FOREST PRODUCTS
THEIR MANUFACTURE AND USE

NELSON COURTLANDT BROWN

Photograph by U. S. Forest Service. *Frontispiece.*

Approximately 5,000 railway cross ties piled for transport to market. About 140,000,000 cross ties are annually required for new track and replacements by our railways. The consumption of forest products such as cross ties, pulpwood, fuel wood, cooperage stock, poles, posts, veneers, distillation wood, etc., constitutes a greater demand on our American forests than lumber itself.

FOREST PRODUCTS
THEIR MANUFACTURE AND USE

EMBRACING THE PRINCIPAL COMMERCIAL FEATURES IN THE PRODUCTION, MANUFACTURE, AND UTILIZATION OF THE MOST IMPORTANT FOREST PRODUCTS OTHER THAN LUMBER, IN THE UNITED STATES

BY

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TO
A. V. B.

PREFACE

THE object of this book is to present to the student or reader the chief commercial features involved in the manufacture and use of the principal forest products except lumber, and to serve as a reference book for those interested in them. The treatment of the subjects, therefore, has necessarily been very brief. A book could easily be written on each subject, but the curricula of the professional forest schools usually do not provide for extensive study and investigation of each product, unless special and separate courses are offered in such subjects as pulp and papermaking.

It is impossible to include in a book of this kind some of the wood-using industries which are closely associated with lumber and its uses, such as the furniture industry, ship building and car construction, etc., because they belong in a separate category. The important problem has been to determine what to include in a book of this kind, and to discriminate and to exclude some of the less essential material. It is planned to make this volume a brief treatise preliminary to a more complete and exhaustive work or group of books to be written at some later date.

Although there are more or less statistical data available on some of the industries treated in this book, there has been very little written in American forestry literature on the principles and practices followed in the production of materials other than lumber. From the viewpoint of invested capital, and value of products,they are of greater importance, collectively, than lumber.

The values and conditions used in this book are largely given for the period prior to the participation of this country in the war. This has been deemed advisable because of the wholly abnormal and somewhat temporary conditions brought about by the war itself.

Much of the data has been obtained as the result of personal investigation and inspection of operations in the South, the Lake States, the Northeast, and the Far West during the past ten years. Some material has also been collected on trips during 1913, 1917, and 1918, to various European countries. Brief bibliographies are appended at the end of each chapter. These were used, to some extent, as sources of information and can be consulted for further study in each subject.

I am greatly indebted to Dr. Hugh Potter Baker and members of the faculty of the New York State College of Forestry at Syracuse and to the United States Forest Service and various individual members of its staff for a number of excellent suggestions as well as material. I am also grateful to the Bureau of Chemistry, the Census Bureau, and Bureau of Foreign and Domestic Commerce, for statistical material.

I wish to acknowledge my special gratitude to the following specialists in their respective fields for review of the various chapters: Mr. A. R. Joyce of the Joyce-Watkins Tie Co. for reviewing the text of the chapter on Cross Ties; Mr. Samuel B. Sisson of the S. B. Sisson Lumber Co., on Poles and Piling; Mr. J. C. Nellis, Assistant Secretary of the National Association of Box Manufacturers, on Boxes and Box Shooks; Mr. E. A. Brand of the Tanners' Council of the United States and Mr. Henry W. Healey, formerly of the Central Leather Co., on Tanning Materials; Mr. Thomas J. Keenan, F. C. S., Editor of *Paper*, on Wood Pulp and Paper; the editorial staff of the *India Rubber World* on Rubber, and Mr. S. J. McConnell of the Keery Chemical Co., on Hardwood Distillation. The chapter on Softwood Distillation has been reviewed and corrected by a prominent operator in the South who requests that his name be withheld from publication.

It was originally deemed advisable to include chapters on such other important materials as certain medicinal and chemical products of the forest, as well as camphor, palm oils and other foreign commodities, and to discuss the relation of the subjects treated to the present and future of forestry in this country. However, it was found that on account of the necessity for economy in space, it would not permit the inclusion of a more elaborate treatment. Many of the chapters have already been curtailed for this reason.

NELSON COURTLANDT BROWN.

JULY, 1919.

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COMMON AND SCIENTIFIC NAMES OF NATIVE AMERICAN TREES MENTIONED IN THE TEXT *

SOFTWOODS

Arborvitæ—see northern white cedar.
Cedar, eastern red or juniper (*Juniperus virginiana, L.*).
Cedar, incense (*Libocedrus decurrens, Torr.*).
Cedar, northern white or arborvitæ (*Thuya occidentalis, L.*).
Cedar, southern white (*Chamaecyparis thyoides, Britt.*).
Cedar, western red (*Thuya plicata, D. Don.*).
Cypress, southern red or bald (*Taxodium distichum, Rich.*).
Fir, balsam (*Abies balsamea, Mill.*).
Fir, Douglas (*Pseudotsuga taxifolia*—also *mucronata, Sudw.*).
Fir, noble (*Abies nobilis, Lindl.*).
Fir, red (*Abies magnifica, A. Murr.*).
Fir, white (*Abies concolor, Lindl. and Gord.*).
Hemlock, eastern (*Tsuga canadensis, Carr.*).
Hemlock, western (*Tsuga heterophylla, Sarg.*).†
Hemlock, western or mountain (*Tsuga mertensiana, Sarg.*).
Juniper—see Cedar.
Larch, eastern or tamarack (*Larix occidentalis, Nutt.*).
Larch, western (*Larix americana, Michx.*).
Pine, Cuban or slash (*Pinus heterophylla*—also *caribæa, Morelet*).
Pine, Jack (*Pinus divaricata, Du Mont de Cours*).
Pine, loblolly (*Pinus tæda, L.*).
Pine, lodgepole (*Pinus contorta, var. murrayana, Engelm.*).
Pine, longleaf (*Pinus palustris, Mill.*).
Pine, North Carolina—see shortleaf and loblolly pines; includes both.
Pine, Norway or red (*Pinus resinosa, Ait.*).
Pine, pitch (*Pinus rigida, Mill.*).
Pine, shortleaf (*Pinus echinata, Mill.*).
Pine, southern yellow—includes longleaf, shortleaf, loblolly and Cuban pines.
Pine, sugar (*Pinus lambertiana, Dougl.*).
Pine, western white or Idaho white (*Pinus monticola, D. Don.*).
Pine, western yellow or California white (*Pinus ponderosa, sarg.*).
Pine, white (*Pinus strobus, L.*).
Pine, Virginia or scrub (*Pinus virginiana, Mill.*).
Redwood (*Sequoia sempervirens, Endl.*).

* Scientific names of exotic species mentioned are generally given wherever found in the text.
† Of the two western hemlocks, this is the only one of large present commercial importance.

Spruce, black (*Picea mariana, B. S. and P.*).
Spruce, Engelmann (*Picea engelmanni, Engelm.*).
Spruce, red (*Picea rubens, Sarg.*).
Spruce, western or Sitka (*Picea sitchensis, Carr.*).
Spruce, white or cat (*Picea canadensis, B. S. and P.*).
Tamarack—see Larch.

HARDWOODS

Ash, black (*Fraxinus nigra, Marsh*).
Ash, white (*Fraxinus americana, L.*).
Aspen, large tooth (*Populus grandidentata, Michx.*).
Aspen, quaking (*Populus tremuloides, Michx.*).
Basswood or linden (*Tilia americana, L.*).
Beech (*Fagus americana, Sweet.*).
Birch, black or cherry (*Betula lenta, L.*).
Birch, red or yellow (*Betula lutea, Michx.*)*.
Box elder (*Acer negundo, L.*).
Buckeye (*Aesculus glabra, Willd.*).
Catalpa (*Catalpa speciosa, Engelm.*).
Cherry, black (*Prunus serotina, Ehrh.*).
Chestnut (*Castanea dentata, Borkh.*).
Chittam or American fustic (*Cotinus americana, Nutt.*).
Cottonwood (*Populus deltoidea, Marsh*).
Cottonwood, black or western (*Populus trichocarpa, Hook.*).
Cottonwood, southern or swamp (*Populus heterophylla, L.*)†.
Cucumber (*Magnolia acuminata, L.*).
Elm, rock or cork (*Ulmus thomasi, Sarg.*).
Elm, white (*Ulmus americana, L.*).
Gum, black (*Nyssa sylvatica, Marsh*).
Gum, red or sweet (*Liquidambar styraciflua, L.*).
Gum, tupelo (*Nyssa aquatica, Marsh*).
Hackberry (*Celtis occidentalis, L.*).
Hickory (*Hicoria spp.*).
Locust, black (*Robinia pseudocacia, L.*).
Locust, honey (*Gleditsia triacanthos, L.*).
Maple, black (*Acer nigrum, Michx.*).
Maple, mountain (*Acer spicatum, Lam.*).
Maple, Oregon (*Acer circinatum, Pursh.*).
Maple, red (*Acer rubrum, L.*).
Maple, silver or soft (*Acer saccharinum, L.*).
Maple, striped (*Acer pennsylvanicum, L.*).
Maple, sugar, rock or hard (*Acer saccharum, Marsh*).
Mesquite (*Prosopis juliflora, DC.*).
Mulberry, red (*Morus rubra, L.*).
Oak, black or yellow (*Quercus velutina, Lam.*).
Oak, bur (*Quercus macrocarpa, Michx.*).
Oak, chestnut or rock (*Quercus prinus, L.*).
Oak, overcup (*Quercus lyrata, Walt.*).

* This is the only birch of large commercial importance, and wherever the tree is referred to without naming the kind of birch, this is the one indicated.

† The principal cottonwood cut for lumber, veneers, staves, etc.

Oak, pin (*Quercus palustris, Muench.*).
Oak, post (*Quercus minor, Sarg.*).
Oak, red (*Quercus rubra, L.*).
Oak, swamp white (*Quercus platanoides, Sudw.*).
Oak, tanbark (*Quercus densiflora,* also *Pasania densiflora, Orst.*).
Oak, white (*Quercus alba, L.*).
Osage orange (*Toxylon pomiferum, Raf.*).
Palmetto, cabbage (*Sabal palmetto, R. and S.*).
Poplar, yellow or tulip (*Liriodendron tulipifera, L.*).
Popple—see Aspen.
Sassafras (*Sassafras sassafras, Karst.*).
Sumach, southern (*Rhus cotinus, L.*).
Sumach, staghorn (*Rhus hirta, Sudw.*).
Sycamore (*Platanus occidentalis, L.*).
Tupelo—see Gum, Tupelo.
Walnut, black (*Juglans nigra, L.*).
Walnut, white or butternut (*Juglans cinerea, L.*).
Willow (*Salix spp.*).

FOREST PRODUCTS

CHAPTER I

GENERAL

INTRODUCTION

In ancient times the harvesting and use of the products of the forest constituted the entire practice of forestry. Then no thought of the future was necessary and there was little discrimination as between the various species and the adaptability and suitability of each to its particular and proper uses. As the raw products of the forest became scarcer and, therefore, more valuable in conformity with the law of supply and demand, new methods were constantly devised, as a result of experimentation, to put our wood supplies to their most profitable use. As our most valuable trees became exhausted, others were required to take their places, and in spite of the rapid introduction of wood substitutes, new uses are being constantly found for wood.

Every species of wood is characterized by its individual structure, color, grain, etc., which serve to distinguish it from other species. It is these same characteristics which must be studied and investigated to determine their adaptability and value for the different wood uses. For example, longleaf pine is strong, stiff, durable and grows tall and straight and, therefore, makes an excellent construction timber; spruce has long, soft, strong and pliable fiber and is comparatively free from resin and, therefore, makes a splendid wood pulp; oak is hard, strong, durable and has a pleasing grain, so it makes an excellent furniture wood. Each kind of wood is especially useful and adaptable for certain specific arts and industries.

Altogether, shelter, next to food is the most important commodity in human economy. According to Fernow, over one-half of our population live in wooden houses and two-thirds of the population use wood for fuel. Besides wood, which constitutes a large part of the total utilitarian value of our forests, they supply the following:

Bark for tanning, medicines, mattings, etc.
Resinous products, such as turpentine, rosin, tar, pitch, etc.
Chemical products, such as wood alcohol, pyroligneous acid, charcoal, creosote, etc.
Seeds, oak and beech mast, walnuts, chestnuts, etc.
Pasture, especially in the West.
Game and fish (of great importance).
Recreation and health, summer pleasure grounds, etc.
Fruits and berries (of minor importance).
Moderation of temperatures and climate.
Regulation of the water flow, prevention of erosion, etc.

ORIGINAL FORESTS

Originally this country was endowed with greater and more varied forests than those of any other nation except Russia. The eastern forests stretched unbroken from the Atlantic Ocean to the treeless prairies of the Middle West. The Rockies and Pacific slope were densely forested except for desert plateaus and interior valleys and high mountain tops.

The original area of forest in the United States has been estimated at 850,000,000 acres. The present area is approximately 545,000,000 acres. The original stand was estimated at 5,200,000,000,000 bd. ft. The present stand is estimated to be about 2,535,000,000,000 bd. ft.

HISTORY OF LUMBER CUT

In accordance with the best available historical reports, the first sawmill erected in this country is generally attributed to Berwick, Maine, where it was erected in the year 1631. Various other mills have been reported as being erected in the old Jamestown Colony of Virginia in 1607 and another in the Plymouth Colony of Massachusetts in 1630, but these records are not as well substantiated as those regarding the sawmill at Berwick.

From the earliest days of the lumber industry in this country, Maine held first place in lumber production and developed a considerable trade with the West Indies and even with Europe in lumber, timbers and spars, etc. With the rapid development in population, and its extension westward, the lumber industry was moved in the same way. From Maine, the center of the lumber industry gradually moved to New York, which was the center of the country's lumber production in 1850. By 1860, the center of production had shifted to Pennsylvania. For several decades following 1870, and, in fact, up to 1904, the center of lumber production was in the Lake states, Michigan holding first place for over twenty years, followed by Wisconsin, which also held the leadership in lumber production for a period of almost twenty years. Within the past two decades there have been rapid changes. Lumber production has increased rapidly and the center of the industry has shifted to the southern states, and now there is once more a period of migration: this time to the Far West.

The following table visualizes the gradual development in the lumber industry from the northeast to the Lake states and then to the Far South and finally to the northwest. In the year 1890, lumber production was just beginning on a large scale in the Pacific northwest, and Washington held sixth place in the order of production by states. By 1900 it had risen to fifth place, in 1904 it occupied second place, and ever since 1905 this state has held first place.

LUMBER PRODUCTION BY STATES FROM 1850 TO 1916

1850	1860	1870	1880
New York	Pennsylvania	Michigan	Michigan
Pennsylvania	New York	Pennsylvania	Pennsylvania
Maine	Michigan	New York	Wisconsin
Ohio	Maine	Wisconsin	New York
Indiana	Ohio	Indiana	Indiana
Michigan	Indiana	Maine	Ohio
Massachusetts	Wisconsin	Ohio	Maine
Illinois	California	Missouri	Minnesota
1890	**1900**	**1910**	**1916**
Michigan	Wisconsin	Washington	Washington
Wisconsin	Michigan	Louisiana	Louisiana
Pennsylvania	Minnesota	Mississippi	Mississippi
Minnesota	Pennsylvania	Oregon	Oregon
Indiana	Washington	Wisconsin	North Carolina
Washington	Arkansas	Texas	Texas
New York	Ohio	Arkansas	Arkansas
Ohio	Indiana	North Carolina	Alabama

The great center of present production is in the South where over 15,000,000,000 bd. ft. of southern yellow pine, out of a total of about 40,000,000,000 bd. ft., or over 37 per cent of the total lumber production in the country is produced, principally in the states of Louisiana, Mississippi, North Carolina, Texas, Arkansas and Alabama in order of importance.

In the year 1899, only 1,736,570,000 bd. ft. of Douglas fir were produced, whereas in 1905, 3,000,000,000 bd. ft. were produced, and in 1916 nearly 5,500,000,000 ft. of Douglas fir were produced. The production of oak has been fairly uniform during the past few decades, but the production of white pine, formerly the leading lumber tree cut in this country, has fallen in production from over 7,742,000,000 bd. ft. in 1899 to 2,700,000,000 in 1916. Other species, such as cypress and yellow poplar, have shown a marked decrease in production during the past two decades, and other species, such as western yellow pine, red gum, birch, cedar, and maple have shown a marked increase in production.

PRESENT FOREST RESOURCES

Of the total stand of timber still uncut, about 75 per cent is in private hands and the remaining 25 per cent in Government hands. The distribution of this timber is as follows, by regions:

STAND OF TIMBER BY REGIONS[1]

	Per Cent
Pacific northwest	46.0
Southern pine region	29.1
Lake states	4.5
Other regions	20.5
Total	100.0

By species, the stand of 2,535,000,000,000 bd. ft. left standing in this country is divided as follows:

STANDING TIMBER BY SPECIES[1]

Species.	Billion Bd. Ft.
Douglas fir	525
Southern yellow pine	325
Western yellow pine	275
Redwood	100
Western cedar	160
Western hemlock	100
Lodgepole pine	90
White and Norway pine	75
Eastern hemlock	75
Western spruce	60
Eastern spruce	50
Western firs	50
Sugar pine	30
Cypress	20
Other conifers	100
Hardwoods	500
Total	2535

[1] From "The Timber Supply of the United States," by R. S. Kellogg, U. S. Forest Service Circ. 166, 1909.

RATE OF CONSUMPTION

In 1880 the annual consumption of lumber in this country was only 18,000,000,000 bd. ft.; now it is about 40,000,000,000 bd. ft. The present supply, at the present rate of consumption, but without allowing for the increase in population, will last about seventy years. (Increment in American forests is only about one-third of that in Europe, and in addition we have about 200,000,000 acres of virgin timber where decay offsets

APPROXIMATE ANNUAL CONSUMPTION OF LUMBER AND WOOD PRODUCTS IN THE UNITED STATES [1]

Products.	Amount of Product.	Equivalent in Thousand Bd. Ft.[2]	Wastage [3] in Production Thousand Cubic Feet.	Total Annual Consumption Thousand Cubic Feet.
Lumber, bd. ft.	40,000,000,000	40,000,000	6,000,000	9,333,333
Fuelwood, cords	100,000,000	50,000,000	100,000	9,100,000
Fence posts, pieces	500,000,000	2,500,000	50,000	800,000
Cross ties, pieces	150,000,000	4,950,000	350,000	762,000
Pulp wood, cords	6,000,000	3,000,000	60,000	600,000
Round mine timbers, cubic feet	165,000,000	990,000	30,000	196,000
Shingles, pieces	12,000,000,000	1,200,000	100,000	160,000
Tannins—wood and bark, cords	1,300,000	650,000	33,000	150,000
Distillation wood, cords	1,500,000	750,000	12,000	147,000
Veneers, bd. ft.	500,000,000	500,000	60,000	143,000
Slack cooperage, staves	1,328,968,000	553,700	70,000	127,000
Slack cooperage, sets of heading	106,000,000	117,000		
Slack cooperage, hoops	353,215,000	265,000		
Tight cooperage, staves	500,000,000	850,000	90,000	122,000
Tight cooperage, sets of heading	40,000,000	133,000		
Poles and piling, pieces	8,000,000	800,000	20,000	116,000
Lath, pieces	3,163,000,000	632,000	10,000	63,000
Excelsior, bd. ft.	100,000,000	100,000	1,000	9,333
Miscellaneous, including rails, house logs, grape stakes, logs used in round, hop poles, converter poles, props, vehicle stock, derrick poles, etc., not included above	....	....	....	200,000
Total consumption	....	....	....	22,029,666
Per capita consumption, estimating population at 110,000,000 people	....	....	....	200.27 cu.ft.

[1] Board feet of lumber have been converted to cubic feet at the rate of 12 bd. ft. = 1 cu. ft., round material at 6 bd. ft. = 1 cu. ft., cords to bd. ft. generally at 500 bd. ft. = 1 cord, and cords to cubic feet at 1 cord = 90 cu. ft. For other conversion factors see tables in Chapter I and various other chapters relating to subject.

[2] It is obvious that certain forms of forest products could not be actually converted into bd. ft., for example, fuelwood and pulp wood. The table is offered for the purpose of rough comparison. The amounts expressed in thousand bd. ft. in this column have not been converted to cubic feet except in the case of lumber, veneers and excelsior.

