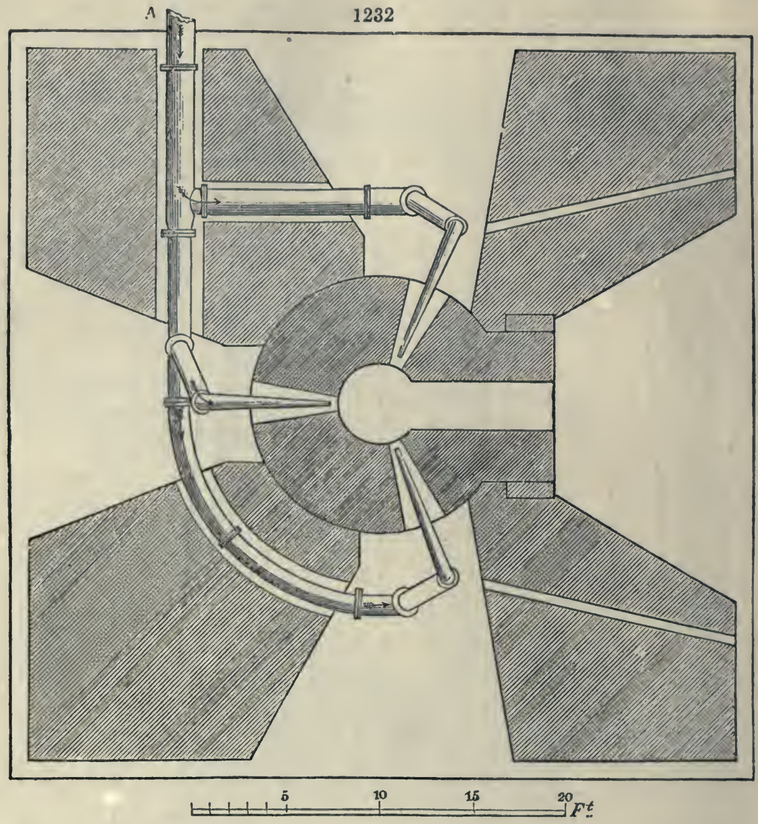
The experiments through which Mr. Neilson's important discovery was introduced into the iron manufacture were made at the Clyde Iron Works, where the fuel generally made use of was coke, derived from splint coal; during its conversion into coke, this coal sustained a loss of 55 per cent. During the first six months of the year 1829, when all the cast iron in the Clyde Iron Works was made by means of the cold blast, a single ton of cast iron required for fuel to reduce it, 8 tons $1\frac{1}{4}$ cwt. of coal converted into coke. During the first six months of the following year, while the air was heated to near 300° Fahr., 1 ton of cast iron required 5 tons $3\frac{3}{4}$ cwts. of coal converted into coke. The saving amounted to 2 tons 18 cwts. per ton of iron,

1231



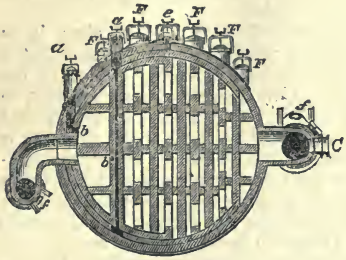
from which must be deducted the coal used in heating the air, which was nearly 8 cwts. This great success induced the Scotch ironmasters to try a higher temperature, and to substitute raw coal for coke; and during the first six months of the year 1833, the blast being heated to 600°, 1 ton of cast iron was made with 2 tons 5¼ cwts. of coal. Add to this 8 cwts. of coal for heating, and we have 2 tons 13¼ cwts. of coal to make 1 ton of iron. An extraordinary impetus was given by this discovery to the iron manufacture of Scotland, where, from the peculiar nature of the coal, and from the circumstance that, with a heated blast, Mushet's blackband ironstone could be exclusively used, its importance was more highly felt than in England and Wales. According to Mr. Finch's statement (Scrivenor's 'History of the Iron Trade'), there were in 1830 only eight works in operation in Scotland, which made in that year 37,500 tons of pig-iron; in 1838 there were eleven works, consisting of 41 furnaces, which made 147,500 tons, being an increase in eight years of 110,000 tons per annum; in 1859 there were fifty furnaces in blast, making 195,000 tons; in 1851, 750,000 tons of pig-iron were made; and in 1856, with 127 furnaces in blast, the make rose to 880,500 tons. The influence of hot blast has likewise been felt in the anthracite districts of South Wales, where that coal is now successfully used, and where several new furnaces have in consequence been erected. In short, notwithstanding the opposition with which the introduction of hot blast was met by engineers, as being destructive of the quality of the iron, so great have been the advantages derived from it that at the present time more than nineteen-twentieths of the entire produce of the kingdom is made in furnaces blown with heated air.

1232



Of late years there has been a constantly increasing demand, especially in the Cleveland district, for more highly heated blast; and furnaces are now blown with air at a red heat, or almost beyond the power of endurance of cast-iron heating pipes. For this purpose the regenerative principle of Siemens has been advantageously applied. It consists of storing up the heat of the burning fuel in cellular piles of fire-brick, which are subsequently made to give up their heat to the blast before it enters the furnace. The most successful form of this apparatus is that known as Whitwell's stove which is represented in *figs.* 1233–1237. It consists of a series of parallel walls of fire-brick, connected by ribs and arches into a system of rectangular flues, which are alternately heated by the combustion of the waste gas from the top of the furnace, and cooled by passing a current of cold air in the reverse direction. For the more perfect combustion of the gases, ventilating holes for the admission of air are perforated through the walls at *a* and *d*. The arches at the top of the stove are provided with moveable covers at E, and similar covered holes are placed at the bottom of the stove at F, for the purpose of clearing out the dust which always accumulates on the brick-work when the furnace is used for heating. *f* is the gas inlet valve; C, the chimney valve used during the heating period; D, the cold-blast inlet valve, and A, the hot-blast valve. The latter is made with a hollow water cooled shell and seat,

1233



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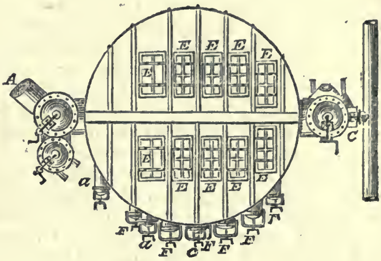

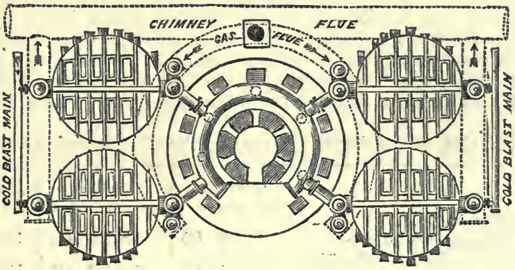

1235

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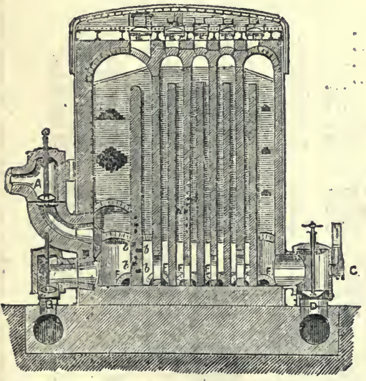

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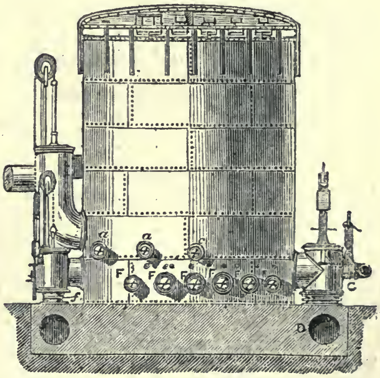

and the outlet main, 3 feet in diameter, is lined with fire-brick 9 inches thick. *Fig.* 1235 shows the general arrangement of these stoves as applied to a blast-furnace at Consett in Durham. They are four in number, each being 22 feet in diameter, and 25 feet high, and containing 250 tons of brick, arranged so as to give 9,000 feet of heating surface. They are worked in pairs, the current being changed every two hours. The furnace makes from 400 to 500 tons of pig-iron per week, with an average consumption of coke of 19 to 19½ cwts. per ton; the ore yields about 45½ per cent. The effective blast-temperature is from 1,100° to 1,300° Fahr.

Mr. Truran, in his work on the iron manufacture of Great Britain, gives it as his opinion that the effects of hot blast have been greatly exaggerated, and that it is to improvements in the preparation of fuel and ore in the furnaces, in blowing engines, and in the smelting process, far more than to the heating of the blast, that we must refer the great reduction in the yields of coal in recent times; he thinks that the comparatively large produce which has been obtained from the Scotch furnaces is to be referred to the general use of carbonaceous ore, which melts at a low temperature; and which, from its comparative freedom from earthy matters, requires but a minimum dose of limestone for fluxing. Against this opinion of an English writer on iron smelting, we may place that recorded by an American metallurgist, Mr. Overman, who has written a large and in many respects a valuable treatise on the manufacture of iron, as conducted in America. 'The economical advantages arising from the application of hot blast, casting aside those cases in which cold blast will not work at all, are immense. The amount of fuel saved in anthracite and coke furnaces varies from 30 to 60 per cent. In addition to this, hot-blast enables us to obtain nearly twice the quantity of iron within a given time that we should realise by cold blast. These advantages are far more striking with respect to anthracite coal than in relation to coke or to bituminous coal. By using hard charcoal, we can save 20 per cent. of fuel, and augment the product 50 per cent. From soft charcoal we shall derive but little benefit, at least where it is necessary to take the quality of the iron into consideration.'

The following Tables, embodying the general results of an extended series of experi-

	Cold Blast	Hot Blast	Ratio, representing Cold Blast by 1000
CARRON IRON, NO. 2.			
Tensile strength in lbs. per square inch	16,683 (2)	13,505 (3)	1000 : 809
Compressive strength in lbs. per inch, from castings torn asunder	106,375 (3)	108,540 (2)	1000 : 1020 } mean 997
Ditto, from prisms of various forms	100,631 (4)	100,738 (2)	1000 : 1001
Ditto, from cylinders	125,403 (13)	121,685 (13)	1000 : 970
Transverse strength from all experiments	.. (11)	.. (13)	1000 : 991
Power to resist impact	.. (9)	.. (9)	1000 : 1005
Transverse strength of bars one inch square in lbs.	476 (3)	463 (3)	1000 : 973
Ultimate deflection of do. in inches	1·313 (3)	1·337 (3)	1000 : 1018
Modulus of elasticity in lbs. per square inch	17,270,500 (2)	16,085,000 (2)	1000 : 931
Specific gravity	7,066	7,046	1000 : 997
DEVON IRON, NO. 3.			
Tensile strength	..	21,907 (1)	..
Compressive strength	..	145,435 (4)	..
Transverse do. from experiments generally	.. (5)	.. (5)	1000 : 1417
Power to resist impact	.. (4)	.. (4)	1000 : 2786
Transverse strength of bars one inch square	448 (2)	537 (2)	1000 : 1199
Ultimate deflection do.	·79 (2)	1·09 (2)	1000 : 1380
Modulus of elasticity	22,907,700 (2)	22,473,650 (2)	1000 : 981
Specific gravity	7,295 (4)	7,229 (2)	1000 : 991
COED TALON IRON, NO. 2.			
Tensile strength	18,855 (2)	16,676 (2)	1000 : 884
Compressive strength	81,770 (4)	82,739 (4)	1000 : 1012
Specific gravity	6,955 (4)	6,968 (4)	1000 : 1002
CARRON IRON, NO. 3.			
Tensile strength	14,200 (2)	17,755 (2)	1000 : 1250
Compressive strength	115,542 (4)	133,440 (3)	1000 : 1156
Specific gravity	7,135 (1)	7,056 (1)	1000 : 989
BUFFERY IRON, NO. 1.			
Tensile strength	17,466 (1)	13,434 (1)	1000 : 769
Compressive strength	93,366 (4)	86,397 (4)	1000 : 925
Transverse strength	.. (5)	.. (5)	1000 : 931
Power to resist impact	.. (2)	.. (2)	1000 : 963
Transverse strength of bars one inch square	463 (3)	436 (3)	1000 : 942
Ultimate deflection do.	1·55 (3)	1·64 (3)	1000 : 1058
Modulus of elasticity	15,381,200 (2)	13,730,500 (2)	1000 : 893
Specific gravity	7,079	6,958	1000 : 989

ments on the relative strength and other mechanical properties of cast iron, obtained by the hot and cold blasts, are extracted from a report presented to the British Association (1837) by Messrs. Eaton, Hodgkinson and William Fairbairn.

Of the three columns of numbers, the first represents the strength or other quality in the *cold* blast iron, the second that in the *hot*, the third is the ratio of these qualities; the figures included in parentheses indicate the number of experiments from which the results have been deduced.

These results contain nearly the whole of the information afforded by the investigation. From the numbers in the tables, it will be seen that in Buffery iron No. 1 cold blast somewhat surpasses hot blast in all the following particulars: 1, direct tensile strength; 2, compressive strength; 3, transverse strength; 4, power to resist impact; 5, modulus of elasticity or stiffness; 6, specific gravity: while the only numerical advantage possessed by the hot-blast metal is that it bends a little more than the cold before it breaks. In No. 2 the advantages of the rival kinds are more nearly balanced, still rather in favour of the cold blast. No. 3 hot-blast Carron iron resists both tension and compression better than cold blast of the same denomination; and No. 3 hot blast from the Devon works in Scotland is remarkably strong, while No. 3 cold blast is comparatively weak, notwithstanding its high specific gravity. On the whole it would appear from the experiments, that while the irons of No. 1 have been somewhat deteriorated in quality by the hot blast, those of No. 3 have been benefited by its mollifying powers; while those of No. 2 have been but very slightly affected; and from the evidence brought forward, it is rendered highly probable that the introduction of a heated blast, whilst it has, perhaps, to a certain extent, injured the softer irons, has improved those of a harder nature; and considering the small deterioration that the irons of the quality No. 2 have sustained, and the apparent benefit of those of No. 3, together with the saving effected by the heated blast, there seems good reason for the process becoming so general as it has done.

The following *general* summary of results, as derived from the experiments of Messrs. Hodgkinson and Fairbairn on the transverse strength of hot and cold blast iron exhibits at one view the ultimatum of the whole investigation:—

	Ratio of Strength: that of Cold Blast being represented by 1000	Ratio of Powers to sustain Impact: Cold Blast being 1000
These irons are from Mr. Hodgkinson's experiments:—		
Carron iron, No. 2	1000 : 990·9	1000 : 1005·1
Devon iron, No. 3	1000 : 1416·9	1000 : 2785·6
Buffery iron, No. 1	1000 : 930·7	1000 : 962·1
These irons are from Mr. Fairbairn's experiments:—		
Coed Talon iron, No. 2	1000 : 1007	1000 : 1234
Coed Talon ditto, No. 3	1000 : 927	1000 : 925
Elsicar and Milton, ditto	1000 : 818	1000 : 875
Carron ditto, No. 3	1000 : 1181	1000 : 1201
Muirkirk, No. 1	1000 : 927	1000 : 833
Mean	1000 : 1024·8	1000 : 1226·3

Dr. Thompson's chemical examination of several samples of hot and cold blast iron is appended to this report. According to the experiments of this distinguished chemist, iron smelted by *hot* blast contains a greater proportion of iron, and a smaller proportion of silicon, carbon, and aluminium, than when smelted by cold air. The mean specific gravity of 8 specimens of Scotch cold blast iron No. 1 was 6·7034; the mean of 5 specimens of hot blast from the Carron and Clyde iron works was 7·0263, so that the density of cold-blast iron is less than that of hot. The mean of 6 analyses of cold-blast iron No. 1 gave 3½ atoms of iron, 1 atom of carbon, silicon, and aluminium; the proportion of these three constituents being very nearly 4 atoms of carbon, 1 atom of silicon, and 1 atom of aluminium; consequently Scotch cold-blast iron consists of 20 atoms of iron (with a little manganese), 4 atoms of carbon, 1 atom of silicon, and 1 atom of aluminium. The mean of 5 analyses of hot-blast iron No. 1 gave 6½ atoms of iron and manganese to 1 atom of carbon, silicon, and aluminium, from which it would appear that cast iron smelted with a hot-blast is *purer* than when the blast is cold. This, however, is not the case, as the numerous analyses of both varieties that have been made during the last few years concur in proving. Hot-blast grey-iron smelted with mineral coal, contains a much higher percentage of silicon than the same variety of cast iron smelted from the same ores by cold blast; in other respects, provided the process of reduction is complete, *i.e.* when little or no iron passes off with the slag, there is very little chemical difference between the two varieties, as will be seen in the following Table, which contains the results of a series of analyses of hot- and cold-blast iron, which Dr. Noad had occasion to make, under circumstances peculiarly favourable for instituting the comparison, the furnaces working with the same ores, and making the same class of iron, viz., good No. 3 grey pig.

Analyses of Cast Iron No. 3, *smelted by Hot Blast.*

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	Mean
Silicon . .	2·500	3·140	3·380	2·440	3·200	3·190	3·120	2·260	2·900
Graphite . .	3·520	3·100	3·210	3·102	3·340	3·320	3·340	3·294	3·290
Sulphur . .	0·045	0·090	0·079	0·069	0·072	0·046	0·072	0·064	0·067
Phosphorus .	0·318	0·422	0·308	0·394	0·422	0·480	0·320	0·374	0·379
Metallic iron per cent.							93·15		

Analyses of Cast Iron No. 3, *smelted by Cold Blast.*

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	Mean
Silicon . .	1·050	1·400	1·029	0·940	1·372	1·486	1·466	1·400	1·268
Graphite . .	3·370	3·184	3·270	3·140	3·333	3·274	3·242	3·197	3·251
Sulphur . .	0·024	0·037	0·045	traces	0·029	0·037	0·028	0·024	0·028
Phosphorus .	0·210	0·314	0·387	0·361	0·372	0·372	0·342	0·354	0·339
Metallic iron per cent.							95·0		

The true reason of the frequent inferiority of hot-blast iron has been correctly given by Mr. Blackwell. Furnaces blown with heated air exert greater reductive power than those in which a cold blast is used. This has led, since the introduction of hot blast, to the extensive use in iron smelting of refractory ores not formerly smelted, a large part of which have been ores of a class calculated to produce inferior iron; and it is to the use of ores of this nature, far more than to any deterioration in quality, arising from a heated blast, that this inferiority of hot-blast iron is to be ascribed.

Utilisation of the waste gases given off from the furnace-head.—The agent in the blast-furnace by which the oxide of iron is reduced is carbonic oxide, the presence of which therefore in great excess is indispensable to the operation of the furnace. The flames rising from the tunnel-head, which makes a blast-furnace at night such an imposing object, are occasioned principally by the combustion of this gas, on coming into contact with the oxygen of the atmosphere. The attention of practical men was first called to the enormous waste of heat which this useless flame entailed by Messrs. Bunsen and Playfair, and the application of the gas to a useful purpose may be ranked next to that of the heated blast, as the most important of the recent improvements in the iron manufacture. The gases evolved from iron furnaces where coal is used as the fuel contain the following constituents: viz. *nitrogen*, *ammonia*, *carbonic acid*, *carbonic oxide*, *light carburetted hydrogen*, *olefiant gas*, *carburetted hydrogen of unknown composition*, *hydrogen*, *sulphuretted hydrogen*, and *aqueous vapour*. The nature of the combustible gas stands in a relation so intimate to the changes suffered by the materials put into the furnace, that its different composition in the various regions of the furnace indicates the changes suffered by the materials introduced as they descend in their way to the entrance of the blast. Now as the examination of this column of air in its various heights in the furnace must be the key to the questions upon which the theory and practice of the manufacture of iron depend, it was of the first importance to subject it to a rigid examination; this accordingly has been done by the above-named eminent chemists, and subsequently by M. Ebelmen. We shall return to a consideration of the results they obtained presently, confining our attention at present to the composition of the gases at the mouth of the furnace, and to the methods which have been adopted to utilise them.

In order to arrive at a knowledge of the composition of these gases, M. Bunsen first studied minutely the phenomena which would ensue were the furnace filled with fuel only: by a careful distillation of a known weight of coal, and analysing of the products, he obtained results embodied in the subjoined table:—

Carbon	68·925
Tar	12·230
Water	7·569
Light carburetted hydrogen	7·021
Carbonic oxide	1·135
Carbonic acid	1·073
Condensed hydrocarbon and olefiant gas	0·753
Sulphuretted hydrogen	0·549
Hydrogen	0·499
Ammonia	0·211
Nitrogen	0·035
	100·000

Now, in the furnace, the oxygen introduced by the blast is consumed in the immediate vicinity of the tuyère, being there converted into carbonic oxide, and the coal loses all its gaseous products of distillation much above the point at which its combustion commences, near, in fact, the top of the furnace; the fuel with which the blast comes into contact is therefore coke, and upon calculating the amount of carbonic oxide produced by the combustion of 68·925 per cent. of carbon, and the nitrogen of the air expended in the combustion, we get as the composition by volume of the gases escaping from a furnace filled with Gasforth coal the following:—

Nitrogen	62·423
Carbonic oxide	33·163
Light carburetted hydrogen	2·527
Carbonic acid	0·139
Condensed hydrocarbon	0·151
Sulphuretted hydrogen	0·091
Hydrogen	1·431
Ammonia	0·070
	100·000

With this preliminary information, Bunsen proceeded to calculate the modification of the gaseous mixture occasioned by the introduction into the furnace of iron-ore and limestone. The materials used for the production of 140 lbs. of pig-iron were:— 420 lbs. calcined iron-ore; 390 lbs. coal; 170 lbs. limestone. From 100 parts of the coal, 67·228 parts of coke were obtained; but from this must be deducted 2·68 ashes, and 1·18 carbon entering into combination with the iron; which leaves as the quantity of carbon actually burnt into carbonic oxide before the tuyère 63·368; part of this carbonic oxide undergoes oxidation into carbonic acid at the expense of the oxygen in the oxide of iron which it reduces; a further quantity of carbonic acid is derived from the limestone; so that the gases returned to the mouth of the furnace by the combustion of the 67·228 parts of coke, the reduction of the corresponding quantity of ore, and the decomposition of limestone, consist of—

Nitrogen	282·860
Carbonic acid	59·482
Carbonic oxide	121·906
	464·248

Add to this the products of the distillation of the coal, and we get the following as the percentage compositions by weight and measure of the gases issuing from the mouth of the furnace:—

	By weight.	By volume.
Nitrogen	59·559	60·907
Carbonic acid	12·765	8·370
Carbonic oxide	26·006	26·846
Light carburetted hydrogen	1·397	2·536
Hydrogen	0·078	1·126
Condensed hydrocarbon	0·108	0·112
Sulphuretted hydrogen	0·053	0·045
Ammonia	0·054	0·058
	100·000	100·000

The calculations of the quantity of heat capable of being realised in the furnace by the combustion of the furnace-gases are founded on the data on the heat of combustion given in the posthumous papers of Dulong, according to which—

1 kilogramme, or 15,444 grains, of

Carbon burning to CO, heats 15,444 grs. of water to	1499°C
„ „ CO^2,	7371°
Carbonic oxide	2502°
Hydrogen	34706°
Light carburetted hydrogen	13469°
Olefiant gas	12322°
Sulphuretted hydrogen	4476°
Ammonia	6060°

Using these numbers, it is found that by the combustion of 100 of the furnace-gases, there are generated from the

59·559 nitrogen	0000
12·765 carbonic acid	0000
26·006 carbonic oxide	65067
1·397 carburetted hydrogen	18826
0·078 hydrogen	2704
0·108 olefiant gas	1331
0·053 sulphuretted hydrogen	238
0·034 ammonia	208
	88374 =

units of heat *generated*, the *unit* being understood to mean the amount of heat necessary to raise 1 kilogramme = 2·204 lbs. = 15,444 grains of water from 0° Centigrade to 1° cent. The amount of heat *realized* in the furnace is limited to that produced by the expenditure of the oxygen, corresponding to 59·559 nitrogen in the production of carbonic oxide; this amounts to 20,001 units: hence follows the remarkable conclusion, that in the furnace which was the subject of experiment not less than 81·54 per cent. of the fuel is lost in the form of combustible matter still fit for use, and that only 18·46 per cent. of the whole fuel is realised in carrying out the processes in the furnace.

A more practical measure of the economy of fuel in the blast-furnace is that given by Mr. Lowthian Bell. See p. 978.

The temperature which should be produced by the flame of the furnace-gases when burnt with air is found by dividing the units of heat, viz. 883·74 arising from the combustion of 1 kilogramme of the gases by the number resulting when the quantity of the products of combustion is multiplied by their specific heat (1·9338 × 0·2696): we thus get the number 3083° F.; but this is below the truth, inasmuch as there is an accession of combustible gases at the mouth of the furnace, arising from the decomposition of the liquid products of the distillation of the coal in its passage over the red-hot fuel. Making proper correction for this, and using numbers derived from actual experiments, Messrs. Bunsen and Playfair calculated the temperature of the gases when generated under favourable conditions at 3214° F., and even this may be increased to 3632° F., a temperature far above that of cast iron, by the using a blast sufficiently heated. In utilising these waste gases, care must be taken not to remove

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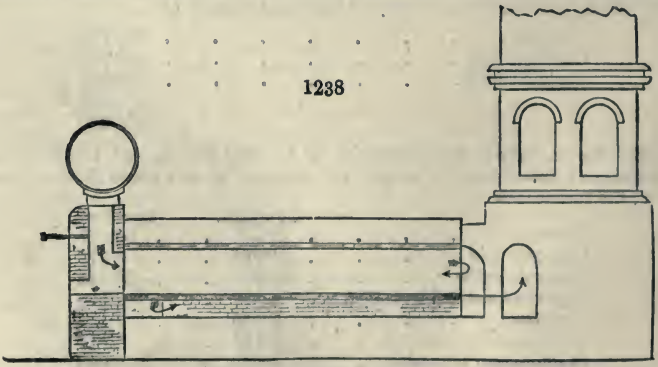
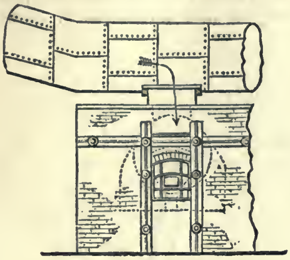


them from the furnace till they really are *waste*, that is, until they have done their work in the furnace. It is obvious that no combustible matter could be removed from the lower regions of the furnace without seriously deranging the operations essential to the reduction and smelting of the ore. In order to remove the gases effectually, and without injury to the working of the furnace, and in such a state as will permit their combustion to be effected with most advantage, the height of the furnace must

1239



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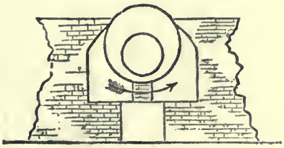

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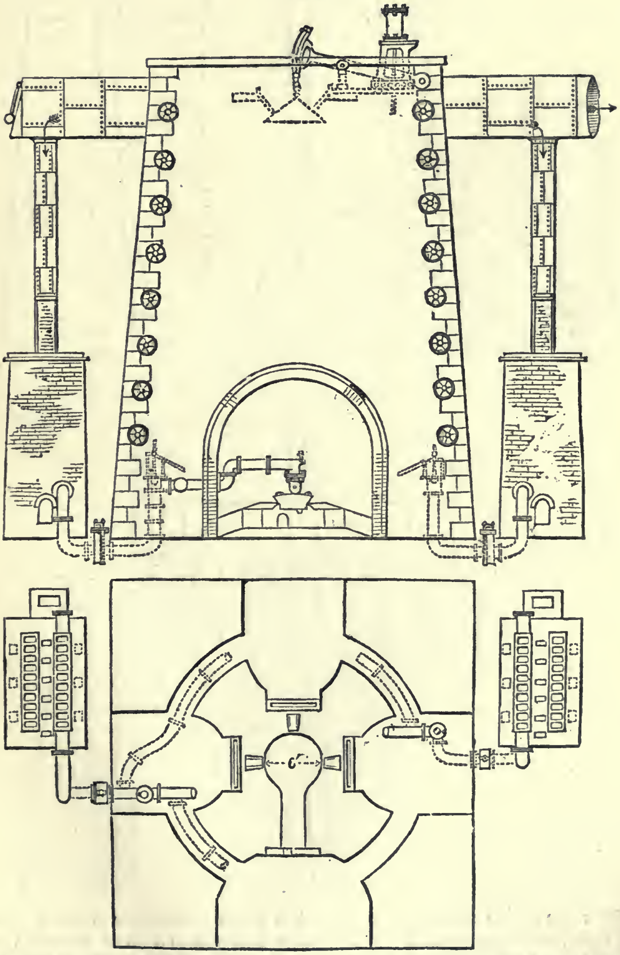
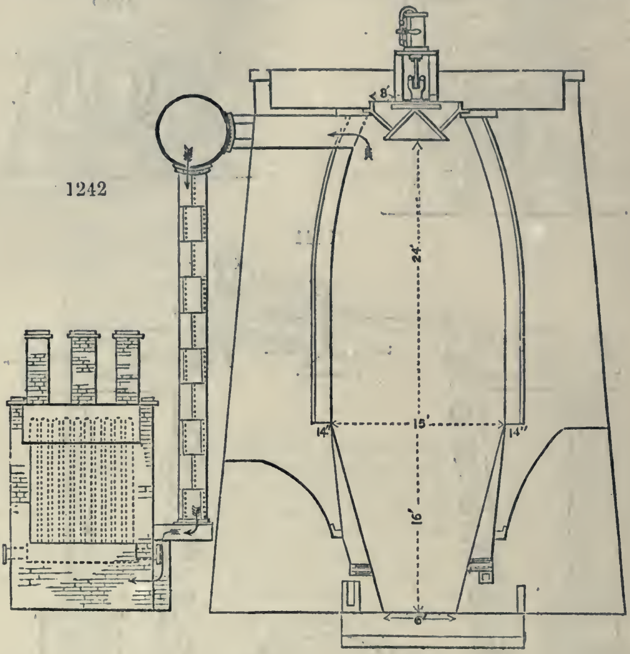


be raised, the full width of the mouth being retained, and the gases must be withdrawn sufficiently far below the mouth for them to be obtained dry, and also beneath the point where they begin to enter into combustion from contact with the atmospheric air.

Various modes of collecting the gases have been tried; the best seems to be that adopted at Ebbw Vale, Sirhowy, and Cwm Celyn. A funnel-shaped casting, equal in its largest diameter to the throat of the furnace, projects into the interior a depth of 4 or 5 feet; the orifice at the bottom, from 3 to 5 feet in diameter, is closed by a conical casting, the apex upwards, from which a chain proceeds to a lever having a counterpoise at the other end. (See *fig.* 1241.) The materials are filled into the funnel-shaped receptacle, and are charged into the furnace with a uniform distribution, by lowering the cone by means of suitable machinery, which again returns it to its place when

1242



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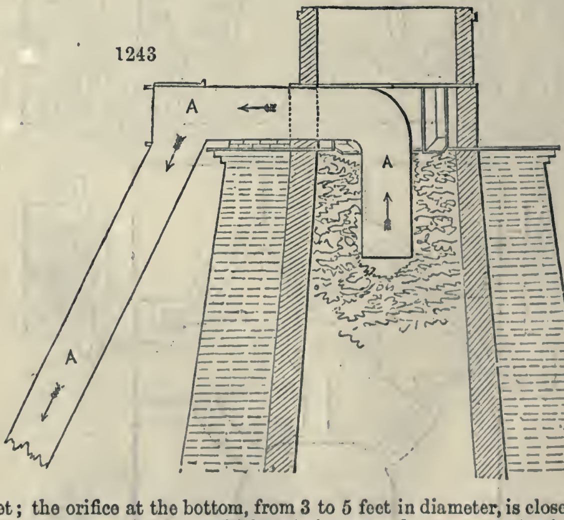


emptied. The circular space around the funnel, inside the furnace, forms a chamber for the reception of the gases, from which they are conveyed by brick tunnels or iron piping to the place of combustion. The whole arrangement will be clearly understood by an inspection of the accompanying plans, *figs.* 1238, 1239, 1240, 1241, 1242, kindly furnished to the writer by the proprietor of the Cwm Celyn and Blaina Iron Works.

Fig. 1243 shows the plan of extracting the gases which is adopted at the Brymbo Iron Works, near Wrexham, the same being the patent of C. E. Darby.

It consists of a large pipe or tube inserted into the middle of the top part of the furnace, which descends a short distance down into the materials, and is carried over the top of the side of the furnace in the form of a siphon, a continuation of which pipe is taken to the boilers, or hot air-stoves, where the gas is burned in the usual way. The principal advantage claimed by this method, is that it puts no check on the free escape of the gases, by which the driving of the furnace is impeded, and the quality of the iron deteriorated. The patentee estimates the saving of fuel with two furnaces making 240 tons of iron per week, by applying the gas to the blast-engine boilers and hot air-stoves, 1,200*l.* a year. Thus:—Consumption of fuel at engine and stoves equal to 7 cwts. of good coal per ton of iron, made at 3½*d.* per cwt., is 2*s.* 0½*d.*, say 2*s.* per ton on 12,480 tons, or 1,248*l.*

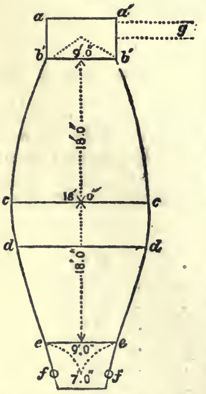
The causes of derangement in the working of blast-furnaces when the gases are drawn off to be utilised elsewhere, have been diligently studied by Mr. George Parry, of Ebbw Vale; and he has kindly furnished us with the following *résumé* of his observations, for insertion in this article—

The manner in which the waste gases were formerly collected was by sinking an iron tube, 7 feet deep, into the throat of the furnace, the diameter of the tube being about 3 feet less than that of the throat, thus leaving an annular space of 18 inches between the walls of the furnace and the sides of the tube. From this space the gases were allowed to pass off by the pressure within the furnace, through a pipe which penetrated the ring and walls. When the tube was kept full of minerals, about ⅓rd or ¼th only of the gas escaped into the open air, the rest passing into the annular chamber; and when this state of things was continued, those troublesome adhesions of masses of semifused materials above and around the boshes, technically termed 'scaffolds,' occurred, with the usual accompaniments of black cinder and inferior iron. It is evident that when the tube was kept full of materials, the contents acted as a loose stopper to the current of hot gases forced up by pressure from beneath, and diverted them towards the annular space where there was no such resistance, thus leaving the minerals in the central parts of the furnace insufficiently supplied with the upward current, and consequently with heat; the minerals, on the other hand, surrounding this cold central cone, were supplied with more than their usual quantity of heat, as was evidenced by the burning of tuyères, and by the destruction of the brickwork in their neighbourhood. In this state of things, the ores in the external portions of the furnace would become reduced and converted into grey metal; while those in the central portion would, according to the degree of deviation of the ascending current of heated gases from them, descend to the point of fusion either thoroughly deoxidised, and slightly carbonised, or possibly with a portion still in the state of oxide, and mixing there with the properly-reduced ores, enter into fusion with them, producing a mixture of irons which must necessarily prove of inferior quality, and a black cinder from the unreduced oxides. When the iron tube in the throat of the furnace was kept only partially filled with minerals, much more gas escaped into the open air, as might have been expected, and consequently more traversed the central parts of the furnace; and it was always observed that when that mode of filling was adopted, the furnace worked much better; but then the object, viz. that of economising the gases, was not attained. Differently-formed furnaces were found to be disturbed in different degrees by this system of drawing off the gases: the old conical *narrow* topped furnaces were affected very much less than the improved modern *domed* top furnace of large capacity, from which all attempts to take off any useful portion of the gases proved absolute ruin. It might be argued, that as the same quantity of blast and fuel were used as heretofore, the ascending current of heated gases ought to produce the same deoxidising and carbonising effect on the superincumbent mass, whatever direction they might take in making their escape at the upper region of the furnace; for if the central part should not have been sufficiently acted upon, the external annulus would have more than its usual share of chemical influences. But when it is considered that iron is only capable of taking up a certain quantity of carbon, and no more, it follows that after having received this dose, its further exposure in the external parts of the furnace where the heated gases abound can do nothing towards supplying the deficiency of carbon in the metal reduced in the central part. From these considerations it became evident, that no system of drawing off the gases around the sides, whether by the insertion of an iron tube into the throat, or by lateral openings through the walls into a chamber surrounding the top of the furnace, can be adopted without more or less injury to its action; and that the only unobjectionable mode would be to take the gases from a chamber above the surface of the minerals, thus equalising the pressure on the whole sectional area of the mouth, and thereby allowing an equally free flow for the ascending current up the middle, as well as up the sides of the furnace. By this method the whole of the waste gases would become utilised, instead of a portion only, and the furnace would be restored to its original state, inasmuch as the direction of the flow of heated gases would not be interfered with by unequal resistance. To form this chamber, the furnace must be covered in, and fed through a hopper, a plan long adopted at the Codner Park Iron Works, with the supposed advantage of scattering the minerals around the sides of the furnace, and preventing their accumulating in the centre: a conical charger of this description, but fixed in the throat of the blast-furnace, was in use at the Cyfartha Works more than half a century ago, the minerals being thrown by baskets to the centre of the cone, and allowed to roll down to the sides of the furnace, thus giving a cup form to the surface of the minerals, the larger lumps of course rolling to the centre, and affording a freer passage in that direction for the upward current. It was not, however, until January 1851, that a trial was made, at the Ebbw Vale Works, of an apparatus of this description for collecting the gases. It was then supplied to one of the old forms of conical furnace with a narrow top, and the trial proved eminently successful, the furnace producing any quantity of iron required according to the burden, as usual. Several other furnaces were similarly furnished in and around the neighbourhood, and it was now thought that the principle of taking off the gases from a chamber above the surface of the minerals, together with the conical mode of charging, were the only indispensable conditions to success for all furnaces; and some even which were originally built too narrow at the mouth were actually improved by the new method of charging, which did not allow of the surfaces of the minerals rising higher than about 6 feet from the top; thus giving to the furnace a diminished height, and, as a consequence of its conical shape, a wider mouth. Further experience, however, demonstrated the fallacy of this general conclusion.