[3] This includes waste in logging such as tops, stumps and cull logs and waste in manufacturing such as bark, kerf, slabs, trimming and edging, etc., but does not include waste by fire, insects, decay, windfall, etc.

growth.) We are using our forests three times as fast as they grow. We use about 200 cu. ft. per capita annually, which is more than that of any other nation. Germany normally uses only 37 cu. ft., France 25, Great Britain 14, and Italy 14. We use nearly twice as much wood per capita to-day as we did fifty years ago.

We are now using distinctively different species from those ten, twenty, or fifty years ago. Hemlock now makes up the principal wood cut in Pennsylvania, Michigan, Wisconsin, and New York. White pine, the former leading wood cut, is now fourth on the list of the country's lumber production. We are commonly using red gum, hemlock, tupelo, beech, sycamore, etc., which formerly were scarcely cut at all for lumber.

The table on page 5 shows the estimated annual consumption of forest products in this country. It is based upon a large number of sources.

ANNUAL PRODUCTION OF LUMBER

For the past decade, the annual production of lumber in this country has been about 40,000,000,000 bd. ft. It is likely that the peak of lumber production in this country was reached in 1909 when 44,500,000,000 bd. ft. of lumber were reported cut. Up to that time lumber production was on a steady increase.

The tendency in the industry has been towards the centralization of production in the largest sized mills. Fifty years ago, few mills had a daily capacity of over 50,000 bd. ft. per day, whereas there are several mills in this country which now have a capacity of around 1,000,000 bd. ft. per day. It is an interesting fact that only 925 sawmills, or 3.08 per cent of the total number of mills operating in this country cut more than 23,000,000,000 bd. ft., or 58.56 per cent of the total production. Each of these mills cut 10,000,000 bd. ft. or more per year. About 70 per cent of the total number of all sawmills in this country, amounting to over 30,000 mills, cut only about 10 per cent of the total lumber product of the country.

As our original virgin forests continue to be depleted, there will be a distinct tendency in the direction of a larger number of small sawmills, which will be operated to cut portions of the forest left by the larger operations, timber found unsuitable at the time of cutting or on second or even third growth which has sprung up after the last cutting or that previously left by the larger companies. In the year 1916, for example, New York state reported 1121 mills, cutting from 50,000 to 500,000 bd. ft. annually in operation out of a total number of 1260 mills. Only one state, North Carolina, reported a larger number of mills than New

York state. The virgin forests of these states have been heavily cut over many years ago. Washington, the state of the largest present lumber production, reported only 444 mills, 126 of which were mills cutting over 10,000,000 bd. ft. annually. Louisiana, the center of the yellow pine production in the South, reported only 329 mills in the year 1916, 121 of which cut over 10,000,000 bd. ft. each.

The following table[1] shows the estimated amount of lumber cut in the twenty-five leading lumber-producing states in this country, in the year 1916:

LUMBER PRODUCTION IN THE UNITED STATES

States.	1916 (30.081 Mills) Bd. Ft.	1899 (31,833 Mills) Bd. Ft.
Washington	4,494,000,000	1,429,032,000
Louisiana	4,200,000,000	1,115,366,000
Mississippi	2,730,000,000	1,206,265,000
Oregon	2,222,000,000	734,538,000
North Carolina	2,100,000,000	1,286,638,000
Texas	2,100,000,000	1,232,404,000
Arkansas	1,910,000,000	1,623,987,000
Alabama	1,720,000,000	1,101,386,000
Wisconsin	1,600,000,000	3,389,166,000
Florida	1,425,000,000	790,373,000
California	1,420,000,000	737,035,000
Virginia	1,335,000,000	959,119,000
Michigan	1,230,000,000	3,018,338,000
West Virginia	1,220,000,000	778,051,000
Minnesota	1,220,000,000	2,342,338,000
Georgia	1,000,000,000	1,311,917,000
Maine	935,000,000	784,647,000
South Carolina	857,000,000	466,429,000
Idaho	849,600,000	65,363,000
Pennsylvania	750,000,000	2,333,278,000
Tennessee	700,000,000	950,958,000
Kentucky	525,000,000	774,651,000
New York	400,000,000	878,448,000
New Hampshire	385,000,000	572,447,000
Montana	383,900,000	255,685,000
All other states	175,551,000	4,921,607,000
Total (all states)	39,807,251,000	35,084,166,000

The above table is interesting in showing how lumber production has varied in the different states during the seventeen years between 1899 and 1916.

[1] From statistics published by the U. S. Forest Service.

The following table[1] shows the quantity of each kind of lumber cut in this country in the years 1916 and 1899. The change in the amount of each of the different species cut is brought out very strikingly in the interim of the seventeen-year period. It represents the decline of the more important species cut in the East and is not only a reflection of the conditions which have obtained in recent years in this country, but it also portends the developments which are likely to take place in this country in the next few years. Our virgin forests are being rapidly cut, and the center of lumber production is rapidly shifting from the yellow pine forests of the southeast to the heavy Douglas fir, spruce, pine and redwood forests of the Pacific Coast.

LUMBER PRODUCTION BY SPECIES

Kinds of Wood.	1916 (Bd. Ft).	1899 (Bd. Ft).
Yellow pine	15,055,000,000	9,657,676,000
Douglas fir	5,416,000,000	1,736,507,000
Oak	3,300,000,000	4,438,027,000
White pine	2,700,000,000	7,742,391,000
Hemlock	2,350,000,000	3,420,673,000
Western yellow pine	1,690,000,000	945,432,000
Spruce	1,250,000,000	1,448,091,000
Cypress	1,000,000,000	495,836,000
Maple	975,000,000	633,466,000
Gum	800,000,000	285,417,000
Yellow poplar	560,000,000	1,115,242,000
Chestnut	535,000,000	206,688,000
Redwood	490,850,000	360,167,000
Larch	455,000,000	50,619,000
Birch	450,000,000	132,601,000
Cedar	410,000,000	232,978,000
Beech	360,000,000	1
Tupelo	275,000,000	1
Basswood	275,000,000	308,069,000
Elm	240,000,000	456,731,000
Ash	210,000,000	269,120,000
Cottonwood	200,000,000	415,124,000
White fir	190,000,000	1
Sugar pine	169,250,000	53,558,000
Hickory	125,000,000	96,636,000
Balsam fir	125,000,000	1
Walnut	90,000,000	38,681,000
Sycamore	40,000,000	29,715,000
Lodgepole pine	30,800,000	1
All other kinds	40,351,000	514,721,000
Total	39,807,251,000	35,084,166,000

[1] Not separately reported.

[1] From statistics published by the U. S. Forest Service.

In the above classification, yellow pine includes principally the three species of pine commonly found in the southeast; longleaf, (*Pinus palustris*), loblolly, (*Pinus taeda*), and shortleaf (*Pinus echinata*), pine. Louisiana is the present center of production of yellow pine. The other important yellow pine states, in order of production are Mississippi, Texas, North Carolina, Alabama, Arkansas and Florida. Although the virgin forests of eastern North Carolina were cut over many years ago, yellow pine cut from the second and third growth of the forests there constitute an important contribution to her present output.

Douglas fir (*Pseudotsuga taxifolia*) is the principal timber tree of the West, and more than one-half of its total production is now cut in Washington. Oregon cuts almost one-third, while California, Idaho, and Montana cut the remainder.

Oak is the third tree in order of lumber cut in this country, and is widely distributed over the entire eastern section of this country. The lumber cut of oak is steadily declining. It includes about twenty species of oak found in merchantable quantities in this country, although there are fifty botanical species recognized, which are divided into two broad classes of red and white oaks. The center of production of oak lumber is in West Virginia, where over 13 per cent of the oak is produced. Arkansas, Tennessee, Kentucky and Virginia are other oak-producing states in order of their cut.

For a long time, white pine held the leadership of lumber production in this country, but it now occupies fourth place and it includes in addition to the original eastern white pine (*Pinus strobus*) in the above statistics, Norway pine, or red pine (*Pinus resinosa*), western white (*Pinus monticola*) of western Montana and Idaho, and a small portion of jack pine (*Pinus divaricata*) of the Lake states.

Hemlock is the fifth tree of importance in this country's lumber cut, and is produced chiefly in Wisconsin and Michigan, which, together produce about 43 per cent of the total product cut. Hemlock includes both the eastern (*Tsuga canadensis*) and western hemlock (*Tsuga heterophylla*). It formerly was produced chiefly in Pennsylvania, which now occupies fourth place. Washington occupies third place. It is also cut in considerable quantities in West Virginia, Maine, and New York.

LUMBER VALUES

Lumber values have not risen in the past few decades to the extent to which many other commodities have, particularly other building and structural material. On account of the over-production of lumber, the price level has been steadily held to comparatively low heights until the outbreak of the recent war.

The over-production of lumber was particularly true in the case of southern yellow pine and Douglas fir, and the prices obtained for them in the various years reflect the situation very forcibly.

The following table shows the average values of the different kinds of lumber cut in this country. The prices are given on the basis of per thousand bd. ft., values specified for the years from 1899 to 1917, as published by the U. S. Dept. of Agriculture, Forest Service Bulletin No. 768, page 38.

AVERAGE VALUE OF LUMBER PER THOUSAND FEET, BOARD MEASURE, BY KINDS OF WOOD, FOR SPECIFIED YEARS, 1899–1917

Kind of Wood.	1917	1916	1915	1911	1910	1909	1907	1904	1899
All kinds	$20.32	$15.32	$14.04	$15.05	$15.30	$15.38	$16.56	$12.76	$11.13
Softwoods:									
Yellow pine	19.00	14.33	12.41	13.87	13.29	12.69	14.02	9.96	8.46
Douglas fir	16.28	10.78	10.59	11.05	13.09	12.44	14.12	9.51	8.67
White pine	24.81	19.16	17.44	18.54	18.93	18.16	19.41	14.93	12.69
Hemlock	20.78	15.35	13.14	13.59	13.85	13.95	15.53	11.91	9.98
Spruce	24.41	17.58	16.58	16.14	16.62	16.91	17.26	14.03	11.27
Western yellow pine	19.59	14.52	14.32	13.62	14.26	15.39	15.67	11.30	9.70
Cypress	23.92	20.85	19.85	20.54	20.51	20.46	22.12	17.50	13.32
Redwood	21.00	13.93	13.54	13.99	15.52	14.80	17.70	12.83	10.12
Cedar	19.40	15.24	16.10	13.86	15.53	19.95	19.14	14.35	10.91
Larch (tamarack)	16.21	12.49	10.78	11.87	12.33	12.68	13.99	11.39	8.73
White fir	17.16	12.25	10.94	10.64	11.52	13.10	15.54	[1]	[1]
Sugar pine	24.69	16.77	17.40	17.52	18.68	18.14	19.84	[1]	12.30
Balsam fir	20.02	16.49	13.79	13.42	14.48	13.99	16.16	[1]	[1]
Lodgepole pine	18.34	15.13	13.57	12.41	14.88	16.25	[1]	[1]	[1]
Hardwoods:									
Oak	24.49	20.06	18.73	19.14	18.76	20.50	21.23	17.51	13.78
Maple	23.16	18.24	15.21	15.49	18.16	15.77	16.84	14.94	11.83
Gum, red and sap	19.56	14.64	12.54	12.11	12.26	13.20	14.10	10.87	9.73
Chestnut	21.54	17.05	16.17	16.63	16.23	16.12	17.04	13.78	13.37
Yellow poplar	27.17	21.89	22.45	25.46	24.71	25.39	24.91	18.99	14.03
Birch	24.07	19.59	16.52	16.61	17.37	16.95	17.37	15.44	12.50
Beech	19.58	16.20	14.01	14.09	14.34	13.25	14.30	[1]	[1]
Basswood	25.96	21.05	18.89	19.20	20.94	19.50	20.03	16.86	12.84
Elm	23.89	19.46	16.98	17.13	18.67	17.52	18.45	14.45	11.47
Ash	30.01	23.85	22.15	21.21	22.47	24.44	25.01	18.77	14.85
Cottonwood	23.19	17.42	17.36	18.12	17.78	18.05	18.42	14.92	10.37
Tupelo	18.06	13.00	12.25	12.46	12.14	11.87	14.48	[1]	[1]
Hickory	29.48	23.84	23.35	22.47	26.55	30.80	29.50	23.94	18.78
Walnut	72.99	42.38	48.37	31.70	34.91	42.79	43.41	45.64	36.49
Sycamore	18.68	14.65	13.86	13.16	14.10	14.77	14.58	[1]	11.04

[1] Data not obtained.

USE OF THE LUMBER CUT

Until recent times no investigations have been made to determine how our lumber cut was utilized. During the period 1909 to 1912, however, the United States Forest Service, in co-operation with the various state agencies made a study of the annual consumption of lumber in nearly all of the states.

A compilation of these statistics shows that our lumber cut is normally used approximately as follows:

Principal Uses.	Per Cent.
Planing mill products such as sash, doors, flooring and general mill work	34
Rough lumber and structural timbers	33
Boxes and crating	11
Export lumber and timbers	7
Car construction	3
Furniture	2
Vehicles and vehicle parts	2
Agricultural implements	1
Woodenware and novelties	1
	94

The remaining 6 per cent is made up of miscellaneous uses such as chairs, handles, musical instruments, tanks and silos, ship- and boat-building fixtures, etc.

The following table shows the annual use of wood in the United States, with the exception of fuel wood and fence posts, according to U. S. Forest Service figures:[1]

	Bd. Ft.
Planing mill products, sash, doors, blinds and general mill work	13,428,862,000
Rough lumber and timbers	13,000,000,000
Boxes and crates	4,550,016,000
Cross ties	4,502,000,000
Export lumber and timbers	3,000,000,000

[1] Partly taken from "Lumber Used in the Manufacture of Wooden Products," by J. C. Nellis, U. S. Dept. of Agric., Bulletin 605, 1918.

	Bd. Ft.
Wood pulp (1916)	2,635,000,000
Car construction	1,262,090,000
Shingles (1911)	1,211,387,000
Furniture	944,678,000
Vehicles and vehicle parts	739,145,000
Slack cooperage (1914)	655,603,000
Distillation (1911)	610,680,000
Lath (1911)	594,222,000
Veneers (1911)	444,886,000
Woodenware and novelties	405,286,000
Agricultural implements	321,239,000
Chairs	289,791,000
Handles	280,235,000
Musical instruments	260,195,000
Tanks and silos	225,618,000
Poles and piling (1911)	250,000,000
Ship and boat building (1915)	200,000,000
Fixtures	187,133,000
Excelsior	100,000,000
Miscellaneous industries and extract wood	1,486,121,000

WASTAGE IN PRODUCTION OF FOREST PRODUCTS

Under conditions of a large virgin timber supply of comparatively low-stumpage value, there is inevitably a large wastage in its utilization. Much of the timber found in the virgin forests of this country is over-mature and defective and its conversion into the various forms of forest products naturally results in great loss. Fires and insects and fungi also destroy enormous quantities of timber in the forest, which otherwise might be profitably utilized.

It is estimated that we use only from 30 to 50 per cent or less of the total amount of wood which is cut in our forests, and this does not take into account the loss by fire, wind, insects, decay, land clearing, etc. In the western and southern European countries, it is estimated that between 90 and 96 per cent of the total forest crop is utilized. Under the conditions obtaining in those countries there is no loss from over-maturity and defects due to that condition, and there is very little damage done by fire, insects and decay, which are the cause of such a tremendous amount of wood wastage in this country. Many of the trees are planted and all are cut before they are allowed to become overmature.

There is a large amount of waste in the production of lumber in this country as well as in the production of such forms of forest products as cross ties, shingles, slack and tight cooperage stock, veneers, etc. There is a much less comparative waste in the production of such forms as pulp wood, fuelwood, distillation wood, poles and piling and round mine timbers because there is little relative loss in reducing the original to the finished form.

It is estimated that in the production of saw logs, there is a loss of wood in logging which amounts to from 15 to 20 per cent or more. This is largely composed of stumps, tops, broken and defective logs, limbs and timber which is undersized or undesirable on account of crooks or defects such as punk, shake, large knots, etc. In addition, moreover, merchantable trees are often overlooked or left lodged in the woods.

In the manufacture of those saw logs which reach the mill, the loss is estimated to be from 40 to 57 per cent, depending upon the local efficiency in the methods of manufacture and the character of the timber, that is, the size of the individual logs, their freedom from defects, their straightness and regularity, the width of the bark, etc. The loss in manufacture may be divided approximately as follows:

LOSS OF WOOD IN MANUFACTURE OF SAW LOGS

Character of Loss.	Percentage of Total Volume of Log.
Bark	9–15
Saw-kerf	10–16
Edging and trimming	8–10
Slabs	9–11
Inefficiency and careless manufacture including loss in handling	4–5
	40–57

The total loss in the production of lumber, therefore, including both logging and manufacturing, may be estimated to be from 55 to 77 per cent. At the present time little of this loss is salvaged, but as our raw wood supplies become further depleted and the various forms of forest products become more valuable, methods will be devised and found profitable to utilize considerable portions of this loss, whereas, under present commercial and economic conditions, it is not generally profitable to convert any large proportion of this waste into other forms. Considerable quantities of slab wood are being used for paper pulp in Maine, New York, and Wisconsin, where the manufacture of wood pulp is largely centralized, and in other sections certain forms are being used for box boards and a great variety of small wooden products which can use odd pieces of wood which would otherwise be wasted after logging or sawmilling operations.

Under present conditions, however, a very large percentage of the wood's waste is left to rot in the woods and the sawmill waste is burned under boilers for the development of power or is consumed in burners especially designed to dispose of this waste. In Europe the woods waste is much less because of the customary practice of cutting the stumps close to the ground, the utilization of the tree trunk to a small diameter in the top, and the conversion of woods waste such as tops, limbwood, defective material, etc., into charcoal, or its direct utilization for fuel wood. In the sawmill operations it is a common practice to use a much thinner saw-kerf, sawing is done almost universally by the use of gang frame saws, there is an almost utter absence of waste of edging and trimming, and there are more efficient methods of handling and manufacture. Furthermore, there is a common willingness among the wood-using industries and the public at large to use waney-edged lumber, a factor which is of considerable importance. The bark is used for tanning purposes in case of spruce and oak, or used for fuel. Other sawmill waste is used for making briquettes in case of sawdust, or for fuel, charcoal and small wooden products such as novelties, woodenware, kitchen utensils, etc.

There is a great amount of waste incurred in the production of cross ties in this country because a large percentage of them are hewn and this means considerable loss in their manufacture. The production of tight and slack cooperage stock involves enormous wastage, particularly in the case of the former. The details of the loss in the production and manufacture of these and other forest products are described in the chapters dealing with those subjects.

CONVERTING FACTORS

The following list of wood equivalents or converting factors have been followed in this book. There are exceptions, however, and additions in the various chapters. These converting factors are the ones used by the U. S. Forest Service.