A large domed furnace was furnished with the same kind of charging-apparatus which proved so successful in former instances; but, to the astonishment of all, it turned out a complete failure, the same derangements occurring as in the former cases, where a portion only of the gases was collected, by sinking a tube into the throat. Now this furnace could not be filled to within 6 or 7 feet of the top, and at that depth the diameter was 13 feet 6 inches, owing to the sharp sweep of the dome; the actual working furnace was therefore 37 feet high, instead of 44 feet, with a mouth 13 feet 6 inches, instead of 8 feet; and as the minerals cannot lie so close against the smooth sides of the walls as they do locked in each other in the more central region of the furnace, a much freer discharge of the gases up the sides must take place; and on boring a hole through the side of the furnace, in the neighbourhood of the boshes, it was found that, 2 feet in, the coke and other minerals were at a white heat, but a little further on towards the centre, lumps of black blazing coal were found, with ironstone which had not even attained a red heat. The charging-apparatus was now raised with the furnace 5 feet, and the minerals drawn up an inclined plane to the charging-cup, thus enabling it to be kept full to within a short distance of the old mouth, after which the furnace worked as usual. That diminished height was not the cause of the bad working of the furnace was afterwards proved, the furnace having been blown out for repairs, and re-lined with brickwork, giving it that form and proportion deemed necessary from the experience gained; the height being now only 37 feet instead of 44, and the diameter of the mouth 7 feet 6 inches, or one-half of that of the boshes. The same charging-apparatus which failed before, mounted 6 feet above the mouth, was used, and the furnace has now been working uninterruptedly for five years, turning out as much as 160 tons of grey pig-iron per week, or, when burdened for white-iron, 200 tons; economising the whole of its gas, and as much under the control of the manager as any furnace, either closed-top or open-top, can reasonably be expected to be. It is clear, therefore, that the covering of the top has nothing whatever to do with the action of a furnace kept full to the mouth, and having the proper form and proportions from that point downwards. The mouth must be understood to be that part of the furnace which represents the mean height of the surface of the minerals, and not the top of the masonry, and the question arises, what proportion should that bear in diameter to the boshes or widest part, and what the latter should be with reference to height in order to secure a maximum economical effect on the quality of the iron made, and on the yield of fuel. This state of perfection can exist only when the *isothermal* lines in the furnace are parallel to the horizon. The temperature of the minerals at any given height above the tuyères being the same through the whole horizontal sectional area at that height, and consequently arriving at the zone of fusion in an equally prepared state. If the mouth of the furnace be too wide, the heated gases have a greater tendency to pass up the sides than through the centre, thus destroying the horizontality of the lines of equal temperature, and giving them a curved form with the *convex* side downwards; hence ores, at different temperatures, and of various stages of preparation, will occupy any given horizontal sectional area of the furnace; these descending together and mixing in the zone of fusion will produce evils in proportion to the extent of the deflection of the curves from a horizontal line. On the contrary, if the mouth of the furnace be too narrow in proportion to the other parts, we may expect an undue portion of the gases to pass up the centre, leaving the minerals around the sides comparatively unacted upon. It is easy to see that evils of the same kind as before must exist here, the isothermal lines becoming now *concave* downwards, instead of *convex*, giving as before, through any horizontal section of the furnace, ores at various temperatures, and at different degrees of deoxidation or carburation, according to the depth which they may have attained in the furnace. There are several instances of furnaces originally built with too narrow tops, being greatly improved by widening them; this may conveniently be done by feeding them through a conical charger, which, by lowering the surface of the minerals, *virtually* increases the width of the mouth: on the other hand, furnaces having the opposite defect of being too wide at the top, may be benefited to some extent, provided the walls are nearly perpendicular, or do not widen too rapidly downwards, by employing as large a cone as it is possible to work in the throat; for, by the use of this feeder, the minerals must fall close to the sides, and the larger lumps roll to the axis of the furnace, and so facilitate the passage of the gases in that direction, besides giving to the surface a concave or cup form, and consequently a diminished height and resistance to the upward current in the middle. This principle of improving the charging of such defective furnaces is even carried out to some extent in feeding open-top furnaces where the gases are wasted. The charging-plate is so placed as to prevent the nose of the barrow from projecting any distance into the furnace; the minerals, being thus discharged close to the edge, the larger lumps have a tendency to roll over towards the centre, leaving the smaller at the ring-walls, to check the upward current in that direction.

The above considerations will materially assist in furnishing an answer to the oft-repeated and very important question, 'What form and proportions should a blast-furnace have to produce the best results in quality of iron, and in economy of fuel, whether worked on the open-top principle, or enclosed for the purpose of utilising the waste gases?' Experience has proved that when the mouth of the furnace is one-half the diameter of the widest part, good work is obtained, and that any deviation from that proportion, if in excess, has been productive of great derangement in its action. The height of the furnace should also bear a certain proportion to the greatest diameter, in order to secure an uniform flow of the ascending current through all its parts; for if the widest part bear too great a relation to the height, the boshes must necessarily be of a low angle, and consequently the minerals around the sides near their top be at too great a distance out of the direct line of passage of the ascending current, and consequently remain only partially prepared for fusion.

1244



The proportions recommended by Mr. Parry, and which have been practically tested most satisfactorily in several instances, are as shown in *fig.* 1244. The mouth *b′ b′* one-half the diameter of the widest part *c c*, and this should not be at a less depth than its own diameter. The sides of the furnace to this depth should be formed slightly dome-fashioned, for the purpose of giving to that region a larger capacity than would be obtained by a conical form. The radius of the curve should be at right angles to the axis of the furnace, and formed by a prolongation of the line representing the greatest diameter. When the radius is set at a great angle with this line, which is often done to give greater capacity to the domed part, the distortion produced by the sharpness of the curve may leave a segment of the minerals unacted upon by the gases in their passage to the mouth, and entail greater evils than would be compensated for by increased capacity. The curve is continued below the widest part of the furnace till it meets the top of the boshes *d d*, the angle of which should not be less than 70°, and start from the point of the tuyères *f f*. The depth also from the widest part to the tuyères should not be less than its own diameter *plus* half the diameter of the tuyères. These proportions give a blast-furnace, of any determinate height fixed upon, the largest possible capacity it is capable of receiving, while remaining free from any distortion of form, likely to give a place for minerals to lie out of the way of the action of the upward gaseous current; when the height exceeds the proportion to its greatest diameter indicated in the figure, an unnecessary sacrifice in its capacity is the only loss entailed. The height above the mouth must be regulated by the kind of hopper used for charging, where it is intended to carry off the gases.

Doubtless when the true principle of collecting these gases without injury to the blast-furnace becomes more generally known, attention will be directed to the easiest and most convenient mode of introducing the minerals. The conical charger has only one disadvantage, that namely of allowing a great waste of gas during the charging; probably some kind of revolving hopper may be contrived to remedy this defect. It is of course assumed that the furnace is supplied with a proper quantity of blast, and of a density proportionable to the diameter across the tuyères, so as to maintain a vigorous combustion of the fuel to the very centre of the hearth, the top of which is indicated by the letters *e e*, for unless this is attained, a cold cone of minerals will remain in the centre, and produce derangements which no degree of perfection in the form of the furnace in the higher region can remove.

Theory of the Blast-furnace.—Analyses of the gases from a furnace at Alfreton, in Derbyshire, at various depths below the surface, gave to Messrs. Bunsen and Playfair the results embodied in the subjoined Table. The furnace was supplied with 80 charges in the course of 24 hours, each charge consisting of 390 lbs. of coal, 420 lbs. of calcined ironstone, and 170 lbs. of limestone, the product being 140 lbs. of pig-iron. The gases were collected through a system of tubes of malleable iron, 1 inch in diameter, and were received in glass tubes 4 inches long, and $\frac{3}{4}$ of an inch in diameter. The well-known skill of M. Bunsen as a gas analyst is a guarantee of the accuracy of the determinations.

Composition of the Gases taken from different depths in the Furnace.

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.
	5 ft.	8 ft.	11 ft.	14 ft.	17 ft.	20 ft.	23 ft.	24 ft.	34 ft.
Nitrogen . .	55·35	54·77	52·57	50·95	55·49	60·46	58·28	56·75	58·05
Carbonic acid .	7·77	9·42	9·41	9·10	12·43	10·83	8·19	10·08	00·
Carbonic oxide .	25·97	20·24	23·16	19·3	18·77	19·43	29·97	25·19	37·43
Light carburetted hydrogen . .	3·75	8·23	4·57	6·64	4·31	4·40	1·64	2·33	0·00
Hydrogen . .	6·73	6·49	9·33	12·42	7·62	4·83	4·92	5·65	3·18
Olefiant gas . .	0·43	0·85	0·95	1·57	1·38	0·00	0·00	0·00	0·00
Cyanogen . .	0·00	0·00	0·00	0·00	0·00	0·00	trace	trace	1·34

From these analyses it appears:—

1. That at a depth of 34 feet from the top, within 2 feet 9 inches of the tuyère, the gas was entirely free from carbonic acid, but contained an appreciable quantity of cyanogen.
2. That the nitrogen is at a minimum at 14 feet.
3. That carburetted hydrogen is found so low as 24 feet, indicating that at that depth coal must be undergoing the process of coking.
4. That hydrogen and olefiant gases are at a maximum at 14 feet.
5. That the proportions between the carbonic acid and carbonic oxide are irregular, which is probably to be explained by the fact that water is decomposed as its vapour passes through the layers of hot coal.

The average composition of the gases evolved from the materials used in the blast-furnace is somewhere between the two following numbers:—

Nitrogen	60·907 . .	57·378
Carbonic acid	8·370 . .	9·823
Carbonic oxide	26·846 . .	24·042
Light carburetted hydrogen	2·536 . .	2.743
Hydrogen	1·126 . .	4·972
Olefiant gas	0·112 . .	0·392
Sulphuretted hydrogen	0·045 . .	0·035
Ammonia	0·058 . .	0·115
	100·000	100·000

The proportion of nitrogen to oxygen, as an average deduced from these analyses, is 79·2 to 27. The product of the combustion of coal gives the same proportions as those existing in atmospheric air, viz. 79·2 : 20·08. The excess of oxygen must therefore depend upon the carbonic acid of the limestone, and the oxygen of the ore given to carbon during the process of reduction. Now, as at a depth of 24 feet the gas collected contained 27·6 and 26·5 oxygen to 79·2 nitrogen, it is held that at this depth the gas must already have accumulated all the oxygen of the ore, and the carbonic acid of the limestone; and the conclusion is drawn that, in hot-blast furnaces fed with coal, the reduction of the iron and the expulsion of the carbonic acid from the limestone takes place in the boshes of the furnace. The exact region of the furnace in which the melting of the iron and the formation of slag are effected is not exactly defined, but it is assumed that the point of fusion is at the top of the hearth. The region of reduction in a furnace smelting with coal must be much lower than when the fuel is coke or charcoal, because a large portion of the body of the furnace must be taken up in the process of coking, and the temperature is thereby so depressed, that it is sufficient neither for the reduction of the ore, nor for the expulsion of carbonic acid from the limestone.

The mean general results obtained by M. Ebelmen from a charcoal-furnace at Clerval are given below. The methods of analysis adopted by this chemist were altogether different from those employed by Messrs. Bunsen and Playfair. For details, we refer to his memoir in the *Annales des Mines*, vol. xix. p. 89, 1851.

No. of analysis . .	I.	II.	III.		IV.	V.	VI.	VII.
Depth below mouth .	3 ft. 3 in.	3 ft. 3 in.	9 ft. 9 in.	9 ft. 9 in.	19 ft. 6 in.	19 ft. 6 in.	27 ft.	Tymp.
Carbonic acid . .	12·01	11·95	4·14	4·23	0·49	0·07	0·00	0·93
Carbonic oxide . .	24·65	23·85	31·56	31·34	35·05	35·47	37·55	39·86
Hydrogen . . .	5·19	4·31	3·04	2·77	1·06	1·09	1·13	0·79
Carburetted hydrogen	0·93	1·33	0·34	0·77	0·36	0·31	0·10	0·25
Nitrogen . . .	57·22	58·56	60·92	60·89	63·04	63·06	61·22	58·17
Totals . . .	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00
Oxygen, per 100 nitrogen	42·5	40·8	32·7	32·7	28·5	28·2	30·7	35·8
Carbon-vapour, per 100 nitrogen . .	32·8	31·7	29·6	29·6	28·5	28·5	30·7	35·9

I. Gas taken a short time after the introduction of the charge: II. the same taken a quarter of an hour after charging: III. gas collected through a cast-iron tube four inches in diameter; it rushed out with a noise and gave a sheet of flame, carrying with it particles of charcoal and dust: IV. gas collected by boring the masonry; it rushed out violently, burning with a blue-coloured flame: V. the same taken an hour after: VI. gas collected by boring the masonry at the back of the furnace about 3½ feet above the tuyère; it burnt with a white flame, giving off fumes of oxide of zinc; it was collected through porcelain tubes: VII. gas collected through gun-barrels lined with porcelain; it was evolved with sufficient force to project scoriæ and even cast iron.

The furnace was working with cold blast under a pressure of ·44 inch of mercury. The charges had the following composition:—Charcoal, 253 lbs.; minerals (various), 397 lbs.; limestone, 254 lbs. Thirty-two charges were driven in twenty-four hours; the furnace was stopped after every twenty charges; the produce being 3,970 lbs. of black cast iron; the daily yield being about 6,175 lbs.

The experiments show that while the carbonic acid progressively diminishes downwards, the carbonic oxide progressively increases, the former altogether disappearing at a depth of 27 feet. On examining the numbers representing the oxygen and carbon referred to 100 nitrogen, it is seen that they diminish progressively to a depth of 19 feet, the oxygen combined varying from 42·5 to 28·2. The proportion of carbon in the same zone rises from 28·5 to 32·8: a result brought about as much by the carbonic acid disengaged from the minerals as from the gaseous products of the distillation of the charcoal. It is seen that the reduction of the mineral is already considerably advanced at the depth of 19½ feet; and this, so to speak, without any consumption of charcoal, but through the conversion of carbonic acid into carbonic oxide. The hydrogen decreases as the carbonic oxide increases; showing that this gas exercises no influence in the reduction of the ore.

The results obtained by M. Ebelmen from a coke-furnace at Seraing were as under:—

No. of experiment	I.		II.	III.	IV.		V.	VI.
Depth	1 ft.	1 ft.	4 ft.	9 ft.	10 ft.	10 ft.	12 ft.	45 ft.
Carbonic acid	11·39	11·39	9·85	1·54	1·08	1·13	0·10	0·00
Carbonic oxide	21·61	28·93	28·06	33·88	35·2	35·35	36·30	45·05
Hydrogen	2·71	3·04	0·97	0·69	1·72	2·08	2·01	0·25
Carburetted hydrogen	0·20	..	1·48	1·43	0·33	0·29	0·25	0·07
Nitrogen	57·06	56·64	59·64	62·46	61·67	61·15	61·34	54·63
Totals	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00
Oxygen, per 100 nitrogen	45·0	45·6	40·0	29·6	30·2	30·6	29·9	41·2
Carbon-vapour, per 100 nitrogen	35·2	35·7	33·0	29·4	29·6	30·0	29·9	41·3

I. Gas obtained by plunging an iron tube, three centimeters in diameter, about one foot into the furnace: II. the same; the gas burnt spontaneously: III. and IV. two consecutive analyses of the same gas: V. the gas was collected by an iron tube: VI. gas collected by piercing the masonry two feet above the tuyères; the gas was accompanied by fumes of cyanide of potassium, but no cyanogen could be detached.

The furnace was 50 feet high; the air was supplied through two tuyères, and was heated to 212°; it was driven at the rate of 26,840 gallons per minute under a pressure of ·5 of mercury. The charges were composed of, unroasted minerals 1,434 lbs., forge cinders 1,434 lbs., limestone 948 lbs., coke 1,765 lbs. The metal was run every twelve hours, and 17,500 lbs. of white crystalline cast iron obtained, which was run on thin plates and run directly to the puddling-furnace. The yield of the mineral was 42 per cent., and the consumption of coke 1,500 per 1,000 of cast iron, rising from 1,800 to 2,000 per 1,000 of iron when the furnace was working for foundry iron.

The analyses show a rapid diminution of carbonic acid, and indicate that in the upper regions of the furnace an energetic reduction of ore takes place by the oxide of carbon under the influence of the high temperature of the ascending gases. Between one and nine feet the limestone is calcined. The reduction of the ore takes place at this region by the conversion of carbonic oxide into carbonic acid, without change of volume and without consumption of carbon. The increase in the hydrogen is too small to induce a supposition that aqueous vapour in decomposing can dissolve any notable quantity of carbon. The gases collected at a depth of about 12 feet represent about the mean composition of the gaseous mixture; from that point to a depth of 45 feet, two-thirds of the total height of the furnace, the gases do not sensibly vary, and are combined almost entirely of carbonic oxide and nitrogen. At 12 feet the oxygen is to the nitrogen as 29·9 to 100; in atmospheric air it is as 26·3 to 100. The difference, 3·6, represents the oxygen arising from the reduction of the silicates of iron constituting the forge cinders, which is thus seen to take place between the tuyère and a depth of 12 feet. These silicates are well known to be decomposed with difficulty, but they are reduced at the high temperature prevailing in that zone of the furnace, and their reduction gives rise to a corresponding quantity of carbonic oxide, to a consumption of fuel, and to a considerable absorption of latent heat. The other minerals are reduced higher up in the furnace, and this is common to all coke-furnaces, being due to the high temperature of the ascending gases, a temperature much higher than exists in charcoal-furnaces, a far larger quantity of combustible being consumed. Hence it is that forge cinders can be successfully used in coke-furnaces; while in charcoal-furnaces the introduction of small quantities only alters the working of the furnace, makes the iron *white*, and corrodes rapidly the walls of the furnace in consequence of the imperfect reduction.

From his eudiometric experiments on the gases from coke- and charcoal-furnaces, M. Ebelmen deduces the following conclusions:—

1. That the amount of carburetted hydrogen is too small to exercise any influence over the chemical phenomena of the furnace.

2. That the atmospheric air thrown into the furnace by the tuyère produces successively carbonic acid and carbonic oxide, at a small distance from the opening. The first of these reactions gives rise to an exceedingly high temperature; the second, on the contrary, causes a great absorption of latent heat, and a corresponding lowering of the temperature of the gaseous current. The limit of the *zone of fusion* bears

relation to the space in which the transformation of carbonic acid into carbonic oxide takes place.

3. That the ascending current, which consists of carbonic oxide and nitrogen, with a little hydrogen, produces in ascending two distinct effects: it communicates one part of its sensible heat to the materials of the descending column; it becomes charged with all the volatile products disengaged at different heights, and it reduces the oxide of iron to the metallic state. Sometimes this transformation gives rise to an increase in the quantity of carbonic oxide; sometimes, on the contrary, it effects the conversion of carbonic oxide into carbonic acid without change of volume, and without combustion of fuel. Whenever the reduction of oxide of iron takes place with the production of carbonic oxide, there is a consumption of fuel, and an absorption of latent heat. It is essential, therefore, to the good working of the furnace, that the minerals should arrive completely reduced to that part where the temperature is sufficiently elevated for the conversion of carbonic acid into carbonic oxide by contact with carbon: this condition is nearly always realised when the oxide of iron is in a free state in the mineral. The reduction of the oxide when in combination with silica requires, on the other hand, a high temperature, and it can only take place in that zone of the furnace where the carbonic acid has completely disappeared.

4. That the zone where carbonic oxide exists alone is much more extended in coke- than in charcoal-furnaces, and is nearer the mouth in the former than in the latter; it falls lower, however, in the cylinder with hot blast, the quantity of heat remaining the same.

5. That the volatile gaseous matters from the distillation of the charcoal pass into the escape gases, and exert no influence on the reduction of the minerals.

The mutual relation of the carbonic acid and carbonic oxide, which is observable in the analyses of M. Ebelmen, is not found in those of Messrs. Bunsen and Playfair; this is attributed by M. Ebelmen to the circumstance that the latter chemists collected their gases through narrow iron tubes, which, becoming intensely heated and partially choked by the fragments of ore and fuel introduced by the rapid stream of gas, so modified the composition of the gases, that the analysis, however carefully conducted, could not represent accurately their real composition. M. Ebelmen collected his gases through wide tubes, and from the lower parts of the furnace, by piercing the solid masonry. It is obvious, however, that none but very general conclusions can be drawn from the analysis of the furnace-gases, in whatever way they may be collected, for their composition cannot be the same under all circumstances, the nature of the fuel, the pressure of the blast, and (as Mr. Parry's experiments prove) the shape of the furnace itself, must each exert an influence in modifying the circumstances which affect their composition. Although, therefore, it is impossible to fix the precise region of the furnace where the reduction of the oxide of iron begins to take place, that is, to define precisely the limits of the 'zone of reduction,' we may, in considering the theory of the production of crude iron, divide the furnace into four zones: 1. The zone of reduction; 2. The zone of carburation; 3. The zone of fusion; 5. The zone of oxidation. The zone of reduction will vary in extent according as the furnace is working with coal or with coke, with hot blast or with cold. The zone of carburation commences just below the top of the bosses, the reduced metal in a soft and malleable state here acquires carbon, its rapid sinking being retarded by the contraction which the sides of the furnace begin to undergo from this point downwards. As the carburized metal passes through the zone of fusion it melts, together with the earthy matters which serve to protect it from the oxidising effects of the fourth zone, that of oxidation, through which it passes in its passage to the crucible. If the temperature of the zones of fusion and oxidation be not much higher than the melting point of specular iron, the metal in the crucible will be white, with little or no graphite; and if the iron remain sufficiently long in the zone of carburation to take up the maximum quantity of carbon, it will be bright iron. The reduction of silicon appears to take place at about the melting temperature of specular iron: it exists therefore in small quantity in white iron, and in the greatest abundance in the grey iron smelted from refractory ores, which require a high temperature.

The proportion of carbonic acid in the gases obtained from different heights in a furnace, has been studied by MM. E. Montefiore Levi and Dr. Emil Schmidt (*Zeitschrift des öster Ingenieurvereines*, 1852). They found that the zone from which this gas is entirely absent is of very limited extent, for although it is not met with at a height of 8 feet from the tuyère, it exists at 9 feet to the extent of 4·78 per cent., above which point it diminishes up to 15 feet, where it is 0. From this point it again increases, amounting at a height of 30 feet to 3·5 per cent. It then gradually diminishes, until, at a point from 37 to 39 feet above the tuyère, it amounts to only 1·69 or 1·91 per cent.; after which it goes on increasing with rapidity and regularity up to the furnace mouth. The carbonic acid existing in the furnace-gases between

15 and 30 feet is referred by these chemists to the decomposition of the limestone used as a flux: and its gradual diminution above this point indicates a reaction of considerable importance, that, namely, of the carbonic acid upon the ignited coke carbon being taken up and carbonic oxide formed. Now, the quantity of carbon taken up by 275 parts of carbonic acid to convert it into carbonic oxide, amounts to 75 parts, and as in the furnace experimented with, 20,000 kilogrammes of limestone, containing about 8,000 kilogrammes of carbonic acid were consumed every 24 hours, a loss of fuel equivalent to 2,173 kilogrammes of carbon was daily occasioned by the conversion of this carbonic acid into carbonic oxide, and this may be considered equivalent to 2,500 kilogrammes of coke with 11 per cent. of ash. The heat absorbed by the conversion of the carbonic acid of the limestone into a gaseous state is found by calculation, taking the specific heat of carbonic acid at 0·22, and the heating power of coke at 600, to be equivalent to that developed by the combustion of 322 kilogrammes of coke. Now it was demonstrated by Dulong that the quantity of heat disengaged in the conversion of carbon into carbonic oxide is much *less* than that disengaged in the conversion of carbonic oxide into carbonic acid, although the same quantity of oxygen is required in both cases. The conversion of carbonic acid into carbonic oxide by passing over ignited carbon is essentially a twofold action: a combination of carbon with oxygen, and a decomposition of carbonic acid into carbonic oxide and oxygen; the former is accompanied by development, the latter by absorption of heat; the latter preponderates to such an extent as to indicate a loss of temperature equivalent to the heat developed by the combustion of 1,609 kilogrammes of coke.

These considerations led the authors to employ burnt lime in working blast-furnaces, and thus to obviate the loss of heat: the results were not at first satisfactory, the management of the furnace being very difficult, and the slags black and pasty; but subsequently the working was regular and good, and the saving of coke and the increase of production are stated to have been very evident; moreover, the raw iron was of better quality, and all the interior parts of the furnace, especially the tymp-stone, remained in a much better state of preservation than when limestone was used. The following table shows the quantity of coke consumed for every 100 kilogrammes of raw iron, and the production during six months. The figures in the first column refer to the furnace, in which limestone alone was used; the second column to the same furnace, in which burnt lime alone was used; and the third column to the furnace in which limestone was used for three months, and burnt lime for the next three months:—

	Quantity of coke in kilogrammes consumed for every 100 kilogrammes raw iron			Reduction during 28 days, in kilogrammes		
	1. With limestone	2. With burnt lime	3. With limestone	1. With limestone	2. With burnt lime	3. With limestone
April	165	145	163	436,000	601,000	459,000
May	165	147	159	447,000	582,000	461,000
June	160	147½	164	477,000	588,000	488,000
			With burnt lime			With burnt lime
July	161	146½	149¾	462,000	555,000	537,000
August	158¾	145	146	465,000	536,000	552,000
September	153	147¾	146	477,000	577,000	600,000
Mean	160½	146¼	154⅔	461,000	573,000	516,000
Average from April to June	...	...	162	...	...	469,000
Average from July to September	...	...	147¼	...	...	563,000

The very regular and uniform results given in this table, show that by the use of burnt lime, the consumption of coke for every 100 kilogrammes of raw iron was reduced by 14 to 15¾ kilogrammes, while at the same time the production of iron increased, within a certain period, as much as 22 to 24 per cent.

Hitherto the opinion of metallurgists, with regard to the use of burnt lime, was rather unfavourable than otherwise, but since the above experiments were made (at Ougrée), it has been employed with good results in England and Wales, and as much as 12 kilogrammes of coke have, it is stated, been saved for every 100 kilogrammes of limestone, which was replaced by 63 of burnt lime.

Mr. Lowthian Bell considers that the economy in the use of caustic lime in blast-furnaces depends chiefly upon the difference in price in the fuel used, as the lime is burnt with small coal in kilns, saving an equivalent of coke, a more expensive fuel in the furnace. He has, however, found that when caustic lime is exposed to carbonic acid at a red heat, there is a re-formation of carbonate of lime to some extent, which is decomposed again at a higher temperature, and that therefore the fuel saved in the furnace is less than the calorific equivalent of that required for burning the lime.

The greatest development in blast-furnace economy has taken place in the Cleveland district, where the amount of fuel required for the production of a ton of pig-iron has been reduced from 35 to 40 cwts. of coke to 20 cwts. and even in some cases as low as 17 cwts. This saving has been produced by increasing both the dimensions of the furnaces and the temperature of the blast, the waste gases being in all cases econo-

Date	Name of Firm	Furnaces	Height	Width of boshes	Capacity
		No.	Feet	Feet	Cubic feet
1851	Bolckow and Vaughan	3	42	15	4,566
1853	Bell Brothers	6	47½	16½	6,174
„	Bolckow and Vaughan	6	54	15	7,166
„	Gilkes, Wilson and Co.	2	45½	14½	5,100
1854	Cochrane and Co.	4	55	16	7,175
„	B. Samuelson and Co.	3	50	14	5,050
„	Bolckow and Vaughan	3	54	15	7,116
„	Gilkes, Wilson and Co.	2	55	14½	6,800
1856	Stockton Furnace Co.	3	50	16	6,341
„	Morton Iron Co.	3	50	15	6,000
1858	Thomas Vaughan	6	56	16	7,000
„	Hopkins, Gilkes and Co.	2	56	16	7,200
„	Jones, Dunning and Co.	2	58	17	8,000
„	Bolckow and Vaughan	1	61	16½	7,960
1861	Gilkes, Wilson and Co.	1	55	16	7,700
„	William Whitwell and Co.	3	60	20	12,778
1862	Bolckow and Vaughan	2	75	16½	11,985
1864	B. Samuelson and Co.	4	69	20	15,500
„	Lloyd and Co.	4	67	20	15,000
„	Thomas Vaughan	6	81	19	16,000
„	Stevenson, Jacques and Co.	3	70	22	17,000
1865	Gilkes, Wilson and Co.	2	75	21	17,700
„	Bell Brothers	2	80	20½	15,500
„	Bolckow and Vaughan	2	95½	16	15,050
1866	Bolckow and Vaughan	1	75	20	12,972
„	Hopkins, Gilkes and Co.	2	75	24	20,000
„	Swan, Coates and Co.	2	75	20	16,090
„	Bell Brothers	2	80	17	11,500
1867	Norton and Co.	2	85	25	26,000
„	Cochrane and Co.	2	76	23	20,024
1868	Gilkes, Wilson and Co.	1	75	24	22,500
„	Stevenson, Jacques and Co.	1	70	23	18,000
„	B. Samuelson and Co.	1	69	21½	16,000
„	Lloyd and Co.	2	80	21½	18,000
„	Jones, Dunning and Co.	3	73	18	12,000
„	Bolckow, Vaughan and Co.	2	95½	22	25,940
„	Bolckow, Vaughan and Co.	1	95½	23	28,800
1869	Thomas Vaughan	3	85	25	26,000
1870	Bell Brothers	4	80	25	25,000
„	Stockton Furnace Co.	2	80	24	24,613
„	Swan, Coates and Co.	1	75	23⅔	22,229
„	Cochrane and Co.	2	90	30	41,149
„	Gilkes, Wilson and Co.	2	85	27	32,000
„	B. Samuelson and Co.	2	85	28	30,000
1871	Bolckow, Vaughan and Co.	2	95½	24	28,950
„	Lackenby Iron Co.	2	85½	25½	26,670
„	Gjers, Mills and Co.	2	85	25	26,000

mised. How very great the change has been may be seen in the preceding table giving the dimensions and dates of the erection of new furnaces at the different works since iron-smelting was commenced in Cleveland in 1851, in furnaces of the Staffordshire type.

Mr. Lowthian Bell, to whom we are indebted for an elaborate work on the chemistry of the blast-furnace, considers that it is not certain whether any greater saving can be effected by the use of furnaces of 30,000 feet cubic capacity than by those of 10,000 or 12,000 feet, as in either case for similar charges he finds the composition of the waste gases and their temperature will be about the same.

Mr. Bell has pointed out that when peroxide of iron is exposed to carbonic oxide at temperatures between 750° and 850° Fahr., that simultaneously with the reduction of the ore to metallic iron, with the production of carbonic acid, a converse action takes place to a small extent, the carbonic oxide being split up into carbon and carbonic acid, the former being absorbed by the partially-reduced ore. This action is supposed to play a considerable part in modifying the ordinarily-accepted theory of blast-furnace action, as it is supposed that the carbon so absorbed is carried down with the ore into the highly-heated region of the hearth and boshes, where the last traces of oxygen are removed by its combustion, and the iron becomes fully carburised.

This absorption of carbon is attended with the disintegration of the ore—a fact which accounts for the disappearance of the lumps of ore in the interior of blast-furnaces when examined through holes in the brickwork of the stack made by accident or design. In such cases the flux and coke retain their original form; but the ore is changed in many cases to a black crumbled mass, in which the separate lumps can no longer be distinguished. The reduction by carbonic oxide of peroxide of iron to the metallic state commences at the temperature of about 300° to 400° Fahr., but at the higher point, of about 800°, the spongy metal is reoxidised when brought into contact with carbonic acid. The reducing action, therefore, of carbonic oxide in blast-furnace gas must at the higher temperature become balanced by the oxidising action of carbonic acid in proportion as the two gases approach to an equality. This is a point of great importance as affording a true measure of the working of a furnace, which may be considered to have consumed its fuel properly, when the gases at the throat are cooled to such a point that the particular dilution of carbonic oxide by carbonic acid, to which they correspond, is no longer capable of reducing the ore. This is attained in the Cleveland furnaces when the volume of carbonic oxide to that of carbonic acid is as 2 to 1, and the temperature from 600° to 700°. Beyond this point the gases have only a calorific value, namely, their sensible heat and the amount that can be developed by their combustion in stoves and boilers instead of coal.

The increase of heat in the blast has in general been attended with a marked economy of fuel up to temperatures of about 1000° Fahr. With more highly heated blast, such as is obtained in the Siemens and Whitwell stoves, it is less certain whether any greater saving can be effected. At Consett a distinct saving is claimed for blast at 1300° over the same furnace when blown at 1000°. At Barrow, on the other hand, no saving was effected by the use of blast at 1500° instead of 1100°, the consumption of coke being the same, in either case about 20·18 cwts. to the ton of pig-iron produced.

Varieties and Chemical Constitution of Cast Iron.—In commerce there are four principal varieties of cast iron, known respectively as Nos. 1, 2, 3, and 4, or *dark grey*, *bright grey*, *mottled*, and *white*; these terms, although convenient, do not, however, indicate the intrinsic value of the iron thus denominated, as the variable qualities of ore, fuel, and limestone may exercise such an influence on the resulting crude iron, as to render a low denomination of one manufacturer of greater commercial value than a higher denomination of other makers. The general characters of the four varieties are these:—No. 1. Colour, dark grey, in large rounded grains, obtained commonly near the commencement of the casting when the furnace is in good working order, and when an excess of carbon is present; in flowing it appears pasty, and throws out blue scintillations. It exhibits a surface where crystalline vegetations develop themselves rapidly in very fine branches; it congeals or fixes very slowly; its surface, when cold, is smooth, concave, and often charged with plumbago; it has but a moderate tenacity, is tender under the file, and susceptible of a dull polish. When melted over again, it passes into No. 2, and forms the best castings. No. 2, colour bright grey, of small-grained structure, and interspersed only with small graphite laminæ; possesses great tenacity, is easily filed, turned, and bored; may even be hammered to a certain extent; does not readily crack from change of temperature. No. 3 is a mixture of white and grey iron. On *strongly mottled* iron, little stars and spots of grey iron are found, interspersed in bright or flowery iron; *weakly mottled* iron exhibits white specks on a grey ground. In *streaked iron*, grey iron is found above and below, and bright iron in the middle, with strong demarcations. No. 4. *White* *iron* varies from tin white to greyish white; it is very brittle, cracking easily, even by change of temperature; it is extremely hard, sometimes even more so than hardened steel, so that it will resist the strongest file, and scratches glass easily. Fracture sometimes laminar, sometimes lamino-radiating, sometimes finely splintered, sometimes dense and conchoidal. As the fracture changes from laminal to conchoidal, the colour likewise varies from white to greyish. Mean specific gravity, 7·5. Expands less than grey cast iron when heated, cannot be welded, because it becomes pasty at the very lowest welding heat. When heated to the melting point it does not suddenly pass into the fused state like grey pig-iron, but is converted before fusing into a soft pasty mass. In this variety of pig-iron the whole of the carbon is united to the iron; it is never used for casting, but always for conversion into malleable iron. The bright iron obtained from spathic iron-ore contains the largest proportion of carbon (5·3 per cent. according to Karsten). The white iron resulting from derangement flows imperfectly, and darts out in casting abundance of white scintillations; it fixes very quickly, and on cooling exhibits on its surface irregular asperities, which make it extremely rough; it is exceedingly hard, though it is easily broken, the fracture being radiated and lamellar; the bar-iron it affords is of inferior description. This kind of iron is always produced when the furnace is carrying a heavy burden of forge cinders containing sulphur and phosphorus.

Thus there are two distinct kinds of white cast iron: 1st. That obtained from ores containing a large proportion of manganese crystallising in iron plates; this variety is highly prized for making steel. 2nd. That resulting from a heavy mineral burden, or from a general derangement of the furnace, or from the rapid chilling of fused grey iron crystallising in small plates; both are hard and brittle, the first more so than the last. Cast iron, which by slow cooling is grey, becomes white when it is cooled rapidly; on the other hand, when white iron is melted and allowed to cool very gradually, a portion of the carbon crystallises out as graphite, and grey cast iron is produced.

In some iron works *six* varieties of pig-iron are recognised, which may be classified thus:—1. First foundry iron, large crystals; 2. Second foundry iron, large and small crystals mixed; 3. Dark grey, all small crystals; 4. Bright grey; 5. Mottled; 6. White, verging on mottled.

The subjoined table exhibits the composition of some different varieties of Continental, English, and American crude irons. The methods of determining the various elements which nearly always accompany cast iron, are given at the end of this article.

	Description	Iron	Carbon, combined	Carbon, free	Phosphorus	Sulphur	Silicon	Manganese	Total	Sp. gr.
German .	*a*	93·66	0·48	3·85	1·22	trace	0·79	trace	100·00	7·077
	b	93·29	2·78	1·99	1·23	,,	0·71	,,	100·00	7·43
	c	91·42	1·44	2·71	1·22	,,	3·21	,,	100·00	7·16
French .	*d*	95·18	..	3·40	0·45	0·03	0·80	,,	99·86	
	e	93·39	1·00	0·18	0·38	3·75	1·30	,,	100·00	7·159
American .	*f*	94·87	0·04	3·07	0·22	trace	1·80	,,	100·00	7·54
	g	96·35	1·14	1·50	0·21	0·01	0·79	,,	100·00	7·67
	h	96·55	2·79	..	0·17	0·06	0·32	,,	99·89	7·53
Silesian .	*i*	91·45	4·94	..	0·12	trace	0·75	3·38	100·64	7·6
	j	90·75	3·62	..	3·26	,,	0·25	2·00	99·88	
Scotch .	*k*	92·63	1·40	1·20	1·30	1·40	2·80	..	100·73	
	l	92·06	2·62		0·46	0·04	3·83	1·80	100·81	
	m	92·76	2·50		0·79	0·04	2·88	1·80	100·77	
English .	*n*	89·45	2·30		0·57	0·02	4·88	2·22	99·44	
	o	94·10	1·87	1·92	0·21	trace	1·30	1·12	100·52	
Welsh .	*p*	95·27	2·42		1·08	0·87	0·36	..	100·00	
	q	93·55	2·80		1·66	0·14	1·85	..	100·00	
	r	91·92	4·00		0·07	0·01	0·21	3·65	98·86	
	s	86·00	4·23		0·06	0·00	0·62	8·40	99·31	
	t	91·29	4·17		0·07	0·01	0·21	4·11	99·86	
	u	94·71	1·21		1·34	2·64	0·10	..	100·00	

a, *Very grey pig*, from Lerbach in the Hartz, cold blast; *b*, *Mottled* iron, from the royal works in the Hartz, cold blast; *c*, *Normal* grey pig, from the same works, hot blast; *d*, Grey charcoal pig, cold blass; *e*, White pig, from Firmy, very short and brittle; *f*, American grey pig, charcoal; *g*, American *mottled* iron; *h*, American charcoal, white iron; *i*, Silesian white charcoal iron, very crystalline; *j*, The same, but less crystalline; *k*, Grey Scotch coke pig, from the Calder iron works; *l*, Scotch coke, No. 3 pig-iron; *m*, Glengarrick, No. 3 pig; *n*, Coalbrookdale Lightmoor best first foundry iron; *o*, Grey pig-iron, from Dudley, Staffordshire; *p*, Ordinary Aberdare white pig; *q*, Grey cinder pig; *r*, White crystalline pig-iron, smelted from manganiferous ore; *s*, The same; *t*, The same; *u*, Ordinary white pig.

Besides the substances enumerated in the above table, other metals, such as copper, arsenic, chromium, titanium, cobalt, zinc, tin, aluminium, and the metals of the alkalis and alkaline earths, are occasionally found in crude iron, but very rarely in quantities that can at all affect the qualities of the product. The elements, the quantitative estimation of which has been given in the above analyses, *do*, however, materially modify the physical qualities of cast iron. We shall, therefore, offer a few observations on each.