Products.	Equivalent in Bd. Ft.	Assumed Dimensions.
Cord (shingle bolts)	600	4′×4′×8′
Cord (fuel)	500	4′×4′×8′
Load (in the rough)	500	1 cord
Pole (telephone)	60	7″×30′
Pole (telephone)	100	9″×30′
Pile	60	7″×30′
Stull	60	10″×16′
Tie (standard)	$33\frac{1}{3}$	6″×8″×8′
Tie (2d class)	28	6″×7″×8′
Tie (narrow gage)	21	6″×7″×6′
Tie	$37\frac{1}{3}$	7″×8″×8′
Tie	42	7″×9″×8′
Derrick pole	60	7″×30′
Derrick set (11 pieces)	480	
Trestle timber	70	10″×20′
Trestle timber	20	7″×12′
House log	30	8″×16′
House log	30	7″×16′
House log	15	7″×10′
Mining timber	10	6″×10′
Prop	10	6″×10′
Converter pole	10	4″×20′
Pole (fence)	8	16′
Pole (fence)	10	4″×20′
Lagging (6 pieces)	10	3″×6′
Cubic foot (round)	6	
Rail (split)	5	½ pole
Piece	7	6″×7′
Stick	7	6″×7′
Slab	2	2″×6″×16′
Post	7	6″×7′
Post (circumference 18 in.)	6	5.7″×7′
Post	5	5″×7′
Linear foot	3	10″×1′
Brace	2	4″×6′
Stay (fence)	½	2″×6′
Stay	2	4″×6′
Shake	⅓	⅜″×6″×2′
Picket	1	3″×5′
Stake (fence)	1	3″×5′

The following list shows the converting factors used in the international timber trade with particular reference to European countries:

	Equivalents.
St. Petersburg standard	165 cu. ft.
	4.67 cu. meters
Logs	1320 bd. ft.
	4.1 loads

	Equivalents.
Squared timber	1650 bd. ft.
	3.3 loads
Boards	1980 bd. ft.
	3.3 loads
Cubic meter (stere)	35.3 cu. ft.
	0.214 standard
	8 standard railway cross ties
	0.2758 cord of 128 cu. ft.
	0.47–0.37 cord of solid wood
Logs	283 bd. ft.
	0.882 load
Squared timber	353 bd. ft.
	0.706 load
Boards	424 bd. ft.
	0.706 load
Softwoods	5.8 quintals
Hardwoods	7.7 quintals
Cubic meter "au reel"	0.20–0.30 cu. meters of sawed lumber
Metric ton	1000 kilos
	10 quintals
	2204.6 lb.
Logs:	
Softwoods	490 bd. ft.
Hardwoods	367 bd. ft.
Squared timber:	
Softwoods	612 bd. ft.
Hardwoods	459 bd. ft.
Boards:	
Softwoods	753 bd. ft.
Hardwoods	551 bd. ft.
Quintal	100 kilos
	220.46 lb.
Logs:	
Softwoods	49 bd. ft.
Hardwoods	37 bd. ft.
Squared timber:	
Softwoods	61 bd. ft.
Hardwoods	45 bd. ft.
Boards:	
Softwoods	74 bd. ft.
Hardwoods	55 bd. ft.
1000 bd. ft.	83.3 cu. ft.
Logs	3.53 cu. m.
	31.125 loads
	0.758 standard
Squared timber	2.83 cu. m.
	2 loads
	0.606 standard
Boards	2.36 cu. m.
	1.666 loads
	0.505 standard

	Equivalents.
Load:	
Logs	40 cu. ft.
	1.133 cu. ft.
	320 bd. ft.
	0.242 standard
Squared timber	50 cu. ft.
	1.416 cu. m.
	500 bd. ft.
	0 303 standard
Boards	50 cu. ft.
	1.416 cu. m.
	600 bd. ft.
	0.303 standard
Cubic foot:	
Logs	6 bd. ft.
Squared timber	12 bd. ft.
Boards	12 bd. ft.
Wagon or carload	22 cu. m.
Logs	6226 bd. ft.
Squared timber	7766 bd. ft.
Boards	9328 bd. ft.
Cord:	
Space	128 cu ft.
	3.624 cu. m., or steres
Shipping ton	40 cu. ft. (round timber)
Hectare	2.47 acres
Acre	0.4047 hec.
Inch	25.4 mm.
Foot	304.8 mm.
	30.48 cm.
French foot	13.12 in. (⅓ m.)

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CHAPTER II

WOOD PULP AND PAPER

GENERAL

PAPER is a material composed of vegetable fibers formed artificially into thin sheets. The word paper comes from the Latin word *papyrus*, a name given to the Egyptian sedge and bulrushes of the Nile Valley. The plant is said to have been used by the Egyptians as early as 2400 B.C. to make sheets for writing purposes as well as for wrapping and other mechanical uses.

Within the past ten to twenty-five years the manufacture of wood pulp has made tremendous strides. It is now one of the principal products derived from the forests aside from lumber. At the present time it is estimated that there are about 6,000,000 cords of wood needed to supply the annual demands of the paper trade in this country. Assuming 500 bd. ft. to the cord, this amount is equivalent to about 3,000,000,000 bd. ft. In 1900 only about 2,000,000 cords were consumed for wood pulp and in 1911 about 4,500,000 cords. Zon estimates that in 1930 about 10,500,000 cords will be required and as high as 16,000,000 cords of wood will be demanded in 1950. The increase in the consumption of wood from 1900 to 1919 has been over 300 per cent.

About 80 per cent to 85 per cent of all paper used in this country is now derived from wood, whereas before the middle of the 19th century, paper was entirely manufactured from other vegetable fibers.

The industry is still in the evolutionary stage of development, both in the matter of kind and quantity of raw materials and in the processes of the manufacture of pulp and paper. At first, basswood was used in the earlier years of the industry in this country and then spruce became our leading pulp wood. Spruce still holds the pre-eminent position. The demands for pulp wood are increasing so rapidly that other processes are being constantly developed to utilize woods that are cheaper and more abundant than spruce.

Vast improvements have been made and are still being made, not only in the processes themselves but in the use of raw material, and in refinements in labor-saving machinery. Large amounts of capital are required for participation in the industry, due largely to the expensive forms of machinery required.

According to the U. S. Bureau of Census for 1909 the industry employed a capital of over $409,000,000 and the manufactured products had an annual value of $267,000,000, giving employment to 81,000 persons. The amount of increase in capital in the decade prior to 1909 was 144 per cent and 110.2 per cent in the value of products.

Photograph by A. M. Richards.

FIG. 1.—About 10,000 cords of pulpwood bolts, 90 per cent of which are peeled. The wood consists of mixed spruce, balsam fir and hemlock. Hinckley Fibre Co., Hinckley, N. Y.

However, the increase in number of persons engaged in the industry was only 53 per cent, which is an indication of increase both in size of machinery used and in the number of labor-saving devices.

Wood has been demonstrated to be the best available raw material. From time to time sporadic attempts are made to introduce other materials, but they are too expensive to assemble and transport, are unavailable in sufficient quantities, or do not make the desirable kinds of paper. Before wood was widely introduced about 1850, paper was entirely made from cotton and linen rags, esparto grass, hemp, straw and a number of other vegetable fibers.

It is estimated that the annual value of our paper products is $780,-

000,000. The principal forms are shown in a report of the War Industries Board, as follows:

RELATIVE VALUE OF KINDS OF PAPER PRODUCED

Kind.	Value.
Newsprint paper	$136,000,000
Book papers	125,000,000
Paper boards	156,000,000
Fine writing paper	142,000,000
Wrapping papers	89,000,000
Miscellaneous papers	132,000,000
Total	$780,000,000

In the production of paper and paper products we use annually, 9,230,000 tons of coal, 21,619,200 gal. of oil and 1,287,000 tons of chemicals. The per capita consumption of paper in the United States is annually about 100 lbs.

HISTORY OF PULP AND PAPERMAKING

Although the Egyptians are sometimes given credit for the earliest development in the manufacture of paper, more recent research has developed the fact that the Chinese must be credited with the first manufacture of paper. The art of papermaking was known in China long before the Christian era. It is likely that the art of papermaking was transmitted from China across India to Persia and Arabia. It is known that the Saracens carried the practice of the art to Spain after their conquest of that country in the 8th century. The industry was gradually developed, but spread very slowly through Europe. From Spain it went to Italy where a paper mill was first operated at Fabriano in the year 1150. This became an important center for papermaking and it is said that paper is still made there at the present time. The first paper mill in France was established in 1189; in Germany in 1390; and the date of 1330 is given as the time of the first paper mill in England.

The introduction and development of papermaking machinery was very slow, because of the current opposition to all forms of labor-saving machinery during the Middle Ages. Forms of paper made in the earliest paper mills in England are still extant and it is generally accepted that the very best kinds of paper were made on the old-fashioned hand presses in the earliest days. In this country early records show that the first paper mill was established in 1690 by William Rittenhouse near Philadelphia. The first paper mill in New England was built by a company which was granted the sole privilege in the vicinity of Massachusetts for ten years, following 1728.

Until the early part of the 19th century, sheets of paper were made entirely by hand, sheet by sheet. Prior to this a device for making paper in an endless web was invented by Louis Nicolas Robert in France, but it was not put to practical use until developed in England by Henry and Sealy Fourdrinier, who perfected the machinery now universally known as the *Fourdrinier* wire, which is the basis of modern paper-making. This will be described later in this chapter.

It is said that the use of wood for making paper dates from as recently as 1840 when Keller patented his process in Germany for a wood-pulp grinding machine. It was not, however, until 1854 that the process was placed upon a commercial basis. It was introduced in this country by Warner Miller in 1866.

The manufacture of so-called chemical pulp, which has a still greater possibility for the future than ground wood pulp, dates back to the year 1867. Tilghman is generally given credit for the discovery of the disintegrating action of sulphurous acid upon wood. This was the basis of the invention of making chemical wood pulp by the sulphite process.

Within comparatively recent years the sulphate and soda processes of reducing wood fibers to the form of pulp have been developed. The sulphate process was first attempted in Sweden and has great possibilities before it in the utilization of woods and saw-mill waste in connection with the exploitation of some of our most abundant woods, such as southern yellow pine and Douglas fir.

With the rapid increase in the demands for wood pulp for all grades of paper, other features including forms of machinery and processes of pulp making have been devised to keep pace with the situation. In 1879 the average price of all forms of paper was $122 per ton, whereas in 1909 it was only $56 per ton.

To the development of engineering and chemistry is attributable more than to anything else, the remarkable progress of this industry. The discovery and improvements in the manufacture of paper pulp by the three chemical methods of reducing the wood fiber; the sulphite, soda and sulphate processes, and the use of the bleaching power of chlorine have made possible the use of a large variety of woods and the production of great quantities of pulp on a commercial scale.

KINDS OF PAPER MANUFACTURED

Generally speaking, there are two classes of paper in common use, as follows: first, papers for recording or printing; and second, papers for mechanical purposes.

In the first group are found the fine linen ledgers and writing papers, printing paper for books, magazines and general printing purposes and news print used for newspaper. General printing papers require a white paper with filling and sizing material. Some grades of printing papers are given a smooth surface by special calendering instead of by loading with clay and sizing. Newspaper is the cheapest of all paper and mechanical wood pulp forms the greater part of its substance. Writing papers are largely sized papers in the best grades, in which only selected rags are used, though of late, chemical wood pulp is used even in the expensive writing papers, and it may be said that nearly all papers, excepting high-grade ledger, contain wood.

In the second group are the cardboards, pasteboards, papier-mache, wrapping papers, and blotting and tissue papers and those of the heaviest forms, such as building paper, carpet and wall paper, etc.

Blotting paper is composed of short-fibered cotton and wood pulp cut fine in the beating engine. This paper is free from sizing of any kind and so is capable of absorbing water or other liquids. It can be dyed to any desired color without impairing its quality. Tissue papers are the thinnest of all papers and are generally made from rags or paper shavings, with varying quantities of wood pulp. Wrapping papers are partly sized papers of coarse material and are largely made from mixtures of sulphite pulp and ground wood, or wholly of sulphate pulp to form kraft paper. Straw, jute and mixtures of hard fibers are also largely employed. Cardboard, pasteboard and other heavy forms of paper are generally made from a pulp formed of waste paper, as well as from sugar cane refuse, waste fiber boxes, etc. They are sometimes made by pressing a number of sheets of other paper together in powerful presses, with a suitable agglutinant. Papier-mache is made chiefly from old paper stock by boiling to a pulp. It is then mixed with glue and starch paste and pressed into moulds.

THE REQUIREMENTS OF DESIRABLE PULP WOODS

The principal requirements which paper manufacturers hold as desirable in woods for making paper pulp are summarized as follows:

1. The wood should contain a long, strong and yet soft and tender

fiber. Woods in which these characters stand out make the best paper and are used with comparative economy.

2. The wood should be relatively free from intercellular constituents, such as resins, gums, tannins, etc. Highly resinous woods and those containing large percentages of tannins, gums, etc., are converted into paper with considerable difficulty and are used only for the cheaper grades of paper.

3. The wood must be available in sufficient quantities, reasonably accessible and, therefore, fairly economical in price. Some woods are admirably adapted to the manufacture of pulp and paper, but are often eliminated because they are not sufficiently available or are in greater demand for other purposes.

4. White fibered woods are preferred since most papers are white or light in color. Bleaching at great expense is required to whiten some woods. Woods which are white or nearly so are much more in demand than those of deep or dark colors.

5. The wood must be sound, reasonably clear of knots, free from rot, dote, bark, pitch pockets, and other defects. Sound wood, clear of all foreign matter or defects is especially required in certain processes of pulp manufacture.

6. The wood itself should contain large quantities of available cellulose. Most woods contain between 40 per cent and 60 per cent of cellulose. Since the basis of all paper is cellulose, it is desirable to select a wood for pulp that contains cellulose in a form that is readily separated without loss by the destructive action of chemicals which are used in cooking processes.

ANNUAL CONSUMPTION OF WOOD

At the present time it is estimated that about 6,000,000 cords of wood are now annually used in this country for wood pulp. The latest available accurate figures are those published by the United States Forest Service for the year 1916, when it was reported that 5,228,558 cords of wood were manufactured into pulp at 230 mills. Of this amount Canada supplied about 700,000 cords, or 15 per cent of the total quantity. There has been a steady increase from year to year in the consumption of wood.

While the number of mills has not increased so rapidly from year to year there has been a strong tendency to increase the size of our American pulp mills. The average number of cords used annually in each pulp mill in 1911 was 16,149 and in 1916 was 22,735. Some mills consume as high as 60,000 cords annually. Some of our modern pulp mills consume between 200 and 250 cords per day. Assuming about 15 cords as the average cut per acre for pulp wood of all kinds, and a yearly consumption of 6,000,000 cords, 40,000 acres of forest are cut over every year for this country's pulp wood supply.

Woods Used.

Nearly every native wood grown in this country is capable of being made into paper. Some woods are, however, obviously much more desirable, based upon the requirements outlined in the foregoing paragraphs. The softwoods are most amenable to treatment and are preferred.

In 1916 at least eighteen different kinds of native woods were used in the manufacture of paper pulp.

Of all woods used, however, spruce holds the pre-eminent position, since the quality and character of this wood is admirably fitted for use, both in the mechanical and chemical processes of pulp making. It is actually used in all of the modern processes. In 1916 it constituted over 59 per cent of the total quantity of wood used for pulp. There is a tendency to decrease the percentage of spruce, as compared with other woods, because of its growing scarcity, and the introduction of new processes which make possible the use of other woods heretofore seldom used for this purpose. Most of the spruce used is the eastern red spruce (*Picea rubens*) although white spruce (*Picea canadensis*) is being used more and more, especially in eastern Canada. Western spruce (*Picea sitchensis*) is rapidly coming into prominence and is used on the northern Pacific coast and in British Columbia. It is abundantly available in this section and it is likely that western spruce, together with other spruces in the Far West, which are available in large quantities will attract the location of many new pulp mills in that district. Spruce is an ideal pulp wood because it has long, strong fibers, which are comparatively free from resins, gums, tannins, etc.; it is light in color, is generally sound and is fairly free from knots, rot, and other defects. It also contains the maximum quantity of cellulose, which can be freed from other substances without great difficulty. Nearly one-fourth of all the spruce used for wood pulp in this country is imported from Canada.

Hemlock ranks second among our leading pulp woods and in 1916 it averaged over 14 per cent of the total pulpwood supply. It is reduced almost entirely by the sulphite process and is very largely used in the Lake states, especially in Wisconsin. The wood is inferior to spruce, since the fibers are much shorter and weaker. Inasmuch as the fibers easily become broken in grinding, it is not adapted for reduction by the mechanical process. However, hemlock is available in large quantities and can be successfully reduced by the chemical process for news, wrapping and other cheaper grades of paper.

Poplar, including the two aspens of the northeast and Canada, ranks third in importance as a pulpwood. It forms about 8 per cent of the total supply. The wood is soft, light in weight and color, but its fibers are short and comparatively weak. It is reduced almost entirely by the soda process and its pulp is mixed with sulphite pulp to give it sufficient strength for manufacture into grades of book paper.

Photograph by A. M. Richards.

FIG. 2.—A pulp mill with a capacity of 60 tons of No. 1 and No. 2 bleached and natural spruce and hemlock sulphite pulp in twenty-four hours. The tall building on the right contains the digester and bleaching rooms. The building in the right foreground is the wood room for rossing, splitting, chipping and screening.

Balsam fir is very commonly mixed with spruce and used as such for mechanically ground pulp. Purchasers of pulpwood usually specify that no large per cent of the wood purchased shall be of balsam fir. The wood is light in color and weight, soft and comparatively free from resins, gums, and other objectionable materials. Papermakers object to it, however, because it is said that the pitch from it covers the felts and cylinder faces making operations difficult. Balsam fir is available in fairly large quantities in the northeast and eastern Canada. It is largely reduced by the mechanical process, and finds a large market for newspaper stock; it is said, indeed, that balsam fir finds its greatest economic importance as a pulpwood. Papermakers aver that pulp which contains a large admixture of balsam fir lacks strength and character.

Pine is being used more and more from year to year and is being reduced chiefly by the soda and the sulphate processes, especially southern yellow pine. In the statistical reports, pine includes principally southern yellow pine but nearly one-half is composed of jack pine. White pine is used to a small extent.

White fir is rapidly coming into common use in the West. This and other firs, together with large quantities of spruce and hemlock, which are available on the northern Pacific coast, will tend to make that region a great center of the future pulp and paper industry. In 1916 more than 49,000 cords of white fir were used for paper pulp.

Some hardwoods like beech, maple, chestnut and cottonwood are also used to some extent. They are largely reduced by the soda process. Large quantities are derived from the residue of chestnut pulp after the tannin has been removed at tannin extract plants in the South, notably at Canton, N. C.

Douglas fir is being used in the northern Pacific coast to some extent, but it is more or less in the experimental stage of development.

Other woods used for pulp are tamarack, elm, basswood, birch, gum, sycamore, cucumber and ash.

Altogether there is a strong undercurrent of desire among manufacturers to experiment in the use of new woods. Spruce has risen so high in price that pulpmakers are generally looking for other sources of raw material and are developing processes which will be applicable to our most abundant kinds of woods, such as southern yellow pine, Douglas fir, western hemlock, redwood, western spruce, cedar and various hardwoods. It is estimated that there is a sufficient amount of sawmill waste that is burned up, or which serves no profitable or economical purpose, to meet all the demands for pulpwood. Upwards of 200,000 cords of sawmill waste in the form of slabs, edgings, etc., are now being utilized in pulpmaking. In Wisconsin especially, large quantities of hemlock waste from sawmills are converted into pulp.

The following table[1] shows the quantity of wood consumed by kinds for 1916, 1911, and 1909.

Consumption by States.

The wood pulp industry is centralized largely in the northeast. Many new mills have recently been erected over the Canadian line in the lower

[1] Taken from statistical reports of U. S. Forest Service and U. S. Census Bureau.

valley of the St. Lawrence River. The location of the industrial center of the manufacture of wood pulp is attributed directly to the fact that raw material is available in this section and the great paper mill centers have been developed there.

Kind of Wood.	Quantity, 1916. Cords.	Quantity, 1911. Cords.	Quantity, 1909. Cords.
Spruce: Domestic	2,399,993	1,612,355	1,653,249
Imported	701,667	903,375	768,332
Hemlock	760,226	616,663	559,657
Poplar: Domestic	329,370	333,929	302,876
Imported	82,326	34,295	25,622
Balsam fir	301,032	191,779	95,366
Pine	170,378	124,019	90,885
Beech [1]	....	44,320	31,390
Maple [1]	....	36,979	
White fir	49,425	36,493	37,176
Cottonwood	22,211	25,043	36,898
All other species	211,086	88,268	151,179
Slabwood and other mill waste	200,844	280,534	248,977
Total	5,228,558	4,328,052	4,001,607

[1] Included with all other species in 1916.

New York occupies the commanding position in the manufacture of wood pulp and paper. It now has about seventy-five pulp mills and consumes more than 1,000,000 cords of wood annually. The centers of the industry in New York are in the upper Hudson River and Black River valleys, the latter centering around the cities of Watertown and Carthage. Maine is the leader in the consumption of wood, using over 1,198,000 cords of wood annually. In 1911 there were thirty-eight pulp mills in Maine and in 1916, thirty-two mills. Wisconsin is third in order of importance.

Owing to the decrease of available material in the northeast, the industry has exhibited a tendency to move to Canada, the Lake states and the northwest and it is estimated that in a few decades many new pulp mills will be located in the Lake states, the Far West and even in the South where new developments in the reduction of southern pine waste give excellent promise. Other leading states in order are New Hampshire, Pennsylvania, Minnesota, Michigan, Oregon, West Virginia, Virginia, Vermont, North Carolina and Massachusetts.