Carbon.—Iron can take up any quantity of carbon up to a little over 5 per cent., at which point it becomes saturated: the compound thus formed is the white crystalline pig or specular iron (*i*) (*r*) (*s*) (*t*); when absolutely pure, its composition is 94·88 iron, and 5·12 carbon: it is a *tetra-carburet*, Fe^4C. The most highly carburetted iron which Faraday and Stodart could produce consisted of 92·36 iron, 5·64 carbon. There seems no reason for admitting, as some metallurgists have done, the existence of a polycarburet of iron, containing 18·3 per cent. of carbon, inasmuch as iron containing under 6 per. cent. appears to be completely saturated. The specific gravity of pure tetra-carburet of iron is 7·66; it is the most fusible of all the carburets of iron, its melting-point being 1600° Cent.; it is brittle and silver-white, and crystallises in oblique prisms, which are frequently tabular. According to Gurlt the carburet of iron existing in grey pig is the *octo-carburet*, Fe^8C, the crystals of which belong to the regular or cubic system, but almost always appears in grey iron in the form of confused octohedral groups. The specific gravity of pure octo-carburet of iron, according to the same authority, is 7·15, and its composition 97·33 iron, and 2·63 carbon; its colour is iron-grey, its hardness is inferior, and its fusibility less than that of specular iron; the groups of crystals often found in cavities in large castings are composed of this peculiar carburet. Gurlt very ingeniously endeavours to show that in grey pig-iron the carbon of the octo-carburet is partially replaced by *silicon*, *sulphur*, and *phosphorus*, and the iron by manganese and other metals. In like manner the carbon of the *tetra-carburet* may be partially replaced by silicon, phosphorus, or sulphur, the eliminated carbon appearing in the form of graphite: the same decomposition is effected by heat, and specular iron, if exposed to a temperature considerably above its fusing-point, becomes *grey*; if cooled slowly, the graphite separates in large flakes, if rapidly, in minute particles. Some metallurgists suppose that in grey cast iron a portion only of the iron is chemically united with carbon, the rest of the metal being dissolved in the carburetted compound in the form of malleable iron. Dr. Noad inclines to the opinion of Gurlt, that the whole mass of the iron is in a state of combination with the electro-negative constituents, such as carbon, sulphur, phosphorus, and silicon. Thus in the white pig-iron of heavy burden (*u*), there is a deficiency of carbon, that element being replaced by sulphur and phosphorus.

Karsten gives as the mean of several analyses, 3·5865 per cent. as the quantity of carbon in cast iron smelted with charcoal from spathic ore. He states that iron containing as little as 2·3 per cent. of carbon still retains the properties of cast iron, particularly the faculty of separating graphite when allowed to cool slowly. With 2 per cent. of carbon iron is not forgeable, and scarcely so if it contain only 1·9 per cent. With this quantity of carbon it is steel, though not of the weldable kind (cast steel); even with so small a proportion of carbon as 1·75 per cent. it is weldable only in a slight degree; the latter property increases as the hardness of the iron decreases. An amount of from 1·4 to 1·5 per cent. of carbon in iron denotes the maximum of both hardness and strength. Iron containing 0·5 per cent. of carbon is a very soft steel, and forms the boundary between the steel (*i.e.* iron which may yet be hardened) and malleable or bar-iron. These limits lie perceptibly higher if the iron be pure; and lower if it contain silicon, sulphur, and phosphorus.

The composition of the various carbides of iron, according to Berthier, is as under:—

	FeC^3	FeC^2	FeC	Fe^2C	Fe^4C	Fe^6C
Iron . .	0·600	0·690	0·819	0·899	0·947	0·9643
Carbon .	0·400	0·310	0·183	0·101	0·053	0·0357

In the blast-furnace, the reduced iron may take up carbon in two different ways: 1. By immediate contact with the incandescent fuel; and 2. By taking carbon from carbonic oxide; thus $Fe + 2CO = FeC + CO^2$. That iron decomposes carbonic oxide is considered by Le Play and Laurent to be proved by the following experiment: pure oxide of iron and charcoal were heated in two *separate* porcelain boats, placed in a glass tube; the air in the tube furnished oxygen to the carbon; carbonic oxide was formed, which was converted into carbonic acid, at the expense of the oxygen of the oxide of iron; the carbonic acid was again transformed into carbonic oxide, by taking up a fresh quantity of carbon, which was again converted into carbonic oxide by taking oxygen from the oxide of iron, and this went on until the whole of the oxide of iron was reduced; the metallic iron then decomposed carbonic oxide, producing carbonic acid and carbide of iron: and this went on till a certain quantity of carbon had combined with the iron, when the action ceased. If the charcoal be very strongly ignited previous to the experiment, the carbonisation of the iron does not take place, neither does pure carbonic oxide carbonise iron when passed over the metal at a red heat: the effect in the experiment above described may therefore be due to the carburetted hydrogen evolved from the charcoal. Iron begins to take up carbon when heated only to the softening-point, the carbon gradually penetrates the metal, converting it first into steel and then into cast iron; conversely melted cast iron gives up carbon to soft iron, which it converts into steel. When white iron (Fe^4C) is heated with acids, nearly the whole of the carbon is eliminated in combination with hydrogen. Grey iron only gives up to hydrogen the carbon which was chemically combined with the iron, the uncombined carbon or graphite remains unacted upon; the dark spot produced upon grey iron by a drop of nitric acid arises from this separation of graphite. For the amounts of carbon in the different varieties of steel, see STEEL.

Phosphorus.—In very few specimens of crude iron is this element wholly absent; when it exists in small quantities only, it is said rather to improve the iron for castings, as it imparts to the metal the property of fusing tranquilly; in a larger proportion, it weakens the iron. In like manner a very small quantity of phosphorus hardens bar iron, without materially influencing the other properties, but when it exceeds ·5 per cent. it renders the bar brittle, *cold-short*, as it is termed. According to Schafhaeutl, both cast iron and steel are improved by phosphorus and by arsenic; he found the latter in the celebrated Dannemora iron, and in the Lowmoor iron, and the former in the equally famous Russian (CCND) iron.

Sulphur.—This element imparts to crude iron the property of becoming viscid, and of solidifying quickly with cavities and air-bubbles. It is not certain to what extent, or if at all, the presence of minute proportions of sulphur reduces either the tenacity or the toughness of cast iron of given quality in other respects. It is stated in the Report of the Commission of Inquiry, as to the manufacture of ordnance on the Continent, on the authority of Schür and Mitscherlich, that in certain Swedish works *pyrites* is thrown into the furnace, with the other constituents of the charge, to produce the fine grey *mottled* iron required for gun founding, and it is added that the effect may be analogous to that of the oxidising flame in a reverberatory-furnace. It is certain that sulphur possesses the property of concentrating carbon in iron: and as mottled iron is a mixture of white and grey iron, it is not difficult to see how the addition of pyrites may determine the formation of this variety of cast iron in a furnace, which without it would produce grey iron only: but it is scarcely credible that any intelligent founder would resort to such a method of making iron for casting cannon, in which the highest possible degree of tenacity is required. The fine grey mottled iron, which from its tenacity is known to be best fitted for large castings, is said to be prepared without difficulty, by charging the furnace partly with roasted and partly with raw ore, and so regulating the blast that the yield shall be regular, and the slag nearly colourless: these two ores, having different degrees of fusibility, are reduced after different periods in the furnace, and hence afford one of them grey, and the other white iron; the result being, provided the minerals are properly proportioned, a mottled iron, harder and more tenacious than grey iron, obtained by mixing or smelting in the cupola. It is desirable that the temperature of the furnace should be kept as low as possible, the production of dark grey graphitic iron resulting always from intensity of heat.

When sulphur is melted with iron containing the largest amount of chemically-combined carbon, sulphuret of iron is formed on the surface; underneath, a layer of graphite, and beneath that, a layer of iron with the *maximum* of carbon; and when *grey* iron containing 3·31 per cent. of graphite is melted with sulphur, *white* iron (containing 94·03 iron, 4·93 combined carbon, and no graphite), is formed. The tendency of sulphurous ores to produce white metal in their treatment in the blast-furnace has long been known. It was supposed that this was occasioned by the too great fusibility which the sulphur gave to the cast iron; but ores containing large proportions of phosphoric acid will produce very grey iron, notwithstanding their fusibility, so that this explanation does not serve: the experiments above described point to the true reason. The sulphur present in the ore (if as sulphuric acid reduced in the furnace) enters into combination with the iron, displacing a corresponding proportion of carbon, which becomes concentrated in the remainder of the metal, forming white iron. To guard against this, and in order to obtain a metal which shall contain a *minimum* amount of sulphur, the slags should contain the *maximum* amount of lime, M. Berthier having shown that this earth decomposes sulphuret of iron at a high temperature, in the presence of carbon. M. Janoyer states that the proportion of lime and silica in the slag may be as 54 to 36: it is doubtful whether such a highly basic cinder would be sufficiently fusible. Direct experiments, however, have shown that the amount of sulphur in cast iron diminishes in proportion as the amount of lime in the slag increases. A still better flux is oxide of manganese, and it is found that when the manganiferous spathose ore constitutes part of the burden of the furnace, sulphur almost entirely disappears from the crude iron. M. Janoyer believes that he has proved experimentally, that the whitening of cast iron smelted from sulphurous ores, is due, in part at least, to the subtraction of a portion of its carbon, and its volatilisation in the form of sulphuret of carbon, by which the temperature of the furnace is lowered; but his experiments on this point require confirmation. The presence of a very small quantity of sulphur acts very injuriously upon bar iron, so small a proportion as $\frac{4}{10000}$ rendering the metal 'hot-short,' that is, incapable of being worked at a red-heat under the hammer. If the quantity of sulphur in the crude iron exceeds 0·4 per cent., it is scarcely possible to manufacture it into good wrought iron.

Silicon.—Like carbon this element enters into combination with iron in all proportions up to as high as 8 per cent. The largest quantity found by Karsten in pig-iron was 3·46 per cent., but in the above table a specimen (*n*) is quoted from Coalbrookedale containing 4·88 per cent.: and Dr. Noad found it in a sample of Nova Scotia iron, as much as 5·8 per cent. Generally speaking, grey cast iron contains more silicon than white, and the greater the quantity of graphite in the crude iron the larger the amount of silicon, because the higher the temperature of the furnace; but this again will depend materially on the quality of the coal, from the ash of which the silicon is probably principally derived. A clean strong coal yielding a small percentage of ash furnishes a cast iron with less silicon than an inferior coal, the mineral burden being the same. Pig-iron smelted with hot blast contains more silicon than when the blast is cold, because of the higher temperature which prevails in the fusion-zone of the furnace. Some analyses illustrating this fact have been already given. According to the experiments of MM. Janoyer and Gauthier the amount of silicon in hot-blast cast iron may be greatly influenced by varying the proportion of limestone in the furnace. Pig-iron obtained with a charge yielding a cinder in which the lime and alumina were to the silica as 7 is to 10, had little strength, breaking readily, and analysis showed that it contained 3 per cent. of silicon. By increasing the amount of lime in the charge, so as to obtain a cinder in which the bases were to the silica as 8 is to 10, and at the same time employing a blast of the highest attainable temperature, the iron produced had a much greater strength. When the proportion of bases to silica in the cinder was as 20 is to 19, the iron contained only an inappreciable amount of silicon, and the strength was increased in the proportion of 65 to 45. When the maximum quantity of lime was used, the consumption of fuel was on the average increased to the extent of 6 per cent.

The experiments of MM. Janoyer and Gauthier induced the furnace manager of the Blaina Iron Works to increase the yields of lime on one of his furnaces to as great an extent as in his judgment it would bear, and when the furnace was under the full influence of the excess of flux to forward him samples of the grey pig for analysis. The following results show that, contrary to the statement of MM. Janoyer and Gauthier, no advantage, as regards a diminution in the amount of silicon, was hereby obtained, the proportion of that element being not perceptibly altered, though there is a slight diminution observable in the percentage of sulphur.

	Grey pig, with usual burden of lime.	Grey pig, with extra burden of lime.
Sulphur	0·067	0·045
Silicon	2·900	2·930

As the presence of silicon in pig-iron affects in a remarkable degree the yield as well as the strength of puddled bars, it is of importance that this element should be removed as effectually as possible by a refining process before the crude iron is submitted to the puddling process. Pigs with 3 per cent. of silicon gave about 6 per cent. of silica, and this requires somewhere about 12 per cent. of iron to form a cinder sufficiently fluid to allow the puddled iron to become aggregated into balls; this can of course be obtained only by *burning* that amount of iron in the puddling furnace after the expulsion of the carbon, and while the mass is in a powdery state. This powdery mass is composed of small granules of iron mixed up with a *gluey* infusible cinder. The puddler turns over this mass repeatedly to expose the iron to the oxidising influence of the furnace; the silica now taking up sufficient oxide of iron to give it fluidity begins to separate from the iron, and forms a pool at the bottom. After some time the puddler, finding the mass of cinder accumulating pretty fast, makes the first attempt to 'ball up.' In order to save as much iron as possible, he keeps the damper down and works the powdery mass at as low a red heat as possible. The balls, even when made, will not bear much heat under the hammer without falling to pieces, hence an imperfect weld in the hammered mass and rolled bar is the result, and although the iron may be chemically pure it is deficient in *strength.* By protracting the process and wasting more iron, there is no doubt but that the iron might be improved, for the cinder would become richer in oxide, more fluid, and consequently offer less resistance to a perfect weld. Iron, on the contrary, with a small percentage of silicon may be 'balled up' directly it is 'dried,' and the short time required for that operation can be conducted at the highest part of the furnace. A good welding of the mass is the consequence: such iron is *strong*, and the labour of the puddler in obtaining it is much less than in the former case. Every pound of silica must have twice its weight of iron to form a cinder sufficiently rich in oxide to allow the particles of iron to become properly agglutinated. Such being the influence of silicon on both the yield and the strength of wrought iron, and such being the waste attendant on its removal in the refinery, it becomes an object of much practical importance to prevent as far as possible the formation of a silicide of iron in the blast-furnace, and the observations of MM. Janoyer and Gauthier on this point require careful verification.

Manganese.—The presence of this element in pig-iron does not appear to exert much influence either for good or for bad on the quality of the metal, and even when it exists in quantity amounting to 4 or 5 per cent. in the crude iron, it disappears almost entirely during the conversion of the cast iron into wrought or malleable. It has already been observed that the cinder from iron smelted from manganiferous ores contains, generally speaking, more sulphur than slags or cinders from iron ores containing no manganese. We have had numerous opportunities of confirming this, and have therefore on this account alone attached more importance to the existence of manganese in iron ores; but our attention has more recently been directed to another point which we think especially worthy the notice of iron manufacturers, namely, to the almost perfect removal of phosphorus from pig-iron containing a very large proportion of that element, and at the same time a high percentage of manganese. We shall merely here quote a few analyses in illustration of the purifying action we have alluded to.

Iron made from a highly phosphorised ore containing no manganese:—

	Phosphorus per cent.
Pig	3·030
Puddled bar	0·838
Rough down bar	0·572

The finished bar was cold-short in the highest degree, it was in fact nearly worthless.

Iron made from a highly phosphorised ore containing a large percentage of mangenese:—

	Phosphorus.	Manganese.
Pig	2·60	7·20
Puddled bar	0·30	0·30
Do.	0·20	
Finished bar	0·11	

The iron was carefully watched during the puddling process. It melted very thin, and took rather more work than usual; as soon as the boiling commenced it was very violent, the metal forcing itself out of the door-hole until it was checked. When it 'came to nature,' as the workmen term it, it worked beautifully and stood any amount of heat, in fact the heat could with difficulty be raised to the requisite degree. The yield was 22 cwts. 2 qrs. 24 lbs. of pig to produce one ton (of 22 cwts.) of puddled bar; this is about the yield of good mine iron when properly puddled. The finished bar exhibited none of the cold-short quality, it was exceedingly ductile, indeed excellent horseshoes were made from it. The puddling cinder had the following composition:—

Silica	8·240
Protoxide of iron	70·480
Oxide of manganese	12·800
Phosphoric acid	7·660
Sulphur	·535
	99·715

Other observations have shown that highly manganiferous pig (without phosphorus) is puddled with difficulty, and sometimes with considerable waste, so that the advantages of an alloy of manganese would seem to be confined to those varieties of crude iron into the composition of which phosphorus largely enters.

Spiegeleisen is at present made, on the large scale, in Germany, Russia, and Sweden, and curiously enough, the ores from which it is reduced are of extremely different and distinct characters in each of these countries. In Germany it is made chiefly from the manganiferous spathic carbonate of iron; in Russia, it is reduced from ferruginous oxides of manganese; and in Sweden, it is produced by smelting a mixture of knebelite and manganiferous garnet, both of which minerals are compound silicates of iron and manganese. In one point, however, they all agree, which is, that in all these ores the oxides of manganese and iron, if not in actual combination as compound silicates, or carbonates, are at any rate in a very intimate admixture with one another, and therein lies one of the most important points connected with this manufacture; for it would appear, wherever true ores of manganese have been added to the usual charge of the blast-furnace, in the expectation of obtaining spiegeleisen rich in manganese, that this has not succeeded, or at most, that only a small fraction of the manganese added has combined with the iron, the major part having been carried off in the slag; for which reason, when it is desired to produce a cast iron containing much manganese, it is requisite that this metal should be added to the charge in the shape of some strongly ferruginous compound, thereby facilitating the process of reduction, since a mixture of the two oxides of manganese and iron is much more easily reduced to the metallic state, and so enabled to unite with the iron from the rest of the charge than oxide of manganese alone, which unless the heat is very intense, and the reducing action of the furnace nearly perfect, is extremely apt to go into the slag in the state of silicate from which it subsequently cannot, or can only with great difficulty, be recovered. The oxides of manganese are, it must be remembered, infinitely less easily reduced, and require more time as well as a much higher temperature than the oxides of iron; and from what has already been said, it will naturally follow that in making spiegeleisen particular attention should be paid to the following points:—

1. The mineral used as a source of manganese should be in itself highly charged with iron, so as to facilitate and ensure the reduction of as large an amount of the manganese contained in it as possible.

2. The charge of the furnace should be highly basic, or, in other words, an excess of limestone or, preferably, burnt lime, should be used.

3. The working of the furnace should be much slower than is usual in iron smelting, in order to allow more time for the reduction of the oxides of manganese.

4. The temperature of the blast-furnace should be as high as possible, using as hot a blast as can be obtained; and, as coke admits of the use of a sharper blast, and affords a greater heat, it is to be preferred to charcoal in this manufacture.

In Russia, the spiegeleisen produced at Nischne-Tagilsk is smelted with charcoal, and is known for its good character, it is reduced from a mixture of the native oxides of iron, which in themselves contain some manganese with ferruginous Braunite, which contains about 40 per cent. metallic manganese, with 10 per cent. metallic iron, in intimate admixture.

In order to increase the amount of manganese in grey pig-iron, which already contained 1·2 per cent. of manganese, so as to obtain a spiegeleisen, trials have been made at Wotkinski, by re-melting this pig-iron in a cupola, with the addition of from 12 to 15 per cent. of clean native oxide of manganese (manganite or pyrolusite), which have resulted in making a spiegeleisen containing between 5 and 6 per cent. metallic manganese.

In Sweden, spiegeleisen has been produced in several parts but principally at Schisshyttan and Ramshyttan, in Dalecarlia, where it is obtained by smelting a mixture of knebelite and manganiferous garnet, which contains an average of about 42 per cent. iron with 13 per cent. manganese, in the blast-furnace (which is 47 feet high, and has two tuyères) with as hot a blast as could be obtained from an iron-pipe apparatus. The fuel employed is a mixture of half charcoal half coke, and the ore is fluxed with 30 per cent. of its weight of limestone. The ore frequently contains visible specks of galena, pyrites, and zinc blende, but it is stated that no sulphur is found in the spiegeleisen, although the slag which, when the furnace is working well, has a peculiar yellowish green colour, is said to contain 4 per cent. sulphur up to as much as 16 per cent. oxide of manganese.

The ordinary spiegeleisen obtained at Schisshyttan contains an average of 13 per cent. manganese, with about 4 per cent. carbon, or 5 per cent. carbon, silicon, &c. Occasionally it has been as high as 17 per cent. Mr. Alexander Keiller, the manager of these works, found that some which averaged 15 per cent. of manganese with only 2½ per cent. carbon was altogether different in appearance, and could not be made to assume the crystalline bladed reflecting fracture, peculiar to spiegeleisen, and from which its name is derived, and in consequence, was regarded with prejudice in the market by the buyers, who judge from appearance alone. He also stated that he had latterly succeeded in producing a cast iron, containing as much as 23 per cent. of manganese, along with only 2 per cent. of carbon; such an alloy would be a considerable step in advance, as it would to a great extent overcome the objection to the employment of spiegeleisen, which, from its containing a large percentage (4 to 5) of carbon, is less suited for the production of very soft qualities of Bessemer steel. An alloy of iron and manganese made in Carniola, containing 33 per cent. of manganese, has a granular fracture very unlike spiegeleisen.

It appears when the quantity of manganese contained in a cast iron exceeds a certain point, that there is a tendency for the carbon to diminish in percentage. Mr. Henderson, of Glasgow, states on this subject: 'It is a well-established fact, that in proportion to the increase of manganese in the alloys with iron, so the carbon decreases, so much so, that when you get to 30 per cent. manganese, the carbon is down to 0·25 or 0·40 per cent.'

In the Filipstad mining district in Sweden, numerous attempts to produce spiegeleisen by adding the native oxides of manganese, particularly Hausmannite, which contains 72 per cent. metallic manganese, and occurs abundantly in that district, had failed, the iron so produced not containing more than about 4 per cent. of manganese, as the excess of that metal was invariably carried off in the blast-furnace slag. We understood that a considerable quantity of Hausmannite had been exported to Sheffield from this part of Sweden in the summer of 1871, for the use of steel manufacturers there. The German manufacture of spiegeleisen, which is by far the largest of all, is principally carried on in the northern part of Nassau, and the southern portion of Westphalia. The ores used for the production of spiegeleisen are found in mineral lodes which traverse the Devonian geological formation on the eastern bank of the Rhine. They are the so-called spathic iron ores, which are carbonates of iron containing variable quantities of carbonate of manganese in intimate combination with one another. They usually contain more or less copper and iron pyrites, with, occasionally, traces of galena and zinc blende, and more frequently a large admixture of quartz, which is picked out as cleanly as possible by hand after the ore has been roasted, when the quartz is more easily distingushed by the eye, since it remains whole whilst the iron has become reddish-brown through oxidation.

The following analyses show the chemical composition of the ores from three of the principal mines:—

	Stahlberg	Kirschenbaum	Huth
Carbonate of iron . . .	74·47	76·04	75·39
„ manganese . .	17·08	13·50	18·20
„ lime . . .	1·34	1·13	1·50
„ magnesia . .	5·75	7·87	5·08
Insoluble matter . . .	1·08	0·95	0·18
	99·72	99·49	100·35
Percentage of metallic iron .	41·70	42·58	42·21
„ „ manganese	8·16	6·46	8·70

Before being smelted, these ores are roasted in kilns from 18 to 20 feet high, with two grates one above the other; they are filled with coke (small) and ore, using 8·4 cubic feet of the former to 2½ tons of the latter, and lighting the whole from the lower grate. The ore in each kiln (about 7 tons) is raked out once a day through an aperture made by removing some of the upper grate bars. The object of this roasting, in which the ore loses about one-third its original weight, is to expel the carbonic acid from the ore and convert it into oxide; it also enables, as before mentioned, the quartz mixed with the ore to be picked out by hand.

At the Lohe blast-furnace, which belongs to the Coeln-Muesener Company, the fuel employed is either charcoal or coke alone or more often a mixture of both. The charges employed are with charcoal alone, 1,035 lbs. roasted ore, with 180 lbs. limestone to each cubic feet of charcoal, which is chiefly made from beech and oak woods; with coke alone, it is 2,197 lbs. roasted ore, with 602 lbs. limestone to each 42 cubic feet of coke; and with the mixture of charcoal and coke the charge was 1,233 lbs. roasted ore, with 360 lbs. of limestone to each 10½ cubic feet of coke, mixed with 20 cubic feet of charcoal. As a rule, about 40 such charges would be run down in the 24 hours, or a total of about from 1,700 to 1,800 centners per week.

The dimensions of the blast-furnace are as follow:—Total height, 42·4 feet; height from sole of hearth to tuyères, 2·1 feet; height from sole to top of hearth, 4·3 feet; height from top of hearth to boshes, 9·0 feet; and thence to top of furnace, 28·5 feet.

The diameter of the hearth, the sides of which were parallel, was 4·3 feet; diameter at boshes, 11·3 feet; and at top of furnace, 5·3 feet: the top being covered with a moveable cover, which opens to admit the charge.

The temperature of the hot-blast was lower than it ought to be; rarely exceeding 572° Fahr. The blast is introduced into the furnace by three tuyères, the diameter of which, and the pressure of blast, being varied according to the nature of the fuel made use of, being from 16·6 lines in diameter, and 16 lines mercurial pressure up to 21 lines diameter, with 22 lines pressure.

It is found by experience that the peculiar bladed texture of spiegeleisen depends more on the percentage of carbon than of the manganese; for with very high percentages of the latter, this crystalline structure is not more, if as much, developed as with low percentages of that metal. This structure is also much better developed if the iron, when tapped, be covered with slag, so as to allow it to cool more slowly, for which reason it is usual to let a considerable quantity of slag accumulate in the furnace, so as to cover the cast when it is tapped out. When the iron is poor in carbon, that portion of the cast which has cooled under the slag is invariably more bladed in texture than when not so covered; but if the iron is very rich in carbon (containing, say, 5 per cent. carbon), but little difference is observable. It is therefore advisable to let the iron run out of the furnace as quickly as possible, as, if not so done, it frequently happens that the iron does not have the desired bladed texture well developed in it. When the percentage of manganese in the cast iron is large, and the iron is tapped very hot, a strong oxidation, with evolution of flames, is seen on the surface of the cast, and presents a very curious appearance.

In these works, in order to get good results, care is taken to work the furnaces slowly, so as to keep the manganiferous ore exposed as long as possible to a powerful reducing action, in order to get as much of the manganese reduced along with the iron as possible; and for this purpose a strong pressure, very hot blast, and very basic charge, are required. The zone of combustion must not (as occasionally happens in Westphalia) be allowed to rise too high above the tuyères; and should this take place, the remedies in general use are, to diminish the pressure of the blast, and use the ore in a finer state of division, and wet it with water. In Westphalia this is generally attributed to the charcoal or coke being of a worse and more open porous texture than usual.

Coke is becoming more and more used, and is now alone employed at the Charlottenhütte, which produces nearly one-half the spiegeleisen made in the district. All accounts agree that it is much superior to either charcoal or the mixture of charcoal and coke, provided only it be of good quality, and free from sulphur; and it is stated, when coke is employed, that several per cent. units more of manganese can be got into the spiegeleisen than when the same charge is smelted with charcoal, and, for this reason, it is particularly suited for smelting ores rich in manganese. It is also stated that in this district the attempts to increase the amount of manganese in the spiegeleisen, by manganese ores added to the charge, have not succeeded, and that the manganese in such additions has for the most part gone into the slag.

The charge at this furnace consists of about ⅔rds roasted spathic ores, ⅓rd brown hæmatite, containing manganese, and a portion of the latter being replaced by a brown manganese ore from Nassau, containing 25 per cent. Fe. and 19 to 20 per cent. Mn., which is now generally used throughout the Rhenish district; with good fuel, and about 50 per cent. of limestone on the weight of the ore, about ½ of the manganese, or even more, may be reduced. When making spiegeleisen, the furnace produces up to 70 tons per day, with a consumption of about 22 cwts. of coke to the ton.

Spiegeleisen, showing an apparently identical fracture to the eye, may vary immensely in its percentage of manganese, and in practice each cast or tapping should be assayed for itself. This, however, is not done in the Siegen district, where, although it is the general custom to regard the spiegel as containing an average of 10 per cent., it will be found in actuality to vary from 7 to 11 per cent. when analysed.

The following analyses show the chemical composition of spiegeleisen from this district when made with coke:—

	Hamm.	Hochdahl.
Carbon . . .	4·129	5·04
Silicon . . .	0·468	0·41
Sulphur . . .	0·015	0·08
Copper . . .	0·291	0·16
Manganese . . .	8·706	7·57
Iron	85·929	86·74
	99·528	100·00

In Styria and Austria, where the coke used is very impure, containing $3\frac{1}{2}$ per cent. of sulphur, only about $\frac{1}{4}$ to $\frac{1}{3}$ of the total manganese is reduced.

At Newark, in New Jersey, spiegeleisen is made from the residues obtained in the treatment of the mixed zinc and iron ores of Franklin, in the same State. The ore is an intimate mixture of franklinite and red zinc ore, with a massive green variety of willemite or silicate of zinc. It occurs in crystalline limestone, forming an irregular bed, which in places is 52 feet thick, the different minerals being very intimately mixed. A mixture of finely-crushed ore, with lime and anthracite, is treated in an oven-shaped calciner, having a cast-iron bed perforated with numerous narrow slits, through which air is blown by a fan in sufficient quantity to burn the coal and oxidise the zinc-vapour as it forms. The oxide of zinc produced in this process passes through a long series of condensing-tubes and cooling-chambers, the current being kept up by exhausting-fans until it is sufficiently cooled to be collected by bags made of cotton cloth. The residue remaining in the furnace after the removal of the zinc is a black cindery mass, containing the whole of the iron and manganese of the franklinite, and the silica of the willemite, besides some undecomposed zinc oxide: it is estimated to contain 25 per cent. of iron, and 4 per cent. of zinc, and is smelted for spiegeleisen. The furnaces employed are very small, being only 20 feet high, and 7 feet across the boshes; the hot-blast is of about 200° temperature, and a pressure of 4 lbs. is used. The fuel used is anthracite, and some limestone is added as a flux. Four blank charges of clean slags are made in twenty-four, to prevent scaffolding. Great difficulty is experienced in working the furnaces, owing to the large amount of zinc remaining in the ore, which deposits in the gas-flues at the throat, and necessitates the use of an elaborate system of wrought-iron condensers for separating the oxide of zinc from the gases, before they can be burnt in the hot-blast stoves and steam-boilers. The oxide of zinc obtained in cleaning out the condenser being too much discoloured to use as paint, is sent to the spelter furnaces for reduction, and makes a very high quality of zinc. The consumption of fuel is very high, being at the rate of $3\frac{1}{2}$ tons per ton of iron. The weekly make of the furnace is about 25 tons.

When making spiegeleisen, the slags are of the usual bright-green colour characteristic of manganese; but when the furnace is too heavily burdened, and produces No. 2 iron, corresponding to the German *Weisstrahlig*, the colour changes to a deep brown. Owing to the large relative proportion of manganese to iron in the residues, the spiegeleisen produced is very rich in manganese, and at times is said to contain as much as 10 per cent.

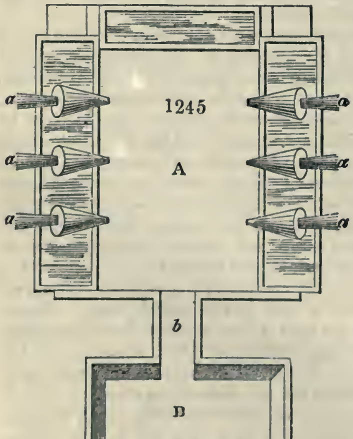
In connection with the production of spiegeleisen, sundry improvements in the manufacture of manganese have been proposed. Among others, the following processes are said to be most advantageously used in America:—

Manganese may be produced in a condition pure, or nearly so, without melting, and used in the manufacture of ferro-manganese and spiegeleisen in a manner producing a better quality of product, in less time, and at less expense than by the old processes. The process consists in a thorough mixture of pulverised oxide of manganese 10 parts, and 3 parts of solid carbon, like coke or charcoal. These ingredients are inclosed in metallic or earthen cases, large enough for the desired charge, and having the opening temporarily closed with a metallic sheet, or covering of earth, to prevent the admission of air while allowing the escapement of gases. These cases are charged in an ordinary furnace to a bright red, bare yellow, and are subjected to this heat for twelve or fifteen hours, according to quantity. In the process the carbon unites with the oxygen, and passes off as carbonic acid gas, and gives as a product nearly pure manganese. To secure spiegeleisen the pig-iron is melted, and about 12 per cent. of the manganese is charged into it and melted. The proportion of ingredients is run off when melted into ingots, as spiegeleisen, when it is used in the ordinary way. Ferro-manganese is produced by charging a greater per cent. of manganese into the molten pig-metal, say 25 or 30 per cent. The manganese counteracts red shortness in the steel, apparently by uniting with the free oxygen or metallic oxides which may be in the steel, being particularly useful in the manufacture of boiler-plate steel.

The inventor considers his process will be most valuable to those using an open hearth steel-melting furnace, such as the Siemens, as it has been for a long time a great desideratum to obtain a pure metallic manganese, especially in manufacturing the softer grades of steel, such as roller-plate, tank-plate, &c. He claims that the use of ferro-manganese conduces to the life of the furnace, because when rails are desired containing from $\frac{1}{4}$ to $\frac{1}{3}$ of one per cent. carbon, the bath of molten metal has to be run down in carbon as low as wrought iron, otherwise when the spiegeleisen is added the percentage of carbon will be higher than desired, and also adding some silicon, which is injurious. It is well known that a much greater heat is required to keep a bath of molten metal liquid, containing no more carbon than wrought iron, than when it contains about ¼ of one per cent. carbon. It has also been proved that a furnace making steel that never runs lower in carbon than ¼ of one per cent. lasts from three to four times as long as one that runs the steel down to wrought iron. Therefore it is cheaper to use manganese or ferro-manganese than spiegeleisen.

The Conversion of Crude or Carburised Iron into Malleable Iron.—This is effected by one or more operations, which are necessarily of an oxidising nature, the object being to eliminate from the cast iron the carbon in the form of carbonic oxide gas, and the silicon, sulphur, phosphorus, and other foreign bodies in the form of oxidised products, which pass either partially or wholly into the scoriæ or cinders. The pig-iron is either subjected to a preliminary decarburation in the oxidising blast hearth, or 'refinery,' and the operation thus commenced afterwards completed in the oxidising air furnace, or 'puddling furnace;' or the complete conversion of the crude iron is effected by one operation in the puddling furnace, by the process called 'boiling.' It is said (*Blackwell*) that, at several works abroad, the attempt to arrest the progress of decarburation in the puddling or boiling furnace at that point in which the conversion has proceeded only so far as to leave the iron in the state of steel, or subcarburet, has been successful, and that a valuable natural or puddled steel, not requiring cementation before conversion into refined or cast steel, has been the result.

English Method of Refining.—The finery furnace is composed of a body of brickwork, about 9 feet square, rising but little above the surface of the ground. The hearth, the bottom of which is of millstone grit, placed in the middle, is 2½ feet deep; it is rectangular, being in general 3 feet by 2, with its greatest side parallel to the face of the tuyères, and it is made of cast iron in four plates. On the side of the tuyères there is a single brick wall, on the three sides sheet-iron doors are placed, to prevent the external air from cooling the metal, which is almost always worked under an open shed or in the open air, but never in a space surrounded by walls. The chimney, from 15 to 18 feet high, is supported upon four columns of cast iron; its lintel is 4 feet above the level of the hearth, in order that the labourers may work without restraint. The air is supplied by the blowing cylinders which supply the blast-furnace, and enter the hearth through 6 tuyères, so arranged that the current issuing from those on the opposite sides of the crucible are not disposed in the same plane. These tuyères, like those in the furnaces in which cast iron is made, are provided with double casings, through which a current of cold water is constantly flowing, and each pipe is furnished with a suitable stop valve for regulating the volume of the blast. The tuyères are placed at the height of the lip of the crucible or hearth, and are inclined towards the bottom, at an angle of from 25° to 30°, so as to point upon the bath of melted metal as it flows. The quantity of air blown into the fineries is considerable, being nearly 400 cubic feet per minute for each finery. The ground plan of a finery is shown in *fig.* 1245, A being the hearth, *b* the tapping-hole, B the chill mould, and *a a a a a a* the nozzles of the tuyères. The operation of refining crude iron is conducted as follows: A fire is lit in the centre of the hearth, which is first urged by a gentle blast; a charge of pig, about 2 tons, is then laid on, and the whole is covered up dome-form with a heap of coke; the full power of the blast is now turned on, the cast iron melts, and flowing down gradually collects in the crucible, more coke being added as the first quantity burns away. The operation proceeds by itself, the melted metal is not stirred about as in some modes of refinery, and the temperature is always kept high enough to preserve the metal liquid. During this stage the coals are observed continually heaving up: a movement due in part to the action of the blast, but in part to an expansion caused in the metal by the discharge of carbonic oxide gas. When all the pig-iron is collected at the bottom of the hearth, which happens in about two hours, it is blown vigorously for some time longer, the tap-hole is opened, and the *fine* metal runs out with the slag into the chill mould, or pit, as it is called, which has been previously washed with a thin clay liquid, to prevent the refined metal from adhering to its surface. The chill mould is in a prolongation of the tapping-hole; it is a heavy cast-iron trough, about 10 feet long, 3 feet broad, and 2 to 2½ inches deep.


1245

The slag, from its inferior specific gravity, forms a crust on the surface on the metal: its separation is facilitated by throwing cold water in large quantities on the fluid mass immediately that the entire charge has left the refinery. This sudden chilling of the metal makes it exceedingly brittle, so that it can be broken into smaller pieces by heavy hammers, for the subsequent operation of puddling, The refined metal is very white, hard, and brittle, and possesses in general a fibrous radiated texture; or sometimes a cellular, including a considerable number of small spherical cavities, like a decomposed amygdaloid rock. The loss of iron in the refinery process is very large, varying from 10 to 20 per cent. In the Welsh iron works, 1 ton of white iron takes from 1¾ to 2 hours to refine, the consumption of coke being from 6 to 8 cwts., and the loss about 3 cwts. Grey iron takes from 7 to 9 cwts. of coke per ton, the time required to refine being from 2½ to 3 hours, and the loss of iron per ton 4 cwts. The pig-iron to be decarburised in the refinery is frequently mixed with rich silicates (forge cinders), and occasionally with oxides of iron, the object being to protect the melted metal in some degree from the oxidising effects of the blast, and to react on the carbon which it contains. The quantity employed depends on the degree to which the pig-iron is carburised. The crude iron, from which wrought iron of the best quality is produced, is that possessing a medium degree of carburation, or what is generally termed grey pig-iron. White iron, which possesses an inferior degree of fluidity to grey pig-iron, and which comes as it is termed more rapidly to nature, is that quality which is most generally employed in the manufacture of wrought iron, especially when the conversion is effected in the single operation of boiling in the puddling furnace; but this species of pig-iron being the result of imperfect re-actions in smelting, is always more impure than grey iron obtained from the same materials, and does not produce wrought iron of the best quality.

The coke employed in the refinery should be as free as possible from shale, and should contain only a low percentage of ash; it should especially be free from sulphuret of iron, which it often contains in considerable quantity, as it is found that nearly the whole of this sulphuret enters into combination with the metal, and does not pass off in the slags.