Consumption by Processes.

Most of the pulpwood is reduced by the sulphite process. In 1916 of the total amount reduced—5,228,558 cords—over one-half, or 2,856,122 cords, were reduced by the sulphite process. This process was applied chiefly to spruce, hemlock, balsam fir and white fir.

The mechanical process was used with nearly 30 per cent of the total supply and was applied chiefly to spruce, and to a much less extent, to hemlock, balsam fir and pine and aspen.

The soda process is largely applied to poplar or aspen, pine and hardwoods. Of the total amount of pulpwood made in this country nearly 14 per cent is reduced by the soda method.

Only about 3 per cent of our wood pulp is made by the sulphate process. It has been introduced and passed the experimental stage in connection with Douglas fir on the Pacific coast and southern yellow pine in the South. It has enormous possibilities for the future and it is likely that it will be applied to a large number of woods now little used for pulp purposes.

The table [1] on page 29 shows the quantity of wood consumed by species and processes of manufacture for 1916.

RAW MATERIAL

Raw material for the manufacture of pulp comes to the mill in a great variety of forms, chief of which are the following:

1. *Logs.* In the past much of the raw material was delivered to the pulp mills in the form of logs, but this is being superseded by delivery in shorter lengths.

2. *Bolts.* A large share of material is now delivered in a form of 4-ft. bolts, either in the peeled condition or with the bark still on.

3. *Chips.* For sulphite pulp some of the pulp mills are pressing their material in the baled form or in the loose state in carload lots.

4. *Sawmill Waste.* Considerable hemlock and spruce slabs and edgings are now being received in larger quantities from year to year. This is especially true in West Virginia, Maine, Pennsylvania and Wisconsin.

Logging and Transportation.

It is estimated that about 80 per cent of the pulp companies own their own standing timber. Up to the present time, the conventional method has been to send logging crews in the woods in the late summer or early fall to put up the annual supply of pulpwood. When logging is done

[1] Taken from Pulpwood Consumption, etc., 1916, by Smith and Helphenstine, U. S. Forest Service, unnumbered circular.

in the spring, barking can be done to best advantage. As soon as the snow comes to sufficient depth the snowhaul with the two-sled is employed to bring the logs down to some drivable stream. This method is very commonly employed in Maine, northern New Hampshire, the Adirondacks and eastern Canada.

In the spring the logs are floated down to the mill and held in large booms until required for use.[1]

PULPWOOD CONSUMPTION—QUANTITY OF WOOD CONSUMED BY KIND AND PROCESSES OF MANUFACTURE—1916

Kind of Wood.	Reduced by				
	Aggregate Quantity. Cords	Mechanical Process. Cords	Sulphite Process. Cords	Soda Process. Cords	Sulphate Process. Cords
Spruce	3,101,660	1,293,508	1,803,217	630	4,305
Hemlock	760,226	84,116	647,738	....	28,372
Aspen	411,696	14,733	2,323	394,577	63
Balsam fir	301,032	77,313	213,569	....	10,150
Yellow pine	90,310	15,663	8,209	29,727	36,711
Jack pine	80,068	13,935	....	61,145	4,988
White fir	49,425	13,560	35,865		
Yellow poplar	37,974	....	....	37,974	
Gum	37,391	....	....	37,391	
Tamarack	33,271	431	3,775	....	29,065
Cottonwood	22,211	2,082	668	19,461	
Basswood	11,481	....	....	11,481	
Douglas fir	7,679	....	....	7,679	
White pine	2,545	1,473	....	....	1,072
Sycamore	2,246	....	....	2,246	
Willow	600	....	....	600	
Buckeye	100	....	....	100	
Cucumber	37	....	....	37	
Beech, birch, and maple	77,762	11	....	77,751	
Slabs and other mill waste	200,844	7,561	140,758	26,620	25,905
Total	5,228,558	1,524,386	2,856,122	707,419	140,631

Use of Sawmill and Other Waste.

Over 200,000 cords of sawmill waste in the form of slabs and edgings are now used for paper pulp. Many lumber companies operating in

[1] For information regarding logging methods, costs, etc., see *Logging*, by R. C. Bryant John Wiley & Sons, New York City.

spruce now convert their smaller and crooked logs into chips, which are used in some sulphite mills.

In a large mill in the Adirondacks cutting 90,000 bd. ft. of lumber per day about 2½ carloads of sulphite chips, which is equivalent to about 15 cords of chips, are secured from 1900 logs per day. All logs which are symmetrical and straight and which are over 6 in. in diameter at the small end are manufactured into lumber. All crooked logs above this diameter and all logs below 6 in. in size at the small end go into pulpwood. All balsam fir logs of the smaller diameters also go into pulpwood.

Value of Pulpwood.

There has always been a great variation in the price paid for pulpwood at the mills. In 1916 the price generally varied for rough pulpwood between about $4.00 and $11.00 per cord, for peeled wood between about $5.00 and $16.00 per cord and for rossed wood between $6.00 and $18.00 per cord. The average cost for wood of all forms in 1916 was $8.76 per cord, delivered at the mill. The price of pulpwood has steadily advanced during the past two decades, until in 1919 $16.00 to $18.00 was quoted.

The total value of the raw material in the form of pulpwood delivered at the mills in 1916 was $45,785,682. In 1909 the total value of the pulpwood consumed was $34,477,540.

REQUIREMENTS FOR THE ESTABLISHMENT OF A PULP MILL

The following are usually considered the principal requirements necessary for the location of a pulp mill.

1. A large initial investment. The machinery required for reduction of wood to the different forms of pulp is known to be the most highly specialized and one of the most expensive forms used in any of our industries. Not only is the machinery very specialized and expensive, but large and substantially constructed buildings are required to house it. Many of our pulp mills cost from $400,000 to $800,000 or more for the initial investment.

2. A large and continuous supply of wood of a desirable kind and reasonably accessible so that it can be delivered sufficiently cheap. The average pulp mill in this country consumes about 22,700 cords per annum.

3. A plentiful supply of clean water. For washing the fibers and carrying the pulp to the machines, enormous quantities of clear, pure water are required.

4. Adequate power. Most of the pulp mills have hydro-electric power developments in connection with them.

5. Accessibility to a good fuel supply.

6. Adequate transportation facilities for both the shipment of the raw material to the mill and the movement by rail or boat of the products to the consuming market.

THE MANUFACTURE OF MECHANICAL PULP

In the manufacture of ground wood or mechanical pulp the wood fibers are torn apart by mechanical abrasion, by compressing the billets of wood against a rapidly revolving grindstone. Spruce is better adapted for this process than any other wood. Other species used are pine, balsam fir, hemlock, aspen, poplar and a few other woods, but a very large per cent (about 85) of the total amount is made up of spruce. In 1916 1,524,386 cords of wood were reduced to pulp by the mechanical process.

The cheaper grades of paper, chiefly news print, are formed of pulp made by the mechanical process. The intercellular substances of wood fibers, chiefly lignin, resins and tannins, are not removed, as in the chemical processes, which dissolve out the undesirable constituents and leave a substance which is largely pure cellulose. In the mechanical process the wood is ground to a fine pulp.

Preparation of the Wood.

The raw material if it is brought to the pulp mill in the log form is taken out of the booms and log storage in the river or mill pond and is carried up into the mill by means of a jacker chain which usually leads to a series of live rolls. The logs are then reduced to a uniform length usually 24 in. Very commonly, pulpwood comes to the mill in the form of 24-in. bolts, either in the peeled or rossed condition or with the bark still on the wood. The logs are reduced to the bolt length by means of a slasher made up of a series of circular saws against which the logs are conveyed. In some mills a large, circular, cut-off saw called a " dropsaw " is used. In the latter case the logs are brought into position by means of log rolls and the saw lowered until they are cut off to the proper length.

One type of six-saw slasher has a capacity of handling 8000 logs up to 14 ft. in length every 10 hours.

Barking.

If the bolts or logs come to the mill in the unbarked state they are conveyed in the bolt form to the barking or rossing machine which removes the wood. The modern barker consists of a heavy, circular, steel disk from 52 to 72 in. in diameter, inclosed in a heavy, iron frame. The steel disk has three knives inserted in it radially in such a manner that the knives cut away the bark as the blocks are held against the rapidly revolving surface. A log rolling attachment is provided to hold the logs in place after the operator has inserted them. The toothed chain revolving around two sprockets, turns the log and the sharp knives automatically remove the bark from the wood.

When the logging of pulpwood is done in the spring or early summer, the bark can best be removed by the use of a bark spud or even an axe. When fall or winter logging is practised the logs are sent directly to the mill in the unbarked condition. There is very little loss of good wood by peeling in the woods, but there is a loss, estimated at 15 to 25 per cent of the solid wood, when the bark is removed by the barking machine. If the bolts were perfectly symmetrical there would be very little loss, but, owing to the unsymmetrical character of the bolts, together with seams, crotches, taper, knots, etc., considerable wood must be removed in order to cut off all the bark. The rapid revolving and rossing take off large quantities of wood along with the bark. Bolts of small diameter lose a greater percentage of wood than large bolts.

A rotary or drum barker has been devised which minimizes this loss. The drum barker consists of a heavy, circular, iron cylinder made of angles or channels fitted with projections to scrape the bark from the logs. As the drum revolves the bark is removed partly by attrition and direct contact with the projecting surfaces. It is estimated that from 10 to 20 per cent of solid wood is removed, but modern devices and improvements are correcting this difficulty. The wood enters the rotary or drum barker at one end and is discharged at the other, while pieces of bark which have been removed fall through the open spaces in the drum.

In many pulp mills where both chemical and ground wood pulp are made the better classes of bolts, that is, those which are relatively free from dirt and contain few knots, are used for chemical pulp, while those of inferior quality are sent to the ground wood mill.

Very often the barking process is carried on more rapidly than the grinding operation which follows it, so that the surplus blocks are carried out into the yard on a cable conveyor or a similar device and stored until needed. In winter, many of the bolts contain ice and dirt, accumulated in the woods. These are sent into a hot box or tub of water where the ice is melted and much of the dirt removed. The soaking they receive also facilitates the grinding process.

In the case of the largest bolts a splitting machine is provided on one end of the barking room to reduce the largest bolts to a size that can be accommodated in the grinders.

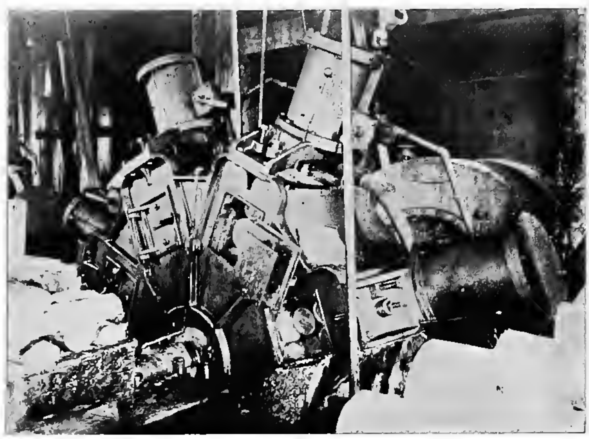
Cold and Hot Ground Wood Pulp.

The most important part of making ground wood pulp lies in the grinding and screening methods which are employed. A great many experiments have been made, but each individual manufacturer generally follows his own ideas on the subject.

There are two distinct kinds of ground wood pulp, namely, cold and hot ground pulp. These vary greatly in degree of coarseness, and in the length and strength of fiber. When wood is ground into fibers in the presence of large amounts of water a fine, even grade of pulp is produced. This is known, commercially, as cold ground pulp. Contrasted to this form the hot ground pulp is produced under conditions of high temperature and comparatively little water. Hot ground pulp is coarse and contains long fibers.

The operation of reducing wood to pulp is carried on in a separate part of the mill, in the grinding room where from 4 to 24 grinders or more are operated simultaneously. The wood is brought in on trucks and stacked up at some point convenient for the operator. The grinding machine consists of a strong, iron, circular box, inclosing a heavy grindstone mounted on a horizontal shaft. These grindstones are made of gritty sandstone and are largely imported from England for the purpose. Some artificial stones are also in common use. The surface of the stone is grooved and pitted to make it rough. In size these stones are usually from 54 to 60 in. in diameter with a 27-in. face. Around the circumference of the casing, openings or pockets are located in which 2-ft. or 4-ft. bolts of wood are placed and pressed against the rotating stone by means of hydraulic pressure. The stones revolve at the rate of about 240 revolutions per minute and from 200 to 400 horse-power are required to drive each grinder. The texture of the stone, the rapidity with which it turns and the rate of pressure of the wood against the stone determine in a large measure the character of the pulp made. A stone with an exceedingly rough surface will produce very coarse fibers, whereas if the stone is permitted to become too smooth or dull, the fibers will be too short and the resultant pulp too fine. Dull stones are sharpened while revolving, by pressing a " burr " or " jigger " made of especially hardened steel, against the surface. Some stones wear unevenly and must be ground, so that they will be perfectly symmetrical. The operator must give constant attention to the stones, so that the maximum quantity of the best quality of pulp may be produced.

In the process of grinding, the door of the pocket is opened, the piston is raised and the pocket filled with blocks, the bolts being placed flatly against the surface of the stone and at right angles to the direction of the revolutions, as shown in the illustrations. When the pocket is filled, the door is closed and the piston lowered. The pressure is exerted at the rate of about 70 lb. per square inch. The temperature of the wood during the process of making cold ground pulp is about 60° F. The stones weigh



Photograph by U. S. Forest Service

Fig. 3.—A four-pocket grinder used to reduce the wood bolts to fiber by the mechanical process of making wood pulp. The bolts are pressed against a rapidly revolving stone.

from about 2500 to 3500 lb. each and have an average life of only about six to eight months. Each grinder has a capacity of from 6 to 9 cords of wood per twenty-four hours. All water used in making cold ground pulp is first passed through filters in order that absolute purity may be insured. One man can tend a pair of grinders.

The water carries the pulp away from the grinders and it is collected and carried off through a large pipe at the base of the grinder.

In making hot ground pulp the water allowed to flow on the grindstone during the process is reduced to a minimum. The friction causes the temperature to rise and the resultant pulp is of entirely different quality from that made by the cold ground process. In making hot ground pulp the fibers are torn away very readily so that the resultant pulp is very much coarser and the fibers longer.

In this process, the grinding machine includes a grindstone mounted in a vertical position on a horizontal shaft and surrounded by a heavy iron casing. Pockets are provided and the pressure afforded in a way similar to that described for the other process. Even in the presence of sufficient water to prevent the pulp from burning, the temperature rises, commonly, to over 160° F. Hot ground pulp is used largely in the manufacture of newspaper. It runs freely on the Fourdrinier wire, since the coarse quality of the fiber permits the water to drain away quickly.

Much higher yields are secured in the hot ground process owing to the fact that the wood is worn away more rapidly and to the use of coarse stones or stones which are finished to grind the maximum amount of pulp in a given period of time.

In a few mills in this country and in Canada magazine grinders have been installed which take a charge of 12 cords of 4-ft. wood sticks. The grinding proceeds during a twelve-hour shift without any special attention being necessary on the part of attendants.[1]

Screening.

The pulp stock, after grinding, is run through a series of screens to remove chips, portions of knots and any foreign material from the pulp. There are many kinds of screens in common use, but they all follow the same general principle. In some stages of the process flat plates, perforated with fine holes are used. This lets the water and fine pulp go through, but retains the coarse material. Revolving drum screens are also used. The latter are arranged in rows, and are 4 ft. by 4 ft. 6 in. with a 10-in. perforation, through which the pulp passes. The feed-pipe supplies the pulp at the end of each drum.

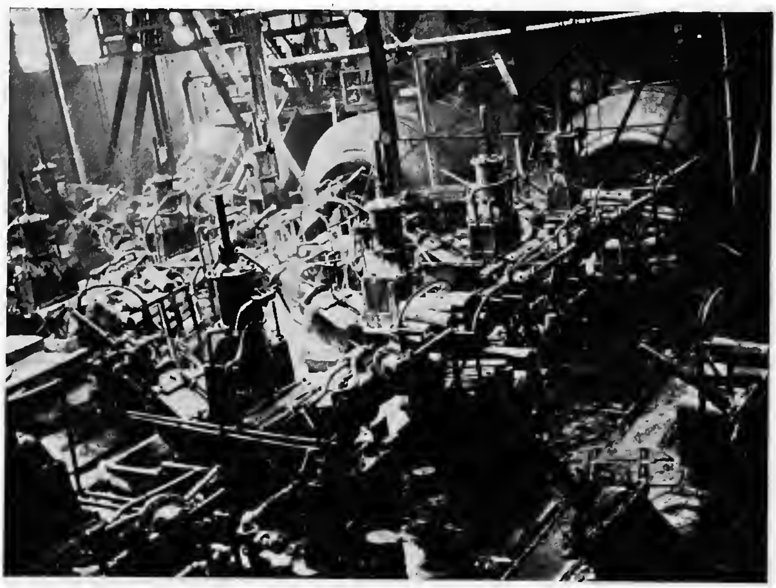
In the case of the plates they are vibrated to do the work of screening. In the case of the centrifugal screens, which are the latest form, a cylinder revolves at a high rate of speed, fine chips being forced through the slits by centrifugal force.

After the pulp has been screened it is treated in a wet press or lap machine in order to remove the large amount of water with which it is mixed. The material which does not pass through the screens is pumped to a refiner where it is again ground up and submitted to the same screening process until reduced to a fine fibrous condition.

[1] See *Paper*, June 25, 1913.

After screening, the pulp is treated in a wet press or lap-machine in order to remove the large quantities of water and leave a pulp suitable for shipment to the paper mill. The watery mixture is pumped continuously into a large receiving reservoir or vat in which a hollow drum rotates. The surface of this drum is made of fine wire gauze. The pulp in solution is caught by this fine gauze and adheres to it while the water passes through the gauze and out through the waste pipe.

This thin layer of pulp is carried by the rotating drum up above the surface of the liquid in the vat and is picked off by a traveling felt which



Photograph by A. M. Richards.

FIG. 4.—Grinder room in a large pulp mill containing 24 wood grinders of the three-pocket type. The grindstones are 60 in. in diameter and have a 28-in. face or grinding surface. Pressure of wood is maintained against the stones at a rate of 70 lb. per square inch. Capacity of grinding room is 180 cords per day of twenty-four hours.

passes over a roller and which comes into contact with the drum. The thin sheet of extracted pulp passes first between small rollers which press out most of the remaining water. From these rollers the sheet of pulp is wound up in a continuous sheet or roll on a large wooden drum until it is sufficiently thick to peel off. At various intervals, the operator cuts across this sheet with a wooden stick, removes the layers of pulp and folds them into convenient sizes for piling or for shipment or baling. When baled, it is commonly submitted to hydraulic pressure to remove all the moisture possible in order to reduce freight rates. Before hydraulic pressure is exerted, the sheets of pulp generally contain from 50 to 75 per cent of moisture.

Yield.

The following table shows the amount of pulp made by the mechanical process from a cord of the principal kinds of wood used.

Species	Pulp Produced in Pound
Spruce	1600–2200
Poplar	1400–2000
White pine	1600–2000
Aspen	1600–1800
Cottonwood	1900–2000
Hemlock	800–1100

Pulp manufacturers generally estimate a yield of about 2000 lb. of air-dry pulp from spruce. The yield by the mechanical process is much greater than by the chemical processes.

The variation in weights given is due to variation in moisture content, condition of wood, methods of manufacture, efficiency in recovery of waste or unscreened wood, etc.

About 85 per cent of all the wood used in the mechanical process is spruce.

The cost of producing mechanical pulp depends upon a number of conditions such as:

1. Cost and kind of wood. The cost of wood has been a variable factor, with the tendency in recent years to increase rapidly. (Wood prices have been discussed earlier in this chapter.)
2. Size and equipment of the plant.
3. General efficiency of the labor, methods and machinery.
4. Nature of pulp produced.

The cost of producing ground wood pulp per ton may be summarized as follows: A variation is given because the cost figures cover a wide latitude depending upon the factors given. It should be understood that these are pre-war estimates.

Under conditions prevailing before the war, the minimum figure of $16.60 would be about the average cost of producing ground wood pulp, but all materials, especially wood and machinery have increased very materially so that the maximum figures are more nearly a reflection of recent conditions.