Refineries are sometimes worked on hot fluid iron, run direct from the hearth of the blast-furnace, a considerable saving, both of time and fuel, being hereby effected. Various proposals have been patented for the employment of fluxes to assist in the removal of the impurities of cast iron, both in the refining and puddling furnaces. Thus Mr. Hampton patented, in 1855, a flux, prepared by slaking quicklime with the solution of an alkali, or alkaline salt. MM. Du Motay and Fontaine propose, in a patent secured in 1856, to purify and decarbonise iron in the refining and puddling furnace, by the employment of fluxes prepared from the scoriæ of the puddling furnace, from oxides of iron and silicates or carbonates of alkalis, or other bases. Mr. Pope (1856) proposes to add the residue obtained by the distillation of Boghead or Torbane mineral to such fuel as is employed in the refining of iron. Mr. Sanderson, of Sheffield (1855), employed for the refining of iron such substances as sulphate of iron, capable of disengaging oxygen or other elements, which will act upon the silicium, aluminium, &c., contained in the metal. These and various other schemes have been suggested with the object of lessening the enormous waste which pig-iron undergoes on its passage through the refinery: for as the process is at present conducted, the partial elimination of the carbon, sulphur, phosphorus, &c., is only effected at the expense of a large quantity of iron, which is oxidised by the blast, and passes in the form of silicate into the slag; the desideratum is the discovery of some method of reducing the oxide of iron, and substituting for it some other base, which will form with silica a sufficiently fusible silicate. Mr. Blackwell suggests that the decarburation of pig-iron might be effected by remelting it in a cupola-furnace, either alone, or with minerals containing nearly pure oxides of iron; the oxide of iron would be reduced by the carbon of the pig-iron, while the silicates of the fuel, with the silica, alumina, and other easily oxidisable alloys eliminated from the crude iron, would be separated in the form of fusible earthy glass. The employment of steam as a purifying agent for crude iron has been patented by several persons. Mr. Nasmyth in 1854 obtained a patent for the treatment of iron in the puddling furnace with a current of steam, which being introduced into the lower part of the iron, passes upwards, and meeting with the highly heated metal, undergoes decomposition, both elements acting as purifying agents. The steam employed is at a pressure of about 5 pounds per square inch, and passes into the metal through a species of hollow rabble, the workman moving this about in the fused metal until the mass begins to thicken, which occurs in from five to eight minutes after the introduction of the steam; the steam-pipe is then removed and the puddling finished as usual.

The advantages are said to consist in the time saved at each heat or puddling operation (from ten to fifteen minutes); the very effective purification of the metal; and the possibility of treating highly carbonised pig-iron at once in the puddling furnace, the preliminary refining being thus avoided. In October 1855, Mr. Bessemer patented for a somewhat similar process for the conversion of iron into steel: the steam highly heated, or a mixture of air and steam, being forced through the liquid iron run from the furnace into skittle-pots, steam being used only at an early stage of the process, and the treatment finished with heated air. In the early part of the same year Mr. Martien of New Jersey obtained a patent for a partial purification of crude iron, by causing air or steam to pass up through the liquid metal, as it flows along gutters from the top-hole of the furnace or finery forge; and he subsequently proposed to include with the air or steam, other purifying agents, such as chlorine, hydrogen, and coal-gas, oxides of manganese, and zinc, &c. Other methods of treating crude iron with air and steam were made the subjects of patents by Mr. Bessemer in December 1855 and January 1856. In October a patent for the employment of steam in admixture with cold blast in the smelting furnace and fining forge, was obtained by Messrs. Armitage and Lee, of Leeds, and in August a patent was obtained by Mr. George Parry, of the Ebbw Vale Iron Works, for the purification of iron by means of highly-heated steam. The fluid iron is allowed to run into a reverberatory furnace previously heated, and the steam is made to impinge upon it from several tuyères, or to pass through the metal. Steel is to be obtained by treating highly carburetted iron with the steam, and then running it into water, and fusing it with the addition of purifying agents, or adding to it in the furnace a small quantity of clay, and afterwards about 10 or 15 per cent. of calcined spathose ore. Mr. Parry observing that when steam was sent through the molten iron, as in Mr. Nasmyth's process, the iron quickly solidified, conceived the idea of communicating a high degree of heat to the steam by raising the steam-pipe a couple of inches above the surface of the metal, so that it might be exposed to the intensely-heated atmosphere of the furnace; and also of inclining the jet at an angle of 45°, so as to give the molten mass a motion round the furnace while the pipe was maintained in the same position at a little distance beyond the centre: when this was done, in a few minutes the iron began to boil violently, the rotatory motion of the fluid bringing every part of it successively into contact with the highly-heated mixture of steam and atmospheric air, and no solidification taking place. Having thus ascertained the proper way of using steam as a refining agent, it occurred to Mr. Parry that, as the presence of silicon in the pigs for puddling affects in a remarkable degree the yield of iron, as well as its strength, it is a matter of consequence that this element should be removed as completely as possible previous to the puddling operation; the steaming of the iron would probably therefore be more profitably applied in the refinery than in the puddling furnace. Pig-iron containing 3 per cent. of silicon gives 6 per cent. of silica, which, to form a cinder sufficiently fluid to allow the balling-up of the iron, would require from 10 to 12 per cent. of iron; and this can, of course, only be obtained by burning that amount of iron in the puddling furnace, after the expulsion of the carbon, and while the mass is in a powdery state. The superheated steam is injected on the surface of the iron in the refinery by water tuyères, similar to those used for hot blast at smelting furnaces; they are inclined at an angle of about 45°; some are inserted at each side of the door of the furnace, and are pointed so as to cross each other, and give the iron a circulating motion in the furnace. The tuyères are from $\frac{3}{8}$ths to $\frac{1}{2}$ an inch in diameter; a little oxide of iron or silicate in a state of fusion on the surface of the iron accelerates the action, as in common refineries, and increases the yield of metal, but to a much greater extent than when blasts of air are used. The steam having been turned on, the mass of iron commences circulating around the inclined tuyères, and soon begins to boil, and the action is kept uniform by regulating the flow of the steam. The most impure oxides of iron may be used in this process, such as tap cinder or hammer slag from puddling furnaces, without injury to the quality of the refined metal made; the large quantities of sulphur and phosphorus which they contain being effectually removed by the detergent action of the heated steam. When 4 cwts. of cinders are used to the ton of pig, 20 cwts. of metal may be drawn, the impurities in the pig being replaced by refined iron from the cinders.

Dr. Noad had several opportunities of witnessing this refining process at the Ebbw Vale Iron Works, and made the following analysis of the cinders and metal, which fully bear out the above statements:—

	Pig-iron	Refined metal
Graphite	2·40	0·30
Silicon	2·68	0·32
Slag	0·68	0·00
Sulphur	0·22	0·18
Phosphorus	0·13	0·09
Manganese	0·86	0·24

	Forge cinders thrown into the refinery	Cinder run out of the refinery
Sulphur	1·34	0·16
Phosphoric acid	2·06	0·129

A ton of grey iron may be refined by steam in half an hour, using seven jets of steam ⅜ths of an inch in diameter, and with a pressure of from 30 to 40 lbs.; the temperature of the steam being from 600° to 700° F., the orifices of the tuyères being 2 or 3 inches above the surface of the iron. As the fluidity of the metal depends upon the heat which it is receiving from the combustion of the fuel in the grate, and not on any generated in it by the action of the steam, it is evident that the supply of the latter in a given time must not exceed a certain limit, or the temperature of the fluid iron will become reduced below that of the furnace. This, however, partly regulates itself, and does not require much nicety in the management, for, if too much steam be given the ebullition becomes so violent, as to cause the cinders to flow over the bridges, giving notice to the refiner to slack his blast. The 'forge cinders' used in the steam refinery contain 66 per cent. of iron; the 'run out' cinder contains only 26; 40 per cent. of iron, or thereabouts, have therefore been converted into refined metal, and the resulting cinder is as pure as the ordinary Welsh mine, with its yield of 25 per cent. of iron. The following is the result of one week's work of the steam refinery:—

	cwts.	qrs.	lbs.
Pigs used	396	0	15
Metal made	393	3	1
Loss	2	1	14
Yield	20	0	14

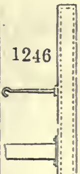
The quantity of cinder (puddling) used was 3½ cwts. per ton of pig. When 1½ cwt. of cinders were used to 1 ton of pig, the yield was invariably 20 cwts. over a make of about 100 tons.

Refining by Gas (*German method*).—The most simple form of gas reverberatory furnace is that known as Eck's furnace (*figs.* 1251 to 1256), which is employed at the government works of Gleiwitz and Königshütte, for refining iron made on the spot. The following description and plan of this furnace are extracted from a report to the Secretary of State for War, from the superintendent of the Royal Gun Factories, Colonel Wilmot, R. A., and the chemist of the War Department, Professor Abel.

The gas-generator (which replaces the fire-place of the ordinary reverberatory furnace) is an oblong chamber, the width of which is 3 feet 9 inches, and the height from the sole to the commencement of the sloping bridge 6 feet 4 inches. It tapers slightly towards the top, so as to facilitate the descent of the fuel, which is introduced through a lateral opening near the top of the generator. Its cubical contents are about 44 feet.

1248

1246



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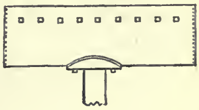


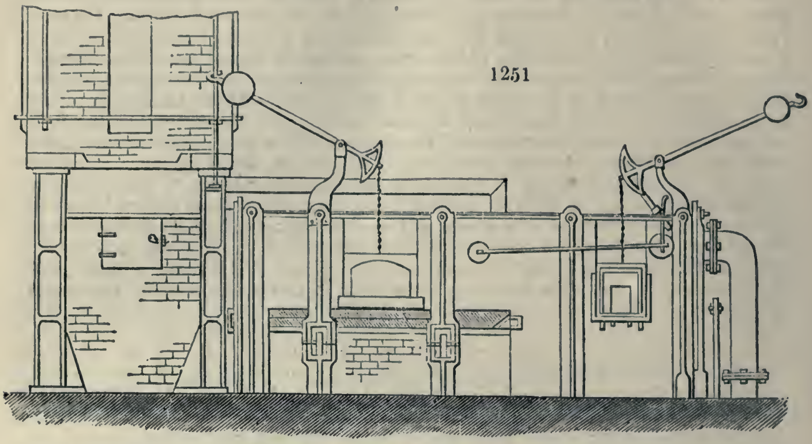
1250

The air necessary for the production of the gas is supplied by a feeble blast, and enters the generator from the two openings or tuyères of a long air-chest of iron plate (*figs.* 1246, 1247, 1248) fixed at the back of the chamber, near the bottom. The space between the air-chest and the sole of the chamber serves as a receptable for the slag and ash from the fuel. There are openings on the other side of the chamber, opposite the tuyères, which are generally closed by iron plugs, but are required when the tuyères have to be cleaned out. There is an opening below the air-chest, through which fire is introduced into the chamber, when the furnace is set to work, and which is then bricked up, until at the expiration of about 14 days it becomes necessary to let the fire die out, when the slag and ash which have accumulated on the sole of the chamber are removed through this opening.

The hearth of the furnace is constructed of a somewhat loamy sand; its general thickness is about 6 inches, its form is that of a shallow dish, with a slight incline towards the tap-hole; the iron is prevented from penetrating through the hearth by the rapid circulation of cold air below the fire-bridge and the plate of the hearth.

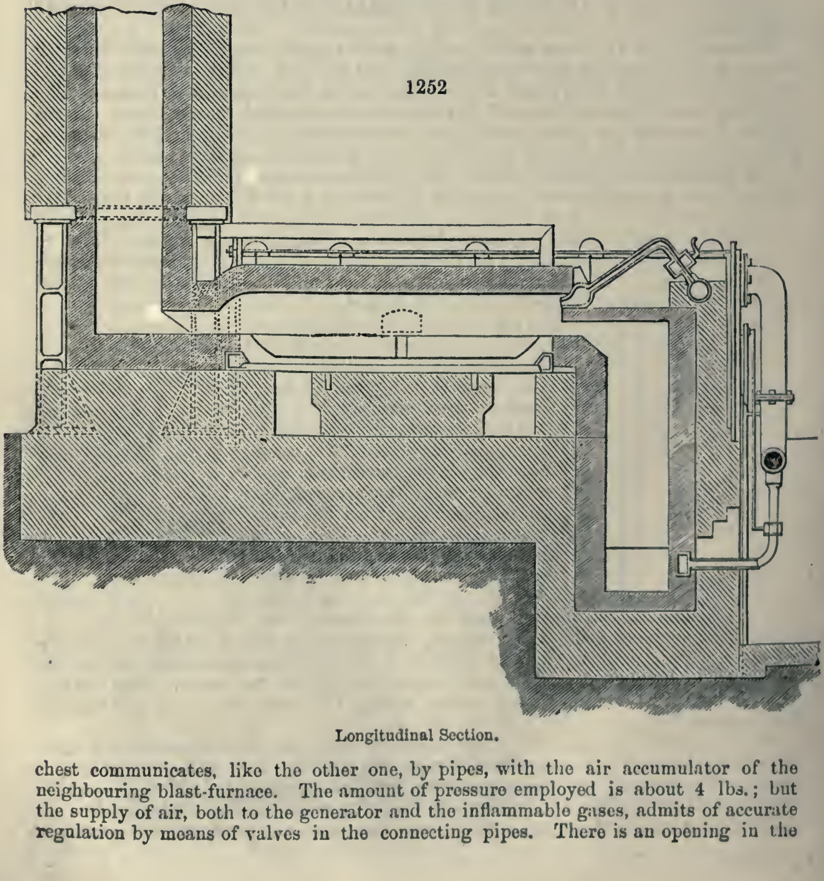
Figs. 1249 and 1250 represent the upper oblong air-chest provided with a series of tuyères, which enter the top of the furnace just over the fire-bridge at an angle of 30°. The air forced into the furnace through the tuyères serves to inflame and burn the gases rushing out of the generator, and the direction of the blast throws the resulting flame down upon the metal on the hearth, in front of the bridge. This air-chest communicates, like the other one, by pipes, with the air accumulator of the neighbouring blast-furnace. The amount of pressure employed is about 4 lbs.; but the supply of air, both to the generator and the inflammable gases, admits of accurate regulation by means of valves in the connecting pipes. There is an opening in the

1251



Eck's Gas Reverberatory Furnace.—Front view.

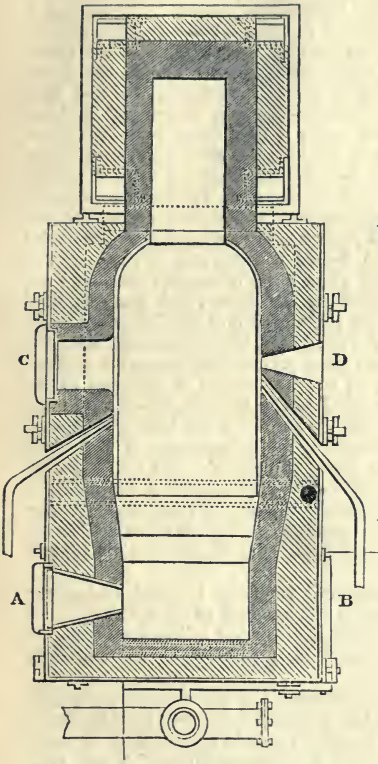
1252



Longitudinal Section.

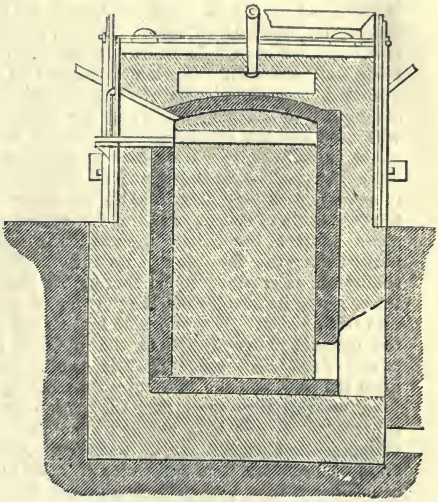
arch at both sides of the furnace, not far from the bridge, into which, at a certain stage of the operations, tuyères are introduced (being placed at an angle of 25°) also connected with the blast-apparatus, and provided with regulating valves.

1253



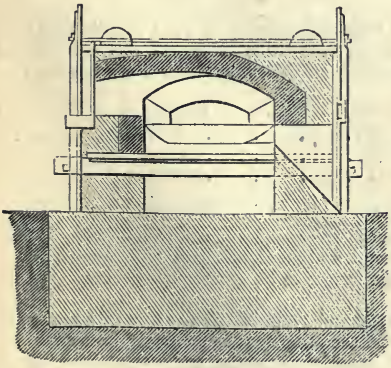
Eck's Gas Reverberatory Furnace.—Plan.

1254



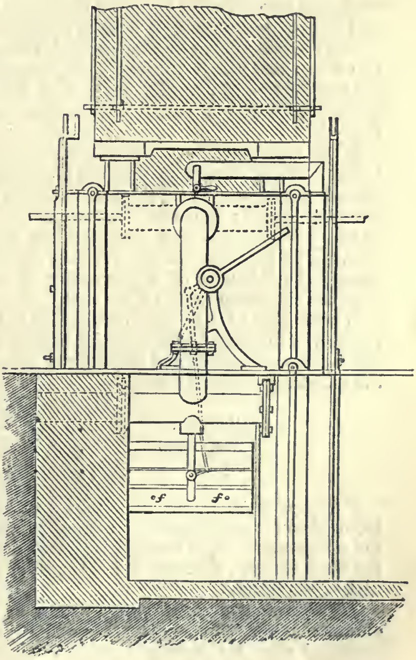
Cross section at A, B, on Plan.

1255



Cross section at C, D, on Plan.

1256



End view.

The refining process is conducted as follows:—The hearth of the furnace having been constructed or repaired, a brisk coal-fire is kindled in the generator, through the opening at the bottom, which is afterwards bricked up. About 20 cubic feet of coals are then introduced from above, and the necessary supply of air admitted to the generator through the lower air-chest. When these coals have been thoroughly ignited, the generator is filled with coals, and a very moderate supply of air admitted through the tuyères below (for the generation of the gas), and those over the bridge (for its combustion) until the furnace is dried, when the supply of air at both places is increased, so as to raise the hearth to the temperature necessary for baking it thoroughly, upon which, about 40 cwts. of iron are introduced; the metal being distributed over the whole hearth as uniformly as possible, and the size of the pieces being selected with the view to expose as much surface as possible to the flame. The fusion of the charge of metal is effected in about three hours, the coal used amounting to about 3¾ cubic feet per hour. The gas-generator is always kept filled with coal, and the supply of air admitted from below is diminished by a regulation of the valve, whenever fresh coal is supplied, as the latter, at first, always yields gas more freely. The arrangement of the upper row of tuyères effects the combustion of gases just as they pass from the generator on to the hearth. The hottest portion of the furnace is of course near the fire-bridge, *i.e.* where the blast first meets with the gases. During the melting process the iron is shifted occasionally, so that the cooler portion near the flue may in its turn become melted without loss of time. When the iron is ascertained to be thoroughly fused, about 5 lbs. of crusted limestone are thrown over its surface for the purpose of converting the dross which has separated into fusible slag. The two side tuyères are now introduced into the furnaces through the openings above alluded to, the width of the nozzle employed depending upon the power of the blast used. The air rushing from these tuyères impinges with violence upon the iron, and the two currents meeting an eddying motion is imparted to the fused metal. In a short time the motion produced in the mass is considerable; the supernatant slag is blown aside by the blast, and the surface of the iron thus exposed undergoes refinement, while it changes continually, the temperature of the whole mass being raised to a full white heat, by the action of the air. The iron is stirred occasionally, in order to insure a proper change in the metal exposed to the action of the blast. A shovelful of limestone is occasionally thrown in (the total quantity used being about 1 per cent. of the crude iron employed). The slag produced is exceedingly fusible, and is allowed to remain in the furnace until the metal is tapped, and on cooling it separates from it completely.

The duration of the treatment in this furnace after the metal is fused, varies from two hours and a half to five hours, according to the product to be obtained. For the preparation of perfectly white iron, the treatment is carried on for five hours. A sample is tapped to examine its appearance when it is believed to be sufficiently treated.

When the charge is to be withdrawn from the furnace, the side tuyère nearest the tap-hole is withdrawn, so that the blast from the opposite tuyère may force the metal towards the hole. The fluid iron, as it flows from the tap-hole is fully white hot, and perfectly limpid; it chills, however, very rapidly, and soon solidifies. A few pails of water are thrown upon those portions of the metal which are not covered with the slag, which flows out of the furnace, the object being to cool it rapidly, and thus prevent the oxidation of any quantity of iron. The loss of metal during the treatment is said not to exceed 5 per cent.

With regard to the purification which the iron undergoes in the gas reverberatory furnace, it appears to be confined chiefly to the elimination of carbon and silicium, the amount of sulphur and phosphorus undergoing but little alteration, as appears from the following analyses (*Abel*):—

	Pig-iron	Refined iron
Silicium	4·66	0·62
Phosphorus	0·56	0·50
Sulphur	0·04	0·03

Nevertheless, the iron thus refined is highly esteemed for all castings which are required to possess unusual powers of resistance; some experiments made to ascertain the comparative strain borne by the refined metal, and the same metal as obtained from the blast-furnace, showing the strength of the former to be greater by one half than that of the latter.

The Operation of Puddling.—In the year 1783 and 1784, Mr. Henry Cort of Gosport obtained two patents, one for the puddling, and the other for the rolling of iron, 'Discoveries,' says Mr. Scrivenor, 'of so much importance in the manufacture, that it must be considered the era from which we may date the present extensive and flourishing state of the iron trade of this country.'

The object of Mr. Cort's process was to convert into malleable iron, cast or pig-iron, by means of the flame of pit-coal in a common air furnace, and to form the result into bar by the use of rollers in the place of hammers. The process was managed in the following manner:—

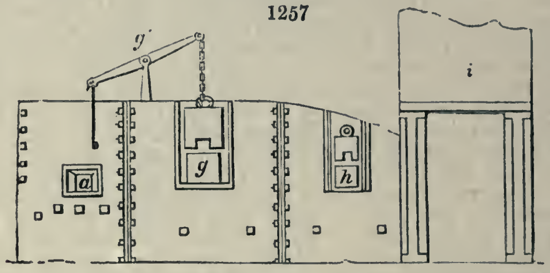
'The pigs of cast iron produced by the smelting furnace are broken into pieces, and are mixed in such proportions according to their degree of carbonisation, that the result of the whole shall be a grey metal. The mixture is then speedily run into a blast-furnace, where it remains a sufficient time to allow the greater part of the scoriæ to rise to the surface. The furnace is now tapped, and the metal runs into moulds of sand, by which it is formed into pigs, about half the size of those which are broken into pieces. A common reverberatory furnace heated by coal is now charged with about 2½ cwts. of this half-refined grey iron. In a little more than half an hour the metal will be found to be nearly melted; at this period the flame is turned off, a little water is sprinkled over it, and a workman, by introducing an iron bar through a hole in the side of the furnace, begins to stir the half-fluid mass, and divide it into small pieces. In the course of about 50 minutes from the commencement of the process, the iron will have been reduced by constant stirring to the consistence of small gravel, and will be considerably cooled. The flame is then turned on again, the workmen continuing to stir the metal, and in three minutes' time the whole mass becomes soft and semifluid, upon which the flame is then turned off. The hottest part of the iron now begins to heave and swell, and emit a deep lambent blue flame, which appearance is called *fermentation*; the heaving motion and accompanying flame soon spread over the whole, and the heat of the metal seems rather to be increased than diminished for the next quarter of an hour; after this period the temperature again falls, the blue flame is less vigorous, and in a little more than a quarter of an hour the metal is cooled to a dull red, and the jets of flame are rare and faint. During the whole of the fermentation the stirring is continued, by which the iron is at length brought to the consistency of sand; it also approaches nearer to the malleable state, and in consequence adheres less than at first to the tool with which it stirred. During the next half hour the flame is turned off and on several times, a stronger fermentation takes place, the lambent flame also becomes of a clearer and lighter blue, the metal begins to clot and becomes much less fusible and more tenacious than at first. The fermentation then by degrees subsides, the emission of blue flame nearly ceases, the iron is gathered into lumps and beaten with a heavy-headed tool. Finally, the tools are withdrawn, the apertures through which they were worked are closed, and the flame is again turned on in full force for six or eight minutes. The pieces being thus brought to a high welding heat are withdrawn and shingled; after this they are again heated and passed through grooved rollers, by which the scoriæ are separated, and the bars thus forcibly compressed acquire a high degree of tenacity.' But this mode of refining did not produce altogether the desired result. It was irregular; sometimes the loss of iron was small, but at others it was very considerable, and there were great variations in the quality of the iron, as well as in the quantity of fuel consumed. These difficulties, were, however, removed by the introduction of the coke finery by the late Mr. Samuel Homfray, of Penydarran, upon which the puddling and balling furnaces came immediately into general use, with the addition of rollers in lieu of hammers.

Mr. Cort's first patent, which is for 'rolling,' is dated January 17, 1783; his second, that for 'puddling,' is dated February 13, 1784. It has been attempted, though we think very unjustly, to detract from Cort's merits as an original inventor, by referring to the patents of John Payne, and Peter Onions, dated respectively November 21, 1728, and May 7, 1783. The first was to a certain extent, undoubtedly, a patent for 'rolling;' for the bars rendered malleable by a process indicated, are '*to pass between the large metall rowlers which have proper notches or furrows upon their surface*;' but there is no proof that any practical use was made of Payne's process, while that of Cort was almost immediately and universally adopted; it may be true, therefore, that Cort was the *rediscoverer* and not the actual *discoverer* of the process of rolling, but this in no way detracts from his merit, inasmuch as by his improvements he was enabled to make available that which was previously useless. The same observation applies to the patent of Onions, which to a certain extent anticipated that of Cort for puddling. Onions employed two furnaces—a common smelting furnace, and a furnace of stone and brick, bound with iron work and well annealed, into which the fluid metal was received from the smelting furnace. When the liquid metal had been introduced into the second furnace by an aperture, it was closed up and subjected to the heat of fuel and blast from below, until the metal became less fluid, and thickened into a kind of paste; this the workman, by opening a door, turns and stirs with a bar of iron, and then closes the aperture again, after which blast and fire is applied until there is a *ferment* in the metal; the adherent particles of iron are collected into a mass, reheated to a white heat, and forged into malleable iron. That the process of puddling is here indicated there can be no doubt, but the actual operation was impracticable until Henry Cort invented the *furnace* in which it could be conducted.

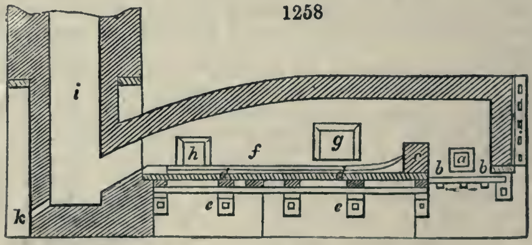
Neither Mr. Cort nor his family appears to have derived much advantage from his important discoveries—discoveries which changed us at once from dependent importers of iron into vast exporters to every country of the world, and which may be considered to have founded the iron industry of Great Britain. So long ago as 1811, the chief representatives of the trade assembled at Gloucester unanimously acknowledged their indebtedness to Mr. Cort for the improvements of which he was the author, and this acknowledgment has been repeated within the last few years by *Robert Stephenson*, *Fairbairn*, *Maudslay and Field*, *Cubitt*, *Rendel*, *Sir Charles Fox*, *Bidder*, *Crawshay*, *Bailey*, and many others. In working out his inventions, Cort is said to have expended a fortune of 20,000*l.*, and when his patents were completed, the leading ironmasters of the country contracted to pay him 10*s.* a ton for their use, so that he would not only have been repaid, but munificently rewarded, had he not unfortunately connected himself with a man named Adam Jellicoe, chief clerk of the Navy Pay Office, who proving to be a defaulter, committed suicide, having previously destroyed the patents and the agreements with ironmasters belonging to his partner, Henry Cort. Upon the death of Jellicoe, the premises, stock, and entire effects of Cort were sold by a summary process obtained by the Navy Pay Office, and the unfortunate man was thus completely ruined.

The *puddling furnace* is of the reverberatory form. It is bound generally with iron, as represented in the side view, *fig.* 1257, by means of horizontal and vertical bars, which are joined together and fixed by wedges, to prevent them from starting asunder. Very frequently, indeed, the reverberatory furnaces are armed with cast-iron plates over their whole surface. These are retained by upright bars of cast iron applied to the side walls, and by horizontal bars of iron, placed across the arch or roof. The furnace itself is divided interiorly into three parts; the *fireplace*, the *hearth*,

1257



1258



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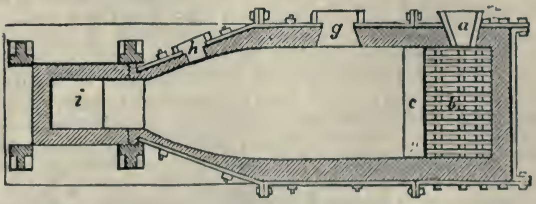
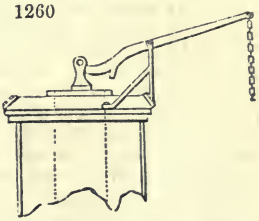


and the *flue*. The *fireplace* varies from 3½ to 4½ feet long, by from 2 feet 8 inches to 3 feet 4 inches wide. The door-way, by which the coke is charged, is 8 inches square, and is bevelled off towards the outside of the furnace. This opening consists entirely of cast iron, and has a quantity of coal gathered round it. The bars of the fire-grate are moveable, to admit of more readily clearing them from ashes.

Fig. 1258 is a longitudinal section referring to the elevation, *fig.* 1257, and *fig.* 1259 is a ground plan. When the furnace is a single one, a square hole is left in the side of the fireplace opposite to the door, through which the rakes are introduced, in order to be heated.

a is the fire-door; *b*, the grate; *c*, the fire-bridge; *d d*, cast-iron hearth-plates, resting upon cast-iron beams *e e*, which are bolted upon both sides to the cast-iron binding plates of the furnace; *f* is the hearth covered with cinders or sand; *g*, is the main working door, which may be opened and shut by means of a lever *g′*, and chain to move it up and down. In this large door there is a hole 5 inches square, through which the iron may be worked with the paddles or rakes; it may also be closed air-tight. There is a second working door *h*, near the flue, for introducing the cast iron, so that it may soften slowly, till it be ready for drawing towards the bridge. *i* is the chimney, from 30 to 50 feet high, which receives commonly the flues of two furnaces, each provided with a damper plate or *register*. *Fig.* 1260, shows the main damper for the top of the common chimney, which may be opened or shut to any degree by means of the lever and chain. *k*, *fig.* 1258, is the tap or floss-hole for running off the slag or cinder.

1260



The sole is sometimes made of bricks, sometimes of cast iron. In the first case it is composed of fire-bricks set on edge, forming a species of flat vault. It rests immediately on a body of brickwork either solid or arched below. When it is made of cast iron, which is now beginning to be the general practice, it may be made either of one piece or of several. It is commonly in a single piece, which, however, causes the inconvenience of reconstructing the furnace entirely when the sole is to be changed. In this case it is a little hollow, as is shown in the preceding vertical section; but if it consists of several pieces, it is usually made flat.

The hearths of cast iron rest upon cast-iron pillars, to the number of four or five; which are supported on pedestals of cast iron placed on large blocks of stone. Such an arrangement is shown in the figure, where also the square hole *a*, *fig.* 1257, for heating the rake irons, may be observed. The length of the hearth is usually 6 feet; and its breadth varies from one part to another. Its greatest breadth, which is opposite the door, is 4 feet. In the furnace, whose horizontal plan is given above, and which produces good results, the sole exhibits in this part a species of ear, which enters into the mouth of the door. At its origin towards the fireplace, it is 2 feet 10 inches wide; from the fire it is separated, moreover, by a low wall of bricks (the fire-bridge) 10 inches thick, and from 3 inches to 5 high. At the other extremity its breadth is 2 feet. The curvature presented by the sides of the sole or hearth is not symmetrical; for sometimes it makes an advancement, as is observable in the plan. At the extremity of the sole furthest from the fire, there is a low rising in the bricks of 2½ inches, called the altar, for preventing the metal from running out at the *floss-hole* when it begins to fuse. Beyond this shelf the sole terminates in an inclined plane, which leads to the *floss*, or outlet of the slag from the furnace. This *floss* is a little below the level of the sole, and hollowed out of the basement of the chimney. The slag is prevented from concreting here, by the flame being made to pass over it, in its way to the sunk entry of the chimney; and there is also a plate of cast iron near this opening, on which a moderate fire is kept up to preserve the fluidity of the scoriæ, and to burn the gases that escape from the furnace, as also to quicken the draught, and to keep the remote end of the furnace warm. On the top of this iron plate, and at the bottom of the inclined plane, the cinder accumulates in a small cavity, whence it afterwards flows away; whenever it tends to congeal, the workman must clear it out with his rake.

The door is a cast-iron frame, filled up inside with fire-bricks; through a small hole in its bottom the workmen can observe the state of the furnace. This hole is at other times shut with a stopper. The chimney has an area of from 14 to 16 inches.

The hearth stands 3 feet above the ground. Its arched roof, only one brick thick, is raised 2 feet above the fire-bridge, and above the level of the sole, taken at the middle of the furnace. At its extreme point near the chimney, its elevation is only 8 inches; and the same height is given to the opening of the chimney. The sole is covered with a layer of finely-pounded cinders from previous workings mixed with mill cinders; formerly the bottoms were of sand, by which great loss of iron was occasioned, and the metal obtained of inferior quality.

The fine metal obtained by the coke is *puddled* by a continuous operation, which calls for much skill and care on the part of the workmen. To charge the puddling furnace, pieces of *fine metal* are successively introduced with a shovel, and laid one over another on the sides of the hearth, in the form of piles rising to the roof; the middle being left open for puddling the metal, as it is successively fused. Indeed, the whole are kept as far separate as possible, to give free circulation to the air round the piles. The working door of the furnace is now closed, fuel is laid on the grate, and the mouth of the fireplace, as well as the side opening of the grate, are both filled up with coal, at the same time that the damper is entirely opened.

The fine metal in about twenty minutes comes to a white-red heat, and its thin-edged fragments begin to melt and fall in drops on the sole of the furnace. At this period the workman opens the small hole of the furnace-door, detaches with a rake the pieces of fine metal that begin to melt, tries to expose new surfaces to the action of the heat, and in order to prevent the metal from running together as it softens, he removes it from the vicinity of the fire-bridge. When the whole of the fine metal has thus got reduced to a pasty condition, he must lower the temperature of the furnace to prevent it from becoming more fluid. He then works about with his paddle the clotty metal which swells up, exhibiting a kind of fermentation occasioned by the discharge of carbonic oxide, burning with a blue flame as if the bath were on fire. The metal becomes finer by degrees and less fusible, or, in the language of the workmen, it begins to *dry*. The disengagement of carbonic oxide diminishes and soon stops. The workman continues meanwhile to puddle the metal till the whole charge is reduced to the state of incoherent sand; the register is then progressively opened. With the return of heat the particles of metal begin to agglutinate, the charge becomes more difficult to raise, or, in the labourer's language, it *works heavy*. The refining is now finished, and nothing remains but to gather the iron into balls. The puddler with his paddle takes now a little lump of metal as a nucleus, and makes it roll about on the surface of the furnace, so as to collect more metal, and form a ball of about 60 or 70 lbs. weight. With a kind of rake called in England a *dolly*, and which he heats beforehand, the workman sets this ball on that side of the furnace most exposed to the action of the heat in order to unite its different particles, which he then squeezes together to force out the scoriæ. When all the balls are fashioned, the small opening of the working door is closed with brick to cause the heat to rise, and to facilitate the welding. Each ball is then lifted out either with the tongs, if roughing rollers are to be used, as in Wales, or with an iron rod welded to the lump as a handle, if the hammer is to be employed, as in Staffordshire. It is usual to introduce a fresh charge when the portion under operation has arrived at the pasty condition; when this is done, the entire process is effected in about 1½ hour.

The charge for each operation is from 4 cwts. to 4¾ cwts. of refined metal, and sometimes the cuttings of bar-ends are introduced, which are puddled apart. The loss of iron is here very variable, according to the degree of skill in the workman, who by negligence may suffer a considerable body of iron to scorify or to flow into the hearth and raise the bottom. Taking the average of 85 furnaces for 21 years' working, Mr. Truran finds the consumption of refined metal to produce one ton of puddle bars to be 21 cwts. 1 qr. 20 lbs. The consumption of coal is likewise subject to variation. With coal of good quality, and suitable for reverberatory furnaces, the ton of puddled bars is produced with a consumption of from 12 to 15 cwts.; but, if the coal be of the anthracitic character, from 18 cwts. to 1 ton will be required. About five puddling furnaces are required for the service of one smelting furnace and one refinery. Each furnace, with good workmen, turns out about 23 tons of puddled bars weekly.

The cast-iron bottom and sides of the puddling furnace are kept cool by currents of air, or, in those portions exposed to the greatest heat, by water. The cinders of the charcoal finery are much esteemed for lining the bottom. When melted into one uniform mass, with the addition of oxide of iron, these scoriæ form a bottom offering great resistance to the action of the melted metal.

Various patents have been taken out within the last four or five years for the employment of chemical agents to assist in the purification of iron in the puddling furnace: some of these have already been alluded to. One of the latest is that of M. Charles Pauvert of Châtellerault, who proposes to employ a cement composed of the following substances:—oxide of iron, 14 parts; highly aluminous clay, 30 parts; carbonate of potash, 1 part; carbonate of soda, 1 part. The iron is to be placed with the cement in layers, and heated in the furnace in the ordinary manner. After cementation it is welded, and then drawn into bars; it is stated to become thus as soft and tenacious as iron made from charcoal. Schafhaeutl's compound, for which a patent was secured in 1835, is said by Overman to furnish very satisfactory results, and where competent workmen are employed, a good furnace is said to make a heat in two hours, producing neither too much nor too little cinder in the furnace. The compound consists of common salt, 5 parts; oxide of manganese, 3 parts; fine white plastic clay, 2 parts. The pig is heated as in common operations. It is melted down by a rapid heat, the damper is closed, and the cinder and metal diligently stirred. In the meantime the above mixture, in small parcels of about half a pound, is introduced in the proportion of 1 per cent. of the iron employed; if, after this, the cinder does not rise, a hammer slag (rolling mill-cinder) may be applied.

Puddling of Iron by Machinery.—The earlier stages at least of the process of puddling a charge of iron involve operations so simple that it is a matter for some surprise that they have not long since been carried out by machinery. The constant stirring of a little pond of molten iron is the thing to be done, and a common bar of iron, with one end bent down at right angles, is the thing to do it with. The necessary motions are in no way complex, and so far very simple machinery should suffice for the operation. The history of attempts at machine-puddling runs back nearly a quarter of a century. But it is only within the last year or two that the practical adoption of puddling-machinery has been attended with success. It is beyond question that the problem presented to the mechanician was formerly invested with difficulties which modern experience proves to have been more or less imaginary. Too much was attempted, and of course little or nothing done. The paramount idea was that the labour of the puddler should be wholly superseded, and the entire process, blooming and all, effected solely by the aid of steam-power. In this lay a great error. There are many processes in the arts which cannot be effected without the very effectual interference of the human arm guided by intelligence, and puddling is pre-eminently one of these. The only available course to adopt is to permit the machine to perform the major part of the hard work, leaving the completion of the process to the man. Mechanism constructed according to this principle has now been at work for some time with excellent results, and the universal adoption of machine-puddling is not, we think, very distant. Mr. Menelaus, of the Dowlais Ironworks, carried out a series of experiments on a very extended scale. The system adopted at Dowlais is that known as Walker's, in which the iron is exposed to the action of flame by the rotation and oscillation of the vessel containing the molten metal, which takes the place of the ordinary hearth. The experiments made at Dowlais were not, however, entirely successful. At the Wombridge Ironworks, Salop, Mr. Henry Bennett, the manager, introduced a system of his own invention. Mr. Bennett read a paper on this machine, and the results obtained from its use, before the Institution of Mechanical Engineers, from which we select the following remarks:—

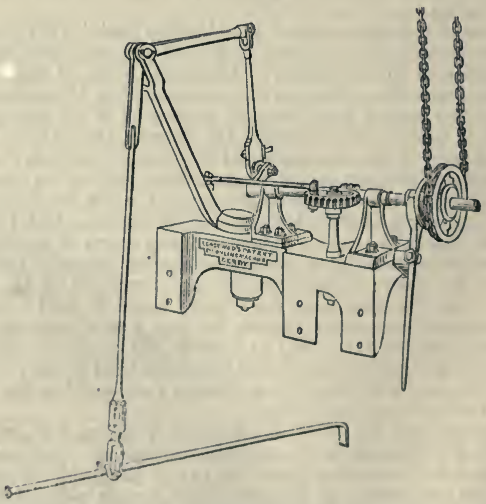
'The importance of the application of machinery to diminish the severe labour of puddling iron, by performing the merely mechanical process of stirring the iron, has led to many attempts in that direction; and, amongst others, it has been attempted to make a rotary furnace for performing the entire operation by machinery. But not till lately has any real success been attained, on account of the practical difficulties that are met with in applying machinery for the purpose, arising from the great heat to which any machinery in the furnace would be exposed, and from the necessity for not interfering with the draught of the furnace, while making the whole machinery simple and strong enough to stand the rough usage of the men employed. The design of the writer in applying machinery to the process of puddling iron has been, therefore, to adhere as closely as possible to the ordinary course of hand-puddling, and to employ the machinery simply to aid the puddler by relieving him of the most laborious part of his work: namely, the stirring or working of the metal in the puddling furnace. At the same time, the objects aimed at have been, by a more rapid and uninterrupted process of stirring the metal, to shorten the time of the puddling, thereby economising the fuel; to improve the quality of the iron, by rendering the process more uniform and perfect than with hand labour; and to increase the work of the furnace, by working larger charges than could be both puddled and balled-up at one heat by hand labour alone.

'With the machine now described, the ordinary puddling tool, or "rabble," is worked backwards and forwards in the puddling furnace by a vertical arm outside the furnace, to which it is connected by a notch in the handle of the rabble, dropped loosely on a pin at the bottom of the arm. The arm is cottered at top into a horizontal slide-bar, working backwards and forwards in a guide-frame overhead; this is driven by a connecting rod from a long iron bar, which extends longitudinally over a whole row of puddling furnaces, and has a longitudinal reciprocating motion given to it by a crank driven by the engine. The guide-frame is centred on a vertical pin immediately over the door of the puddling-furnace, and is moved transversely from side to side with a slow traverse by a crank and worm-wheel, driven by a worm on a longitudinal shaft extending over the series of puddling furnaces, alongside the reciprocating bar. By this means the rabble, instead of moving backwards and forwards always in the same line, is worked successively over every part of the puddling furnace, in lines radiating from the working hole in the door of the furnace, corresponding exactly to the action in hand-puddling. In a double furnace, with a door on each side, one of the machines is fixed over each door, and the two rabbles are made to be always working in different parts of the furnace, by the two traversing cranks of the guide-frames overhead being set at right angles to each other. The whole of the machinery is kept clear above the furnace outside, and completely protected from the heat, and quite out of the way of the men; nothing being exposed to the heat except the rabble or puddling-tool, the same as in hand-puddling. The puddler changes the rabble from time to time as it gets heated, by simply lifting it off the pin on the working arm, and replacing it with a fresh tool, without stopping the machine; and when the iron begins to thicken, or is "coming to nature," he takes the opportunity of each change of tool to make a few strokes by hand, in order to collect the metal from the extreme sides of the furnace into the centre. When the iron is ready for balling-up, the machinery is disconnected, without stopping it, by merely knocking out the cotter which fixes the working arm in the slide-bar; the arm then drops out, leaving the furnace-door entirely free for the puddler to ball up the iron, without his being in any way inconvenienced by the machinery continuing at work overhead.

'By the use of this machine, more work is put into the iron while it is in the boiling state than can be done by hand, the speed of working being one-half greater; and the working is kept up uninterruptedly, without any intervals of rest, such as in hand labour, during which the metal would remain stationary in the furnace. The double furnace, worked from each side, effects a great economy in the consumption of fuel, as compared with a single furnace; and puddles double the quantity of iron in the same time. With the machines at work at the Wombridge Ironworks, the consumption of coal in the double furnace, with a charge of 10 cwts., is only 17 cwts. of coal per ton of puddled bar, as compared with 28 cwts. per ton in the single furnace with a charge of 5 cwts. The number of heats worked by the machine per turn of from nine to ten hours is six heats of 6 cwts. each in the single furnace, and five heats of 10 cwts. each in the double furnace.'

Mr. Eastwood, of Derby, has patented, and is using with much success, a puddling-machine, of which the accompanying woodcut (*fig.* 1261) gives a sufficient example.

1261



This machine is of the simplest and most compact character, while it is efficient in work, giving the same motion to the rabble as is done by manual labour; and working the iron about so thoroughly that the whole is boiled quicker, better, and much cleaner than a man will or can always do it, thus securing a more uniform and better quality of iron, with less percentage of waste: at the same time a larger quantity of iron may be worked with ease in each heat, thus effecting a saving of fuel, time, and labour, and the workmen being relieved, lessens the liability of the underhands absenting themselves from work in hot weather, or when the iron is grey, through which so much loss is sustained in almost every work, and the puddler is still enabled to change his rabble as readily as before, and work in the ordinary way, independently of the machine. The machine, as represented, is made to bolt to the back side of the front furnace-plate, and its action is as follows:—The chain giving motion to the shaft, the crank by the connecting-rod working the lever, and the rabble being attached, is drawn from back to front, and is made to traverse from one jamb to the other, by the worm on the shaft turning the worm-wheel connected to the jib by the connecting-rod; thus every turn of the wheel alters the position of the jib, and the rabble is sent in another direction, but never in the same direction, owing to the wheel having an uneven number of teeth, therefore every part of the furnace bottom is worked over. It is under perfect control, the hand lever throwing in and out of gear the clutch on the side of the chain pulley, thus starting and stopping it at will. It does in no way interfere when the furnace is being rebuilt.

In a future page mechanical contrivances introduced by Dr. Siemens and Mr. Danks will be especially noticed.

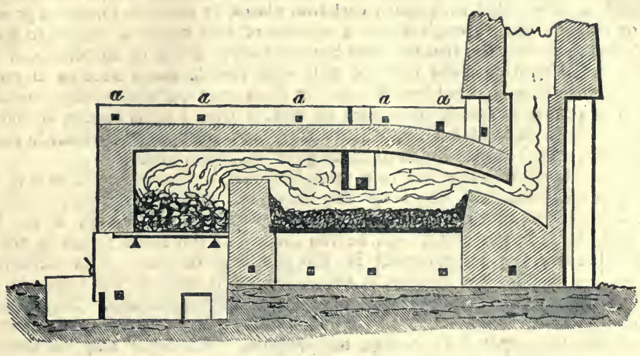
The 'Boiling' Process.—In this operation, which was the invention of Mr. Joseph Hall, pig-iron is converted into malleable iron without the intervention of the refinery, and without any excessive waste: it is, therefore, of great value, especially as it allows of the use of better qualities of pig-iron than those usually employed. The construction of the 'boiling' furnace does not materially differ from that of the 'puddling' furnace, except in the depth of the hearth, that is, in the distance from the work plate below the door to the bottom plate, which, in the former, is double, or nearly so, that of the latter. In the puddling furnace the distance between the bottom and top seldom exceeds twenty inches, while in the boiling furnace it varies from twenty to thirty. In *puddling* the furnace is charged with metal alone, but in boiling *cinder* is charged along with the metal, and the temperature rises much higher. The bottom of the furnace is covered with broken cinders from previous workings, or with the tap cinder from the puddling furnace, which has been subjected to a process of calcination in kilns; this material, which constitutes an admirable protection to the iron plates of the furnace, is called by the workmen 'bull dog;' its preparation was patented by Mr. Hall in 1839. It is made in the following manner: the tap cinder from the puddling furnace is placed in layers in a kiln, and so arranged that a draught shall pass through from the fire-holes on one side to those of the other; the kiln is filled up to the top with broken cinders, and over the whole is laid a layer of coke; about the third or fourth day, the more fusible part of the cinder begins to run out of the bottom holes, leaving in the kiln a fine rich porous silicate of iron, which is the substance used for lining the boiling furnace, the fluid portion being rejected. In 8 or 10 hours the 'bull dog' is melted by the intense heat of the furnace, covering the bottom, and filling up all the interstices in the brickwork; the heat is now somewhat lowered by diminishing the draught, and the charge of pig (from 3½ to 4½ cwts.) introduced in fragments of a convenient and uniform size, together with 30 or 40 lbs. of cinder; the doors of the furnace are now closed, and all access of cold atmospheric air prevented, throwing fine cinder or hammer slag round the crevices, and stopping up the work-hole with a piece of coal. In about a quarter of an hour the iron begins to get red hot; the workman then shifts the pieces so as to bring the whole to a state of uniformity as regards heat. In about half an hour the iron begins to melt; it is constantly turned over, and at intervals of a few minutes cinder is thrown in; the surface of the mass is seen to be covered with a blue flame; it soon begins to rise; a kind of fermentation takes place beneath the surface, and the mass, at first but 2 inches high, rises to a height of 10 or 12 inches, and enters into violent ebullition. During the time that this 'fermentation' is taking place, constant stirring is required to prevent the iron from settling on the bottom. The *boiling* lasts about a quarter of an hour; after which the cinder gradually sinks, and the iron appears in the form of porous spongy masses of irregular size, which are constantly stirred to prevent their adhering together in large lumps, to facilitate the escape of the carbon, and to separate the cinder which, when the operation has been successfully conducted, flows over the bottom apparently as liquid as water. The iron is now 'balled up,' as in the operation of puddling. The objections to the boiling process are: the wear and tear in the furnace which occurs in treating grey pig-iron, particularly that of the more fluid description; the slowness of the operation, and the amount of manual labour which it entails to produce good results. In some works the crude iron is run directly into the boiling furnace from the blast-furnace, by which much saving of coal is effected, and a product of a more uniform quantity obtained; but the labour of the workman becomes more oppressive from the additional heat to which he is subjected from the close proximity of the blast-furnace. Ironmasters are not agreed as to the respective merits of the 'boiling' and 'puddling' systems; some maintain that the former is more economical than the latter, which involves 'refining;' others think that boiling iron has a tendency to communicate to it the 'red short' quality. According to the observations of Mr. Truran, in several works where both methods are employed, the largest quantity of iron is first passed through the refinery.

Mr. Hall, the inventor of the boiling system, in descanting on the merits of his process, describes how, with the same pig, the iron may be made weak and cold short; or tough, ductile, and malleable. For the first proceed thus:—Pass the pig through the refinery, then puddle agreeably to the old plan on the sand bottom; that is, melt it as cold as possible; drop the damper quite close before the iron is all melted, dry the iron as expeditiously as may be, with a large quantity of water; and, lastly, proceed to ball in a proper number of 'young' balls; the result will be a very inferior quality of manufactured iron. On the other hand, to produce a malleable iron of very superior quality, first charge the furnace with good forge pig-iron, adding, if required, a sufficiency of flux, increasing or diminishing the same in proportion to the quality and nature of the pig-iron used. Secondly, melt the iron to a boiling consistency. Thirdly, clear the iron thoroughly before dropping down the hamper. Fourthly, keep a plentiful supply of fire upon the grate. Fifthly, regulate the draught of the furnace by the damper. Sixthly, work the iron into one mass, before it is divided into balls; when thus in balls, take the whole to the hammer as quickly as possible, after which roll the same into bars. The bars being cut into lengths, and piled to the desired weights are then heated in the mill furnace, welded and compressed by passing through the rolls, and thus finished for the market. In this way, from the pig to the finished mill bar, one entire process that of the refinery, is saved. Mr. Hall states that, by his process, he can obtain malleable iron of any character (premising that the ores from which the pig is smelted are of good quality), from the softness of lead to the hardness of steel, and further that he can exhibit different qualities in the same bar, one end being crystalline, nearly as brittle as glass, the other end equal to the best iron that can be produced for fibre and tenacity, while the middle exhibits a character approximating to both; and, as a further illustration of the excellence of the iron that may be made by the 'pig-boiling' process, he refers to a specimen in the Geological Museum, Jermyn Street, London, labelled 'Specimen of two-and-a-quarter inch round iron, tied cold, manufactured at the Bloomfield Ironworks, Tipton, Staffordshire.' This specimen has been called a 'Staffordshire knot'; it was made from a bar 2¼ inches in diameter, and nearly 7 inches in circumference: also to a 'Punched Bar,' ½ inch thick, made at one process for the smithy, commencing with a ½-inch punch, and terminating with one 6½, without exhibiting the slightest fracture.

Mr. Hall was led to the discovery of the 'boiling' principle, by noticing the exceedingly high fusion which took place on subjecting puddling-furnace slag to a high degree of heat, and the excellence of the bloom of iron produced by the operation: it occurred to him, that if such good iron could be made from cinder alone, a very superior product ought to be obtained from good pig-iron, with equally good fluxes, and the result of experiments fully answered his expectation, though for a long time he was unable to make his discovery practically useful, on account of the difficulty of getting furnaces constructed capable of rendering the intense heat required and the corroding action of the fluxes. Puddling furnaces were then made of brick and clay, with sand bottoms. He succeeded at last, by lining the interior of the furnace with iron, and protecting them with a coating of prepared tap cinders.

In America the 'puddling' and 'boiling' processes are both in use. Overman gives preference to the latter as being the most profitable, but it can only be employed to a limited extent for lack of cinder; in a rolling-mill forge, therefore, half the furnaces are employed for boiling, and half for puddling, the latter supplying cinder for the former. In the eastern States, where the fuel is anthracite, double puddling furnaces are employed, and a blast is used, the incombustibility of this variety of coal rendering it impossible to get the requisite heat merely by the draught of the chimney. *Fig.* 1262 represents an anthracite furnace bisected vertically through the grate, hearth, and chimney. It differs from the ordinary puddling furnace chiefly in the greater depth of the grate, which is made to contain from 20 to 24 inches of coal, and in the lesser height of the chimney, which, as a blast is employed, need only be sufficiently high to carry the hot gases out of the furnace; the letters *a*, *a*, *a*, *a*, *a*, indicate the position of the iron cross binders, which serve to bind together the cast-iron plates of the enclosure, and to prevent the sinking of the roof from the expansion and contraction of the brickwork.

1262



The blast machines are fans, the best form of which is shown in *fig.* 1263 (*Overman*). The wings of this fan are encased in a separate box; a wheel is thus formed, which rotates in the outer box; the figure shows a horizontal section through the axis. The wings are thus connected, and form a closed wheel, in which the air is whirled round, and thrown out at the periphery. The inner case, which revolves with the wings, is fitted as closely as possible to the outer case, at the centre near *a*, *a*, *a*, *a*. The speed of the wings is sometimes as much as 1,800 revolutions per minute. The motion of the axis is produced by means of a leather or India-rubber belt and a pulley. This variety of fan is used at the puddling furnaces at Ebbw Vale, where the fuel is small coal.

1263

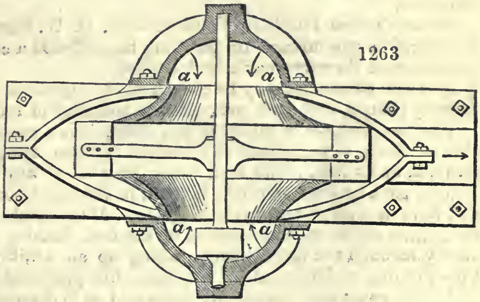
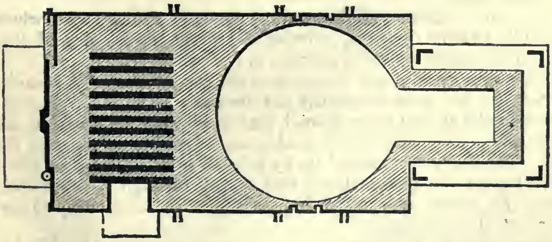


Fig. 1264 is a horizontal section of the double anthracite puddling furnace. The grate measures 3 feet by 5. The width of the furnace externally is from 5½ to 6 feet. The hearth is usually 6 feet in length. It has two work-doors, one directly opposite the other. Two sets of workmen are required, therefore, at the same time; double the quantity of metal is charged, and the yield is twice that of a single furnace; the economy is in the room, fuel, and labour; one good puddler only being required to manage the operation. Double puddling furnaces are also used in several works in England; but as Mr. Truran observes, the economical advantages attending them in point of fuel are lost if the puddlers do not work well to time: they must bring their heats to the respective stages simultaneously, for if one is kept waiting for a short period by the other, the loss of iron more than balances the reduced consumption of coal. The difficulty of obtaining men who will work well in concert has operated against the use of the double furnace, which would otherwise certainly supersede the

1264



single; as, combined with the process of running the iron in liquid from the blast-furnace, the consumption of fuel is under the one-half of the quantity demanded with single furnaces.

Puddling furnaces are sometimes constructed with what are called 'water boshes.' The hearth is surrounded with heavy cast-iron plates, in which is formed a passage of 1 inch or 1½ inch bore, through which a current of cold water is caused to flow, the object being to protect the furnace from the destructive action of the heat and cinder. Overman found such furnaces to work well with fusible metal such as is produced from a heavy burden on the blast-furnace, or from ores containing phosphorus; but with iron requiring a strong heat, such as results from a light burden on the blast-furnace, or when it contains impurities firmly and intimately combined, puddling furnaces with cooled boshes failed to make good malleable iron.

We do not know whether the iron manufacturers in England will assent to the following proposition, laid down by the American metallurgist, viz:—'That the smaller the amount of coal consumed, or the lower the temperature of the hearth in the blast-furnace, the better will be the quality of the metal; that is, the more fit it will become for improvement in the puddling furnace. The advantage of heavy burden in the blast-furnace is not only that it reduces the first cost of the metal, but makes a far superior article for subsequent operations. The worst cold-short, or sulphurous metal, smelted by a low heat, is quite as good as the best metal from the best ore smelted by a high temperature.' Whatever may be thought of the latter part of this quotation, no iron manufacturer will deny that careful attention to the blast-furnace is the best security of success in the puddling furnace, and that success in the one is in proportion to the economy observed in relation to the other.

Siemens's Gas Puddling Furnace.—Mr. C. W. Siemens in the application of his regenerative gas-furnace to puddling has effected a considerable improvement. His process must therefore be fully described.

It is thought that it may be convenient to reproduce the figure in section of the gas-furnace from p. 599, as it prevents the necessity of referring back to that article.

The gas-producer is shown in *fig.* 1265; it is a rectangular fire-brick chamber, one side of which, B, is inclined at an angle of from 40° to 60°, and is provided with a grate, C, at its foot. The fuel, which may be of any description. such as coal, coke, lignite, peat, or even sawdust, is filled in through a hopper, A, at the top of the incline, and falls in a thick bed upon the grate. Air is admitted at the grate, and in burning, its oxygen unites with the carbon of the fuel, forming carbonic acid gas, which rises slowly through the ignited mass, taking up an additional equivalent of carbon, and thus forming carbonic oxide. The heat thus produced distils off carburetted hydrogen and other gases and vapours from the fuel as it descends gradually towards the grate, and the carbonic oxide already named diluted by the inert nitrogen of the air and by any small quantity of unreduced carbonic acid, and mixed with these gases and vapours distilled from the raw fuel is finally led off by the gas-flue to the furnace. The ashes and clinkers that accumulate in the grate are removed at intervals of one or two days.

E is a pipe for the purpose of supplying a little water to the ashpit, to be decomposed as it evaporates and comes in contact with the incandescent fuel, thus forming some hydrogen and carbonic oxide, which serve to enrich the gas; G is a small plug-hole, by which the state of the fire may be inspected, and the fuel moved by a bar if necessary; and D is a sliding damper by which the gas-producer may be shut off at any time from the flue.

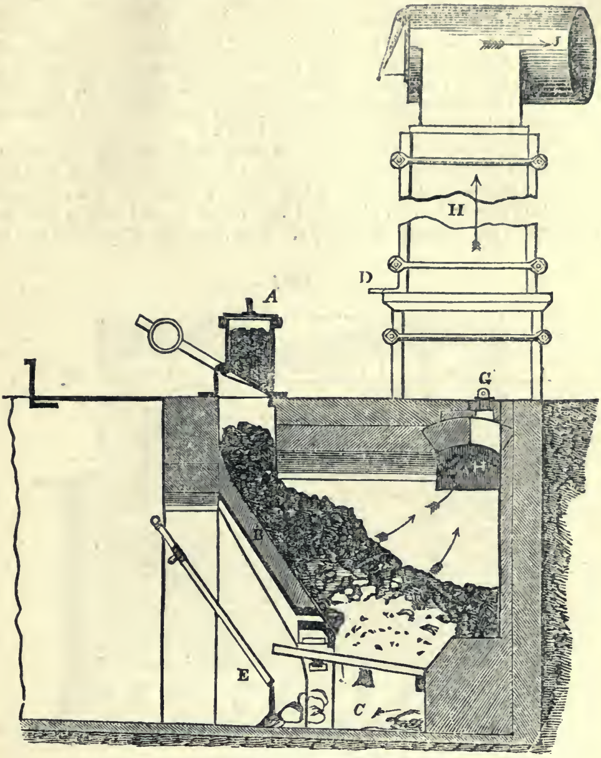
It is necessary to maintain a slight outward pressure through the whole length of the gas-flue leading to the furnaces, in order to prevent the burning of the gas in the flue through the indraught of air at crevices in the brickwork.

Where the furnaces stand much higher than the gas-producers, the required pressure is at once obtained; but more frequently the furnaces and gas-producers are placed nearly on the same level, and some special arrangement is necessary to maintain the pressure in the flue. The most simple contrivance for this purpose is the 'elevated cooling tube.' The hot gas is carried up by a brick stack, H, to a height of 8 or 10 feet above the top of the gas-producer, and is led through a horizontal sheet-iron cooling-tube, J, (*fig.* 1265), from which it passes down either directly to the furnace, or into an underground brick flue.

The gas rising from the producer at a temperature of about 1000° Fahr., is cooled as it passes along the overhead tube, and the descending column is consequently denser and heavier than the ascending column of the same length, and continually overbalances it. The system forms, in fact, a siphon in which the two limbs are of the usual length, but the one is filled with a heavier gaseous fluid than the other.

In erecting a number of gas-producers and furnaces the inventor generally prefers to group the producers together, leading the gas from all into one main flue, from which the several furnaces draw their supplies.

1265



The puddling furnace, proper, is shown in *figs.* 1266, 1267, and 1268.

1266

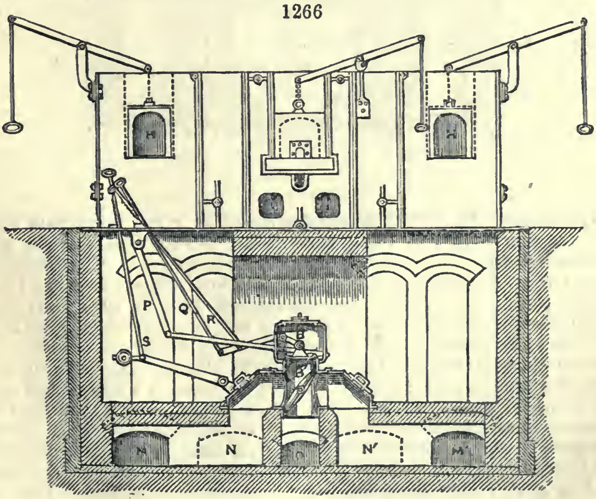


Fig. 1266 is a front elevation of the furnace, showing the gas reversing valve and flues in section.

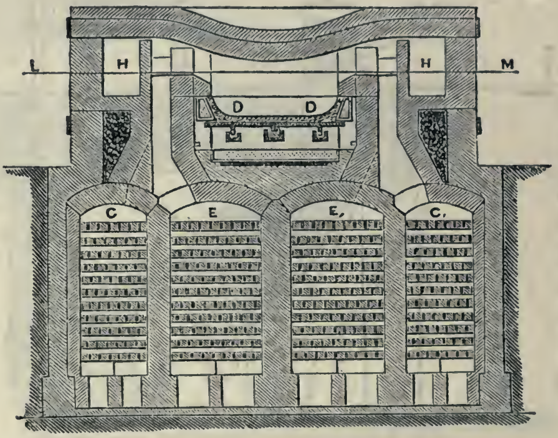
Fig. 1267 is a longitudinal section at A, B, C, D (*fig.* 1268).

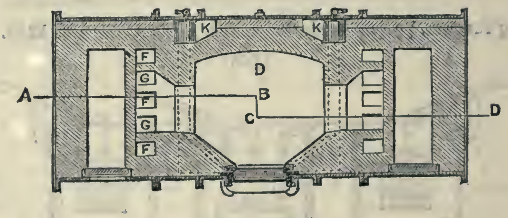
Fig. 1268 is a sectional plan at L, M (*fig.* 1267).

The peculiarity of the regenerative gas-furnace, as applied either to puddling, or to any other process in which a high heat is required, consists in the utilisation *in the furnace* of nearly the whole of the heat of combustion of the fuel, by heating the entering gas and air by means of the waste heat of the products of combustion, after they have left the furnace, and are of no further use for the operation being carried on. The waste heat is, so to speak, intercepted on its passage to the chimney, by means of masses of fire-brick stacked in an open or loose manner in certain chambers, called 'regenerator chambers,' C, E, E^1, C^1 (*fig.* 1267).

On first lighting the furnace the gas passes in through the gas regulating valve, B (*fig.* 1266), and the gas reversing valve, B^1, and is led into the flue, M, and thence into the bottom of the regenerator chamber, C (*fig.* 1267); while the air enters through a corresponding 'air reversing valve,' behind the valve B^1, and passes thence through the flue, N, into the regenerator chamber, E. The currents of gas and air, both quite cold, rise separately through the regenerator chambers, C and E, and pass up through the flues, G, G, and F, F, F (*fig.* 1268), respectively, into the furnace above, where they meet and are lighted, burning and producing a moderate heat. The products of combustion pass away through a similar set of flues at the other end of the furnace into the regenerator chambers, C^1, E^1, and thence through the flues, M^1, N^1, and through the gas and air reversing valves, into the chimney flue, O. The waste heat is thus deposited in the upper courses of open fire-brick work filling the chambers, C^1, E^1, so heating them up, while the lower portion, and the chimney flue, are still quite cool; then, after about an hour, the reversing valves, B^1 (through which the air and gas are admitted to the furnace), are reversed, by means of the levers, P, and the air and gas enter, through those regenerator chambers, E^1, C^1, that have just been heated by the waste products of combustion, and in passing up through the open brickwork they become heated, and *then* on meeting and entering into combustion in the furnace, D, D, they produce a very high temperature, probably 500° Fahr. higher than when admitted cold; the waste heat from such *higher temperature of combustion* heating up

1267





1268

the previously cold regenerator chambers, C, E, to a correspondingly higher heat. After about an hour's work the reversing valves, B^1, are again reversed, and the air and gas enter the first pair of regenerator chambers, C, E, but which are now very hot, and therefore the air and gas become very hot, and enter the furnace in this state, meeting and entering into combustion, and thus producing a still higher temperature, *probably* 500° *higher still,* and again heating the second pair of regenerator chambers, C^1, E^1, *so much higher,* which enables them to again heat the air and gas to a still higher degree, when the valves, B^1, are again reversed. Thus an *accumulation* of heat and an accession of temperature is obtained, step by step, so to speak, until the furnace is as hot as is required; for unless cold materials are put in to be heated, and thus abstract heat, the temperature rises as long as the furnace holds together, and the supply of gas and air is continued. The heat is at the same time so thoroughly abstracted from the products of combustion by the regenerators that the chimney flue remains always quite cool. The command of the temperature of the furnace and of the quality of the flame is rendered complete by means of the gas and air regulating valves shown at B in *fig.* 1266, and by the chimney damper. These are adjusted to any required extent of opening by the notched rods Q, R, and S, (*fig.* 1266) respectively, so that having the power of producing as high a temperature as can be desired, there is also the power of varying it according to the requirements in each case.

The bed of the furnace D D (*fig.* 1267), is of the ordinary construction, formed of iron plates, and is provided with water-bridges at the ends, as shown, to protect the 'fettling' (or oxide of iron used for lining the furnace) from being melted away. The overflow from one of the water-bridges is led into a sheet-iron tank below the bed, and then away. The evaporation from this tank keeps the bottom plates cool and preserves the cinder covering them from melting off, and the steam is carried away by a draught of air entering through two holes, I, I (*fig.* 1266), below the tap-hole, and passing off by small ventilating shafts K, K (*fig.* 1268), at the back of the furnace.

A heating chamber, H (*fig.* 1267), is arranged at each end of the furnace, in which the charge of pig-iron may be heated to redness before it is introduced into the puddling chamber, D, D.

The advantages of this furnace for puddling, are that the heat can be raised to an almost unlimited degree; that the flame can be made at will oxidising, neutral, or reducing, without interfering with the temperature; that indraughts of air and cutting flames are avoided; and that the gas fuel is free from ashes, dust, and other impurities, which are carried into an ordinary puddling furnace from the grate. In this last respect the new furnace presents the same advantages as puddling with wood.

The ordinary furnace received charges of 484 lbs. each, and yielded on an average 426 lbs., representing a loss of 12 per cent., whereas the gas-furnace received charges averaging 424 lbs., and yielded 413 lbs., representing a loss of less than 2·6 per cent.

It is important to observe, moreover, *that the gas-furnace turned out eighteen heats in three shifts per* 24 *hours,* instead of only 12 heats per 24 hours, which was the limit of production in the ordinary furnace.

This rate of working was attained without the employment of any arrangement for heating the pig-iron before charging it into the furnace, the heating chambers at the ends not having been used. The adoption of the plan of heating the metal beforehand, a system already extensively in use both in this country and on the Continent, effects a further saving of 10 to 15 minutes in the time required for working each charge, as well as a considerable economy in fuel.

The quality of the iron produced from the gas-furnace was proved decidedly superior to that from the ordinary furnace, being what is technically called *best best* in the one, and *best* in the other case, from the same pig.

The economy of fuel was greatly in favour of the gas-furnace. The saving of fuel in puddling cannot be less than 40 to 50 per cent. in quantity, while a much cheaper quality may be used.

The composition of 'fettling' was, however, greater in the gas-furnace, and the superior yield was naturally attributed by the forge managers to that cause.

By the use of the water-bridge the amount of 'fettling' required is reduced to an ordinary proportion, the average quantity of red ore used being 92·6 lbs. per charge, besides the usual allowance of bull dog, while the yield per charge of 483·3 lbs. of grey forge pig has been increased to 485 lbs. of puddled bar.

Danks's Revolving Puddling Furnace.—It appears that experiments were first commenced by Mr. Samuel Danks in May 1868, in the Cincinnati Railway Works. In 1869, the first experiments being successful, other revolving furnaces were set to work, and in 1870 they were generally adopted in those works. In a little time several iron producing companies in America being convinced of the advantages of Danks's process, adopted his revolving furnace for puddling. The following description by Mr. Samuel Danks will fully explain the arrangements of his puddling furnace.

The furnace has a fire-grate, in outward appearance like the ordinary puddling furnace, but it differs from this considerably in several particulars. It has a fan blast under the grate to urge the fire and produce gas. It has also jets of fan blast *over* the fire, injected for the purpose of ensuring the more perfect combustion of the fuel. This blast is regulated by a valve, by which the workman has a perfect control of the quantity of gas produced and consumed, and he is thus enabled to make the temperature suit the requirements of the charge in the different stages of the puddling process. The ashpit and fire-hole are closed by doors to prevent the escape of the blast through the fire, and the fire-hole has a coil of wrought-iron water-pipe cast into it, for the purpose of allowing a stream of water to circulate around it to keep it cool. The bridge-plate between the fire and the charge of metal has also a coil of water-pipe cast into it for the same purpose. It has a lining of fire-brick on the side next to the fire, and a covering of fettling on the side next to the charge. It also has a course of fire-brick on the top, and is thus perfectly protected on all sides. Fastened on to the bridge-plate is a ring with a flat surface on one side, which ring has a pipe or pipes cast into it, and is made in one piece or in sections. The pipes are for the purpose of admitting water to keep the ring cool, and the flat face is the part that the end of the revolving furnace rubs against, and forms a butt joint. This face should be cast on a metal chill to harden the part exposed to abrasion from the end of the revolving chamber rubbing against it.

The revolving chamber is made of two end-pieces, so formed as to be banded with wrought-iron bands, and to have detachable rings on the part most exposed to the fire. It rests on carrying rollers, to allow its free rotation. It has also suitable ribs for strengthening it, and holes for rivetting the rings and staveplates upon it. These two ends are connected together by a series of staveplates to form a cylinder, and are of suitable length according to the desired size of the chamber. They have hollow ribs, running longitudinally, which serve the double purposes of holding the fettling and keeping it cool, and when rivetted together, form an open-ended cylinder, one end of which butts against the ring that is fastened to the bridge-plate, where the gases are admitted over the bridge from the grate, and the other open end serves the purpose of a doorway for the reception of the charges of metal, and for their removal; also for the escape of the products of combustion through a moveable head-piece which connects the revolving chamber and the chimney. This moveable piece answers the purpose both of door and flue. It can be moved at pleasure by means of a suitable apparatus overhead, and when in its place for puddling, the escaping gases pass through it into the stationary flue, and from thence to the chimney or boiler. When it is removed for the introduction or removal of the charge, the end of the revolving chamber is open, and balls of great weight can be very readily removed. When the moveable piece is adjusted for puddling, it is held in position by suitable props. It has also an arrangement of water-pipes for keeping it cool, and a stopper-hole in front, so that the operations going on inside can be seen at all times.

The vessel is made to revolve by means of a toothed wheel, fixed longitudinally upon it. A suitable engine is attached to each machine, so that the chamber can be made to revolve at any speed that may be required according to the different stages of the operation.

The chamber is lined in the following manner:—The 'initial' lining is composed of a mixture of pulverised iron ore and pure lime, worked with water into the consistency of a thick paste. About one-third of the inner surface of the chamber is covered with this mortar in a layer projecting about one inch over the hollow ribs. After about four hours, the first part of the lining, as described, will be found hard, and in the same way the remaining parts are filled in and are allowed to set. The furnace is then ready to receive the fettling. About one-fifth of the whole quantity required in the shape of pulverised iron ore is thrown in upon the above-mentioned lining. The furnace is heated up, and is made to revolve slowly until the iron ore is found to be completely melted. The apparatus is then stopped, and that part of the molten iron ore, which has not been consumed by glazing the 'initial' lining surface, runs to the lowest level of the furnace, and there forms a pool, into which there are put a number of small and large lumps of iron ore, of such dimensions as will be required to allow the said lumps to project over the surface of the liquid ore by from two to six inches. This first part of the fettling is allowed to set when a fresh quantity of pulverised ore is thrown in. The furnace is again made to rotate slightly until the newly-added ore is liquefied, when the apparatus is again stopped, and the pool is filled with lumps as before. In this manner the whole of the inner surface is gradually fettled, and care is taken to regulate the position of each pool so that the vessel or apparatus shall at all times find itself properly balanced. From 2 to 2½ tons of iron ore are required to fettle a 700-lb. rotary furnace. Rather more than the ordinary quantity of hammer or rolled cinder is used, and upon that the iron is charged either in a solid or molten condition. When charged in the shape of pig-iron, the melting-down occupies from 30 to 35 minutes, during which a partial rotation is given to the furnace from time to time in order to expose equally all sides of the charge to the flame. When the whole of the charge is thoroughly melted, the furnace is made to revolve once or twice per minute only during the first five or ten minutes, in order to obtain the most perfect action of the cinder upon the molten iron. A stream of water is injected through the stopper-hole along and just above the line of contact between the floating cinder and the inner surface of the vessel on the descending side. A certain portion of uncontaminated cinder is thereby solidified on the metal surface, and is carried down into or below the bath of molten iron in a continuous stream, which, in rising up through the iron, combines with the impurities of the latter in a far more effectual and complete manner than any mode of puddling hitherto known can effect. On the expiration of the said five or ten minutes, the iron begins to thicken, and the motion is stopped. The heat is then raised, so that the cinder shall be perfectly liquefied, and thereby float over the iron. That cinder contains all the impurities which have been liberated from the charge, and it is essential to prevent its further contact with the iron. The vessel is therefore brought into such a position that the tap-hole shall be just over the level of the iron, which by this time has become partly pasty. The puddler gently pushes back the iron, and the cinder is made to run off. The tap-hole, by a slight motion of the vessel, is then brought high enough over the level of the iron, and is stopped up. The heat is again raised, and the furnace is put in motion at a velocity of from six to eight revolutions per minute, by which means the charge is dashed about violently in the furnace. Should a sufficient degree of decarburisation not have been produced at that point of the operation, then the liquidity which the iron will assume under the increased temperature will prove the fact. A high temperature being kept up, and the charge being continually turned over, the particles begin to adhere when the velocity of the apparatus is lowered to from two to three revolutions per minute, upon which the ball then very speedily forms. Should any loose pieces be detected in the furnace, the puddler moves them all to the same side of the ball, and by giving a partial rotation to the furnace he causes the ball to fall upon them, and thereby forms them into one mass. The puddler solidifies the front end of the ball by a few blows from a tool applied through the stopper-hole. The props of the moveable piece are then removed, and the flue hanging from the overhead rail is moved away. A large fork suspended from a crane is moved into the vessel along one side, and the ball, which by a turn of the vessel is rolled on to the fork, is then removed by means of a crane. The ball is then worked in a squeezer. The requisite quantity of cinder and metal is again charged. The flue is replaced, and the process continued. From eight to ten charges are made before any re-fettling is required, when the parts most worn are repaired. The bloom comes from the squeezer in a very solid condition, and is either reheated, or rolled off into puddled bar, &c., at once.

The inventor claims for his revolving furnace the following advantages:—A great saving in the cost of labour, and also in the consumption of coal, varying according to the size of the furnace; a superior and more regular quality of puddled iron from a given quality of pig; a yield of puddled iron much in excess of the charge of pig-metal, instead of the usual loss, the extra yield being obtained by the reduction of the rich fettling used in the machine; eight to ten heats, whether from 5 to 10 cwts. are made in a day of ten hours when suitable metal is used; the refining process is very complete, the whole of the phosphorus and silica and the sulphur, to a large extent, being removed by the chemical action of the lining mixture; the very heavy and exhaustive labour of puddling is performed by steam-power, thereby enabling one skilled man to attend to the working of a large quantity of iron; the bringing to nature and balling of the iron are completed by the rotary action without the use of rabbling, except when the heat has to be divided into smaller balls; and the capacity may be suited for heats of any weight from 5 cwts. upwards. The cost of the furnace, weight of product considered, is about the same as that of the usual hand-puddling furnaces.

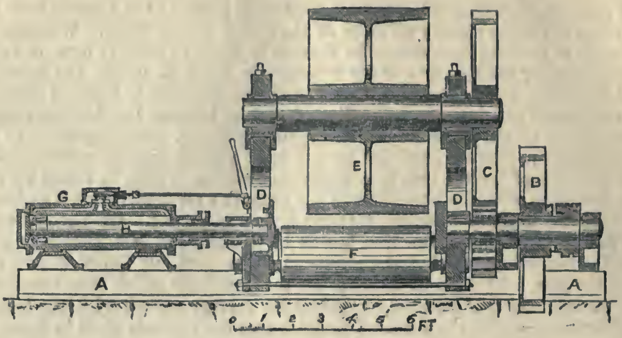
It is almost needless to say that the existing arrangements for hammering and rolling puddled iron would not be suitable where such large masses of metal have to be dealt with. In proportion as the subsidiary appliances are carried out upon a proper scale, so will be the advantageous results obtained from the puddling apparatus.