COST OF PRODUCING GROUND WOOD PULP

Items	Cost per Ton of Pulp
Wood	\$7.00–\$11.00
Labor	2.50– 2.75
Repairs	1.00– 1.25
Water (storage, rent, dams, etc.)	.75– .90
Grinding stones	.15– .18
Felts	.12– .15
Wire, screens, etc	.08– .11
Miscellaneous, overhead, etc.	5.00– 6.00
	\$16.60–\$22.34

In a report submitted to the Newsprint Service Bureau, May 13, 1919, the cost per ton of producing mechanically ground wood pulp was put at \$26.90.

Under the item, miscellaneous, are included a great many costs not included elsewhere, such as oil, fuel, general overhead charges, such as taxes, interest, insurance, depreciation, selling charges, commissions, etc.

Mechanically ground pulp can be produced much cheaper than any other forms of pulp but it is the most inferior in grade, printing quality, strength and durability.

THE MANUFACTURE OF SULPHITE PULP

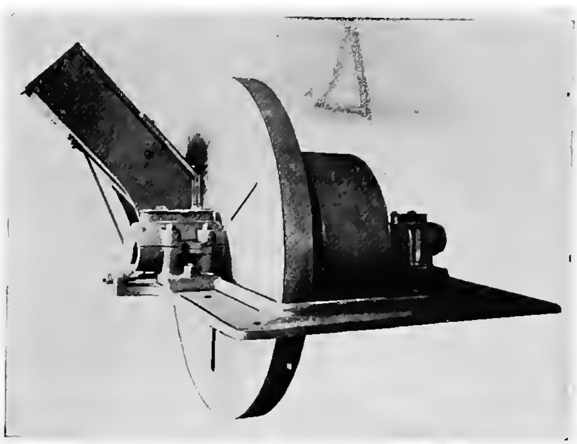
More wood is reduced to pulp by the sulphite method than by any other process. As already noted, there are three processes of chemical reduction, namely, the sulphite, sulphate, and soda. The sulphite is by far the most important of these. In 1916 there were reduced by the sulphite method 2,856,122 cords of wood which represents more than 50 per cent of the total amount consumed in that year. Nearly two-thirds of all the wood used for sulphite pulp was composed of spruce of which there were 1,803,217 cords. The remainder was composed of hemlock, balsam fir, and white fir. Most of the white fir is reduced by this process. Practically no hardwoods are reduced to pulp by the sulphite method.

The sulphite method of manufacturing wood pulp in its general aspects is practically the same the world over and varies only in minor details and with the local conditions in each pulp mill.

The wood is prepared by practically the same process of preparation as has been described in the case of manufacture by the mechanical process, that is, wood is cut to 2-ft. lengths and is either peeled in the woods or rossed or barked at the mill. Wood, however, is more carefully selected for this process than for ground wood pulp.

Chipping.

As the blocks of 2-ft. bolts come from the wood room they are passed on a conveyor to the chippers. The chipperman makes a final inspection of each bolt before it goes into the machine, and the large blocks which escaped the splitter and the undesirable species are sent back. Any blocks having any bark attached are sent to the helper who removes the bark with a hatchet.



Photograph by Pusey-Jones Co.

FIG. 5.—Wood chipper used to reduce the bolts of wood to chips for use in the manufacture of chemical pulp.

The chipper is very similar to the rossing machine except that it is much heavier in construction. It consists of a solid steel wheel with knives inserted, the only openings being at these points to allow the chips to pass through. This is covered with a heavy metal case to keep the chips from flying. The blocks are fed into the machine and against this wheel so that they strike the knives nearly perpendicular to the grain. The revolution of the wheel causes the knife to make a sliding cut and a slice is taken off the end of the block. As the wheel revolves at about 2000 R.P.M. this cutting is done so fast that the piece cut off is broken into small chips. These chips fall down into a pit below the machine and are carried to the screen by a cable and belt conveyor. Chips are generally about $\frac{5}{8}$ in. in length and $\frac{1}{16}$ to $\frac{3}{16}$ of an in. or more in thickness.

Screening.

The chips pass from this belt into a large revolving screen, or in some cases, a flat jigger screen is used. As the chips pass along this screen which has small openings at the head end, gradually increasing in size, the fine slivers and dust are removed first. Next, the good chips themselves pass through the holes and the knots and large pieces drop out at the lower end. These chips drop into a trough and are conveyed to a storage bin, directly over the digesters and cooking room, while the waste is conveyed to the boiler house and used for fuel.

Acid Manufacture and Storage.

In the sulphite process, the acid plant is one of the most important parts of the mill. Acid making is a truly chemical process and in these mills it is as much a part of the industry as the cooking or reduction of the wood. The basis of this cooking liquor or acid is sulphurous acid and is made by passing sulphur dioxide gas through water.

In modern mills pure sulphur is burned either in caldrons or rotary burners in the presence of an excess of oxygen. Part of the sulphur burns to sulphur dioxide but a portion burns only to the oxide or monoxide. In order to further oxidize this it is passed through a large oxidizer, which is very similar to a Bunsen burner. Here oxygen is admitted and the gas burns to the dioxide. The gas is then drawn through a series of three water coolers where it passes through lead pipes surrounded with cold running water. This cools the gas down to about 70° C. A set of fans is arranged in this system and by their work they suck the gas this far, furnishing the draft for the burner and oxidizer. The gas passes from the last cooler directly into the fans and in the tower system of acid manufacture is driven into large towers filled with limestone. The gas enters these towers at the bottom and as it passes upward, it comes in contact with many small streams of water which are trickling down over the stone, the water being admitted at the top. The sulphur gas also unites with a part of the limestone which has been dissolved by the water and forms a solution of acid calcium sulphite which constitutes the cooking liquor. As the liquor reaches the bottom of the system it is pumped into large wooden storage tanks and there kept until needed.

The acid, coming down through one tower is not sufficiently strong to eat away the lignin, resins, etc., of the wood which must be reduced. The proper strength is obtained by pumping the liquor from the bottom of the first tower, up and into the top of a second, where it again passes through a dense cloud of gas, as it runs down over the limestone. This liquor is then pumped from the bottom of this second tower, up and into a third and the process is repeated. On reaching the bottom of this third tower the acid is strong enough to do its work and is pumped away. At this stage it is strong enough to "eat" metals and is particularly harmful to iron and steel. This makes it necessary to handle the substance in lead pipes and containers or wooden tanks, etc.

Several other systems of sulphite acid manufacture are in use, tanks and flat vats filled with milk of lime being charged with sulphur dioxide to form acid calcium sulphite, but the tower system is believed to be the most efficient and economical.

In handling the gas, great care must be taken to keep all copper and brass out of the way as the gas will unite with the copper to form copper sulphide. In fan blades and all parts which must be hardened, a hardened lead is used. This consists of a mixture of lead and antimony.

The limestone which is used in these towers is not pure lime carbonate and as the lime is dissolved away a large amount of refuse in the form of sand, and other minerals is left. This must be cleaned out at intervals of from three to five days. As it is necessary to shut down a system entirely while it is being cleaned, an extra system must be maintained and run while any other system is closed for cleaning and refilling with stone.

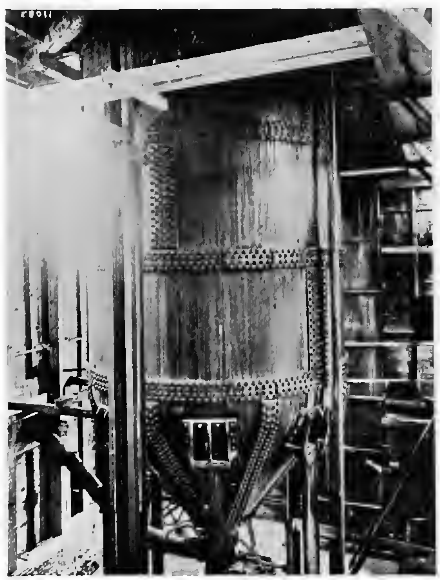
A test of the acid is made every hour and record is sent into the office each day.

Statistics show that it requires a three-tower system, with two towers making acid twenty-four hours a day for six days of the week and twelve hours on one day to supply this cooking liquor for a 100-ton mill. This varies in winter and summer as more acid and stronger acid can be made in the winter with cold water than in the summer when the water is warm. This requires the burning of 8000 lb. of sulphur and the use of about 25 tons of limestone per day.

Cooking.

The cooking, which is the chemical process which reduces the wood elements to soluble compounds leaving only the cellulose, is carried on in large steel retorts, which taper to a neck at each end and vary in size according to the desired capacity. The outside measurements of a 3-ton digester are 32 ft., neck to neck, and it is 10 ft. in diameter. A 5-ton retort is 45 ft., neck to neck, and is 10 ft. 6 in. in diameter. Retorts vary in size from 3 to 20 tons. Modern mills use the largest size because of the economy in operation. These retorts are lined with two layers of acid-proof brick and silicon cement, which prevents the acid from acting on the metal and also keeps the heat in. The lid or cover and valve parts, especially the " blow-valve " at the bottom, are made of hardened lead as the acid has little effect upon this. About three-quarters of the way up the retort is a small pit cock from which liquor can be drawn from the retort. It is by this method that the man in charge (cook) tells when the wood is cooked.

The steam, which furnishes the heat for the cook, is admitted at the bottom and drawn off at the top of the retort through a vent.



Photograph by U. S. Forest Service.

FIG. 6.—Digester used to "cook" chips in the manufacture of sulphite pulp.

In carrying out this operation, the blow valve or outlet valve at the bottom of the retort is closed and the retort is filled up to the top with the chipped wood. The wood chips are usually stored in large bins directly above the retorts, to which they were conveyed from the screen in the wood room. When the retort is full of chips, it is pumped almost full of acid from the acid storage tanks. A space of about 6 ft. is left, from the top of the acid to the top of the retort. This is to allow for boiling and overflow. The lid is then put in place and securely bolted down. The steam is then turned on and it is allowed to cook for about eight hours.

under a pressure of about 80 lb. and a temperature of about 340° F. Readings are taken hourly and reported.

Cooking spruce, balsam and hemlock usually requires about eight hours, but this may vary widely, according to size of digester, strength of the acid and freeness of the vent. If the vent becomes clogged it may require much longer to cook. In one case it took thirty-one hours to cook a 3-ton digester of hemlock, because of a clogged vent. Instances are known where the packing has been blown out of the top of a digester, from this cause. The vapors which pass out through this vent are piped into the acid storage tank where they deposit the acid which they contain and warm up the acid in storage.

When the cook is finished the steam is turned off and the blow valve at the bottom is opened. The pressure in the retort forces the semi-liquid mass out through the large pipe and into a large wooden tank called a blow-tank or blow-pit. The excess steam which is freed in this process passes out of the tank through a chimney into the open air.

Care must be taken in manufacturing the acid, as acid too weak does not thoroughly disintegrate the wood and produces a so-called hard stock which is full of small slivers. Acid that is too strong will dissolve the wood.

Washing.

After the pulp has sufficiently cooled so that the blow-pits can be opened, it is washed thoroughly with water to remove all of the liquid which it contains. As soon as the stock is washed, it is pumped into the feed tank from which it passes onto the screens as needed.

The blow pits are simply large wooden tanks which catch the pulp and liquor as it rushes out of the retort, and allows the steam to escape at the top. These tanks are made large enough to accommodate at least three digesters full of pulp. This is done so that the digesters can continue to run, even if the pulp mill should close down because of breaks or any other reason.

Screening.

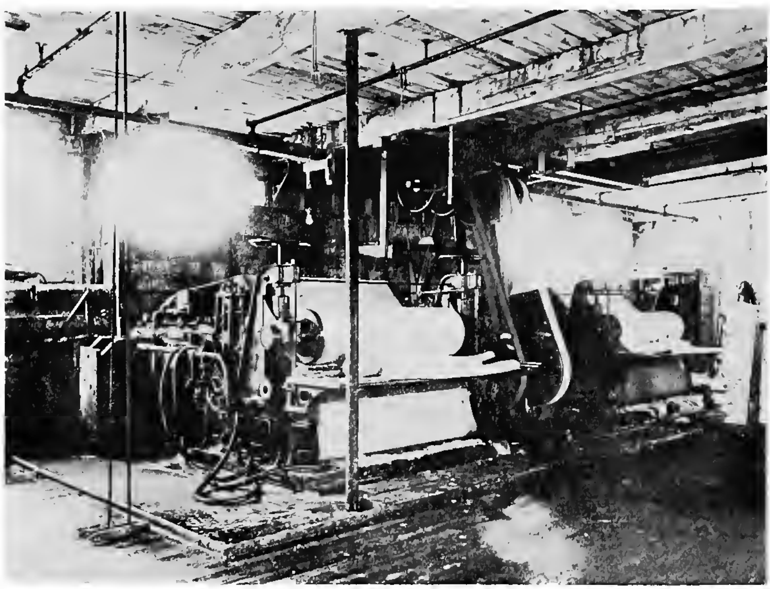
The screens used in this process are of the flat plate type, each plate fitted with a vibrator which aids the fibers in passing through the V-shaped slits. These screens are arranged in four lines, with a slant from head to foot so that the pulp-laden water will flow freely over the plates.

After washing, the pulp is pumped into the feed tank where it is mixed with a surplus of water so that the fibers are suspended individually. It is then pumped from this tank to the first line of screens. Here the best part of the pulp passes through the screens and is carried away by the water and goes out onto the press machines where it is collected.

There are several styles of screens employed for screening the pulp but these are usually used for special purposes and in mills in which the pulp is made directly into a certain kind of paper.

Collection of Pulp on Lap or Press Machine.

From the screens, the pulp passes out and into a tank which is equipped with a revolving cylindrical screen. As the screen revolves, the water



Photograph by U. S. Forest Service.

FIG. 7.—Wet machine or press—the final step in the manufacture of paper pulp. The sheets are stacked up as shown on the extreme right and then pressed and baled for shipment to the paper mill.

passes through the meshes and outlet, leaving the pulp adhering to the mesh. The screen revolves, carrying the pulp upward and it is removed by a felt which is carried over a set of rolls where the pulp is deposited on a large wooden roll. This pulp is cut off from time to time, as it becomes thick and is folded up into bundles for shipment or use directly in the paper mill. Laps made up in this way contain about 60 per cent of water.

Drying.

In the manufacture of dry pulp the pulp passes from the screens into a box containing a revolving cylindrical screen and is picked up and carried on a felt the same as in the case of the lap machine. In this case, however, it is carried through a series of three sets of press rolls which press the water out of the sheet of pulp. This sheet is then carried over a set of about 30 hot cylindrical drums which are arranged very similarly to those of a paper machine. These drums are heated by steam and are kept at a temperature of about 250° F. As the dry pulp comes off the rolls it is wound on a reel at the end of the machine. There are two of these reels and while one is winding up the pulp that on the other is rewound and run through a set of knives and re-wound in rolls 2 ft. long and weighing about 200 lb. These rolls are then tied, and loaded into the car for shipment.

Dry pulp is never made in a mill where the pulp is going directly into paper as it is unnecessary to drive off all of this water. Dry pulp is made for long shipment and long storage.

Power.

Power in a pulp mill is not restricted to any one type. In many places water power is used entirely. Steam is also used and electricity is used where it can be manufactured cheaply.

A 100-ton mill requires about 1500 h.p. to operate it.

Cost of Production.

The cost of manufacture of pulp varies in different mills but a good average before the war would be about $35.00 a ton, unbleached. The process of bleaching added about $12.00 to this initial cost.

Spruce and hemlock, in the summer, are practically alike and sell at the same price, but in winter they vary greatly, both in quality and sale price.

At a large pulp mill in New York the following costs were determined over a period of several months in 1916:

COST OF PRODUCING SULPHITE PULP

Items.	Cost per Ton.
Wood	$16.59
Mill labor	3.61
Sulphur	3.24
Machine repairs and supplies	2.09
Machine labor (repairs)	1.30
Power, heat and light	1.29
Yard labor	.63
Fuel	.44
Limestone	.36
Oil, grease, etc.	.14
Stable and teams	.29
Repairing buildings	.38
Miscellaneous expenses	.51
Total manufacturing expenses	$35.24

To the above general items may be added the general expenses which are not usually included in the cost of manufacturing but which are obviously part of the total expenditures. These items are as follows:

Items.	Cost per Ton.
General superintendency and officers' salaries	$ .55
Office salaries	.52
Insurance and taxes	1.24
Selling	.09
Interest on investment	1.65
Miscellaneous, including travel	.31
Postage, printing, telephone, telegraph	.12
Incidentals	.06
Total	$4.54

Adding the general expenditures and the manufacturing expenses the total expenditures amounted to $39.78 per ton of unbleached sulphite pulp.

At the time these cost figures were obtained sulphur cost $25.00 per ton gross, f.o.b. mill, limestone, $.80 per ton net, f.o.b. mill, and coal $3.40 per ton gross, f.o.b. mill.

In the summer of 1916 No. 1 spruce sulphite pulp brought $65.00 per ton. No. 1 hemlock sulphite pulp, $58.00 per ton, bleached sulphite pulp, $97.00 per ton and screenings, $16.00 per ton.

THE MANUFACTURE OF SULPHATE PULP

The manufacture of pulp by the sulphate process represents the most recent development in the chemical reduction of wood fibers. The process really dates from 1883 when Dahl introduced the soda treatment on straw. A short time thereafter it was used in connection with wood. It is now used chiefly on those conifers which do not lend themselves readily to reduction by the other processes. The high resinous content of many of our most abundant forest trees cut for lumber has been the great deterring factor in the use of these woods for paper pulp. Great success has recently been attained in the reduction of southern yellow pine and other saw-mill waste which heretofore had been largely a total loss. Since the greatest waste in all forest industries occurs in saw-mill and logging operations, and since our greatest lumber operations are in southern yellow pine and Douglas fir forests, this method holds great promise for the future.

In 1916, 144,631 cords of wood were reduced by the sulphate process. The largest single amount was made up of southern yellow pine, of which 36,711 cords were reduced by this process. Hemlock composed 28,372 cords, tamarack 29,065 cords and balsam fir 10,150 cords.

The preparation of the wood for reduction by this process is the same as for the sulphite method. The boiling is done with a solution of caustic soda containing small amounts of sulphate and sulphide of soda. The sulphate of soda is used as the source of alkali and sodium sulphide in an incineration process.

The successful manufacture of kraft paper, a strong, brown wrapping paper from sulphate pulp, offers every indication of a large development in the South where a relatively cheap and plentiful supply of raw wood material is available.

Sulphate pulp has recently been imported from the Scandinavian countries to the amount of over 36,000 tons annually and kraft paper itself to the amount of over 22,000 tons yearly. Sufficient wood waste is said to be available in the southern states to manufacture at least 10,000 tons of kraft paper per day.

The sulphate process, in contrast to conditions obtaining in this country, has superseded the soda process in Europe several years ago and is still far more important in its yearly output. For some specialities, sulphate paper is regarded with great favor. In white papers from bleached sulphate pulp, the product is soft and pliable in contrast with the harder and more " rattling " sulphite papers. However, for the future, the use of sulphate pulp for kraft papers has the greatest promise.

The process may be described briefly as follows:[1]

After the reduction of the wood billets to the form of chips as has been described in connection with the sulphite process, they are digested under pressure in a liquor containing a solution of various sodium compounds. In the ordinary operation, according to this process, these compounds consist of sodium hydroxide, sodium sulphide, sodium carbonate, and sodium sulphate. Of these compounds the first two are the active agents in the digesting process and combine with about 50 per cent of the weight of the dried wood to soluble organic sodium salts. The time required for cooking depends upon the nature of the wood and the character of the pulp desired. After cooking, the pulp is separated from the waste liquor by washing in large tanks. The liquor is later evaporated and the residue is partly burned in rotary furnaces and after being subjected to high temperatures, the sodium sulphate is added to replace the soda lost during the recovery process.

After cooking and washing, the pulp is run through press rolls and formed into bundles. Then, after drying, it is sent to the pulp mill.

THE MANUFACTURE OF SODA PULP

The manufacture of wood pulp by the soda process was discovered about 1880. The preparation of the wood for use in the soda process is exactly the same as has been described in connection with the sulphite pulp. That is, the wood is barked and then chipped and screened.