On this account the drawings of the 'Squeezer,' recommended by Mr. Danks has been introduced into these pages.

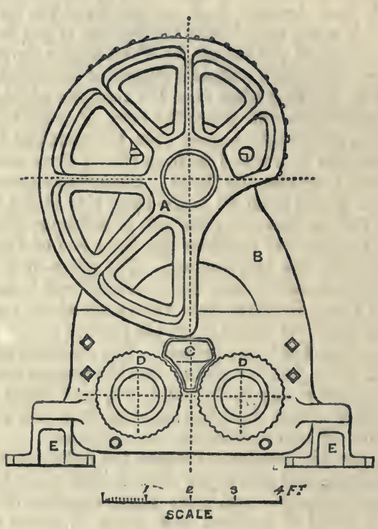
Squeezer.—Fig. 1269 is a front sectional elevation, showing a section of the steam-hammer or ram; a section of the squeezer-cam and roll; housings, bed-plate, and driving gear wheels.

Fig. 1270 is a section of squeezers, showing the squeezer-cam, rolls, the head of

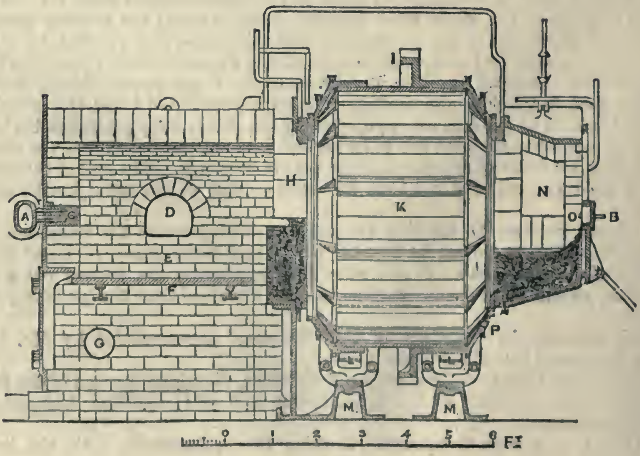
1269



1270



1271



steam-ram, housing, and the ends of bed-plates. A is the squeezer-cam; B, the housing; C, the head of steam-ram; D D, the rolls; and E E, the ends of bed-plates.

The following is a description of the drawings of Danks's improved revolving puddling furnace:—

Fig. 1271 is a sectional elevation of the furnace, showing the fire-grate, E; wind jet pipes G, which convey fan-blast into the fire-chamber over the fire, for the purpose of effecting as perfect a combustion of the gases as is desirable, producing a quick and intense heat; H, is the passage for gases; I, the gear-holder. The bridge is shown, with the plate having water-pipes passing through it, protected on the one side with fire-brick, and on the other with fettling. The revolving chamber, K, is also shown; with the tapping-hole, B; carrying-rollers, L; also the ends of bed-plates, M M; and moveable piece, N; with stopper-hole, B, which latter is suspended from an overhead tract.

Fig. 1272 is an end view, showing the arrangement of bed-plate, C; carrying-rollers and gear-wheels, upon a pillar-block, B; also an end view of the revolving chamber, supported by standard, A, with a section of fettling; a portion of the fire-bridge is also shown.

1272

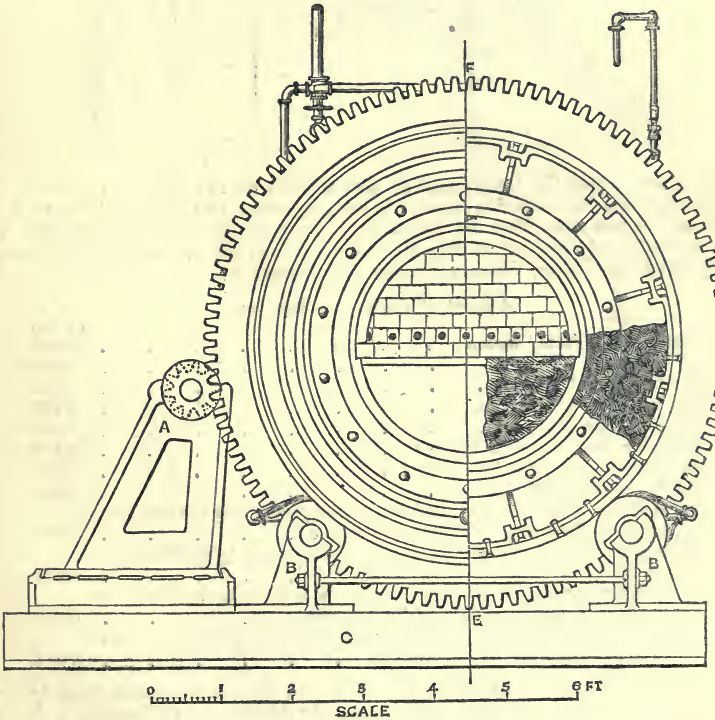


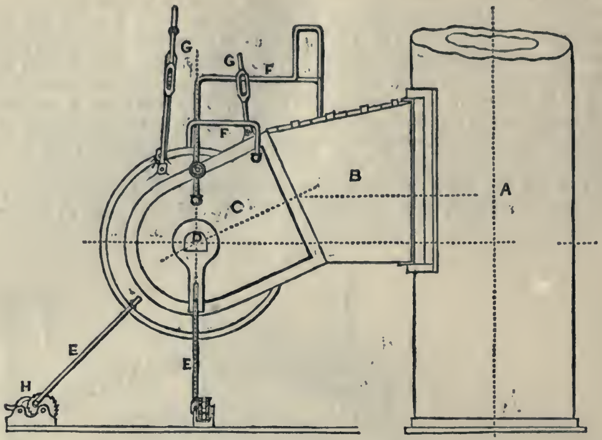
Fig. 1273 presents a front view of the furnace, showing the moveable piece, C; with its stopper-hole, D; props, E E; arrangements and water-pipes, F F; rods and swivels for suspending the moveable piece, G G; stationary flue, B; and chimney-stack, A.

In the autumn of 1856 the attention of ironmasters was powerfully excited by a proposal from Mr. Bessemer to manufacture malleable iron and steel from crude iron, without fuel. The first experiment was only partially successful, but Mr. Bessemer, conscious of the correctness of his principle, pursued his investigations with undiminished zeal, and the result was that he was rewarded by the most decided success. See STEEL.

One of the objections urged against the Bessemer process was, that the high temperature to which the iron was subjected destroyed its fibrous character.

It is more than probable that iron containing only 0·05 per cent. of carbon has almost lost the property of becoming fibrous by any treatment; for, without going so far as to assert that the development of fibre depends on the presence of carbon, or that carbon exercises a specific function in bringing about this molecular condition of the iron, analysis shows that the toughest and most flexible bar-iron contains a far larger quantity of carbon than that above indicated, as will be seen by the following analyses by Gay-Lussac, Willson, Karsten, and Bromeis :—

1273



Amount of Carbon in Bar-Iron.

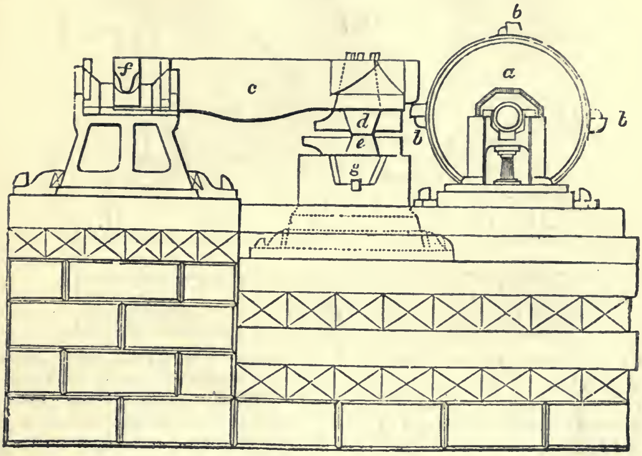
	Carbon
Best bar-iron from Sweden	0·293
Do. do.	0·240
Bar-iron from Creusot	0·159
Bar-iron from Champagne	0·193
Bar-iron from Berry	0·162
Cold-short bar-iron from Moselle	0·144
Soft bar-iron analysed by Karsten	0·200
Hard bar-iron by Karsten	0·500
Three different varieties produced from white pig-iron by the Swabian method of refining, analysed by Bromeis	0·318
Three different varieties produced from white pig-iron by the Swabian method of refining, analysed by Bromeis	0·354
Three different varieties produced from white pig-iron by the Swabian method of refining, analysed by Bromeis	0·400
Three varieties produced from various kinds of pig-iron by the Mägdesprung method of refining	0·324

Machines for Forging and Condensing Iron.—To prepare the puddle balls for the rolling mills, they have to undergo the process of 'shingling,' or 'blooming'; this is effected either by the hammer or by the squeezer: the latter has almost entirely superseded the former, as it effects the object at less cost, though, perhaps, with hardly such good results as to quality. These mechanisms are moved either by steam-engines or by water-wheels. We shall offer some details concerning them.

The main driving-shaft usually carries at either end a large toothed wheel, which communicates motion to the different machines through smaller toothed wheels. Of these there are commonly six, four of which drive four different systems of cylinders, and the two others work the hammer and the shears. The different cylinders of an iron work should never be placed on the same arbor, because they are not to move together, and they must have different velocities according to the diameter. In order to economise time and facilitate labour, care is taken to associate on one side of the motive machine the hammer, the shears, and the reducing cylinders, and on the other side to place the several systems of cylinders for drawing out the iron into bars. For the same reason, the puddling furnaces ought to be grouped on the side of the hammer, and the reheating furnaces on the other side of the works.

The hammers, *fig.* 1274, are made entirely of cast iron; they are nearly 10 feet long, and consist usually of two parts, the helve *c*, and the head or pane *d*. The latter enters with friction into the former, and is retained in its place by wedges of iron or wood. The head consists of several faces or planes receding from each other, for the purpose of giving different forms to the ball lumps. A ring of cast iron, *a*, called the *cam-ring bag*, bearing moveable cams, *b b*, drives the hammer, *d*, by lifting it up round its fulcrum, *f*, and then letting it fall alternately. In one iron work this ring was found to be 3 feet in diameter, 18 inches thick, and to weigh 4 tons. The weight of the helve (handle) of the corresponding hammer was 3½ tons, and that of the head of the hammer 8 cwts.

1274



The anvil, *e*, consists also of two parts; the one called the pane of the anvil, is the counterpart of the pane of the hammer; it likewise weighs 8 cwts. The second, *g*, named the stock of the anvil, weighs 4 tons. Its form is a parallelopiped, with the edges rounded. The *bloom* or rough ball, from the puddle-furnace, is laid and turned about upon it, by means of a rod of iron welded to each of them, called a *porter*. Since the weight of these pieces is very great, and the shocks very considerable, the utmost precautions should be taken in setting the hammer and its anvil upon a substantial mass of masonry, as shown in the figure, over which is laid a double, or even quadruple, flooring of wood, formed of beams placed in transverse layers close to each other. Such beams possess an elastic force, and thereby partially destroy the injurious reaction of the shock. In some works a 6-feet cube of cast iron is placed as a pedestal to the anvil.

Forge-hammers are very frequently mounted as levers of the first kind, with the centre of motion about one-third or one-fourth of the length of the helve from the cam-wheel. The principle of this construction will be understood by inspection of *fig.* 1275. The short end of the lever, which is struck down by the tappet, 6, is driven against the end of an elastic beam, *t*, and immediately rebounds, causing the long end to strike a harder blow upon the anvil, *s*.

1275

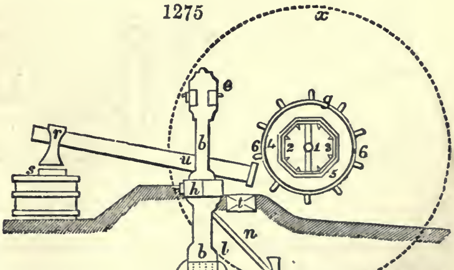


Fig. 1275 is the German forge-hammer; to the left of 1 is the axis of the rotatory cam, 2, 3, consisting of eight sides, each formed of a strong broad bar of cast iron, which are joined together to make the octagon wheel. 4, 5, 6, are cast-iron binding-rings or hoops made fast by wooden wedges; *b*, *b*, are standards of the frame-work, *e*, *l*, *m*, in which the helve of the forge-hammer has its fulcrum near *u*; *h*, the sole-part of the frame;

another cast-iron base or sole is seen at m; n is a strong stay, to strengthen the frame-work; at r two parallel hammers are placed, with cast-iron heads and wooden helves; s is the anvil, a very massive piece of cast iron; t is the end of a vibrating beam, for throwing back the hammer forcibly from it by recoil; x, y, is the outline of the water-wheel which drives the whole. The cams or tappets are shown mounted upon the wheel, 6, g, 6.

Squeezers are machines which condense a ball by pressure. They are either single or double; their construction will be readily understood from *fig.* 1276, which represents a single level-squeezer of the simplest construction: the bed-plate, *a*, is cast in one piece; it is 6 feet long, 16 inches wide, and 12 inches high. The whole is screwed down on a solid foundation of stone, brick, or timber: *b* is the moveable part, which makes from 80 to 90 motions per minute. The motion is imparted by the crank *c*, which in turn is driven by means of a strap and pulley by the elementary power. The diameter of the fly-wheel is from 3 to 4 feet. The anvil *d* is about two feet in length and from 12 to 14 inches in width; it is a moveable plate, at least 3 inches thick, which if injured can be replaced by another; the face of the working part of the lever exactly fits the anvil, and consists of plates attached by means of screws. It is desirable to have all these face plates in small parts of 8 or 10 inches in width, by this means they are secured against breaking by expansion and contraction. The whole machine, including the crank and everything, is made of cast iron, and weighs from 4 to 5 tons. According to Overman this machine is both cheap and durable, and will squeeze 100 tons of iron per week.

1276

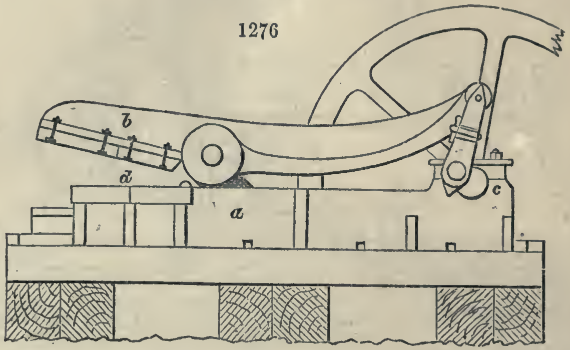


Fig. 1277 represents the double squeezer, employed at many English iron works. The drawing is taken from a machine at the Dowlais Iron Works, figured in Mr. Truran's work. Many other forms are in use.

1277

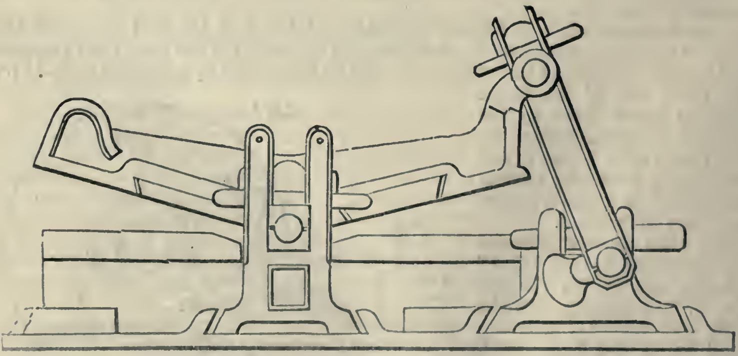
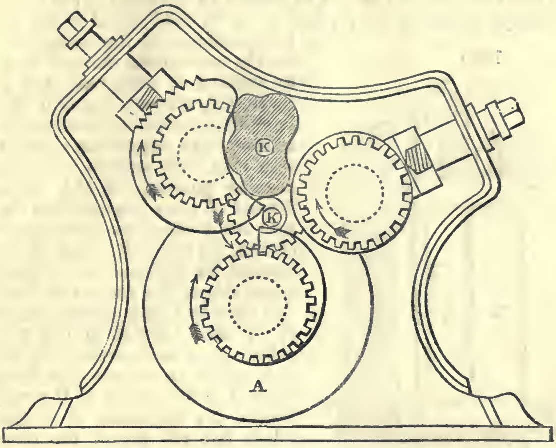
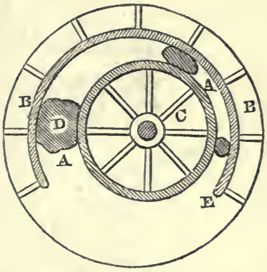


Fig. 1278 represents Brown's patent bloom squeezer. The heated ball of puddled iron K, thrown on the top is gradually pressed between the revolving rollers as it descends, and at last emerges at the bottom, where it is thrown on to a moveable 'Jacob's ladder,' by which it is elevated to the rolls. This machine effects a considerable saving of time, will do the work of 12 or 14 furnaces, and may be constantly going as a feeder to one or two pairs of rolls. There are two distinct forms of this machine; in the one figured the bloom receives only two compressions; in another, which is much more effective it is squeezed four times before it leaves the rolls and falls upon the Jacob's ladder. Another form of squeezer is shown in *fig.* 1279.

1278



1279



A table A A with a sledge rising up from it to a height of about 2 feet, so as to form an open box, is firmly imbedded in masonry; within this is a revolving box, C, of similar character, much smaller than the last, and placed excentrically in regard to it. The ball or bloom D is placed between the innermost revolving box C and the outer case A A, where the space between them is greatest, and is carried round till it emerges at E, compressed and fit for the rolls.

Cylinders.—The compression between cylinders now effects, in a few seconds, that condensation and distribution of fibres, which 40 years ago could not be accomplished till after many heats in the furnace, and many blows of the hammer. The cylinders may be distinguished into two kinds: 1, those which serve to draw out the ball, called *puddling rolls*, or roughing rolls, and which are, in fact, reducing cylinders; 2, the cylinders of extension, called *rollers*, for drawing into bars the massive iron after it has received a welding, to make it more malleable. This second kind of cylinders is subdivided into several varieties, according to the patterns of bar iron that are required. These may vary from 2 inches square to less than one-sixth of an inch.

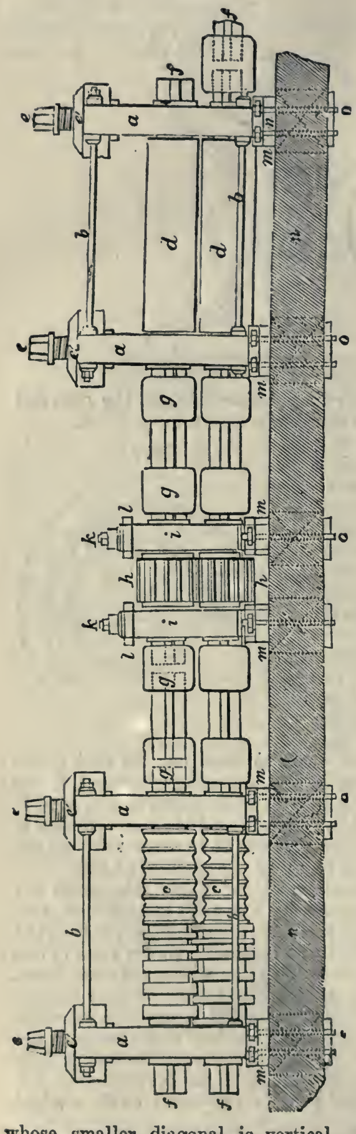
Beneath the cylinders there is usually formed an oblong fosse, into which the scoriæ and the scales fall when the iron is compressed. The sides of this fosse, constructed of stone, are founded on a body of solid masonry, capable of supporting the enormous load of the cylinders. Beams of wood form in some measure the sides of this pit, to which cylinders may be made fast, by securing them with screws and bolts. Massive bars of cast iron are found, however, to answer still better, not only because the uprights and bearers may be more solidly fixed to them, but because the basement of heavy metal is more difficult to shatter or displace, an accident which happens frequently to the wooden beams. A rill of water is supplied by a pipe to each pair of cylinders, to hinder them from getting hot; as also to prevent the hot iron from adhering to the cylinder, by cooling its surface, and perhaps producing on it a slight degree of oxidisement.

The shafts are 1 foot in diameter for the hammer and the roughing rolls; and 6 inches where they communicate motion to the cylinders destined to draw the iron into bars.

The *roughing rolls* are employed either to work out the lump or ball immediately after it leaves the puddling furnace, as in the Welsh forges; or only to draw out the piece, after it has been shaped under the hammer, as is practised in most of the

Staffordshire establishments. These roughing cylinders are generally 7 feet long, including the trunnions, or 5 feet between the bearers, and 18 inches diameter; and weigh in the whole from 4 to 4½ tons. They contain from 5 to 7 grooves, commonly of an elliptical form, one smaller than another in regular progression, as is seen in *fig.* 1280. The small axis of each ellipse, as formed by the union of the upper and under grooves, is always placed in the vertical direction, and is equal to the great axis, or horizontal axis of the succeeding groove; so that in transferring the bar from one groove to another, it must receive a quarter of a revolution, whereby the iron gets elongated in every direction. Sometimes the roughing rolls serve as preparatory cylinders, in which case they bear towards one extremity rectangular grooves, as the figure exhibits. Several of these large grooves are bestudded with small asperities analogous to the teeth of files, for biting the lump of iron, and preventing its sliding. On a level with the under side of the grooves of the lower cylinder, there is a plate of cast iron with notches in its edge adapted to the grooves. This piece, called the apron, rests on iron rods, and serves to support the balls and bars exposed to the action of the rollers, and to receive the fragments of ill-welded metal, which fall off during the drawing. The *housing frames* in which the rollers are supported and revolve, are made of great strength. Their height is 5 feet; their thickness is 1 foot in the side perpendicular to the axis of the cylinders, and 10 inches in the other. Each pair of bearers is connected at their upper ends by two iron rods, on which the workmen rest their tongs or pincers for passing the lump or bar from one side of the cylinders to the other.

1280

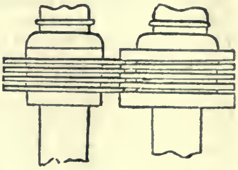


The cods or bushes are each composed of two pieces; the one of hard brass, which presents a cylindrical notch, is framed into the other which is made of cast iron, as is clearly seen in *fig.* 1280.

The iron bar delivered from the square grooves, is cut by the shears into short lengths, which are collected in a bundle in order to be welded together. When this bundle of bars has become hot enough in the furnace, it is conveyed to the rollers, which differ in their arrangement according as they are meant to draw iron from a large or small piece. The first, *fig.* 1280, possess both elliptical and rectangular grooves; are 1 foot in diameter and 3 feet long between the bearers. The bar is not finished under these cylinders, but is transferred to another pair, whose grooves have the dimensions proper for the bar, with a round, triangular, rectangular, or fillet form. The triangular grooves made use of for square iron have for their profile an isosceles triangle slightly obtuse, so that the space left by the two grooves together may be a rhombus, differing little from a square, and whose smaller diagonal is vertical. When the bar is to be passed successively through several grooves of this kind, the larger or horizontal diagonal of each following groove is made equal to the smaller or upright of the preceding one, whereby the iron must be turned one fourth round at each successive draught, and thus receive pressure in opposite directions. Indeed, the bar is often turned in succession through the triangular and rectangular grooves, that its fibres may be more accurately worked together. The decrement in the capacity of the grooves follows the proportion of 15 to 11.

When it is intended to reduce the iron to a small rod, the cylinders have such a diameter, that three may be set in the same housing frame. The lower and middle cylinders are employed as roughing rollers, while the upper and middle ones are made to draw out the rod. When a rod or bar is to be drawn with a channel or gutter in its face, the grooves of the rollers are suitably formed.

1281



To draw out square rods of a very small size, as nail-rods, a system of small rollers is employed, called *slitters.* Their ridges are sharp-edged, and enter into the opposite grooves 2½ inches deep; so that the flat bar in passing between such rollers is instantaneously divided into several slips. For this purpose the rollers represented in *fig.* 1281, may be put on and removed from the shaft at pleasure.

The velocity of the cinders varies with their dimensions. In one work, cylinders for drawing out iron of from one-third to two-thirds of an inch thick, make 140 revolutions per minute; while those for iron of from two-thirds of an inch to 3 inches, make only 65. In another work, the cylinders for two-inch iron, make 95 revolutions per minute; those for iron from two-thirds of an inch to an inch and a third, make 128; and those for bars from one-third to two-thirds of an inch, 150. The *roughing rollers* move with only one-third the velocity of the drawing cylinders.

The shingling and plate-rolling mill is represented in *fig.* 1280. The shingling mill, for converting the blooms from the balling furnace into bars, consists of two sets of grooved cylinders, the first being called *puddling rolls* or *roughing rolls*; the second are for reducing or drawing the iron into mill-bars, and are called simply *rolls.*

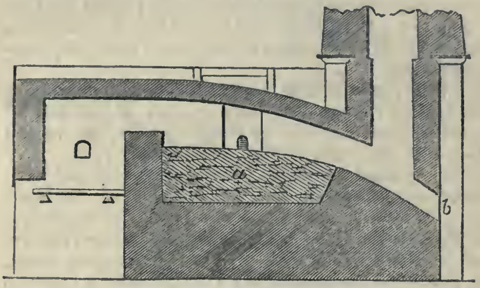
a, a, a, a, are the powerful uprights or standards called *housing frames,* of cast iron, in which the gudgeons of the rolls are set to revolve; *b, b, b, b,* are bolt rods for binding these frames together at top and bottom; *c,* are the roughing rolls, having each a series of triangular grooves, such that between those of the upper and under cylinders, rectangular concavities are formed in the circumference with slightly sloping sides. The end groove to the right of *c,* should be channelled like a rough file, in order to take the better hold of the blooms, or to bite the metal as the workmen say; and give it the preparatory elongation for entering into and passing through the remaining grooves till it comes to the square ones, where it becomes a mill-bar. *d, d,* are the smooth cylinders, hardened upon the surface, or *chilled,* as it is called, by being cast in iron moulds for rolling iron into plates or hoops. *e, e, e, e,* are strong screws with rectangular threads, which work by means of a wrench or key, into the nuts *e′ e′ e′ e′,* fixed in the standards; they serve to regulate the height of the plummer blocks or bearers of the gudgeons, and thereby the distance between the upper and under cylinders. *f* is a junction shaft; *g, g, g,* are solid coupling boxes, which embrace the two separate ends of the shafts, and make them turn together. *h, h,* are junction pinions, whereby motion is communicated from the driving shaft *f,* through the under pinion to the upper one, and thus to both upper and under rolls at once. *i, i,* are the pinion standards in which their shafts run; they are smaller than the uprights of the rolls. *k, k,* are screws for fastening the head pieces *l* to the top of the pinion standards. All the standards are provided with sole plates *m,* whereby they are screwed to the foundation beams *n* of wood, or preferably iron, as shown by the dotted lines; *o, o,* are the binding screw bolts. Each pair of rolls at work is kept cool by a small stream of water let down upon it from a pipe and stop-cock.

In the cylinder drawing, the workman who holds the ball in tongs passes it into the first of the elliptical grooves, and a second workman, on the other side of the cylinders, receives this lump and hands it over to the first, who repasses it between the rollers after bringing them somewhat closer to each other by giving a turn to the adjusting pressure screws. After the lump has passed five or six times through the same groove it has got an elliptical form, and is called in England a *bloom.* It is next passed through a second groove of less size, which stretches the iron bar. In this state it is subjected to a second pair of cylinders, by which the iron is drawn into flat bars four inches broad and half an inch thick. Fragments of the ball or bloom fall round about the cylinders, which are afterwards added to the puddling charge. In a minute and a half the rude lump is transformed into bars with a neatness and rapidity which the inexperienced eye can hardly follow. A steam-engine of thirty horse-power can rough down in a week 200 tons of coarse iron.

This iron, called mill-bar iron, is however of too inferior a quality to be employed in any machinery, and it is subjected to another operation, which consists in welding several pieces together, and working them into a mass of the desired quality. The iron bars, while still hot, are cut by the shears into a length proportional to the size of the iron bar that is wanted, and four rows of these are usually laid over each other into a heap or pile which is placed in the *re-heating* furnace, and exposed to a free circulation of heat, one pile being set crosswise over another. In a half or three quarters of an hour the iron is hot enough, and the pieces now sticking together are carried in successive piles to the bar drawing cylinders to be converted into strong bars, which are reckoned of middle quality. When a very tough iron is wanted, as for anchors, another welding and rolling must be given. In the re-heating ovens the loss is from 8 to 10 per cent. on the large bar, and from 10 to 12 in smaller work. The consumption of coals in heating the large piles averages 7 cwts. to the ton of iron charged; in the smaller sizes 10 cwts.; and in heating the guide rolled iron 10 cwts.

The re-heating furnace is shown in section in *fig.* 1282: it differs but little from a puddling furnace. The whole interior, with the exception of the hearth *a*, is made of fire-brick; the hearth is made of sand. For this purpose a pure siliceous sand is required; the coarser the better. The hearth slopes considerably towards the flue, the object of which is to keep the hearth dry and hard. The iron wasted in re-heating combines with the silica of the sand, forming a very fusible cinder, which flows off through the opening at *b*, at which there is a small fire to keep the cinder liquid. The thickness of the sand bottom is from 6 to 12 inches, resting on fire-brick; it generally requires re-making after two or three heats. The height of the fire-brick arch, or its distance from the sand bottom, is from 8 to 12 inches. The area of the fireplace averages 12 feet, and the width of the furnace varies from 5 to 8 feet. When the piles are charged into the furnace, the door is shut, and fine coal is dusted around its edges to exclude the cold air; the temperature is raised to the highest intensity as quickly as possible, and the workman turns the piles over from time to time that they may be brought to an uniform welding heat in the shortest possible time.

1282



It is thought by many that a purer iron is obtained by subjecting the balls as they come out of the puddling furnace to the action of the hammer at first rather than to the roughing rollers, as by the latter process vitrified specks remain in the metal, which the hammer expels. Hence in some works the balls are first worked under the forge-hammer, and these *stampings* being afterwards heated in the form of pies or cakes, piled over each other, are passed through the roughing mills.

Bars intended for boiler or tin plates are made from the best cold-blast mine iron. The raw pig is refined in the usual manner with coke, the loss amounting to from 2½ to 3 cwts. per ton. It is then refined a second time with charcoal, the loss amounting again to from 2½ to 3 cwts. per ton. After this second refining, it is beaten into flat plates white hot by the tilt hammer and thrown into cold water; the sudden chilling makes it more easily broken into small slabs. The slabs are piled in heaps and welded in the *hollow* fire, coke being the fuel; the slabs are laid across the fire, and do not come into contact with the fuel; the blast is thrown under the fuel, and the heat is immense; when the piles are nearly at the fusing point, they are withdrawn and passed under the rollers; they are again heated in the hollow fire, then again rolled and heated a third time in the ordinary reverberatory furnace, after which they are drawn out into flat bars for boiler-plates, or for tin plate: the loss in these operations amounts to from 3½ to 4 cwts. per ton. About 9 heats are accomplished in 12 hours, each heat consisting of 2¼ cwts. of refined metal, and consuming 5 baskets of charcoal.

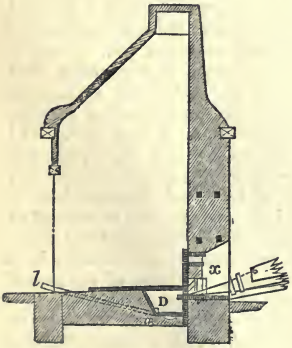
The bars intended for tin plates are repeatedly heated and rolled until of the requisite thinness, the plates are then cut into squares, and annealed by exposing them for several hours to heat in covered iron boxes, being allowed to cool very slowly; this gives the plates the proper degree of pliancy. The next operation is that of *pickling*; the plates are immersed in dilute sulphuric acid for the purpose of removing from their surfaces all oxide and dirt; after remaining in the acid for the requisite time, they are thoroughly washed in successive troughs of water, and then dried in sawdust; finally, the surfaces of the metal are prepared for the reception of the tin, by rubbing them with leather upon cushions of sheepskin. The spent sulphuric acid is run out into evaporating pans, and the sulphate of iron crystallised out. In order to tin the plates, they are immersed in a bath of melted tin, the surface of which is covered with tallow or palm-oil; when sufficiently covered, they are transferred to the *brusher* on the left-hand side of the tinner; he passes a rough brush rapidly over each side of the plate, whereby the superfluous tin is removed; he then plunges the plate again into the tin-bath, and passes it on to his left hand neighbour, who gives it a washing. The plate passes through several hands before it is dried. Great skill is required in the tinning process; nevertheless, in a well-conducted work the *wasters* do not amount to more than 10 per cent.; a small percentage of which are so bad as to require to be re-worked. Great care is taken to avoid waste, tin being worth about 150*l.* per ton. A box of 225 sheets of tin plates, 10 inches by 14, consumes about 8½ lbs. of tin. See TIN PLATE.

On the Continent, iron is frequently refined from the cast metal of the blast-furnaces by three operations, in three different ways. In one, the pig being melted, with aspersion of water, a cake is obtained, which is again melted in order to form a second cake. This being treated in the refinery fire, is then worked into a *bloom.* In another system, the pig-iron is melted and cast into plates: these are melted anew in order to obtain crude balls, which are finally worked into blooms. In a third mode of manufacture, the pig-iron is melted and cast into plates, which are roasted, and then strongly heated, to form a bloom.

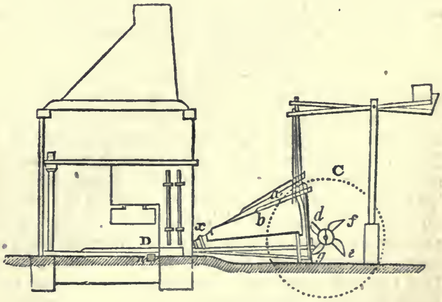
The French fusible ores, such as the silicates of iron, are very apt to smelt into white cast iron. An excess of fluxes, light charcoals, or too strong a blast, produce the same results. A surcharge of ores which deranges the furnace and affords impure slags mixed with much iron, too rapid a slope in the boshes, too low a degree of heat, and too great condensation of the materials in the upper part of the furnace; all tend also to produce a white cast iron. In its state of perfection, white cast iron has a silver colour, and a bright metallic lustre. It is employed frequently in Germany for the manufacture of steel, and is then called *steel floss*, or *lamellar floss*, a title which it still retains, though it be hardly silver-white, and has ceased to be foliated. When its colour takes a bluish grey tinge, and its fracture appears striated or splintery, or when it exhibits grey spots, it is then styled *flower floss.* In a third species of white cast iron we observe still much lustre, but its colour verges upon grey, and its texture is variable. Its fracture has been sometimes compared to that of a broken cheese. This variety occurs very frequently. It is a white cast iron, made by a surcharge of ore in the furnace. If the white colour becomes less clear and turns bluish, if its fracture be contorted, and contains a great many empty spaces or air-cells, the metal takes the name of *cavernous floss* or *tender floss.* The whitest metal cannot be employed for casting. When the white is mixed with the grey cast iron, it becomes *riband* or *trout* cast iron.

The German Refining Forge.—*Figs.* 1283, 1284, represent one of the numerous refinery furnaces once common in the Hartz. The example is taken from the Mandelholz works, in the neighbourhood of Elbingerode. *Fig.* 1284 is an elevation of this forge. D is the refinery hearth, provided with two pair of bellows. *Fig.* 1283 is a vertical section, showing particularly the construction of the crucible or hearth in the refinery forge D. C is an overshot water-wheel, which gives an alternate impulsion to the two bellows *a b* by means of the revolving shaft *c*, and the cams or tappets *d f e g*.

1283



1284



D, the hearth, is lined with cast-iron plates. Through the pipe *l*, cold water may be introduced, under the bottom plate *m*, in order to keep down, when necessary, the temperature of the crucible, and facilitate the solidification of the *loupe* or bloom. An orifice *n*, *figs.* 1283, 1284, called the *chio* (floss-hole), allows the melted slag or cinder to flow off from the surface of the melted metal. A copper pipe or nose piece conducts the blast of both bellows into the hearth, as shown at *b x*, *fig.* 1284.

The substance subjected to this mode of refinery is a grey carbonaceous cast iron, from the works of Rothehütte. The hearth D, being filled and heaped over with live charcoal, upon the side opposite to the tuyère *x*, *figs.* 1283, 1284, long pigs of cast iron are laid with their ends sloping downwards, and are drawn forwards successively into the hearth by a hooked bar, so that the extremity of each may be plunged into the middle of the fire, at a distance of 6 or 8 inches from the mouth of the tuyère. The workman proceeds in this way till he has melted enough of metal to form a *loupe*. The cast iron, on melting, falls down in drops to the bottom of the hearth; being covered by the fused slags, or vitreous matters more or less loaded with oxide of iron. After running them off by the orifice *n*, he then works the cast iron by powerful stirring with a rabble, till it is converted into a mass of a pasty consistence.

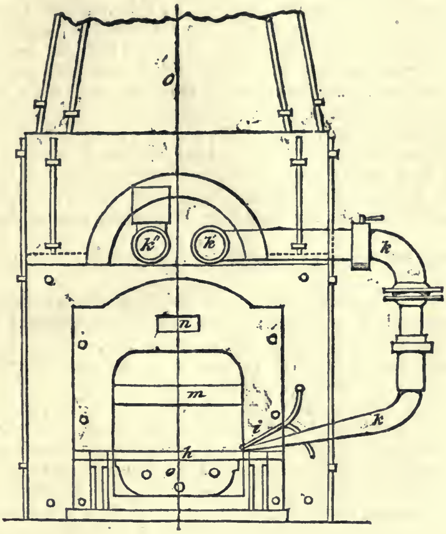
During this operation, a portion of the carbon contained in the cast iron combines with the atmospherical oxygen supplied by the bellows, and passes off in the form of carbonic oxide and carbonic acid. When the lump is coagulated sufficiently, the workman turns it over in the hearth, then increases the heat so as to melt it afresh, meanwhile exposing it all round to the blast, in order to consume the remainder of the carbon, that is, till the iron has become ductile, or refined. If one fusion should prove inadequate to this effect, two are given. Before the conclusion, the workman runs off a second stratum of vitreous slag, but at a higher level, so that some of it may remain upon the metal.

The weight of such a *loupe* or *bloom* is about 2 cwts., being the product of 2 cwts. and $\frac{7}{10}$ths of pig-iron; the loss of weight is therefore about 26 per cent. 149 pounds of charcoal are consumed for every 100 pounds of bar iron obtained. The whole operation lasts about 5 hours. The bellows are stopped as soon as the bloom is ready; this is immediately transferred to a forge-hammer, the cast-iron head of which weighs 8 or 9 cwts. The bloom is greatly condensed thereby, and discharges a considerable quantity of semi-fluid cinder. The lump is then divided by the hammer and a chisel into 4 or 6 pieces, which are re-heated, one after another, in the same refinery fire, in order to be forged into bars, whilst another pig of cast iron is laid in its place, to prepare for the formation of a new bloom. The above process is called by the Germans *Klump-frischen*, or lump refining. It differs from the *Durchbrech-frischen*, because in the latter the lump is not turned over in mass, but is broken, and exposed in separate places successively to the refining power of the blast near the tuyère. The French call this *affinage par portions*; it is much lighter work than the other.

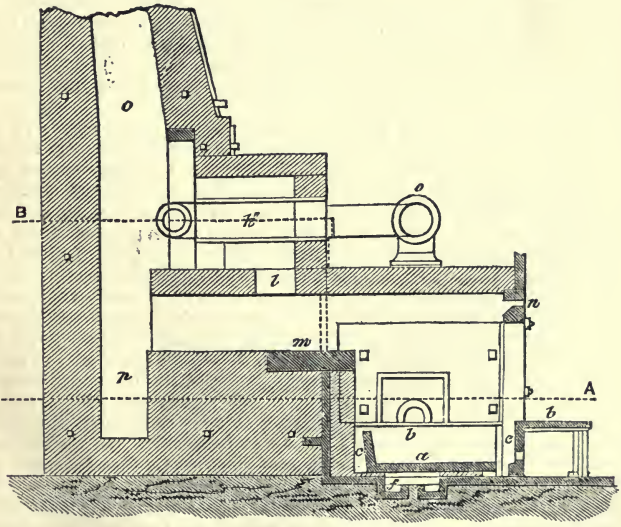
Charcoal Finery or Lancashire Hearth.—We are indebted for the following accurate account of this important finery to Dr. Percy, who gives it in his work on iron and steel:—

The furnace (*figs.* 1285 and 1286) consists essentially of a shallow quadrangular hearth, formed of cast-iron plates *a*, *b*, *c*, *d*, and *e*. The hearth-bottom *a*, is horizontal; the tuyère side *b*, slightly inclined inwards; the opposite side *n*, and the back *c*, inclined outwards; the front *e* is vertical, and in it there are three round holes for tapping off the cinder. Under the hearth-bottom is an open shallow cast-iron box, having a gutter on one side *f*, and a round hole in the centre of the bottom *f*, surrounded with a border not quite so high as the box is deep. The box and gutter are cast in one piece. During the working of the furnace cold water is continually flowing through *f*, and running out at *f*; by this arrangement the hearth-bottom is kept cool. The side walls above the hearth are protected within by cast-iron plates, (*figs.* 1285 and 1286). Hot blast is used, and there is one iron water tuyère *i*, nearly semicircular in section, which passes through a thick cast-iron plate set in one of the side plates *g*. The narrow end projects over the side of the hearth $\frac{3}{4}$ inch, and the axis is inclined at an angle of about 10° with the horizon. As the charcoal is confined round and above the tuyère, the plate *g* is exposed to great heat, and consequently destruction; it is made very thick, and may be readily replaced when required. In front of the hearth is a table or platform of cast iron *h*, resting on the ends of cast-iron standards. This table is essential for the necessary manipulations. The arrangement for heating and conveying the blast to the tuyère is represented at *k*, *k'* *k''*. The heating apparatus consists merely of a siphon-pipe of cast iron, set horizontally and exposed to the waste gases of the furnace. There is a throttle valve at *k* for stopping and regulating the blast; the nozzle end of the blast-pipe may be raised or lowered at will by a telescope sliding piece, and may be turned in any direction by means of the union joint below *k* (*fig.* 1286). The waste gases escape partially through the square opening *l*; at *m* is a cast-iron plate, on which pigs or blooms are laid so as to become heated; at *n* is an opening through which an iron bar may be introduced to move the objects on the plate *m*, or clean the arched passage leading from this part to the stack *o*, to which, at the

1285



1286



bottom, is often attached a large chamber destined to intercept sparks. There is an ash-pit *p*, from which the ashes may be removed through an opening at p^1, which is closed with a cast-iron door.

All being in working order, and the ball obtained in the previous heat removed, charcoal-dust is put on the fore-side, and the hearth is spread with clean charcoal. The pig-iron, which is in plates 2 inches or 3 inches thick, and has been previously heated on the plate in the flue, is transferred to the hearth, the charge being 200 lbs. Fresh charcoal is added and the blast turned on, when, in about half an hour, the metal will have completely melted down, and in dropping through the blast from the tuyère, have become partially oxidised; by the action of the oxide of iron thus formed, and of the basic silicate of protoxide of iron remaining in the hearth at the close of the last operation upon the molten pig-iron, the latter is decarburized to a considerable extent, and, in consequence, becomes less fusible and more pasty. After perfect fusion of the metal, the refining process begins; this consists in incessantly breaking up the metal with an iron bar, and carrying towards the tuyère the raw portions, which being more highly carburised and more fusible than the rest, always run down to the bottom and there harden. The metal, which has thus more or less solidified, is broken up and submitted to the action of the blast, until all is sufficiently refined; this operation lasts about half an hour. Subsequently, all the metal is brought up to the top of the hearth, and again melted down with a lively heat to form the ball, fresh charges being thrown into the hearth, and the unmelted portions being kept up at intervals with an iron bar to prevent their adhering to the ball before having been melted. The ball is then taken out and hammered into a prismatic shape, which is cut into pieces to be welded in another fire. The whole process lasts from 1¼ to 1½ hour.

The blast is frequently used at a temperature of 100° C., and at a pressure of 2½ inches of mercury.

The cut-up pieces to be drawn out under the hammer are welded and heated in hearths much resembling in size and construction the charcoal finery itself, or in an Ekman's furnace, now extensively used for this purpose.

The quality of the iron is tried in various ways: as, first, by raising a bar by one end, with the two hands over one's head, and bringing it forcibly down to strike across a narrow anvil at its centre of percussion, or one-third from the outer extremity of the bar; after which it may be bent backwards and forwards at the place of percussion several times; 2, a heavy bar may be laid obliquely over props near its end, and struck strongly with a hammer with a narrow pane, so as to curve it in opposite directions; or while heated to redness, they may be kneaded backwards and forwards at the same spot, on the edge of the anvil. This is a severe trial, which the hoop L, Swedish iron, bears surprisingly, emitting as it is hammered a phosphoric odour, peculiar to it and to the bar iron of Ulverstone, which also resembles it in furnishing a good steel. The forging of a horse-shoe is reckoned a good criterion of the quality of iron. Its freedom from flaws is detected by the above modes; and its linear strength may be determined by suspending a scale to the lower end of a hard-drawn wire, of a given size, and adding weights till the wire breaks. The treatises of Barlow, Tredgold, Hodgkinson, and Fairbairn may be consulted with advantage on the methods of proving the strength of different kinds of iron in a great variety of circumstances.

Dry Assay of Iron-ores.—The object of a *dry assay* of an iron ore is to ascertain by an experiment on a small scale the amount of iron which the ore should yield when smelted on the large scale in the blast-furnace. For this purpose the metal must be deoxidised, and such a temperature produced to melt the metal and the earths associated with it in the ore, so that the former may be obtained in a dense button at the bottom of the crucible, and the latter in a lighter glass or slag above it. Such a temperature can only be obtained in a wind furnace connected with a chimney at least 30 feet in height, and when made expressly for assaying the furnace, is generally built of such a size that four assays may be made at the same time, viz., about 14 inches square, and 2 feet in depth from the under side of the cover to the moveable bars of iron which form the grate. In order that the substances associated with the iron in the ore should form a fusible compound, it is usually requisite to add a flux, the nature of which will depend upon the character of the ore under examination. Berthier divides iron-ore into five classes: 1. The almost pure oxides, such as the *magnetic oxide, oligistic iron,* and the *hæmatites*; 2. Ores containing silica, but free or nearly so from any other admixture; 3. Ores containing silica and various bases, but little or no lime; 4. Ores containing one or more bases, such as *lime, magnesia, alumina, oxide of manganese, oxide of titanium, oxide of tantalum, oxide of chromium,* or *oxide of tungsten,* but *little* or no *silica;* 5. Ores containing *silica, lime,* and *another base,* and which are fusible alone. Ores of the first class may be reduced without any flux, but it is always better to employ one, as it greatly facilitates the formation of the button; borax may be used, or better, a fusible earthy silicate, such as ordinary flint-glass. Ores of the second class require some base to serve as a flux, such as carbonate of soda, a mixture of carbonate of lime and clay, or of carbonate of lime and dolomite. Ores of the third class are mixed with carbonate of lime in the proportion of from one half to three-fourths of the weight of the foreign matter present in the ore. Ores of the fourth class require a flux of silica in the form of pounded quartz, and generally also some lime; the manganesian spathic ores which belong to this class may be assayed with the adddition of silica alone, but the magnesian spathic ores require lime. Ores of the fifth class require no flux.

Method of conducting the assay.—One hundred grains of the ore finely pulverised and passed through a silk sieve are well mixed with the flux, and the mixture introduced into the smooth concavity made in the centre of a crucible that has been lined with charcoal; the lining of the crucible is effected by partially filling it with coarsely-powdered and slightly-damped charcoal or *brasque*, which is then rammed into a solid form by the use of a light wooden pestle. The mingled ore and flux must be covered with charcoal. The crucible thus filled is closed with an earthen lid luted on with fire-clay; and it is then set on its base in the air-furnace. The heat should be very slowly raised, the damper remaining closed during the first half-hour. In this way the water of the damp charcoal exhales slowly, and the deoxidation of the ore is completed before the fusion begins; if the heat were too high at first the luting would probably split, and moreover, the slag formed would dissolve some oxide of iron, which would be lost to the button, and thus give an erroneous result. After half an hour the damper is gradually opened, and the furnace being filled with fresh coke, the temperature is raised progressively to a white heat, at which pitch it must be maintained for a quarter of an hour; the damper is then closed, and the furnace is allowed to cool. As soon as the temperature is sufficiently reduced, the crucible is removed and opened over a sheet of brown paper; the *brasque* is carefully removed, and the button of cast iron taken out and weighed. If the experiment has been entirely successful the iron will be found at the bottom of the crucible in a small rounded button, and the slag will be entirely free from any adhering metallic globules, and will resemble in appearance green bottle-glass; should, however, the slag contain small metallic particles, the experiment is not necessarily a failure, as they may generally be removed by washing and the magnet. But if on breaking the crucible, the reduced metal should be found in a partially melted state, and not collected into a distinct mass, it indicates either too low a temperature or an improper selection of fluxes, and the experiment must be repeated. The iron obtained is not chemically pure, but contains carbon, and if the ore is manganiferous, manganese; the result is therefore somewhat too high, though indicating with sufficient exactness for all manufacturing purposes the richness of the ore assayed.

Humid Assay of Iron-ores.—The quantitative determination of the various substances that occur in iron-ores, demands on the part of the operator a considerable amount of skill and patience, and can only be profitably undertaken by those who have acquired in the laboratory a thorough acquaintance with analytical operations. As, however, much attention has of late years been bestowed on the composition of iron-ores, and as certain elements, viz. *manganese*, *sulphur*, and *phosphorus*, are frequently present, which very considerably affect their commercial value, we deem it right to give a detailed account of the operations to be performed in order to arrive at an accurate knowledge of the composition of an ore.

Taking for illustration a specimen of the most complicated composition, the substances besides iron to be looked for, and estimated, are *water* (*hygroscopic* and *combined*), *organic matter*, *sulphur* (as *sulphuric acid*, and as *bisulphide of iron*), *phosphoric acid*, *carbonic acid*, *silicic acid*, *oxide of manganese*, *alumina*, *lime*, and *alkalis; lead*, *tin*, *copper*, and *arsenic*, are also occasionally met with; these metals are sought for when a suspicion of their presence is entertained, by a special operation on a large quantity of ore.

Too great care cannot be bestowed on the *sampling* of ores intended for analysis; to expend so much time and labour on an isolated specimen (unless for a special object) is worse than useless; the sample operated upon should be selected from a large heap, which should be thoroughly gone over, and several dozen pieces taken from different parts; these should be coarsely powdered and mixed, and about half a pound taken from the mass should be preserved in a well-corked bottle for examition.

1. *Determination of water* (*hygroscopic* and *combined*).—About 50 grains of the ore are dried in the water-oven till no further loss of weight is experienced; the loss indicates the hygroscopic water; the residue is introduced into a tube of hard glass, to which is adapted a weighed tube containing chloride of calcium; the powder is then gradually raised to a low red heat; the combined water is thereby expelled, and its amount determined by the increase in weight of the chloride of calcium tube. Some ores (the hydrated hæmatites) contain as much as 12 per cent. of combined water.

2. *Sulphuric acid and sulphur.*—From 30 to 50 grains of the ore are digested with hydrochloric acid, filtered and washed. The filtrate, concentrated if necessary by evaporation, is precipitated by great excess of chloride of barium. Every 100 parts of the sulphate of baryta produced indicate 34·37 parts of sulphuric acid. The insoluble residue on the filter is fused in a gold crucible with nitre and carbonate of

soda, the fused mass is dissolved in hydrochloric acid, evaporated to dryness, moistened with strong acid, diluted and filtered; from the filtrate the sulphuric acid is precipitated as sulphate of baryta, every 100 parts of which indicate 13·748 parts of sulphur, and 25·48 parts of bisulphide of iron.

In the analysis of hæmatites it is necessary to bear in mind that perchloride of iron is partially reduced when boiled with finely-divided iron pyrites and hydrochloric acid, sulphuric acid being formed.—*Dick.*

3. *Phosphoric acid.*—From 50 to 75 grains of the ore are digested with hydrochloric acid and filtered; the clear solution, which should not be too acid, is boiled with *sulphite of ammonia*, added gradually in small quantities till it either becomes colourless or acquires a pale green colour, indicating that the peroxide of iron originally present has been reduced to protoxide; the solution is nearly neutralised with carbonate of ammonia, excess of acetate of ammonia added, and the liquid boiled; strong solution of perchloride of iron is then added drop by drop, until the precipitate which forms has a distinct red colour; this precipitate, which contains all the phosphoric acid originally present in the ore, is collected on a filter, washed, and redissolved in hydrochloric acid, tartaric acid added, and then ammonia. From this ammoniacal solution, the phosphoric acid is finally precipitated as ammonio-phosphate of magnesia, by the addition of chloride of ammonium, sulphate of magnesia, and ammonia. The precipitate is allowed 24 hours to subside; it is then collected on a filter, and if it has a yellow colour, which is almost invariably the case, it is redissolved in hydrochloric acid, and more tartaric acid being added, it is again precipitated by ammonia: 100 parts of the ignited pyrophosphate of magnesia correspond to 64·3 parts of phosphoric acid.

Alkalis.—It was ascertained by Mr. Dick, that nearly the whole of the alkali present in an iron ore is contained in that portion which is insoluble in hydrochloric acid. The residue from about 50 grains of the ore is placed in a platinum capsule, moistened with ammonia, and exposed for several hours to the action of hydrofluoric acid gas in a closed leaden dish; it may be necessary to repeat the operation if much silica is present; it is then slowly heated to dull redness, and dissolved in dilute hydrochloric acid; the solution is mixed with excess of baryta-water and filtered; the excess of baryta is removed by carbonate of ammonia, and the solution is evaporated to dryness and ignited; the residue is redissolved in a little hot water, and a few drops of oxalate of ammonia added. If no precipitate or cloudiness occurs, it may be once more evaporated to dryness and gently ignited: the residue is chloride of potassium, 100 parts of which indicate 63 parts of potash. Should oxalate of ammonia have occasioned a precipitate, it must be filtered off, and the clear liquid evaporated. The search for potash is troublesome and lengthy; it may be altogether omitted in a technical analysis.

Determination of the remaining constituents.—25 or 30 grains of the finely-powdered ore are digested for about half an hour with strong hydrochloric acid, diluted with boiling distilled water and filtered. The residue on the filter being thoroughly washed, the solution is peroxidised, if necessary, by the addition of chlorate of potash, nearly neutralised by ammonia, boiled with excess of acetate of ammonia, and rapidly filtered while hot; the filtrate (which should be colourless) together with the washings, is received in a flask, ammonia is added, and then a few drops of bromine, and the flask closed with a cork. In a few minutes, if manganese be present, the liquid acquires a dark colour; it is allowed to remain at rest for 24 hours, then warmed, and rapidly filtered and washed; the brown substance on the filter is hydrated oxide of manganese: it loses its water by ignition, and then becomes $Mn^3 O^4$, 100 parts of which correspond to 93 parts of protoxide.

The liquid filtered from the manganese contains the *lime* and *magnesia*; the former is precipitated by oxalate of ammonia, and the oxalate of lime formed converted by ignition into carbonate, in which state it is either weighed, having been previously evaporated with carbonate of ammonia, or it is converted into sulphate by the addition of a few drops of sulphuric acid, evaporation and ignition. The lime being separated, the magnesia is thrown down as ammonio-magnesian phosphate by phosphate of soda and ammonia, and after standing for 24 hours it is collected on a filter, washed with cold ammonia-water, dried, ignited, and weighed; 100 parts of carbonate of lime correspond to 56·0 of lime; 100 parts of sulphate of lime to 40·1 of lime, and 100 parts of pyrophosphate of magnesia to 35·7 of magnesia.

The red precipitate collected on the filter after the boiling with acetate of ammonia, consists of the basic acetates of *iron* and *alumina*, together with the *phosphoric acid.* It is dissolved in a small quantity of hydrochloric acid, and then boiled in a silver or platinum basin with considerable excess of pure caustic potash; the alumina (with the phosphoric acid) is hereby dissolved, the insoluble portion is allowed to subside, and the clearer liquor is then decanted, after which the residue is thrown on a filter and washed; the filtrate and washings are supersaturated with hydrochloric acid, nearly neutralised with ammonia, and the alumina finally precipitated by carbonate of ammonia. From the weight of the ignited precipitate, the corresponding amount of phosphoric acid determined by a separate operation is to be deducted, and the remainder is calculated as *alumina.* The residue left after digesting the ore with hydrochloric acid, consists principally of *silica*, but it may also contain *alumina*, *peroxide of iron*, *lime*, *magnesia*, and *potash*. For practical purposes it is rarely necessary to submit it to minute examination; should such be desired, it must be dried, ignited, and weighed, then fused in a platinum crucible with four times its weight of mixed alkaline carbonates, the fused mass dissolved in dilute hydrochloric acid, and evaporated to dryness, the residue moistened with strong hydrochloric acid, and after standing at rest for some hours, digested with hot water, filtered, and the *silica* on the filter ignited and weighed. The *alumina*, *lime*, *oxide of iron*, and *magnesia* in the filtrate are separated from each other according to the instructions given above; the *potash* is estimated by a distinct process.

Carbonic acid.—This acid, which constitutes a considerable part of the weight of that large and important class of ores the *clay ironstones*, is estimated by noting the loss sustained after adding to a weighed portion of the ore sulphuric acid, and thus evolving the gas; or more roughly, by the loss sustained in the entire analysis. Another method is to fuse 20 or 25 grains of the ore with 60 or 80 grains of dry borax, and noting the loss, which consists of water and carbonic acid; by deducting the water obtained in a previous experiment, the quantity of carbonic acid is obtained. This method, however, can scarcely be recommended, on account of the corrosion of the crucible, though the results are very accurate.

Determination of the iron.—This is performed on a separate portion of the ore, either by the volumetric method of Marguerite, or by that of Dr. Penny: both give very exact results. Marguerite's method is based on the reciprocal action of the salts of protoxide of iron and permanganate of potash, whereby a quantity of the latter is decomposed exactly proportionate to the quantity of iron. The ore (about 10 or 15 grains) is dissolved in hydrochloric acid, and the metal brought to the minimum of oxidation by treating the solution with *sulphite of soda* (or better, *sulphite of ammonia*), and boiling to expel the excess of sulphurous acid; the solution of permanganate of potash is then cautiously added drop by drop, until the pink colour appears, and the number of divisions of the burette required for the purpose accurately noted. The solution should be considerably diluted, and there must be a sufficient quantity of free acid present to keep in solution the peroxide of iron formed and also the oxide of manganese. The whole of the iron must be at the *minimum* of oxidation, and the excess of sulphurous acid must be completely expelled; if the latter precaution be neglected an erroneous result will be obtained, as the sulphurous acid will itself take oxygen from the permanganic acid, and thus react in the same manner as iron.

To prepare the permanganate of potash, 7 parts of chlorate of potassa, 10 parts of hydrate of potassa, and 8 parts of peroxide of manganese are intimately mixed. The manganese must be in the finest possible powder, and the potash having been dissolved in water, is mixed with the other substances, dried, and the whole heated to very dull redness for an hour. The fused mass is digested with water, so as to obtain as concentrated a solution as possible, and dilute nitric acid added till the colour becomes of a beautiful violet; it is afterwards filtered through asbestos. The solution must be defended from the contact of organic matter, and kept in a glass-stoppered bottle. If the solution be evaporated, it yields beautiful red acicular crystals: it is better to employ the crystals in the preparation of the test-liquor, as the solution keeps much better when no *manganate* is present. To prepare the normal or test-liquor, a certain quantity, say 15 grains, of pianoforte wire are dissolved in pure hydrochloric acid; after the disengagement of hydrogen has ceased, and the solution is complete, the liquor is diluted with about a pint of water, and accurately divided by measurement into two equal parts, the number of burette divisions of the solution of permanganate required to produce in each the pink colour is accurately noted; and this number is then employed to reduce into weight the result of the analysis of an ore. A useful normal liquor is made by dissolving 100 grains of the crystallised permanganate in 10,000 grains of water.

Penny's method is based on the reciprocal action of chromic acid and protoxide of iron, whereby a transference of oxygen takes place, the protoxide of iron becoming converted into peroxide, and the chromic acid into sesquioxide of chromium. The process is conducted as follows:—A convenient quantity of the specimen is reduced to coarse powder, and one half at least of this is still further pulverised until it is no longer gritty between the fingers. The test solution of bichromate of potash is next prepared: 44·4 grains of this salt in fine powder are weighed out, and put into a burette graduated into 100 equal parts, and warm distilled water is afterwards poured in until the instrument is filled to 0. The palm of the hand is then securely placed on the top, and the contents agitated by repeatedly inverting the instrument until the salt is dissolved and the solution rendered of uniform density throughout. Each division of the solution thus prepared contains 0·444 grain of bichromate, which Dr. Penny ascertained to correspond to half a grain of metallic iron. The bichromate must be pure, and should be thoroughly dried by being heated to incipient fusion. 100 grains of the pulverised iron-stone are now introduced into a Florence flask with 1½ oz. by measure of strong hydrochloric acid and ½ oz. of distilled water. Heat is cautiously applied and the mixture occasionally agitated until the effervescence caused by the escape of carbonic acid ceases, the heat is then increased, and the mixture made to boil, and kept at moderate ebullition for ten minutes or a quarter of an hour. About 6 oz. of water are next added and mixed with the contents of the flask, and the whole filtered into an evaporating basin. The flask is rinsed several times with water, to remove all adhering solution, and the residue on the filter is well washed. Several small portions of a weak solution of *red* prussiate of potash (containing 1 part of salt to 40 water) are now dropped upon a white porcelain slab, which is conveniently placed for testing the solution in the basin during the next operation. The prepared solution of bichromate of potash in the burette is then added very cautiously to the solution of iron, which must be repeatedly stirred, and as soon as it assumes a dark greenish shade it should be occasionally tested with the red prussiate of potash. This may be easily done by taking out a small quantity on the end of a glass rod, and mixing it with a drop of the solution on the porcelain slab. When it is noticed that the last drop communicates a distinct blue tinge, the operation is terminated; the burette is allowed to drain for a few minutes, and the number of divisions of the test-liquor consumed read off. This number multiplied by 2 gives the amount of iron per cent. The necessary calculation for ascertaining the corresponding quantity of protoxide is obvious. If the specimen should contain iron in the form of peroxide, the hydrochloric solution is deoxidised as before by sulphite of ammonia. The presence of peroxide of iron in an ore is easily detected by dissolving 30 or 40 grains in hydrochloric acid, diluting with water, and testing a portion of the solution with *sulphocyanide of potassium.* If a decided blood-red colour is produced, peroxide of iron is present. If it be desired to ascertain the relative proportions of peroxide and protoxide of iron in an ore, two operations must be performed: one on a quantity of the ore that has been dissolved in hydrochloric acid in a stout stoppered bottle; and another on a second quantity that has been dissolved as usual, and then deoxidised by sulphite of ammonia or by metallic zinc. It is advisable to employ the solution of bichromate much weaker than proposed by Dr. Penny, and to employ a burette graduated to cubic millimeters. A good strength is 1 grain of metallic iron = 10 cubic centimeters of bichromate-solution.

Metals precipitable by sulphuretted hydrogen from the hydrochloric solution.—A weighed portion of the ore, varying from 200 to 2,000 grains, is digested for a considerable time in hydrochloric acid: the solution is filtered off; the iron in the filtrate reduced when necessary by sulphite of ammonia, and a current of sulphuretted hydrogen passed through it. A small quantity of sulphur which is always suspended is collected on a filter and thoroughly washed; it is then incinerated at as low a temperature as possible. The residue (if any) is mixed with carbonate of soda, and heated upon charcoal before the blowpipe: any globules of metal that may be obtained are dissolved and tested.

Analysis of Pig-iron.—The most important constituents to be determined are *carbon* (combined and uncombined), *silicon*, *sulphur*, *phosphorus*; those of less consequence, or of more rare occurrence, are *manganese*, *arsenic*, *copper*, *zinc*, *chromium*, *titanium*, *cobalt*, *nickel*, *tin*, *aluminium*, *calcium*, *magnesium*, and the *metals of the alkalis.*

1. *Determination of the total amount of carbon.*—About 100 grains of the iron in small pieces are digested, at a moderate temperature, in 6-oz. measure of a solution formed by dissolving 6 oz. of crystallised sulphate of copper, and 4 oz. of common salt in 20 oz. of water and 2 oz. of concentrated hydrochloric acid. The action is allowed to proceed until all, or nearly all the iron is dissolved. *Carbon* and *copper* are left insoluble; these are collected on a filter, and washed first with dilute hydrochloric acid (to prevent the precipitation of subchloride of copper), then with water, then with dilute caustic potash, and finally with boiling water. The mixed carbon and copper are dried on the filter, from which they are easily removed by a knife-blade, and are mixed with oxide of copper, and burned in a combustion tube in the usual way, with a current of air, or, still better, of oxygen. The carbonic acid is collected in Liebig's apparatus, from which the amount of carbon is calculated.

2. *Graphite*, or *uncombined carbon.*—A weighed portion of the finely-divided iron (filings or borings may be used) is digested with moderately strong hydrochloric acid, the combined carbon is evolved with combination with hydrogen, while the graphite is left undissolved. It is collected on a filter, washed, and then boiled with a solu-

tion of caustic potash, specific gravity 1·27, in a silver dish; the silica which existed in the iron in the form of silicon is hereby dissolved; the clear caustic solution is drawn off by a pipe or siphon, and the black residue repeatedly washed; it is dried at as high a temperature as it will bear, and weighed; it is then heated to redness in a current of air, until the whole of the carbon is burnt off. A reddish residue generally remains, which is weighed, and the weight deducted from that of original black residue, the difference gives the amount of graphite.

3. *Silicon.*—The amount of this element is determined by evaporating to dryness a hydrochloric solution of a weighed quantity of the metal: the dry residue is redigested with hydrochloric acid, diluted with water, boiled and filtered; the insoluble matter on the filter is washed, dried, and ignited, until the whole of the carbon is boiled off; it is then weighed, after which it is digested with solution of potash, and the residue, if any, washed, dried, ignited, and weighed: the difference between the two weights gives the amount of silicic acid, 100 parts of which indicate 47 parts of *silicon.*

4. *Phosphorus.*—A weighed portion of the metal is digested in nitro-hydrochloric acid, evaporated to dryness, and the residue redigested with hydrochloric acid. The solution is treated precisely as recommended for the determination of phosphoric acid in ores; every 100 parts of pyrophosphate of magnesia indicate 28·56 parts of phosphorus.

5. *Sulphur.*—In *grey* iron this element is very conveniently and accurately estimated by allowing the gas evolved by the action of hydrochloric acid on a weighed quantity (about 100 grains) of the metal, in filings or borings, to pass slowly through a solution of acetate of lead acidified by acetic acid: the sulphur, the whole of which takes the form of sulphuretted hydrogen, enters into combination with the lead, forming a black precipitate of sulphide of lead, which is collected, washed, and converted into sulphate of lead by digesting it with nitric acid, evaporating to dryness, and gently igniting: 100 parts sulphate of lead = 10·55 sulphur. The most minute quantity of sulphur in iron is detected by this process. If, however, crude *white* iron is under examination, this method does not give satisfactory results, on account of the difficulty with which it is acted upon by hydrochloric acid; it is better, therefore, to treat the metal with nitro-hydrochloric acid, evaporate to dryness, re-digest with hydrochloric acid, and then precipitate the filtered solution with great excess of chloride of barium; or the finely-divided metal may be fused in a gold crucible, with an equal weight of pure nitrate of soda, and twice its weight of pure alkaline carbonates; the fused mass is extracted with water acidified with hydrochloric acid, and finally precipitated by chloride of barium.

Manganese.—This metal is determined by the process described for its estimation in ores; the iron must exist in the solution in the form of sesquioxide.

Arsenic and Copper.—The nitro-hydrochloric solution of the metal is evaporated to dryness, re-digested with hydrochloric acid, and filtered. The iron in the clear solution is reduced to protochloride by boiling with a sufficient quantity of sulphite of ammonia, the solution is boiled till it has lost all smell of sulphurous acid. It is then saturated with sulphuretted hydrogen, and allowed to stand for 24 hours in a closed vessel, the excess of gas is boiled off, and the precipitate, if any, collected on a small filter and well washed; it is digested with monosulphide of potassium, which dissolves the sulphide of arsenic, leaving the sulphide of copper untouched; the latter is decomposed by heating with nitric acid, and the presence of copper evinced by the addition of ammonia, which produces a fine blue colour; the sulphide of arsenic is precipitated from its solution in sulphide of potassium by dilute sulphuric acid; it may be redissolved in *aqua regia*, and the nitric acid having been expelled by evaporation, the arsenic may be reduced in Marsh's apparatus.

Nickel and Cobalt.—These metals, if present, will be found in the solution from which the copper and arsenic have been precipitated by sulphuretted hydrogen. The solution is peroxidised, and the sesquioxide of iron precipitated by slight excess of carbonate of baryta, after which the nickel and cobalt are precipitated by sulphide of ammonium.

Chromium and Vanadium.—These metals, which should be looked for in the carbonaceous residue obtained by dissolving a large quantity of the iron in dilute hydrochloric or sulphuric acid, are detected as follows (*Wöhler*):—The ignited residue is intimately mixed with one-third of its weight of nitre, and exposed for an hour in a crucible to a gentle ignition. When cool, the mass is powdered and boiled with water. The filtered solution is gradually mixed, and well stirred with nitric acid, taking care that it may still remain slightly alkaline, and that no nitrous acid is liberated which would reduce the vanadic and chromic acids. The solution is then mixed with an excess of solution of chloride of barium as long as any precipitate is produced. The precipitate, which consists of vanadate and chromate of baryta, is decomposed with slight excess of dilute sulphuric acid, and filtered. The filtrate is neutralised with ammonia, concentrated by evaporation, and a fragment of chloride of ammonium placed in it. In proportion as the solution becomes saturated with chloride of ammonium, *vanadate* of ammonia is deposited as a white or yellow crystalline powder. To test for chromium only, the mass after fusion with nitre is extracted with water, and then boiled with carbonate of ammonia; the solution is neutralised with acetic acid, and then acetate of lead added; the production of a yellow precipitate indicates *chromic* acid.

Aluminium.—This metal is best separated from iron, by first reducing the latter to the state of protoxide by sulphite of ammonia, then neutralising with carbonate of soda, and afterwards boiling with excess of caustic potash, until the precipitate is black and pulverulent. The solution is then filtered off, slightly acidulated with hydrochloric acid, and the alumina precipitated by sulphide of ammonium.

Calcium and Magnesium.—These metals are found in the solution from which the iron and aluminium have been separated; they both exist probably (together with the aluminium) in the cast iron in the form of *slag*, and are best detected in the black residue which is left on dissolving the iron in dilute sulphuric or hydrochloric acid. After digesting this residue with caustic potash, and burning away the graphite, a small quantity of a red powder is left, which is composed of silicic acid, oxide of iron, alumina, lime, and magnesia; if 500 grains of cast iron are operated upon, a sufficient quantity of insoluble residue will be obtained for a quantitative determination of its constituents.

Eggertz's Methods.—Eggertz's method of determining combined carbon in iron or steel depends upon the discoloration produced by carbon in solution of pernitrate of iron, which, under ordinary circumstances, is colourless, or at most of a greenish tint. The standard series of colours is made by dissolving quantities weighing 1 diagramme of steel of known composition in nitric acid at low temperature, and diluting with water to a standard volume. The solutions which give different shades of brown are preserved in glass tubes.

A similar weight of the steel to be examined is dissolved in pure nitric acid under the conditions observed in making the standard series. The solution is decanted from the residue, poured into a burette of the same diameter as the tubes containing the standard series, and diluted with water until it matches one of the tints. The amount of carbon is then found by calculation from the relative volumes of the solutions of steel, with a medium amount of carbon, say 0·8 per cent., gives a yellowish green solution; a very hard variety, with 1·5 per cent. brownish red; and the softest, with 0·40 per cent., only a slight greenish tinge.

The Swedish classification of Bessemer steel by numbers, based upon the percentage of carbon determined by the above process, is as follows:—

No. 1 contains 2 per cent.; No. 1·5, 1·75; No. 2, 1·5; and so on, up to No. 4·5, with only 0·25 per cent., below which point the scale is not extended.

The following determinations of carbon in various kinds of iron and steel made in Sweden are by Eggertz:—

Softest Swedish Bessemer iron contains	0·08	per cent. of carbon
Soft steel	0·75	„ „
Best quality of cast steel	1·4 to 1·5	„
Natural forge steel	0·99 „ 2·44	„
Cement steel	0·5 „ 1·90	„
Cast steel	0·36 „ 1·9	„
Hardest welding cast steel	1·80	„
Malleable cast iron	0·88 „ 1·52	„
Draw plate steel	3·30	„

The following modification of this process is adopted at Seraing, in Belgium, for the determination of carbon in mild Bessemer steel. Two samples, each weighing 0·2 gramme, of the ingot to be tested are taken; one being in the state of filings, and the other of borings. These are treated with 20 cubic centimeters of nitric acid, of specific gravity 1·2; the solution being effected in a water-bath at 80°. For the test-standard the same weight of two different samples, of the hardest steel made in the works, whose carbon has been already determined and containing 0·61 and 0·63 per cent. respectively, are dissolved up in the same manner. The whole of the four solutions are then brought down to one tint by adding water to the darker ones, care being taken to conduct the operation in tubes of exactly the same diameter. The amount of carbon can then be computed from the volume of the solutions. If the difference in the results given by the two samples does not exceed 4·03 per cent., the arithmetical mean between them is adopted as the true amount; but should it be larger, the operation is repeated.

In order to obviate the necessity of making standard solutions for every set of determinations, different coloured liquids have been employed with a view of obtaining a permanent scale of colours. Among these may be mentioned caramel, or burnt sugar, which gives various shades of yellow and brown, but alters very quickly; and partially decomposed solution of indigo in sulphuric acid, which is said to keep its characteristic colour without alteration for a considerable time. Another recommended by Hetman consists of a mixture of bichromate of potash and nitrate of cobalt. In most cases, however, the direct system of comparison with solutions obtained of steel of known composition is preferred.

Silicon.—The determination of silicon in iron and steel is a matter of some difficulty, as the mere weighing of the ignited insoluble residue from the hydrochloric acid solution and calculation of the silica found, as silicon, depends upon the assumption that the iron is free from silicates, which is often contrary to the fact, especially in malleable iron, which may contain a notable amount of intermingled slag that has not been perfectly expelled in the welding, and exists as a mechanical impurity, having no relation whatever to the real composition of the metal. This defective interpretation of the ultimate analyses is probably the cause of the contradictory statements current as to the amount of silicon that may be present beneficially in metallic iron. Eggertz has introduced a method of determining silicon in the presence of slags, which is based upon the fact that when iron is slowly acted on by bromine, or a solution of iodine, it dissolves, and the silicon set free is converted into silica, which is completely soluble in a boiling solution of carbonate of soda, while that in combination in the slag, if any be present, is not acted upon. The same method may be employed with cast iron, as blast-furnace slag, which sometimes occurs in it as a mechanical impurity is not sensibly acted upon either by iodine, bromine, or carbonate of soda.

The process is conducted as follows:—Three grammes or ·45 grain of iron in the state of filings or borings sufficiently small to pass through a sieve with meshes $\frac{1}{70}$th of an inch in diameter, is treated with five times its weight of iodine, in a volume of fifteen cubic centimeters of water contained in a beaker of about six or seven times that capacity. Water that has been boiled to free it from air is used, and the operation must be performed at as low a temperature as possible, in order to permit oxidation of the iron by the air; it is usual, therefore, to keep the beaker cool by the use of ice. When the iron is completely dissolved, the solution is increased to three times the original volume by the addition of very cold water, in order to prevent the separation of basic salts of iron, and is well stirred and left to settle. The lighter scales of graphitic carbon remain in suspension, but are poured off with the bulk of the liquid into a filter 2 inches in diameter, with only about one-tenth of the original quantity of the insoluble residue which forms a heavy powder at the bottom of the beaker. A few drops of hydrochloric acid are added, and the liquid stirred with a glass rod; if this produces a disengagement of gas, the whole of the iron is not dissolved, and a little iodine and carbonate of soda are added in order to complete the solution. The acidified water must be poured quickly on the filter in order to prevent the decomposition of the slag. When the whole of the residue is transferred to the filter it is washed with cold water until the whole of the iron is found to be completely removed when tested by a solution of ferrocyanide of potassium. The filtrate is evaporated to dryness with the addition of hydrochloric acid in order to recover any small amount of silica that may have gone into solution with the iron. The original residue, which may contain graphite silica and slag, is transferred without drying into a large platinum crucible, and after concentrating the waste water to 6 cubic centimeters, a saturated solution of carbonate of soda is added, and the crucible is heated for one hour in a water-bath, the liquid being stirred from time to time with a platinum spatula in order to dissolve any lumps in the insoluble residue. The solution is then carefully poured from the insoluble mass in the crucible on to a small filter, and a fresh quantity of carbonate-of-soda solution is added and boiled for another hour when the whole contents of the crucible are thrown upon the filter and washed. The alkaline solution of silica is acidified with hydrochloric acid added to that containing the iron, and evaporated to dryness in a water-bath. This operation is repeated with the addition of fresh acid until the silica is perfectly freed from iron, when it is filtered, dried, ignited, and weighed, as often as may be necessary to ensure its complete purity which must be further tested by heating it with hydrochloric acid. When 3 grammes of iron are treated 0·016 gramme of silica corresponds to 0·001 gramme of silicon. The insoluble residue from the carbonate-of-soda solution may contain graphite, slag, oxide of iron, and titanic acid. There is no way of distinguishing the amount of oxide of iron present as such, in addition to that in combination with silica, except by assuming the composition of the slag to be constant, which is not the case.

Eggertz found by the use of this process that the amount of silicon in good bar iron may vary from 0·01 to 0·10 per cent.; but in two samples of Krupp's cast steel it was as high as 0·30 per cent. Slag has been found usually in mere traces in cast steel, but in one instance it mounted to 0·2 per cent. Malleable iron, however, contained much more. In wire iron from a charcoal hearth 0·38 p. c. was found, in armour-plates from 0·75 to 3·00 p. c., and in a rail as much as from 4·00 to 5·00 p. c.—H.B.