This process lends itself especially to the reduction of various hardwoods and pine. In 1916, 394,577 cords of aspen were reduced by this method. In fact aspen composes more than one-half of all of the pulp wood reduced by this method. Other hardwoods, such as beech, birch, maple, yellow poplar, gum and cottonwood are also frequently reduced by the soda process. In 1916 there were 707,419 cords reduced by this method.

The Digesters.

The object of boiling the wood under pressure with chemicals is to

[1] Taken partly from an article on the manufacture of sulphate pulp by Carl Moe, in *Paper*, July 26, 1916.

dissociate the valuable fibrous portion of the plant from the resinous and non-fibrous portion. As a result of this boiling the wood loses about one-half of its weight.

The digesters are of various styles and shapes and may be either spherical, cylindrical, or egg-shaped, being constructed to revolve at a slow rate of speed, or they may be fixed permanently in an upright position. Digesters of the spherical type are usually about 9 or 10 ft. in diameter and the cylindrical digesters are from 40 to 50 ft. high and from 12 to 15 ft. in diameter. These digesters vary in size from 3 to 20 tons capacity.

The inside of these digesters which are used in this alkaline process do not have to be lined with brick as do the digesters used in the acid process.

The mixture in the digesters is heated by means of steam at a pressure of from 80 to 100 lb. per square inch. This steam may be blown directly into the digester or may pass through a large coil at the bottom of the digester. Each of these systems has its advantages and disadvantages, as in the former the steam is condensed by the material in the digester and so increases its volume while, in the latter, it is drawn off from the coil.

In the manufacture of soda pulp, revolving digesters are most commonly used and are found to produce the best results. Here a pressure of from 60 to 80 lb. is also found to produce the best results.

Cooking.

The cooking and the manufacture of the cooking liquor in this process are not nearly so complicated as in the sulphite process. Here the wood chips are emptied into the digesters and are covered with a 6 to 9 per cent solution of sodium hydroxide (caustic soda—$NaOH$) and this is cooked at a temperature of about 240° F. and a pressure of from 60 to 80 lb., for a period of from eight to nine hours.

When the cook is completed, the valve at the bottom of the digester is opened and the semi-liquid solution passes out as a result of the pressure in the retort. This is called "blowing" and the material passes into a large wooden tank called a "blow-pit." Here the steam which escapes is passed into the open air through a large pipe running from the top of the tank.

Washing.

The next step is to wash the pulp free from the spent cooking liquor and soluble portions which it contains. As the caustic soda is recovered by a well-defined process, the water used in washing is reduced to a minimum amount. All of this liquor is saved and is conveyed by pumps and pipe lines to an evaporator where the soda is recovered.

The next step in the process is bleaching the fibers, which is touched on briefly elsewhere. All soda pulps intended for conversion into paper must be bleached.

The Recovery of Spent Liquors.

The spent cooking liquor and the washings are pumped into an evaporator which is operated by a multiple effect vacuum apparatus where the water is removed and it is reduced to a thick syrup. This concentrated liquor is then burned in special furnaces, this burning consuming all of the organic matter and leaving a black mass which consists mainly of carbonate of soda. The mass is then washed with water to remove the carbonate which is later converted into caustic soda by being boiled with lime.

Collecting the Pulp.

The remainder of this process is exactly like that of any other process and will not be taken up in detail here as it has been described in the two preceding processes.

Reviewed briefly it consists of a very thorough screening of the pulp to separate the fibers from the slivers and any other large, uncooked pieces of wood or foreign material. The pulp is then screened from the water and run out in the form of laps containing from 40 to 60 per cent of water or run out in dry rolls which contain about 18 to 20 per cent of water.

Tests of this pulp for water content, strength, etc., are made and the pulp is either shipped to the paper mills where it is made into paper or it is made directly into paper at the mill where it is reduced from the wood.

A great advantage in the reduction of wood by the soda process lies in the fact that comparatively little care is necessary in preparing the wood because of the great solvent power of the alkali. The process will reduce small pieces of bark and even small knots as well as the chips.

THE MANUFACTURE OF PAPER FROM WOOD PULP

The manufacture of paper consists of the formation of a continuous sheet or web made of minute structural units of pulp. The processes of papermaking are of a mechanical and physical nature to a large extent in contrast to the manufacture of wood pulp by the various chemical processes. It is upon cellulose and a proper knowledge of its nature that the entire paper industry is based. Cellulose is the basis of the vegetable kingdom and makes up the greater part of all woody tissue. Considered chemically, it is one of the most inert substances known and possesses the property of great resistance to the natural destructive agencies. Cellulose never occurs free in nature but always in combination with other members of the fatty series. Cellulose in its pure form is obtained by the removal of other substances during the chemical processes, whereas mechanical ground pulp is merely the physical reduction of the wood fibers to a pulp form.

In the preparation of the cellulose fibers for the manufacture of paper, vast quantities of water are used but there is no loss of product through its solubility because cellulose is insoluble in water. In many mills from 50 to 70 gal. of water are required for washing every pound of paper that is manufactured. Cellulose has little affinity for chlorine and this is of importance because it permits of the use of chloride of lime and other chlorine compounds for bleaching purposes.

The strength of any paper is due primarily to the strength and cohesion of its constituents. A careful dissection of any paper will show that the fibers are interlacing in all directions. The deposition of the fibers from suspension in water, the interlacing of the fibers, and the isolation of the individual fibers are the basic principles of papermaking.

In comparing the mechanical and chemical pulps the principal distinction is that the mechanical pulp is not pure cellulose, and, consequently, a very inferior grade of paper is secured. The chemical pulp has had the resins, gums and other fatty constituents, as well as the wood cells themselves, removed, leaving only the fibers of cellulose. Mechanical pulp, moreover, produces fibers which are short and brittle, whereas the wood fibers in chemical pulp are long, slender and flexible. Paper made from mechanical pulp oxidizes readily and turns yellow on continued exposure to the air, owing to the organic residues contained in it. It is also relatively weak and is used only for newspapers and cheap wrapping papers. Paper made from chemical pulp is manufactured into the finer grades of book and writing papers, etc.

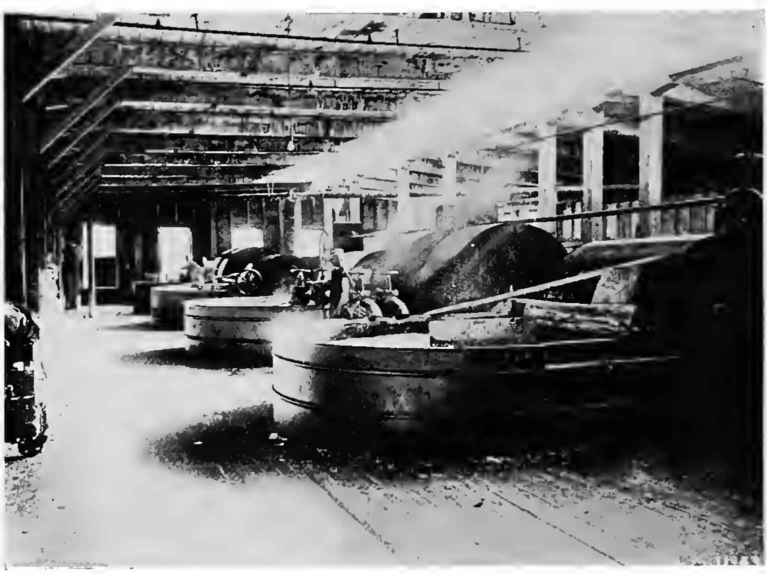
Bleaching.

After the manufacture of pulp has been completed it is necessary to bleach it to bring out the proper color. Although considerable pulp is bleached, in comparison with the total amount manufactured the percentage put through the bleaching process is relatively small. Sulphite pulp is a pinkish gray color and is used directly in grayish papers. The mechanical pulps which are gray or brown in color according to the method of manufacture are used in papers which are generally not required to be white and, therefore, are seldom bleached.

Whenever sulphite, sulphate, or soda pulps are to be bleached they are put through a process of oxidation. The compounds used generally are hypochlorites, usually suspensions of chloride of lime, or electrolytic bleach consisting of calcium or sodium hypochlorite solutions, etc. The bleaching process, which is rather expensive, increases the value of the paper to a considerable degree.

Beating.

After bleaching, or in case the pulp is not put through the bleaching process, the complete separation of the individual fibers is necessary.



Photograph by U. S. Forest Service.

Fig. 8.—Beating machines.

This is done by beating which gives the pulp evenness of texture so that proper felting and an interlacing of the fibers can be secured in the final process of papermaking. The fibers are also made flexible and of uniform length and the ends are frayed out so that they will enmesh more readily.

The machine used for the reduction of the pulp by beating is called the " Hollander," or more commonly the beating engine. It consists of an oblong trough with semi-circular ends, and " midfeather," running partly along the center so as to form a continuous channel round which the pulp can circulate. On one end is situated the beating rolls which are provided with a set of knives or bars which may be raised or lowered to press more or less on a bedplate of stationary knives or bars. These machines vary in size but usually have a capacity from 1000 to 1200 lb. at one time. The ordinary beater is about 2 ft. deep at one end and about 2 ft. 6 in. deep at the other. The movement of the pulp in the machine is caused by the paddle-like action of the arms of the roller. A large proportion of the power used by the paper mill goes to the beater room. Experiments have shown that large beaters are much more economical of power and are much more efficient than the smaller ones. Recently concrete has been introduced for the trough construction in place of iron.

A beater with a roll or drum having 100 bars and a bed-plate with 20 bars of 40 in. in length and running at 200 R.P.M. should prepare about 1½ lb. of paper of average substance per minute.

Sizing and Loading.

When the pulp is bleached a certain amount of bleaching chemicals remain in the substance and it is necessary to remove this either by washing, or by the use of chemicals. Washing is generally considered the best as it readily removes the chlorine.

After washing, the pulp is passed through the beater. During the beating operation, the sizing and loading are added. In the manufacture of ink or water-resisting papers, the operation is practically limited to rosin as a "size." It generally requires about 3 or 4 lb. of rosin to size 100 lb. of paper. The prepared rosin size is added to the pulp in the beater, together with alum or sulphate of alumina which finishes the reaction and fixes the rosin size upon the pulp. Starch, silicate of soda, soap, casein, gelatin, and many other substances are used as sizing for papers for special purposes.

In the manufacture of high-grade papers, it is necessary to fill up the surface pores so that the surface will be smooth. This is done by the addition of very fine clays, such as kaolin, talc or sulphate of lime, or baryta. There are other fillers and loading agents but these are the most common. The greater the percentage of filler used, it is obvious that the smaller is the proportion of wood pulp, and, therefore, paper that is heavily filled is not so strong and durable. In composition the filler may constitute from 2 to 30 per cent of the finished paper product.

Coloring.

The dyeing or coloring of paper pulp is also done during the beating process and requires considerable care and study. As cellulose is exceedingly inactive it is usually necessary to use mordants in order to fix the colors. Soluble coal tar dyes are very commonly used, but there are only comparatively few which are suitable for the coloration of paper pulps. Mineral pigments are often used as well to secure certain bright colors. Poorly dyed papers will bleach when moistened or if exposed to light. The coloring of paper pulps is still in the process of development.

Paper Machine.

After the beating process, during which the size, filler and dyes are added, a trap door in the bottom of the beater is released and the mixture

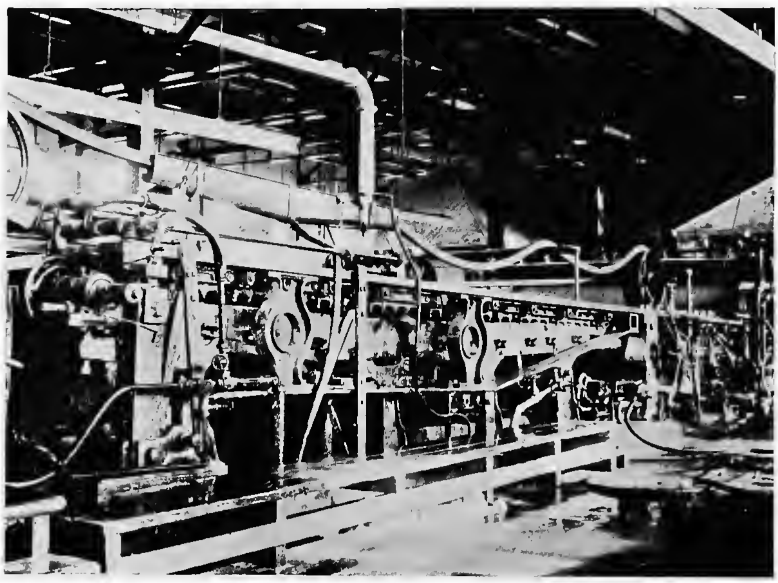


FIG. 9.—Fourdrinier wire, the most specialized machine in the manufacture of paper. The stock is deposited on the wire at the left and the water content is drawn off. A rocking motion of the frame causes the pulp to "felt" properly and the fibers to intertwine.

flows out through a pipe and into a tank called the stuff chest where it is stored until needed at the paper machine. The paper machine is the most intricate of specialized machines used in the paper mill and is the key to the successful making of paper. It consists of an endless wire screen called the fourdrinier wire which revolves around a series of rollers. On this screen, the pulp pours in a steady even stream and as the water which carries the pulp passes through the screen it leaves the fibers behind to form an endless sheet. This sheet which still contains a large percentage of water next passes on to a felt and is carried through three sets of very heavy rollers which are pressed together under great pressure. These press rolls squeeze out a large portion of the remaining water. The sheet then passes over a series of heated rollers which gradually dry out the remaining moisture and produce the finished sheets of paper.

There have been great developments in the refinements of the fourdrinier machines during recent years. From machines making news

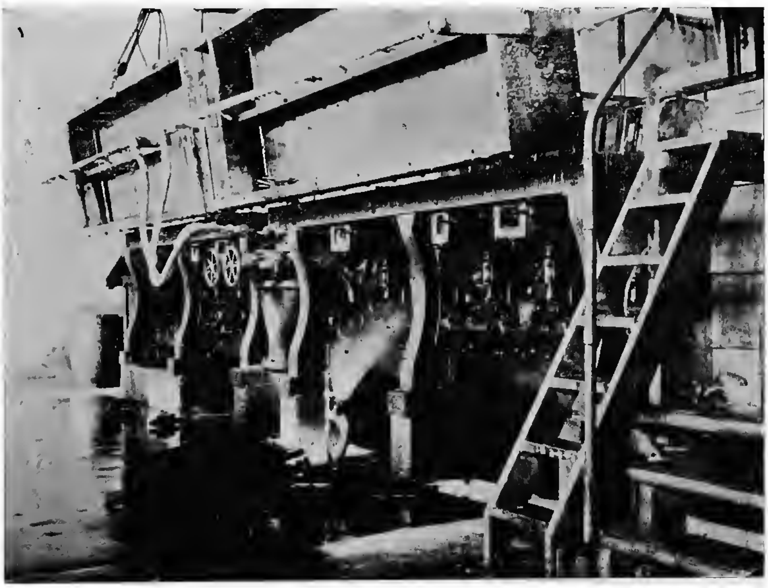


Fig. 10.—Diaphragm plate screen tilted for washing. This screen is located at the head of the paper machine and its function is to screen the paper stock before it passes on to the Fourdrinier wire.

print paper of the width of 90 in. at a speed of 200 ft. a minute, the parts of these machines have been lengthened and widened and refined until at the present time these machines have a width of 206 in. and can produce paper at the rate of 700 ft. a minute.

The pulp is carried out to the fourdrinier wire by means of an apron and a special mechanical arrangement prevents the formation of too thick a layer on the screen. On the fineness of the screen depends the quality of the paper made, but it usually contains from 60 to 70 or more strands of wire per inch. The frame which supports the rollers and the screen is usually arranged so that it can be vibrated sidewise at all times while the machine is in operation. This vibration assists in intertwining and interlacing the fibers and consequently gives a much stronger sheet of paper. The length and number of strokes determine the character of the paper to a large extent, the long, slow strokes being best for sulphate papers, while the short and fast strokes are best for finer grades of paper. Suction boxes, or vacuum rolls, traverse the under surface of the screen and aid in removing the excess of water by sucking it out.

Press Rolls.

As the paper passes on the screen it is detached from the wire and passes over a heavy felt which carries it through three sets of rolls which press out a considerable portion of the remaining water. Many machines are fitted with a set of rollers having many small perforations through which the remaining water is partly sucked out. An endless felt carries the paper over the dryer.

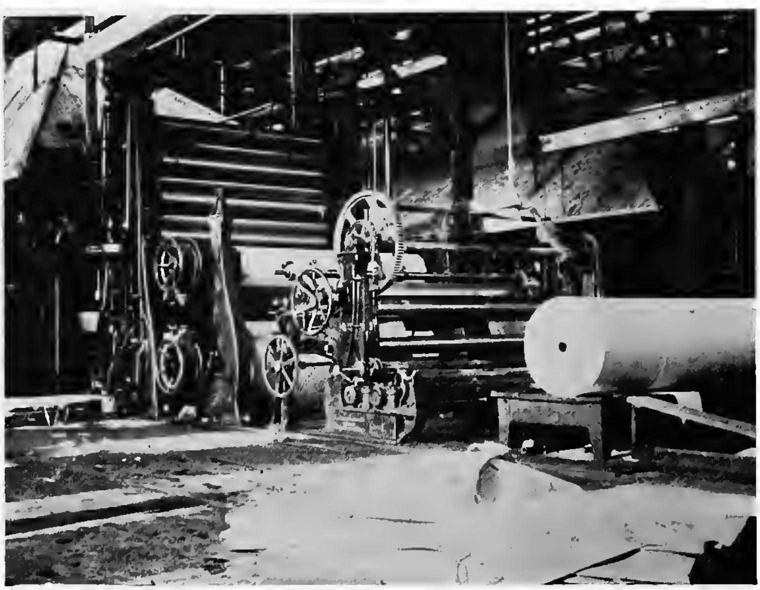


FIG. 11.—This shows the end of the drier (at left) the calender stack, reels, rewinder and cutter. On the right is a roll of paper which has been re-wound and cut. The calender irons out the wrinkles in the paper and surfaces it. Paper is re-wound to make neat and compact rolls and is cut to the desired length of roll.

Drying Rolls or Driers.

From the press rolls the sheet passes over the drying rolls which consists of a series of from 16 to 36 or more large heated steel drums. The number of drums used depends upon the speed of the machine and the weight of the paper. The felt is also used in connection with them to keep the sheet of paper pressed tightly against the hot rolls which are heated by steam introduced from one side.

After passing through the long series of drying rolls, the paper is run through calenders to produce what is known in the trade as supercalendered paper. In this operation the surface of the paper is given a glazed finish.

Cutting.

As the paper goes from the driers it may vary from 60 to 156 in. or more in width. It is seldom that this width is desired commercially, so the sheets must be unwound and cut to the desired width and rewound once more. For this purpose a special cutter and winder is used. The paper is then sorted, tested, and wrapped for shipment.

IMPORTS OF PULP WOODS AND WOOD PULP

The following table shows the imports of pulpwoods and wood pulp to this country for the years 1914 to 1918, inclusive, according to the figures of the Department of Commerce. Each year of these imports ends on June 30th. Practically all of the importation of pulpwoods is from Canada, whereas the wood pulp comes normally from Sweden and Norway as well as from other countries and Canada. The tables show how the war seriously interfered with the imports of wood pulp to this country, since the total amount has decreased markedly from the importation in 1914.

Most of the imports of pulpwood comes to this country in the peeled condition. The imports of pulp wood have increased during the period of the war, particularly the wood brought in in the peeled condition.

IMPORTS OF PULP WOODS, 1914 TO 1918, INCLUSIVE

	Rough.		Peeled.		Round.	
	Amount.	Value.	Amount.	Value.	Amount.	Value.
	Cords.		Cords.		Cords.	
1914	180,316	$1,063,721	630,803	$4,062,835	255,844	$2,118,010
1915	247,400	1,458,020	551,203	3,516,460	187,047	1,507,750
1916	187,000	1,131,350	627,200	3,050,732	104,714	1,282,058
1917	214,180	1,307,884	630,810	4,285,282	162,818	1,205,057
1918	210,527	1,045,781	822,810	7,821,335	138,000	1,021,306

IMPORTS OF WOOD PULP 1914–1918, INCLUSIVE

	Mechanical Pulp.		Chemical Pulp.	
	Amount.	Value.	Amount.	Value.
1914	354,967,673 lbs.	$2,733,595	783,759,522 lbs.	$14,289,743
1915	187,253 tons	3,141,119	400,669 tons	16,739,092
1916	186,406 tons	3,148,173	320,640 tons	13,719,677
1917	270,107 tons	7,018,404	429,368 tons	35,443,390
1918	189,599 tons	6,138,831	314,553 tons	25,450,259

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CHAPTER III

TANNING MATERIALS

GENERAL

Nearly all plants of the vegetable kingdom contain an astringent principle known as tannin. This agent has the property of acting upon animal skins in order to make them strong, flexible, impervious to water, imputrescible, and resistant to decay and wear. Practically all of the commercial tannin, however, is derived from a relatively few species of plants and is secured from only small portions of these. The principal forms of tannin are derived from a variety of barks, woods, leaves, fruits, nuts, etc., which contain varying amounts of tannin and tannic acid. Tannin occurs chiefly in solution in the cell sap, as well as in tannin vesicles and the cortical cells of the bark.

In this country, hemlock bark was, for a long time, the principal source of tannins. Some oaks also supply bark of sufficiently high tannin content to be of commercial interest.

With the rapid cutting of our virgin forests and the gradual disappearance of hemlock, however, the principal source of supply has been seriously depleted, and the tanners have turned to a number of other materials such as chestnut wood and a variety of foreign products, the importation of which has been steadily increasing within the past few years, particularly, quebracho, gambier, mangrove bark, sumach, myrobolan nuts, valonia and several others.

It is estimated that the total annual value of the vegetable tanning materials used by the tanners and dyers of this country is from $25,000,000 to $30,000,000.

The harvesting, manufacturing, and importation of tanning materials constitute one of the most important of the forest product industries.

Hemlock bark has been of the greatest economic value in the past because it occurred in comparatively large quantities and, therefore, was relatively cheap. It is also readily made available for use. As a result of this situation, the chief centers of the tanning industry have developed, principally in the great hemlock regions, the obvious reasons being it was easier to transport the lighter hides to the centers of tannin production, rather than the heavy barks.

For several years past it has been customary to use tanning materials containing not less than 8 to 10 per cent of tannin, but a method has been devised whereby chestnut wood which has a very variable content of 3 to 11 per cent can be utilized. This method consists of extracting the soluble matter from the wood and concentrating the extract in a vacuum to a very dense liquid or dry powder. This extract may contain, as a result of this process, as much as 30 to 70 per cent of tannin.

With the exception of this wood and quebracho, tannin is a product found chiefly in the portions of a tree which are of little commercial importance otherwise, namely: in the bark, portions of the roots, the heartwood (only in case of quebracho and chestnut), the husk of the fruit and in a few other cases in the leaves and twigs. The tannins found in the various sources are not precisely the same in their chemical constituents. Two acids are formed, namely; gallic and pyrogallic.

At the present time there are at least 600 consumers of tannin in the United States and aside from foreign materials, they use about 625,000 cords of hemlock bark, 290,000 cords of oak bark and 380,000 cords of chestnut wood.

HISTORICAL

Records of early civilization indicate that the tanning of leather to preserve it was practiced by the Chinese over 3000 years ago. It is said the Romans tanned their animal skins with oil and alum and occasionally with oak bark. The Indians of this country were found using bark to preserve buffalo skins. It is reported that the first tannery erected in this country was built in Virginia in the year 1630 but the industry developed most widely and successfully in Massachusetts. There were 51 tanneries in New England in 1650. Oak bark was used principally at first and was generally preferred to hemlock. The abundant supply of hemlock, however, brought it into early and prominent use. At this time, there was a strong demand for the export of skins and hides to Europe, and it is said by the year 1810 the value of the product of American tanneries was about $200,000,000. Salem and Peabody in Massachusetts became great centers of industry and Boston became the great leather market of the United States. About 40 to 50 years ago, owing to the rapid cutting of available oak and hemlock forests, the center of the production of tanning materials moved toward the

West and South. Pennsylvania became the great center of bark production and many acres of virgin hemlock were cut down for their bark alone.

Until 1895 to 1900 foreign tanning materials, on account of cost of transportation, could not be sold in this country in competition with the domestic supply. But, owing to the increase in wages and the decrease in the domestic supply and the fact that the forests are

Photograph by U. S. Forest Service.

FIG. 12.—Peeling hemlock bark on the Cataloochee Tract, Haywood Co., North Carolina. The bark is removed in 4-ft. sections and, after drying, is piled ready for hauling to the railroad. This crew consisted of four men including the foreman.

becoming more remote from the tanneries, entailing greater cost of transportation, the price of hemlock and oak bark delivered at the plants increased to such an extent that a great deal of foreign "leaf" (meaning accrued and unextracted tanning materials) came into use. These could be imported great distances because the tannin content ranged from 2½ to 4 or more times the content of hemlock and oak bark.

The outbreak of the war in 1914, however, together with the scarcity of ocean tonnage, made more imperative the demand upon the domestic supply of oak bark, hemlock bark and chestnut wood extract. In 1905 the average price paid per cord of 2000 lb. for hemlock bark in Pennsylvania was $7.54 and for oak bark, $8.40. By 1915 the prices became stronger and values from $9.00 to $12.00 per cord were quoted f.o.b. cars at shipping points for hemlock bark and still better prices for oak bark.

With the growing scarcity of the barks in the East, the California tanbark oak which contains from 10 to 20 per cent or more of tannin was developed. In 1905 over 50,000 cords of an average value of $19.04 per cord were produced. In the northwest the western hemlock (*Tsuga heterophylla*) began to be developed for its bark. Of the 2200 tons of bark used annually in the tanneries of Oregon and Washington, it is said that two-thirds are of western hemlock. The industry is still in its infancy in the northwest and it is likely that western hemlock will supply a much larger share of the requirements there in the future. It contains from 10 to 12 per cent of tannin.

The most important development in the tanning industry within recent times in this country came with the discovery of a method to extract the tannin from chestnut wood on a commercial basis. This phase of the industry has developed rapidly within the past twenty years, especially in North Carolina, Virginia and Tennessee, where a plentiful supply of chestnut of sufficient tannin content is available in the mountainous portions of those states. In several of the chestnut extract factories of the South, part of the residue left after the tannin has been removed from the chips is converted into paper. The future of the chestnut extract industry is not altogether assured, owing to the uncertainty of the ultimate effect of the blight or bark disease on the chestnut forests of this country.

The entrance of foreign tanning materials in competition with those produced in this country has had a profound effect on the industry at large. As the demand for tanning materials increased in this country and the domestic supply became more limited, inaccessible and expensive, it became possible to import exotic tannins. Quebracho from the Argentine has been imported in steadily increasing amounts since 1900, when the important South American quebracho fields were developed and exported on an extensive scale. The value of quebracho wood and extract imported to this country in 1917 was about $6,575,000.

Other foreign tanning materials that have entered our market and have been extensively used within the past two decades are gambier, mangrove bark, myrobalan nuts, sumach and valonia. These and others are described later in this chapter.

The world's supply of tanning materials is apparently very abundant and it is estimated by authorities that many sources little developed at the present time may be depended upon for vast quantities in the future. Especially is this true of many tropical plants of Africa, the Far East and South America. The great hemlock forests of Washington and Oregon have been scarcely touched in so far as their tannin resources are concerned, and they constitute an important storehouse of tannin for future use. Western hemlock bark has a higher tannin content than that of the eastern hemlock. At the present rate of cutting quebracho in South America, which amounts to about 1,000,000 tons, and which supplies an important part of the tanning supplies of England, Germany, France and Italy, as well as the United States, it is estimated that the supply of this source alone will last 168 years [1] and the annual growth more than offsets the yearly cut.

PRINCIPAL SOURCES AND TANNIN CONTENTS

The following table shows the most commonly used domestic and foreign tanning materials with the percentage of tannin which they usually contain. These are the tannin contents as recognized by the Leather and Paper Laboratories of the Bureau of Chemistry: [2]

DOMESTIC	*Tannin.*	*Class of Tannin.*
Hemlock bark (*Tsuga canadensis*)	8–10%	catechol
Chestnut wood (*Castanea dentata*)	4–10%	catechol
California tanbark oak (*Quercus densiflora*)	10–29%	catechol
Chestnut oak bark (*Quercus prinus*)	8–14%	catechol
Black oak bark (*Quercus velutina*)	6–12%	catechol
Red oak bark (*Quercus rubra*)	4– 8%	catechol
White oak bark (*Quercus alba*)	4– 7%	catechol
Western hemlock bark (*Tsuga heterophylla*)	10–12%	catechol
American sumach (*Rhus glabra*) Southern States	25%	pyrogallol
"Staghorn" or "Virginian" (*Rhus typhina*)	10–18%	pyrogallol
FOREIGN		
Quebracho wood (*Quebrachia lorentzii*) South America	20–28%	catechol
Gambier (*Uncaria gambier* and *U. acida*)	35–40%	pyrogallol
Myrobalans (*Terminalia chebula*) nuts	30–40%	pyrogallol
Valonia (*Quercus ægilops*) acorn cups, Eastern Mediterranean	Up to 45%	pyrogallol
Sicilian sumach (*Rhus coriaria*) Italy	20–35%	pyrogallol
Mangrove bark (*Rhizophora mangle*) tropics	15–40%	catechol
Divi-divi (*Cæsalpinia coriaria*) Central America, pods	40–45%	pyrogallol
Golden wattle (*Acacia pycnantha*)	About 40%	pyrogallol
Kino (*Pterocarpus senegalensis*) Africa	Up to 75%	catechol
Algarobilla (*Cæsalpinia brevifolia*) Chili	Average 45%	pyrogallol
Pistacia lentiscus, Sicily, Cyprus, Algeria	12–19%	catechol

[1] From "Tanning Materials of Latin America," by T. H. Norton.

[2] Supplied by Dr. F. P. Veitch.

The following table, furnished by the Tanners' Council of the United States, shows the approximate quantity of tanning materials consumed annually in this country:

TANNING MATERIALS CONSUMED CALENDAR YEAR 1918

Material.	Solid Extracts, Pounds.	Liquid Extracts, Pounds.	Crude Tanning Material, Pounds.
Chestnut	48,148,878	316,229,621	74,794,423
Hemlock	2,952,660	17,442,192	723,077,392
Oak	3,815,056	34,380,396	485,134,791
Quebracho	79,137,089	94,371,395	2,989,851
Wattle [1]	154,013	36,792	2,200,452
Mangrove	1,405,265	45,891	5,764,495
Myrobalans	124,583	188,908	6,719,494
Gambier	782,512	225,236	3,176,398
Sumach	1,080,110	1,670,909	5,930,990
Valonia [1]	10,120	100	7,008
Divi divi	500,514	89,101	13,217,926
Larch	243,483	2,049,208	900
Quercitron [1]	3,726	18,722	10,433
Algarobilla [1]	1,950		
Quermos [1]	2,580	64,690	
Not specified	3,048,623	28,464,866	5,335,272
Runaway or recovered extract [2]	84,620	9,776,692	
Blended (chestnut and oak only) [2]	17,000	4,938,616	1,018,824
Sulphite cellulose [3]	194,094	6,185,361	

[1] Figures obtainable for January–May only. Other months probably included in "Not specified."
[2] Figures cover July–December inclusive only. Other months probably included in "Not Specified."
[3] Figures cover August–December inclusive only. Other months probably included in "Not Specified."

CHROME TANNING MATERIALS

	Pounds.
Bichromates	13,344,547
Other chrome compounds	8,239,942

PRODUCTION OF HEMLOCK BARK

Hemlock bark has for a long time constituted the principal source of tanning materials used in this country, and has been commonly employed in tanning leathers ever since the beginning of the industry in America. The nearest competitor was oak bark, the annual consumption of which, however, has been for many years less than one-half that of hemlock bark. Oak bark has been particularly preferred by some tanners from the earliest days of the industry largely because it has been associated in minds of tanners and the trade that it produced the best class of leather but tests in recent years show that the oak bark inherently gives no superior quality to the leather apart from appearance. Government tests show that harness leather made of hemlock is largely superior to oak.

In 1900 hemlock led in the production of bark, with 1,170,131 cords, or 72 per cent of the total amount of bark produced in this country, and, in 1909, it still led, producing 698,335 cords, or 65 per cent of the total production of bark in the United States.

The average price of hemlock bark per cord of 2240 lb.[1] in the United States has risen from $6.28 in 1900 to $9.21 in 1909. Since the later year, however, the price has dropped off until the cutting of hemlock bark was almost abandoned except in the more accessible districts. On a large contract of 250,000 tons in West Virginia $8.00 per ton was paid in 1912 for hemlock bark delivered at the tannery. With the outbreak of the European War, however, the price rose rapidly. It is said that in Wisconsin only about 20,000 cords had been cut in 1915, whereas in 1916, over 100,000 cords were estimated to have been cut. In 1917 prices of from $11.00 to $14.00 or more were paid per cord for hemlock bark in New York, Pennsylvania, West Virginia and Wisconsin.

The reason for the small amount of bark produced in Wisconsin was because of the small yield of leather per 100 lb. of hide in comparison with Pennsylvania and Michigan bark. But it can be used advantageously with foreign tanning materials, the yield of leather being greatly increased by the blend so that it was profitable to use foreign tanning materials and extracts such as quebracho, for example, which cost more per unit of tannin than the Wisconsin bark did.

The principal producing states were formerly Maine and Massachusetts, and still later New York and Pennsylvania. Important hemlock regions like the Catskill Mountains of southern New York were largely cut out for their bark alone. The principal present producing centers in order of importance are Pennsylvania, Wisconsin, Michigan, New York, West Virginia, and Maine. These six states produce over 90 per cent of the total hemlock bark production of the country.

Harvesting Hemlock Bark.

The proper season for harvesting bark is, of course, when the bark will slip off most easily. The spring of the year when the sap is flowing freely and the leaves are breaking out is the very best time for removing

[1] In Pennsylvania, Michigan and Wisconsin, the ton is generally considered to be 2000 lb.; in the south it is generally 2240 lb.

the bark. In the northern portion of the hemlock region, that is, from Maine to Wisconsin, the season is often from early in May to early in July, or later, whereas in Pennsylvania, West Virginia and Virginia, the season may be from April to June. It is found that peeling is accomplished much more rapidly during the warm damp weather within the peeling period, and even better, during the morning and evening than during the noon.

Photograph by U. S. Forest Service.

FIG. 13.—Hauling and loading hemlock bark in the Southern Appalachian Mountains. The bark is brought down the steep slopes on sleds, for a distance of from one to two miles and loaded on flat cars.

The peeling crew is often organized to work on a piece basis, so much being paid for felling, peeling, stacking, hauling, and loading on the cars. The work is usually done in connection with the logging operation although it has been done very often for the bark alone. The bark formerly was stacked and measured by the full cord (128 cu. ft.), 8 ft. long, 4 ft. high, 4 ft. wide, but for many years it was paid for by weight—"merchantably dry." A rough conversion factor of one cord equal to one long ton, is commonly used. Wisconsin bark has the reputation of being somewhat thinner than Michigan bark and yielding less leather by weight and consequently brings a lower price.

It is generally understood that about one-half a cord of bark can be secured from 1000 bd. ft. of standing timber. This, however, particularly applies to trees of 20 in. and up in diameter. A smaller tree, of course, yields more bark per 1000 ft., than the larger trees. In some regions it is assumed that one acre of average hemlock timber will yield about 7 cords of bark. This factor is naturally a very variable one, but is commonly used in estimating the bark yield from a forest. With the increase in the value of bark, more careful methods are being used in bark peeling, and bark is removed to a much smaller diameter than heretofore. In the Lake States, the volume of bark is said to be equivalent to about 19 per cent of the total cubic volume of the trees, and varies little with the size of the tree. In the Southern Appalachian Mountains it is said that the volume varies from 15 per cent for 6-in. trees up to 19 per cent for trees 26 in. and over in diameter. The bark of the larger trees is often from 2 to 3 in. in thickness at the stump, and gradually grows thinner towards the tip of the trees.

A peeling crew is commonly composed of four workers; one spudder, one fitter, and two log buckers. The fitter is usually in charge of the crew, and directs the activities. He first cuts two rings around the tree about 4 ft. apart, and then splits the bark from ring to ring. The spudder then proceeds to peel off the bark by inserting the spud between the bark and the wood, and gradually pries it off. The crew then fells the tree, and the bark is removed from the entire length of the bole by cutting circular rings at 4-ft. intervals up the trunk and by prying off the bark with the spud as explained above. As the tree falls, the log cutters remove the limbs or any brushwood that may interfere with the work of sawing up the trunk or the removal of the bark.

The pieces of bark as they are removed are leaned against the trunk to season. This process requires generally from one week to a month, depending upon the weather conditions. After the spudder removes the bark and the bole is sawed into log lengths, the crew proceeds to the next tree.

The bark, when merchantably dry, in the summer or in the fall, is hauled out by means of sleds or wagons to the nearest loading point on the railroad or "sleigh haul." Sometimes the bark is left until the winter when it can be hauled directly on sleighs. A whole cord is often loaded on a sleigh at one time. Sometimes log chutes are used to bring down the bark, but this method is only employed on the most mountainous topography. On some operations special sleds are constructed for carrying from $1\frac{1}{2}$ to $2\frac{1}{2}$ cords to the load.

One crew of men will frequently fell the timber and peel enough bark to make from 3 to 4 cords per day. Four men will peel from 6 to 8 cords daily, and also cut the timber into saw logs. The latter sized crew is estimated to peel about 240 to 270 cords in a season. Seven men will often load four cars daily, each car having a capacity of from 6 to 7 cords of bark.

Photograph by U. S. Forest Service.

FIG. 14.—Method of hauling hemlock bark from a mixed forest along the Castleman River in Garrett Co., Maryland. From one to two cords or more are often hauled in each load.

The cost of producing hemlock bark may be summarized as follows: These costs were secured in 1914 as an average of several prominent bark-peeling operations.

COST OF PRODUCING HEMLOCK BARK

Operation.	Cost per Cord.
Cutting and peeling	\$2.30 to \$2.60
Hauling to landing	.90 to 1.20
Loading	.50 to .60
Railway hauling	.20 to .30
Supervision	.25 to .40
	\$4.15 to \$5.10

The following table shows the number of cords of hemlock bark per 1000 bd. ft. for trees of different diameters in the southern Appalachian mountains. The Doyle-Scribner rule was used.[1]

NUMBER OF CORDS OF BARK FOR TREES OF DIFFERENT DIAMETERS

D. B. H., Inches.	Cords per M Bd. Ft.	D. B. H., Inches.	Cords per M Bd. Ft.
12	2.8	22	.8
13	2.3	23	.7
14	1.9	24	.7
15	1.6	25	.6
16	1.3	26	.6
17	1.2	27	.5
18	1.1	28	.5
19	1.0	29	.5
20	.9	30	.4
21	.8		

The following table shows the volume of hemlock bark in stacked cords, for trees of various diameters.[2]

VOLUME OF HEMLOCK BARK IN CORDS FOR TREES OF DIAMETERS FROM 8 TO 29 INCHES

D. B. H., Inches.	Volume of Bark Cord.	D. B. H., Inches.	Volume of Bark Cord.
8	.03	19	.20
9	.05	20	.22
10	.06	21	.25
11	.07	22	.28
12	.08	23	.31
13	.09	24	.34
14	.10	25	.37
15	.12	26	.40
16	.14	27	.43
17	.16	28	.46
18	.18	29	.50

PRODUCTION OF CHESTNUT OAK BARK

The oaks have always held a very prominent position as a source of high-grade tanning materials because of the excellent nature of the effect on various skins. Oak bark is especially esteemed for sole leathers. The bark of chestnut oak is not only used directly in tanneries, but is also widely employed for making tannin extract. The two tannin-producing oaks are the chestnut oak and tanbark oak. The former is

[1] From data secured by Walter Mulford, 1905–1906.
[2] From "Hemlock in Vermont," by A. F. Hawes.

found principally in the East along the southern Appalachian Mountain regions, while the latter is found entirely in southern Oregon and California.