The following Statistics of some of the principal iron-producing countries will be of interest and use :—

Pig-iron Manufacture of Great Britain.

	1868	1869	1870	1871	1872
	tons	tons	tons	tons	tons
ENGLAND :					
Northumberland	17,495	15,942	33,623	34,165	38,766
Durham	499,592	658,506	676,964	759,244	760,172
Yorkshire, North Riding .	699,494	766,410	916,970	1,029,885	1,122,114
„ West Riding . .	100,050	105,765	77,717	114,549	148,636
Derbyshire	159,312	188,353	179,772	270,485	283,375
Lancashire	325,367	436,662	422,728	520,359	524,041
Cumberland	116,864	129,107	255,178	336,569	440,574
Shropshire	145,154	197,443	112,300	129,467	133,046
North Staffordshire . .	229,913	231,913	303,378	268,300	275,925
South „ . .	532,234	569,562	588,240	725,716	673,470
Northamptonshire . . .	35,584	41,500	43,166	60,512	59,424
Lincolnshire	33,999	33,786	31,690	30,122	36,989
Gloucestershire . .	75,847	81,306	93,601	99,997	46,226
Wiltshire					44,255
Somersetshire . . .					7,600
WALES :					
Denbighshire	37,046	38,530	42,695	41,893	41,464
Flintshire					13,228
Glamorganshire	399,291	348,485	478,423	510,087	465,603
Brecknockshire	29,000	32,201	30,000	30,086	30,000
„ anthracite .	38,143	27,909	28,500	34,761	25,000
Monmouthshire	427,821	392,387	452,450	470,982	481,342
SCOTLAND :					
Six counties	1,068,000	1,150,000	1,206,000	1,160,000	1,090,000
Total . . .	4,970,206	5,445,757	5,963,515	6,627,179	6,741,929

List of Works having Bessemer Converters in Great Britain in 1872.

No.	Name and Situation of Works	Number of converters	Capacity of converters
			tons
1	Henry Bessemer and Co., Sheffield.	2 2	3 5
2	John Brown and Co., *Limited*, Sheffield	2 2 2	10 7 6
3	Charles Cammell and Co., *Limited*, Sheffield . . .	8	5
4	Weardale Iron Co., Towlaw	4	2½
5	The Glasgow Bessemer Steel Co., *Limited*, Atlas Works, Glasgow	2	3
6	Samuel Fox and Co., Stockbridge Works, Deepcar . .	2 2	5 3
7	Lloyds, Foster, and Co., Old Park, Wednesbury . .	4	3
8	Bolton Iron and Steel Works, Bolton	4	6
9	London and North-Western Railway, Crewe . . .	2	3
10	Lancashire Steel Co., Gorton	2 2	5 6
11	Mersey Steel and Iron Works, Liverpool . . .	4	5
12	Manchester Steel and Railway Plant Co., Gibraltar Works, Newton Heath, Manchester	4	3
13	Barrow Hæmatite Steel Co., Barrow . . .	18	6
14	The Dowlais Iron Co., Dowlais	6	5
15	Ebbw Vale Co., Ebbw Vale	7	6
16	Bessemer Steel and Ordnance Co., *Limited*, Greenwich .	2	5
17	West Cumberland, Workington	4	7½
18	Phœnix Iron Co., Rotherham.	2	3½
19	Carnforth Hæmatite Iron Co., *Limited*	2	6

IMPORTS AND EXPORTS OF IRON.

Iron imported in 1863 *and* 1864.

	1863			1864		
	Tons	Declared value	Computed value	Tons	Declared value	Computed value
		£	£		£	£
Iron-ore . . .	62,167	46,486	...	74,163	57,424	...
Pig-iron . . .	11,269	...	66,306	20,126	...	120,756
Chromate of iron .	10,471	87,370	...	12,325	49,082	...
Unwrought iron, in bars	46,635	...	527,748	53,918	...	625,283

Imports according to the Returns of the Board of Trade, for the three years ending 1872.

Description of iron, &c.	Quantities			Declared value		
	1870	1871	1872	1870	1871	1872
	tons	tons	tons	£	£	£
Iron in bars, unwrought . .	74,179	74,538	82,888	667,345	707,771	918,808
Steel, unwrought . . .	31,718	22,302	39,602	667,174	682,457	1,170,201
Iron or steel, wrought or manufactured	8·070	7,569	7,557	113,368	83,046	109,494
Total . .	113,967	104,409	130,047	1,447,887	1,473,274	2,198,403

Exports of Pig and Puddled Iron.—The value of the exports of pig and puddled iron from the United Kingdom has greatly increased of late years:—

Description of iron, &c.	Quantities			Declared value		
	1870	1871	1872	1870	1871	1872
	tons	tons	tons	£	£	£
Iron:						
Pig	753,339	1,057,458	1,332,726	2,229,045	3,229,408	6,721,966
Bar, angle, &c. . . .	321,455	349,084	313,876	2,615,245	2,921,777	3,635,558
Railroad	1,059,392	981,197	947,548	8,756,552	8,084,819	10,237,768
Wire (not telegraph) . .	23,447	26,200	33,605	439,546	446,159	674,743
Tin plates	99,851	119,605	118,234	2,362,872	2,900,625	3,812,744
Hoops, sheets, and boiler plates	181,484	200,337	208,423	2,119,629	2,399,203	3,430,970
Cast and wrought of all sorts	233,721	243,298	269,614	3,334,372	3,588,364	4,778,758
Old, for re-manufacture . .	106,749	139,812	108,181	501,536	672,696	661,931
Steel, unwrought . . .	34,962	39,189	45,285	1,103,936	1,198,428	1,491,240
Steel and iron combined . .	11,175	13,038	11,130	575,357	682,855	614,842
Total . .	2,825,575	3,169,219	3,388,622	24,038,090	26,124,138	46,060,547

Iron Production in the United States.

Year	Anthracite iron	Charcoal iron	Bituminous coal and coke iron	Total
	tons	tons	tons	tons
1854	339,432	342,298	54,485	736,218
1855	381,866	329,922	63,390	784,178
1856	443,133	370,470	69,554	883,137
1857	390,385	330,321	77,451	798,157
1858	361,430	285,313	58,351	705,094
1859	471,745	284,041	84,841	840,627
1860	591,211	278,331	122,228	919,770
1861	409,229	195,278	127,037	731,545
1862	470,315	186,660	130,687	787,662
1863	577,638	212,005	157,961	947,604
1864	684,018	241,853	210,125	1,135,996

Year	Anthracite iron	Charcoal iron	Bituminous coal and coke iron	Total
tons	tons	tons	tons	tons
1865	479,558	262,342	189,682	931,582
1866	749,367	332,580	268,396	1,350,343
1867	798,638	341,361	318,647	1,461,626
1868	893,000	370,000	340,000	1,603,000
1869	971,150	392,150	553,341	1,916,641
1870	930,000	365,000	570,000	1,865,000
1871	956,608	385,000	570,000	1,912,608
1872	1,367,812	505,587[1]	959,671[2]	2,830,070
1873	1,249,673	524,127[3]	921,634[4]	2,695,435

[1] Includes 224 tons of peat pig-iron.

[2] Includes 37,246 tons of mixed anthracite and coke pig-iron.

[3] Includes 1,600 tons of mixed peat and charcoal pig-iron, and 1,778 tons of mixed charcoal and bituminous coal pig-iron.

[4] Includes 48,000 tons of mixed anthracite and coke pig-iron.

Rolling Mills in the United States in which Bessemer steel rails are rolled, and the number of converters in each mill.

	Number	Capacity
		tons
Rensselaer Ironworks. John A. Griswold and Co., Troy	2 1	5 1½
Cambria Ironworks. Cambria Iron Co., Johnstown	2	5
Pennsylvania Steel Works. Pennsylvania Steel Co., Harrisburg	2	5
(4–5 ton converters in course of erection)		
Newburg Rolling Mill. Cleveland Rolling Mill Co., Newburg	4	5
North Chicago Rolling Mill Co., Chicago	2	5
Union Rolling Mill Co., Chicago	2	5
Bethelem Rolling Mill.[1] Bethelem Iron Co., Bethelem	2	5
Joliet Iron and Steel Works.[2] Joliet Iron and Steel Co., Joliet	2	5
Edgar Thomson Steel Works.[3] Pittsburg	2	5

[1] These works made their first blow on Saturday, October 4, 1873; and their first steel rail on Saturday, October 11, 1873.

[2] These works made their first blow January 26, 1873, and their first steel rail March 15, 1873.

[3] In course of erection.

Production of Rolling Mills in United States.

	1856	1872	1873
Merchant bar and rod	...	500,000	400,000
Sheet and plate	...	200,000	250,000
Hoop	...	30,000	30,000
Nails and spikes	...	175,000	200,000
Axles, &c	...	95,000	100,000
Iron and steel rails	...	941,992	850,000
Total of rolled iron, nett tons	498,001	1,941,992	1,830,000

Below is a summary in nett tons of the ascertained and estimated production of iron and steel in the United States in 1872 *and* 1873.

	1872	1873
Iron and steel rails	941,992	850,000
Other rolled and hammered iron	1,000,000	980,000
Forges and bloomeries	58,000	50,000
Cast steel	32,000	28,000
Bessemer steel	100,000	140,000
Siemens-Martin steel	3,000	3,500
Pig-iron	2,830,070	2,695,434

The following Table from a well-written paper, which appeared in the 'New York Times,' with especial reference to the meeting of the American Iron Trade Convention, is of considerable value, as showing the progress of the iron trade since 1849 :—

Year	Total rails made in United States	Total rails imported	Total consumption of iron and steel rails	Miles of railroad built in each year
	tons of 2,000 lbs.	tons of 2,000 lbs.	tons of 2,000 lbs.	
1849	24,318	69,163	93,481	1,369
1850	44,083	159,080	203,163	1,656
1851	50,603	226,350	276,953	1,961
1852	62,478	294,750	357,228	1,926
1853	87,864	358,794	446,658	2,452
1854	108,019	339,439	437,755	1,360
1855	138,674	153,019	291,693	1,654
1856	180,018	186,594	366,612	3,643
1857	161,918	215,166	377,084	2,486
1858	163,612	90,894	254,606	2,365
1859	194,154	83,958	279,412	1,821
1860	205,038	146,610	351,648	1,846
1861	187,818	89,388	277,206	651
1862	213,912	10,186	224,098	863
1863	275,768	20,506	296,274	1,050
1864	335,369	142,457	477,826	738
1865	356,292	63,327	419,619	1,177
1866	430,778	117,878	548,656	1,742
1867	462,108	184,840	646,948	2,449
1868	506,714	300,160	806,874	2,979
1869	593,586	336,500	930,086	5,118
1870	620,000	472,403	1,092,403	5,525
1871	775,733	566,202	1,341,935	7,779
1872	941,992	530,850	1,472,842	6,427

The German Steel Trade.

Year	Number of works	Quantity of steel produced in centners	Value in thalers	Number of workmen employed
1860	167	506,241	4,038,424	3,915
1861	167	685,177	5,492,112	4,938
1862	185	818,327	6,181,921	6,161
1863	177	1,085,009	7,733,613	9,482
1864	170	1,427,179	11,940,473	10,756
1865	169	1,990,861	16,299,105	12,947
1866	215	2,288,674	19,312,838	12,821
1867	214	2,451,826	19,415,933	12,201
1868	203	2,456,736	19,215,301	11,415
1869	206	3,226,387	22,659,803	12,578

Iron made in the districts of Bonn and Dortmund.

	1860	1864	1871
	tons	tons	tons
Pig-iron	270,000	500,000	722,000
Pig steel iron . .	4,359	33,735	141,589
Castings	58,650	84,926	133,764
Bar and roller . .	192,031	283,893	491,204
Iron plate . . .	33,312	59,007	85,739
Wire	17,500	26,694	48,200
Steel	18,415	61,553	174,063
	593,237	1,049,808	1,816,756

Iron of all kinds produced in the German Customs Union.

	centners	lbs. avoirdupois
1866	110,231	20,933,070
1867	„	22,272,126
1868	„	25,286,944
1869	„	28,260,518
1870	„	27,822,471

IRON-BARK TREES. Certain species of *Eucalyptus*, valued for their wood, are so called in Australia.

IRON LIQUOR. A solution of acetate of iron, used as a mordant by calico-printers.

IRON, METEORIC. See Aerolites.

IRON MINERALS *not used as Ores:—*

1. *Iron-Alum* or *Halotrichite.*—A sulphate of alumina and sulphate of iron, with 43 per cent. of water. Occurs in fibrous silky masses of a yellow colour. It is found in the exhausted beds of Hurlet and Campsie, near Paisley. It occurs in Persia, where it is used for making ink; and in Rhenish Bavaria.

2. *Iron-Apatite* or *Zwieselite.*—A phosphate of iron and manganese. See Zwieselite.

3. *Iron, Arsenate of; Pharmacosiderite; Würfelerz.*—This mineral, which is rather rare, occurs in great beauty associated with copper-ores in Cornwall; it has an olive-green colour, and is rather brittle. Its composition, according to the analysis of Berzelius, is: arsenic acid, 40·4; peroxide of iron, 28·1; protoxide of iron, 12·6; water, 18·9.

4. *Iron, Chromate of; Octohedral Chrome-ore; Chromite.*—This mineral occurs in serpentine, or in crystalline limestone, near this rock. It was first discovered at Gassin, in the Var department in France, and is found in Saxony, Silesia, Bohemia, and Styria; also in Norway; and in large masses in the Ural, near Katharinenberg. It has been found also in great abundance in Unst and Fetlar, in the Zetlands; the mineral is opaque, with a semi-metallic lustre; colour, iron or brownish-black, streak yellowish to reddish-brown. A specimen from Norway, analysed by Von Kobell, gave protoxide of iron, 25·66; sesquioxide of chromium, 54·08; alumina, 9·02; magnesia, 5·36; and silica, 4·83: another specimen, from Chester in Pennsylvania, yielded to Sebert protoxide of iron, 36·00; oxide of chromium, 39·61; alumina, 13·0; and silica, 10·60. It is used in the preparation of various pigments. For the treatment and use of the ore, see Chrome.

5. *Iron-Chrysolite* or *Fayalite.*—An anhydrous silicate of iron, in which iron is replaced by manganese. It is found in the Mourne mountains.

6. *Iron-Flint.*—A quartz containing 5 per cent. of oxide of iron. It is found in St. Just and Marazion in Cornwall.

7. *Iron-Natrolite.*—A variety of natrolite, in which one-fourth of the alumina is replaced by peroxide of iron. See Natrolite.

8. *Iron, Oxalate of; Oxalite; Humboldtine.*—This mineral, which occurs in the form of capillary crystals in the brown coal at Kolosoruk, near Bilin, in Bohemia, and at Gross Almerode in Hessia, is composed, according to the analysis of Rammelsberg, of oxalic acid, 42·40; protoxide of iron, 41·13; and water, 16·47.

9. *Iron, Phosphate of; Blue Iron; Vivianite.*—The colour of this mineral varies from indigo-blue to blackish green; the earthy variety is white in the beds, but changes blue on exposure to the air; heated in a closed tube it yields much water, intumesces, and becomes spotted with grey and red; before the blowpipe on charcoal, it fuses to a grey, shining, metallic granule. Transparent indigo-coloured crystals of phosphate of iron, sometimes an inch in diameter and two inches long, occur, with iron and copper pyrites, in the tin and copper veins at St. Agnes in Cornwall. It was first found in the auriferous veins at Vöröspatak in Transylvania; the earthy varieties are very common in Cornwall, Styria, North America, Greenland, and New Zealand. A specimen from St. Agnes, Cornwall, gave Stromeyer—phosphoric acid, 31·18; protoxide of iron, 41·23; water, 27·48: and another from New Jersey yielded to Rammelsberg—phosphoric acid, 28·40; protoxide of iron, 33·91; peroxide of iron, 12·06. It is sometimes used as a pigment, but is of no use as a smelting ore.

10. *Iron, Pitchy Hydrate of; Pitticite; Eisensinter.*—This mineral occurs in many old mines, especially those near Freiberg; and also at Schneeberg in Saxony, Pleiss in Silesia, and Bleistadt in Bohemia. It is probably a product of the decomposition of mispickel: its composition, according to the analysis by Stromeyer, being $Fe^{2}O^{3}$, $AsO^{5} + Fe^{2}O^{3},SO^{3} + 15HO = 35$ peroxide of iron, 26 arsenic acid, 9 sulphuric acid, and 30 water. According to *Freiesleben*, it is first fluid, and gradually separates in a solid

form. In external characters it agrees with *Diadochite*, which is $Fe^2O^3,2PO^5 + 4Fe^2O^3,SO^3 + 32HO$, according to Gmelin from Plattner's analysis, viz. peroxide of iron, 36·69; phosphoric acid, 14·81; sulphuric acid, 15·15; water, 30·35.

11. *Iron, Sulphate of; Native Green Vitriol.*—This is formed by the oxidation of sulphide of iron.

12. *Iron, Tungstate of; Wolfram,*—occurs, with tin ore, forming fine crystals, at Altenberg in Saxony; at Schlackenwald in Bohemia; and in France, in quartz veins. In Cornwall, especially near Redruth, it renders the tin ore valueless until it is removed. An analysis of a specimen from Cumberland gave Berzelius, tungstic acid, 78·77; protoxide of iron, 18·32; protoxide of manganese, 6·22; and silica, 1·25. See Wolfram.

13. *Yenite or Lievrite; Hisingerite or Thraulite; Nontronite; Pinguite;* and *Chloropal*, are rather rare minerals, composed of peroxide of iron and silica. The first may contain about 12 per cent. of lime; the others are destitute of this earth, but contain from 10 to 20 per cent. of water: the amount of silica in these minerals ranges between 30 and 40 per cent.

14. *Iserite.*—A variety of titaniferous iron-ore.

IRON PYRITES. Native bisulphide of iron. See Pyrites.

IRON, TELLURIC. A name given to native iron, of which there is no proof of meteoric origin. See Iron.

IRON WOOD. A name given to several of the hard, heavy, and close-grained woods. The *Metrosideros vera*, or true iron-wood, is a native of Java and Amboyna. The Chinese use it for making anchors. The *Metrosideros polymorpha* is the wood of which the Sandwich Islanders make their clubs. *Metrosideros buxifolia* is a New Zealand shrub, the wood of which is called in the country *Aki* or *Lignum vitæ.* Other varieties of these woods are produced by the *Sideroxylon*, found in many tropical countries. In North America the timber of the *Ostrya virginica* is known as iron-wood.

ISINGLASS (*Colle de Poisson*, Fr.; *Hausenblase*, Ger.) Ichthyocolla, ἰχθυόκολλα, from ἰχθὺς, a fish, and κόλλα, glue, or Fish-glue, is a whitish, dry, tough, semi-transparent substance, twisted into different shapes, often in the form of a lyre, and consisting of membranes rolled together. Good isinglass is unchangeable in the air, has a leathery aspect, and a mawkish taste, nearly insipid; when steeped in cold water it swells, softens, and separates in membranous laminæ. At the boiling heat it dissolves in water, and the solution, on cooling, forms a white jelly, which is semi-transparent, soluble in weak acids, but is precipitated from them by alkalis. It is gelatine, nearly pure; and if not brittle, like other glue, this depends on its fibrous and elastic texture. The whitest and finest is preferred in commerce. Isinglass is prepared from the air-bladders of sturgeons, and especially the great sturgeon, the *Accipenser huso*, which is fished on the shores of the Caspian Sea, and in the rivers flowing into it, for the sake chiefly of its swimming-bladder. It is also obtained from the *A. stellatus* and the *A. Güldenstadtii.* At Hamburg, German isinglass is made from the swimming-bladder of the common sturgeon (*A. sturio*). We are informed that in Russia the *Siluris glanis* is also caught for the purpose of obtaining isinglass.

The preparations of isinglass in Russia, and particularly at Astracan, consists in steeping the swimming-bladders in water, removing carefully their external coat, and the blood which often covers them, putting them into a hempen bag, squeezing them, softening them between the hands, and twisting them into small cylinders. They are ready for the market immediately after being dried in the sun, and whitened with the fumes of burning sulphur.

In some districts of Moldavia another process is followed. The skin, the stomach, the intestines, and the swimming-bladder of the sturgeon are cut in small pieces, steeped in cold water, and then gently boiled. The jelly thus obtained is spread in thin layers to dry, when it assumes the appearance of parchment. This being softened in a little water, then rolled into cylinders, or extended into plates, constitutes an inferior article.

The swimming-bladder of the cod, and many other fishes, also furnishes a species of isinglass, but it is much more membranous, and less soluble than that of the sturgeon.

The properties of isinglass are the same as those of gelatine or pure glue; and its uses are very numerous. It is employed in considerable quantities to clarify ale, wine, liqueurs, and coffee. As an article of food to the luxurious in the preparation of creams and jellies, it is in great request. Four parts of it convert 100 of water into a tremulous jelly, which is employed to enrich many soups and sauces. It is used along with gum as a dressing to give lustre to ribbons and other silk articles.

It is by covering thin silk with a coat of isinglass that court-plaster is made. A solution of isinglass covered with carmine forms an excellent injection-liquor to the anatomist. M. Rochen has made another pretty application of isinglass. He plunges into a limpid solution of it, made by means of a water-bath, sheets of wire-gauze set in window- or lamp-frames, which, when cold, have the appearance of glass, and answer instead of it for shades and other purposes. If one dip be not sufficient to make a proper transparent plate of isinglass, several may be given in succession, allowing each film to harden in the interval between the dips. The outer surface should be varnished to protect it from damp air. These panes of gelatine are now generally used for lamps instead of horn, in the maritime arsenals of France. See GELATINE.

Isinglass is known commercially as *Leaf Isinglass, Long and Short Staple,* and *Book Isinglass.* Dr. Royle speaks of the *Samovey leaf, book,* and *long and short staple,* in his paper *On the Production of Isinglass along the coasts of India, with a Notice of its Fisheries.* We receive from the Brazils, *Pipe, Lump,* and *Honeycomb Isinglass.*

Our *Importations* of isinglass in 1871 and 1872 were :—

	1871		1872	
	Cwts.	£	Cwts.	£
From Russia	558	12,518	737	18,276
„ Germany	186	4,678	179	3,942
„ Egypt	87	3,305	...	...
„ Brazil	883	14,356	767	12,197
„ British India . . .	525	5,460	443	4,857
„ Straits Settlements . .	1,703	26,897	729	10,755
„ British Guiana . . .	95	1,645	...	...
„ Other countries . .	229	3,330	431	6,812
Total . . .	4,266	72,189	3,286	56,839

ISOMERISM, from ἴσος, equal, and μέρος, part. Identity of elements and proportions with variations in physical properties. Thus, oil of turpentine and oil of citron are isomeric, each having the composition $C^{20}H^{16}$ ($\mathbf{C^{10}H^{16}}$). The study of the laws of atomic constitution is one of the most important within the range of physico-chemical science, and, beyomd all others, it demands the highest powers of the philosopher, united with the mechanical care of the microscopic analyst. The tendency of science leads to the conviction that many of the bodies which we now regard as distinct elements are only isomeric; and such groups as chlorine, iodine, bromine, and fluorine, as sulphur, selenium, and boron, and as carbon and silicon, may, with the advance of our knowledge, be shown to be modified conditions of one form of matter.

Several groups of isomeric bodies may be recognised, namely: *isomeric,* properly so called, when compounds have the same percentage composition, and exhibit analogous decompositions; *metameric,* when compounds have the same percentage composition, but do not exhibit analogous decompositions under similar circumstances; and *polymeric,* when compounds have the same percentage composition, but different molecular weights.

The subject of Isomerism is fully treated in Watts's 'Dictionary of Chemistry.'

ISOMORPHISM. Mitscherlich was the first to observe that many groups of substances, simple or compound, having an *analogous* constitution, crystallise in forms of the same crystalline character, or differ but little in their angles. Thus, *alumina, red oxide of iron,* and *sesquioxide of chrome* crystallise in forms of the rhombohedral system.

Carbonate of lime, carbonate of magnesia, carbonate of iron, and *carbonate of manganese,* are also isomorphous forms, belonging to the rhombohedral system.

Sulphate of baryta, sulphate of strontia, and *sulphate of lead,* crystallise in isomorphic forms of the prismatic system.

For a development of this law, consult Brooke and Miller's 'Mineralogy,' Dana's 'System of Mineralogy,' and 'Watts's Dictionary of Chemistry.'

ISOPURPURATE OF AMMONIUM. See MUREXIDE.

ITABIRITE. A rock composed of specular iron ore (micaceous iron) and quartz. It takes its name from Itabira, in Brazil, where it often accompanies the occurrence of gold.

ITACOLUMITE. A fine-grained schistose rock, composed mainly of quartz, with more or less mica, talc, or chlorite. Some varieties are flexible when in thin slabs. By many geologists it is regarded as a metamorphic sandstone. It derives its name from Mount Itacolumi, in Brazil. Diamonds have occasionally been found imbedded in itacolumite; and it has been supposed that some connection exists between the distribution of this rock and the occurrence of diamonds.

IVORY. (*Ivoire*, Fr.; *Elfenbein*, Ger.) The osseous matter of the tusks and teeth of the elephant, and of the tusks of the hippopotamus, and the horn of the narwhal.

Formerly, the name ivory was given to the main substance of the teeth of all animals; but it is now, by the best anatomists and physiologists, restricted to that modification of *dentine*, or tooth-substance, which, in transverse sections or fractures, shows lines of different colours, or striæ, proceeding in the arc of a circle, and forming by their decussation minute or curvilinear lozenge-shaped spaces. By this character, which is presented by even the smallest portion of an elephant's tusk, in transverse section or fracture, true ivory may be distinguished from every other kind of tooth-substance, and from every counterfeit, whether derived from tooth or bone. It is a character—this engine-turned decussatory appearance—which is as characteristic of fossil as of recent ivory. Although, however, no other teeth except those of the elephant present the characteristics of true ivory, there are teeth in many other species of animals which, from their large size, and the density of their principal substance, are useful in the arts for purposes analogous to those for which true ivory is used; and some of those dental tissues, such as those of the large tusks of the hippopotamus, are more serviceable for certain purposes, especially in the manufacture of artificial teeth by the dentist, than any other kind of tooth-substance. The utility of teeth in commerce and in the arts, depends chiefly on a peculiar modification in their laws of growth. For the most part teeth, as in our own frames, having attained a certain size and shape, cease to grow. They are incapable of renewing the waste to which they are liable through daily use, and when worn away, or affected by decay, they perish. Teeth of this kind are said to be of limited growth; but there are other teeth, such as the front teeth of the rat, rabbit, and all the rodent tribe, the tusks of the boar and hippopotamus, the long descending canine tusks of the walrus, the still longer spiral horn-like tusk of the narwhal, and the ivory tusks of the elephant, which are endowed with the property of perpetual growth; that is, they grow as long as the animal lives.

'In teeth of unlimited growth, fresh pulp, fresh capsule, and in some instances also fresh enamel organs are formed, and added to the pre-existing constituents of the tooth matrix, in proportion as those are calcified or converted into tooth-substance; and as fast as the ivory and enamel may be worn away from the summit of such a tooth, will ivory and enamel be formed at its base, and thus the growth of the tooth is uninterrupted. The ratio of the addition of the formative principles is at first greater than the ratio of abrasion, and the tooth not only grows, but increases in size. When, however, the animal has attained its full growth, the tooth, for the most part, is reproduced without increase of size, or, at most, augments only in length, and that in cases where its summit is not perpetually worn down by being opposed to that of an opposite tooth.'

With respect to the distribution of the elephant, the same authority (*Professor Owen*) has the following remarks:—

'In the present creation, elephants are restricted to the African and Asiatic continents. The African elephant, as is well known, is a distinct species from the Asiatic one; and some of the Asiatic elephants of the larger islands of the Indian Archipelago, as those of Sumatra, if not specifically distinct from the elephants of Continental Asia, form, at all events, a strongly marked variety. With reference, however, to the commercial relations of ivory, it is chiefly worthy of notice that in the Asiatic elephants, tusks of a size which gives them the value of ivory in commerce are peculiar to the males, whilst in the African elephants both males and females afford good-sized tusks, although there is a sexual difference of size in this species, those of the males being the largest. In former times, and, as it would seem, before man existed to avail himself of this beautiful animal substance for use or ornament, the large animals furnishing true ivory, proboscidian quadrupeds, as they are termed, from their peculiar prehensile nasal appendage, were much more widely spread over the globe, and existed in far greater numbers than in the present day, more numerous in individuals, more numerous in species, manifesting so great diversities in the conformation of their grinding teeth, as to have led the naturalist and the palæontologist to divide them into two genera, called *Elephas* and *Mastodon*. A true elephant roamed in countless herds over the temperate and northern parts of Europe, Asia, and America. This was the creature called by the Russians Mammoth; it was warmly clad with both hair and fur, as became an animal deriving sustenance from the leaves and branches of trees, which grow as high as the 65th degree of north latitude. Some of the ivory of commerce is, or used to be, derived from the tusks of this extinct species.'

The ivory of the tusks of the African elephant is most esteemed by the manufacturer for its density and whiteness.

The outside of the tusk of the elephant is covered by the cortical part, which is softer and less compact than the interior substance, with the exception of the brown plate that sometimes lines the interior cavity. The hardest, toughest, whitest, and most translucent ivory has the preference in the market; for many purposes the horn of the narwhal being considered the best. The horn of the narwhal is sometimes 10 feet long.

The ivory of the hippopotamus is preferred by dentists; it is much harder than that of the elephant, its colour is a purer white, and it is almost free from grain. The teeth of the walrus, sometimes called the sea-cow, which hang perpendicularly from the upper jaw, are also used for the same purpose. The masticating teeth of some of the large animals are occasionally used as ivory; those of the spermaceti whale are of a flattened oval section, and resemble ivory in section, but they are dark coloured towards the centre, and surrounded by an oval band of white ivory.

Ivory has been used for ornamental works from the earliest periods. Phidias is stated to have been famous for his works made in ivory combined with gold, and described as the *Torentic Art*. The ivory statues of the ancients appear to have been formed upon centres, or cores of wood covered with plates of ivory.

In our days ivory has been extensively employed by the miniature painter; it is used by the turner in the manufacture of numberless useful and ornamental articles; the cutler makes his best knife-handles from it; and the philosophical-instrument maker constructs his scales from this material.

When ivory shows cracks or fissures in its substance, and when a splinter broken off has a dull aspect, it is reckoned of inferior value. Ivory is distinguishable from bone by its peculiar semi-transparent rhombohedral net-work, which may be readily seen in slips of ivory cut transversely.

Ivory is very apt to take a yellow-brown tint by exposure to air. It may be whitened or bleached by rubbing it first with pounded pumice-stone and water, then placing it moist under a glass shade luted to the sole at the bottom, and exposing it to sunshine. The sunbeams without the shade would be apt to occasion fissures in the ivory. The moist rubbing and exposure may be repeated several times.

For etching ivory a ground made by the following recipe is to be applied to the polished surface:—Take of pure white wax, and transparent tears of mastic, each 1 oz.; asphalt, ½ oz. The mastic and asphalt having been separately reduced to fine powder, and the wax being melted in an earthenware vessel over the fire, the mastic is to be first slowly strewed in and dissolved by stirring; and then the asphalt in like manner. This compound is to be poured out into lukewarm water, well kneaded, as it cools, by the hand, into rolls or balls about 1 inch in diameter. These should be kept wrapped round with taffety. If white resin be substituted for the mastic, cheaper composition will be obtained, which answers nearly as well; 2 oz. asphalt, 1 oz. resin, ½ oz. white wax, being good proportions. Callot's etching ground is made by dissolving with heat 4 oz. of mastic in 4 oz. of very fine linseed oil; filtering the varnish through a rag, and bottling it for use.

Either of these grounds being applied to the ivory, the figured design is to be traced through it in the usual way, a ledge of wax is to be applied, and the surface is to be then covered with strong sulphuric acid. The effect comes better out with the aid of a little heat; and by replacing the acid, as it becomes dilute by absorption of moisture, with concentrated oil of vitriol. Simple wax may be employed, instead of the copperplate engraver's ground; and strong muriatic acid, instead of sulphuric. If an acid solution of silver or gold be used for etching, the design will become purple or black on exposure to sunshine. The wax may be washed away oil of turpentine. Acid nitrate of silver affords the easiest means of tracing permanent black lines upon ivory.

Ivory may be dyed by using the following prescriptions:—

1. *Black dye.*—If the ivory be laid for several hours in a dilute solution of neutral nitrate of pure silver, with access of light, it will assume a black colour, having a slightly green cast. A still finer and deeper black may be obtained by boiling the ivory for some time in a strained decoction of logwood, and then steeping it in a solution of red sulphate or red acetate of iron.

2. *Blue dye.*—When ivory is kept immersed for a longer or shorter time in a dilute solution of sulphate of indigo (partly saturated with potash), it assumes a blue tint of greater or less intensity.

3. *Green dye.*—This is given by dipping blued ivory for a little while in solution of nitro-muriate of tin, and then in a hot decoction of fustic.

4. *Yellow dye*—is given by impregnating the ivory first with the above tin mordant, and then digesting it with heat in a strained decoction of fustic. The colour passes into orange, if some Brazil wood has been mixed with the fustic. A very fine unchangeable yellow may be communicated to ivory by steeping it 18 or 24 hours in a strong solution of the neutral chromate of potash, and then plunging it for some time in a boiling hot solution of acetate of lead.

5. *Red dye*—may be given by imbuing the ivory first with the tin mordant, then plunging it in a bath of Brazil wood, cochineal, or a mixture of the two. Lac-dye may be used with still more advantage, to produce a scarlet tint. If the scarlet ivory be plunged for a little in a solution of potash, it will become cherry-red.

6. *Violet dye*—is given in the logwood-bath, to ivory previously mordanted for a short time with solution of tin. When the bath becomes exhausted, it imparts a lilac hue. Violet ivory is changed to purple-red by steeping it a little while in water containing a few drops of nitro-muriatic acid.

With regard to dyeing ivory, it may in general be observed that the colours penetrate better before the surface is polished than afterwards. Should any dark spots appear, they may be cleared up by rubbing them with chalk; after which the ivory should be dyed once more to produce perfect uniformity of shade. On taking it out of the boiling hot dye-bath, it out to be immediately plunged into cold water, to prevent the chance of fissures being caused by the heat.

Aniline dyes.—Any of these colours give a fine and permanent colour to ivory.

If the borings and chips of the ivory-turner, called ivory dust, be boiled in water, a kind of fine size is obtained.

Ivory made flexible.—Ivory articles may be made flexible and semi-transparent, by immersing them in a solution of pure phosphoric acid of sp. gr. 1·130, and leaving them there till they lose their opacity; they are then to be taken out, washed with water, and dried with a soft cloth; it thus becomes as flexible as leather. It hardens on exposure to dry air, but resumes its pliancy when immersed in hot water. Necks of children's sucking-bottles are thus made.

The following account of the methods of preparing this material, we extract from Holtzapffel's 'Mechanical Manipulation':—

'On account of the great value of ivory, it requires considerable judgment to be employed in its preparation, from three conditions observable in the form of the tusk: first, its being curved in the direction of its length; secondly, hollow for about half that extent, and gradually taper from the solid state to the thin feather edge at the root; and thirdly, elliptical or irregular in section. These three peculiarities give economy, as the only waste should be that arising from the passage of the thin blade of the saw: even the outside strips of the rind, called spills, are employed for the handles of penknives, and many other little objects; the scraps are burned in retorts for the manufacture of ivory black, employed for making ink for copper-plate printers, and other uses, and the clean sawdust and shavings are sometimes used for making jelly.

'The methods of dividing the tooth, either into rectangular pieces or those of a circular figure required for turning, are alike in their early stages, until the lathe is resorted to. The ivory saw is stretched in a steel frame to keep it very tense; the blade generally measures from fifteen to thirty inches long, from one and a half to three inches wide, and about the fortieth of an inch thick; the teeth are rather coarse, namely, about five or six to the inch, and they are sloped a little forward, that is, between the angle of the common hand-saw tooth and the cross-cut saw. The instrument should be very sharp, and but slightly set; it requires to be guided very correctly in entering, and with no more pressure than the weight of its own frame, and is commonly lubricated with a little lard, tallow, or other solid fat.

'The cutter begins generally at the hollow, and having fixed that extremity parallel with the vice, with the curvature upwards, he saws off that piece which is too thin for his purpose, and then two or three parallel pieces to the lengths of some particular works, for which the thickness of the tooth at that part is most suitable; he will then saw off one very wedge-form piece, and afterwards two or three more parallel blocks.

'In setting out the length of every section, he is guided by the gradually-increasing thickness of the tooth; having before him the patterns or images of his various works, he will in all cases employ the hollow for the thickest work it will make. As the tooth approaches the solid form, the consideration upon this score gradually ceases, and then the blocks are cut off to any required measure, with only a general reference to the distribution of the *heel*, or the excess arising from the curved nature of the tooth, the cuts being in general directed as nearly as may be to the imaginary centre of curvature. The greater waste occurs in cutting up very long pieces, owing to the difference between the straight line and the curve of the tooth, on which account the blocks are rarely cut more than five or six inches long, unless for some specific object.'

Mr. P. L. Simmonds has given the following as the weights of large elephants' tusks :—

	lbs.
Mr. Gordon Cumming had one weighing	173
Mr. Cawood, of Graham's Town, had a pair weighing . . .	330
From Camaroon, shipped to Liverpool	164
A tusk imported at Bristol	147
At the Great Exhibition of 1851, tusk	162

IVORY BLACK (*Noir d'ivoire*, Fr.; *Kohle von Elfenbein*, Ger.) is prepared from ivory-dust, by calcination, in the very same way as is described under Bone Black. The calcined matter being ground and levigated on a porphyry slab affords a beautiful velvety black, much used in copperplate printing.

IVORY, FICTILE, is plaster-of-Paris which has been made to absorb, after drying, melted spermaceti, by capillary action; or it may be prepared according to Mr. Franchi's process as follows :—Plaster and colouring matter are employed in the proportions of a pound of superfine plaster-of-Paris to half an ounce of Italian yellow ochre. They are intimately mixed by passing them through a fine silk sieve, and a plaster cast is made in the usual way. It is first allowed to dry in the open air, and is then carefully heated in an oven; the plaster cast, when thoroughly dry, is soaked for a quarter of an hour in a bath containing equal parts of white wax, spermaceti, and stearine, heated just a little beyond the melting-point. The cast on removal is set on edge, that the superfluous composition may drain off; and before it cools, the surface is brushed, with a brush like that known by house-painters as a sash tool, to remove any wax which may have settled in the crevices; and finally when the plaster is quite cold, its surface is polished by rubbing it with a tuft of cotton wool.

IVORY NUT or *Vegetable Ivory*. This substance is the hardened albumen of the seeds of a species of palm known as the *Phytelephas macrocarpa*. The palm grows in the low valleys of the Peruvian Andes. The seeds are known in commerce as *Corosso nuts*, and are enclosed in large capsular fruit, somewhat resembling a negro's head, and hence locally termed *Cabeza de Negro*. The albumen has a structure somewhat resembling that of ivory; but it more nearly resembles white wax. The ivory nut is occasionally used by the turner for small ornamental objects, but not for any important work.

END OF THE SECOND VOLUME.

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