Chestnut oak (*Quercus prinus*) is found most abundantly in Virginia, West Virginia, Tennessee, North Carolina, Kentucky, and southern Pennsylvania, in order of importance. It seldom grows in pure stands but is associated with a number of other oaks and hardwoods. It grows chiefly on the northern and eastern slopes of the mountains. Its bark is exceedingly ridged, some indentations often being 3 in. deep. The peeling operations are carried on generally from late in March to middle of June or later, and the general plan of peeling the bark is very similar with chestnut oak as with hemlock.

The presence of considerable quantities of chestnut oak, together with the hemlock forests have established the location of many tanneries in western Virginia and in West Virginia. An increasing amount of chestnut oak bark is being consumed from year to year. There is serious danger of the supply of this wood being exhausted if the present rate of consumption continues. Many of the chestnut oak forests grow in more or less inaccessible places, and in portions of northeastern Tennessee it was estimated that only 2 per cent of the entire cut of the chestnut oak was converted into lumber, whereas 75 per cent was cut exclusively for the bark alone. In northwestern Virginia a tannery which has been in operation for thirty years on chestnut oak bark alone, is now gradually accepting the bark of other oaks. The bark competes, moreover, with hemlock bark and chestnut extract. The managers of tanneries claim that hemlock bark is best employed by combining it with chestnut oak bark. Chestnut oak extract is also used with chestnut wood extract to give strength, tenacity, and greater impermeability to leather.

In 1911 the ruling price in Virginia and West Virginia for chestnut oak bark was about $8.50 per cord delivered on cars. During the summer of 1916 prices had risen to from $11.00 to $12.00 or more. During 1917 and 1918, it had risen to still higher figures. The average cost of harvesting chestnut oak bark prior to the war was about as follows:

Operation.	Cost per Cord.
Cutting, peeling and stacking	$1.00 to $1.35
Hauling to railway, average 6 miles	1.50 to 2.00
Loading on car, and supervision	.20 to .40
Total	$2.70 to $3.75

In addition to the above charge the stumpage should be added, but it is frequently not taken into consideration as a stump charge is placed on the saw and tie logs.

On an operation of over 3000 acres, 10 miles from the railway in West Virginia, the method of procedure was as follows: In the early spring 30 men were engaged for the work which was well located in a side valley. The men worked together in sections laid off for them, and they were paid $1.00 per cord for cutting the tree into tie logs, with the exception of the better butt logs (used for saw logs), and for peeling and stacking the bark. One man can cut and peel from 1 to 2 cords a day, and buck up the tree. A gang of 30 men in this operation turned out about 900 cords in a month. This is equivalent of 30 cords per man per month, or slightly more than an average of 1 cord per man per working day. A portable mill was then brought in and the ties and butt logs sawed up. The haul starts as soon in May as the condition of the roads permit, and continues until about the middle of August. A team will haul about a cord a load, and one load per day, on which the special contract price was $3.50 per cord for hauling. The wagons are weighed at the railway with the load on, and, after the load is removed. Each teamster is credited with the number of pounds for each load. The bark is loaded into cars containing about 7 to 8 cords each, for which work a charge of $3.00 per car is paid. In this particular region it was estimated that it required about 4 trees averaging 16 in. in diameter at breast height to make a cord of bark.

The cost on this operation, where a long haul was involved was as follows:

Operation.	Cost per Cord..
Stumpage	$1.30
Peeling	1.00
Hauling 10 miles	3.50
Loading on cars	.40
	$6.20

Average prices f.o.b. cars $11.50 per cord.

Profit $4.70 per cord, which includes overhead charges, depreciation, and some equipment.

The following table shows the yield of chestnut oak bark in cords or long tons for a tree of average diameter in the southern Appalachian Mountains:[1]

[1] From "Chestnut Oak in the Southern Appalachians," by H. D. Foster and W. W. Ashe, Forest Service, Circular 135.

AVERAGE YIELD OF CHESTNUT OAK BARK IN CORDS FOR TREES OF DIFFERENT DIAMETERS

D. B. H., Inches.	Yield of Bark Cord.	D. B. H., Inches.	Yield of Bark Cord.	D. B. H., Inches.	Yield of Bark Cord.
10	.06	17	.12	24	.22
11	.06	18	.13	25	.24
12	.07	19	.15	26	.26
13	.08	20	.16	27	.28
14	.09	21	.17	28	.30
15	.10	22	.19	29	.32
16	.11	23	.20	30	.34

CHESTNUT EXTRACT

The discovery of a method whereby the tannin content of chestnut wood could be extracted and placed on the market to compete successfully with other tanning materials, has brought about many changes in the tanning industry, particularly within the past fifteen or twenty years. More than two-thirds of all the tannic acid products made in the United States is now derived from chestnut wood.

The extract of tannin from chestnut wood is largely confined to the southern states, particularly in Virginia and North Carolina. The wood in those localities contains from 6 to 11 per cent of tannin, whereas, although the chestnut tree is commonly found in the northern states as well, it does not contain a sufficiently high percentage of tannin to make its extraction as profitable as that in the South. Chestnut extract is commonly used in mixture with other tannins.

The growth of the chestnut wood extract business has been very rapid. In 1900 only 64,043 bbl. were used, whereas by 1906 the total value of this extract was over two-thirds of the value of all extracts used in the United States.

The process of manufacturing chestnut extract consists of chipping the wood in a "hog." These machines will grind around 5 cords per hour. Some plants use disk chippers similar to those used in a wood pulp reduction plant. There are several separate processes used in the extraction of tannin from the chestnut wood, but the following is probably the most common one employed. The finely ground chips are placed in large cylindrical wooden tanks. The tank is flooded then with weak liquor heated to a high temperature. The liquor is continually passed from extractor to extractor and the process continues from two to four days. The process is usually carried on in batteries of 10 extractors.

The liquor is then filtered and evaporated to the desired density or concentration. Multiple evaporators are used for this purpose and about 1400 gal. of water are evaporated for every cord of wood leached in open extractors. In a plant producing 250 bbl. of extract daily about 225,000 gal. of water must be evaporated. In the evaporation process the minimum temperature of the steam is said to be 220° F. The temperature in the other steps is still lower. Finally the concentrated liquor is pumped into a series of settling tanks. After settling and cooling, the concentrated liquor is placed into tank cars for shipment.

Photograph by U. S. Forest Service.

FIG. 15.—A large leather tannery at Andrews, North Carolina. Two years' supply of bark piled ready for use on the left. Hemlock bark has been the mainstay for tanning leathers until the advent, in recent years, of foreign materials such as quebracho, myrobalan nuts, sumach, valonia, mangrove bark, etc.

The yield of 25 per cent tannin extract secured from a cord of chestnut wood containing 160 cu. ft. is from 700 to 900 lb. The cost of chestnut wood delivered at the plant varies from about $4.50 to $5.00 per cord of 160 cu. ft. before the war. The average price secured for extract of about 25 per cent strength was about $4.06 per unit of tannin in 1914. Consequently, the yield was from $8.00 to $9.50 per cord with a producing charge of about $7.50 to $8.00 per cord, the balance being interest and profit.

The factories making chestnut extract are exceedingly complicated and specialized industries and considerable capital for investment is required. The above figures of production, cost and yield are largely taken from Benson.[1]

TANBARK OAK

Tanbark oak (*Quercus densiflora*) is a native of southern Oregon, and of California, where the harvesting of tanning bark has been an important industry for many years. Commercial tanning has been in progress on the Pacific Coast ever since the gold wave of 1849–1850. As early as 1852 Sonoma County had a tannery producing $30,000 worth of leather per year, and by 1859 there were 29 tanneries. In the ten-year period 1881 to 1890, 240,000 cords were produced in California. Excellent prices have been obtained for this bark, which contains an exceedingly high tannin content—about 29 per cent.

The tree ranges from southwestern Oregon along the coast range to Santa Barbara in southern California. It is commonly associated in its native habitat with the redwoods.

The Santa Cruz district produces the largest present supply, and the source of supply is being rapidly exhausted. It is estimated that in 1900 about 75 per cent of the total available supply had been cut and peeled for the bark. Some second growth is appearing, but it is exceedingly slow in its development. A great deal of the oak has been cut for the bark alone.

The largest remaining available supply is now found in northern Mendocino and Humboldt Counties. The relative inaccessibility of many of these forests, and the consequent long haul involved has been an important deterrent factor in preventing the cutting of a large portion of the remaining supply. It is estimated that the total remaining stand of tanbark is 1,425,000 cords, which, at the present rate of cutting is estimated to last about forty to forty-five years. The average yield is about 200 to 300 cords " per claim " of 160 acres, or from $1\frac{1}{4}$ to $2\frac{1}{2}$ cords per acre. In estimating the yield it is said that six average trees will make a cord of bark in the most important producing sections. The peeling season is from May 20th to August 10th, but varies with the weather, altitude, temperature, etc. This oak is extremely sensitive to heat and cold, and a cold spring will delay the opening of the peeling season, and cold weather will cause the bark to adhere closely to the tree. About one-half a day is required for two men to peel a large tree. The peelers never begin on a tree unless they can finish peeling during the day, as the

[1] From "By-Products of the Lumber Industry," by H. K. Benson, Department of Commerce, 1916.

bark may tighten over night. The peelers work in pairs. The tree is first girdled and felled and the bark removed in 4-ft. sections in the very same way as has been described for hemlock bark. The bark is removed up to a point about ½ in. in thickness on the trunk. As the bark is removed, it is laid on the ground or stood against the trunk with the fresh side upward. Workmen commonly peel 2 cords a day on the average, and trees down to a diameter of 4 to 8 in. are stripped of their bark. Sometimes bark from standing trees is removed as far as it can be conveniently reached and the rest of the tree is left to die. This

Photograph by U. S Forest Service.

Fig. 16.—A peeling operation on tanbark oak near Sherwood, Mendocino Co., California. After the tree is felled and the limbs removed, circular rings are cut through the bark at 4-ft. intervals and the bark pried off with the axe as illustrated.

wasteful method has seriously interfered with the future of the industry in California.

Owing to the lack of railway facilities, considerable bark in this region is hauled to the coast and loaded on schooners. A schooner load is commonly about 200 cords of bark.

The future supply of tanbark oak in California must be obtained from forests now largely inaccessible and from second growth timber, and more conservative methods should be employed in the woods by protection from fire, by leaving the smaller trees until they have acquired a larger size and by more complete utilization of the tree. The cutting of this oak commonly goes hand in hand with the lumbering of the redwoods.

WESTERN HEMLOCK

Although of little present importance as a source of tanning materials, the two species of western hemlock (*Tsuga heterophylla* and *T. mertensiana*) constitute an important resource of tannins. They have been little exploited up to the present time because the tanning industry has been little developed in the northwest where these trees are found. There are very great possibilities, however, for the future because of the fact that there are estimated to be 100,000,000,000 bd. ft. of hemlock still standing in the forests of western Washington and Oregon. This constitutes, therefore, a veritable store house of tanning materials which may be used in the future. At the present time the prohibitive cost of shipping western hemlock bark to the eastern tanning factories precludes its wide use throughout the country. The bark of the western hemlock is much thinner than that of the eastern hemlock but contains more tannin by weight. The western hemlock contains from 10 to 12 per cent against 8 to 10 per cent in case of the eastern species.

Investigation of hemlock in the northwest indicates that the bark of trees in the Cascade Mountains contains a higher percentage of tannin than those in the coast region; furthermore, the percentage of tannin increases with the increase of elevation and the bark from the trees in Washington probably contains a higher tannin content than the same trees grown in Oregon.

The following comparative analysis was made by H. C. Tabor to determine the tannic acid content of sample hemlock bark from Washington, Pennsylvania and Quebec:

COMPARATIVE ANALYSIS OF HEMLOCK BARK FROM WASHINGTON, PENNSYLVANIA AND QUEBEC

	Tannin, Per Cent.	Non-tannin. Per Cent.	Reds. Per Cent.	Wood Fibers, Per Cent.
Washington	17.04	6.40	1.56	75.00
Pennsylvania	13.28	7.52	3.48	75.72
Quebec	10.16	4.56	1.92	83.36

The peeling season for western hemlock is much earlier than for eastern hemlock and the bark is often harvested as early as February. However, the season usually runs from May to August of each year. The process follows along the same general plan of that described for eastern hemlock. There are several difficulties, however, in harvesting western hemlock bark which do not occur in the eastern states. The timber, being of much larger size, presents difficulties in getting out the bark, and loggers who operate largely with steam logging devices do not care to bother with bark as a by-product. Owing to the very rainy climate, the bark seasons out with some difficulty. It is handled, treated, and used in the same way as the eastern hemlock.

There are no accurate statistics of the present annual production of western hemlock bark, but it has been estimated that it supplies about two-thirds of the present annual requirements of the tanneries in the northwest. With the further development of that rapidly growing section, and the installation of more and larger tanneries, it is believed western hemlock will assume greater importance as a source of tanning materials.

BLACK OAK BARK AND OTHER DOMESTIC MATERIALS

Black oak (*Quercus velutina*) or yellow oak has recently come into some prominence as a source of tanning materials, especially by the manufacture of a certain extract which is called "*Quercitron.*" Its center of production is in Pennsylvania and the southern Appalachians. These trees yield a fairly thick bark, and have a tannin content of from 6 to 12 per cent. It is produced in the same manner as has been described for the bark of the chestnut oak. Its principal drawback is that it mildews rather easily and care must be exercised, therefore, in the drying process and in stacking in the woods. Leather made from it has a violent yellow color. The price ranges somewhat below that for chestnut oak. In West Virginia in 1910 it brought the high figure of $10.30 per cord f.o.b. cars. Since then its price has risen still higher on account of the demand for tanning materials during the war. There are no figures available as to the total output, but it is relatively small as compared to other barks.

Other barks and materials produced in the United States are as follows:

White oak bark is used to a limited extent in the eastern and southeastern states. Its tannin content is from 4 to 7 per cent. The bark is rather thin, however, and it is not believed that its use will increase very much in the future.

Sumach leaves, when dry contain a large percentage of tannin; from 10 to 25 per cent. There are two tannin producing varieties of native sumach, namely, *Rhus typhina* and *Rhus glabra*. The principal source of these species is in Virginia and the southeastern states. Both grow farther north, but the tannin content of the sumach from the north is so much lower that it is not commercially profitable to harvest it. In the south the leaves are collected in the fall just before they turn red as the tannin content is dissipated from the leaves as they turn color in the fall. The leaves are then dried and ground into a powder in which form they are shipped to the tannery. The price on native sumach varies from $.90 to $1.40 per hundred pounds in carload lots at the shipping point.

Palmetto extract is secured from the root of the cabbage palmetto (*Sabal palmetto*). These roots contain about 10 per cent of tannin. It has not been developed to any large extent commercially, but it has possibilities for the future. Large quantities of palmetto are found along the shores of the southeastern states.

Canaigre is the common name of the species of *Rumex* which contains around 30 per cent of tannin. It occurs extensively in the southwest, but the cost of producing and hauling it to market is so excessive that it can not enter into competition with the other native grown or imported tanning materials.

QUEBRACHO

There are several trees which go by the name " Quebracho " but the real quebracho (*Quebrachia lorentzii*) is now regarded as the most important source of tanning materials in the world, and, according to the figures of importation for the year ending June 30th, 1914, furnished 87 per cent of the total value of tanning agents brought to this country, amounting in all to $3,864,000. In 1909 it supplied 38 per cent of all the tanning extract used in the United States.

The native habitat of quebracho is along the water courses and plains of Central South America, embracing Southern Brazil, Southeastern Bolivia, Paraguay, Uruguay and northern Argentina. It is included within a district of about 300,000 square miles. Its present commercial exploitation is limited to northern Argentina and the province of Chaco in Paraguay where the work is carried on largely by German-Argentine companies and one American firm. The quebracho industry dates from about the year 1888 when exports were first made from Argentine on a large scale. The first wood came to this country in 1897.

The name is derived from the Portuguese meaning " axe breaker." The wood is one of the hardest and heaviest known, the specific gravity being about 1.30 to 1.40. A cubic foot of wood weighs from 75 to 78 lb.

It is extensively used for railway cross ties in Argentine where it is said to resist decay for over fifty years. The tree is generally small and poorly shaped; the quebracho forests resembling the live-oak stands of the southeast and southern California. Individual trees are generally only from 15 to 30 in. in diameter and 20 to 40 ft. in total height. Its center of production is now in rather remote districts along the Parana River, where the forests are very scattered and open. When seasoned, the wood is cut and converted into logs for shipment with great difficulty on account of its exceeding hardness.

The tannin is found chiefly in the heartwood, although the sapwood and the bark as well contain small percentages of it. Excepting chestnut, it is the only wood which has been developed and used on a large scale for this purpose, all the other materials consisting of bark, leaves, or other parts of the tree.

A number of analyses of the percentage of tannin contained in quebracho wood give the following results:[1]

QUEBRACHO TANNIN CONTENTS

Portion of Tree.	Percentage of Tannin.
Heartwood	20.24
Sapwood	3.4
Bark	6.84

The wood is generally accredited with 20 to 28 per cent of tannin. One analysis of the wood gave the following results:[1]

Material.	Per Cent of Total.
Tannin	28.20
Foreign substances	1.70
Extract ash	.40
Water	11.85
Insoluble matter	57.85
Total	100.00

The first of the above tables indicates that the tannin content of the sapwood and bark is so low, and the weight of the wood so great, that it is only profitable to transport the heartwood long distances to market.

[1] From "Tanning Materials of Latin America," by T. H. Norton, Department of Commerce, 1918.

Consequently, the bark and sap are removed from logs in the forest. Furthermore, the great weight of the heartwood causes a large portion of the product to be shipped to Europe and this country in the form of extract, rather than in the log.

The trees after felling and the removal of bark, branches and sapwood are bucked into logs of from 4 to 16 ft. in length or more and then hauled by oxen to the nearest railway. They are transported in some cases, several hundred miles to Buenos Aires and Montevideo, the great quebracho wood markets. Some companies have a monthly output of from 500 to 1000 tons of wood. There are five factories for the conversion of the wood into extract on the upper Paraguay River. Some companies which cut quebracho for cross ties, selling at $1.50 to $2.50 apiece, have found that there is more profit in getting out wood for extract or for direct export than for the local railways. The industry has developed so widely that the quebracho forest region has contributed an important source of income to Argentine and Paraguay.

In the process of extraction, the wood is reduced to small chips or shavings and then placed into closed copper extractors with a capacity of about 530 cu. ft. each. Steam is admitted and the leaching process is consummated rapidly. Consequently very concentrated liquors are secured. These are cooled and clarified in the dark to prevent oxidation. The extract is then evaporated in vacuum pans to a rather thick consistency until only 20 to 25 per cent of water remains. This extract on cooling, becomes solid. Analysis of quebracho extract shows about 65 per cent of soluble tannin content, 8 per cent insoluble tannin and 7 per cent of non-tannins.

The industry has assumed large proportions in the Argentine and the war has greatly stimulated prices. Since the year 1900, the value of the exports of logs has increased over 100 per cent up to 1913 and the value of extract over 800 per cent.

In the year 1913 the Argentine statistics show that the total export of logs and extract was 463,648 metric tons. The principal countries which received this material were as follows:

Countries.	Metric Tons.
United Kingdom	83,035
United States	37,835
Italy	30,144
Belgium	27,212
Germany	8,695

The following table shows the imports of quebracho wood and extract into the United States for the ten-year period 1907 to 1917. It shows the effect of the lack of tonnage due to the war on the imports.

IMPORTS OF QUEBRACHO WOOD AND EXTRACT INTO THE UNITED STATES 1907 TO 1917

Fiscal Year.	Quebracho Wood.		Quebracho Extract.	
	Tons, Long.	Value.	Pounds.	Value.
1907	66,810	$840,779	76,034,000	$2,320,000
1908	40,871	612,971	79,187,000	2,260,000
1909	66,113	731,795	102,005,000	2,741,000
1910	80,210	1,058,647	87,531,000	2,796,000
1911	66,617	984,841	85,721,000	2,894,000
1912	68,174	982,315	67,281,000	2,223,000
1913	102,766	1,299,995	74,545,000	1,903,000
1914	73,911	899,603	88,589,000	2,441,000
1915	54,995	753,981	120,450,283	3,676,749
1916	106,864	1,598,465	81,501,952	5,432,468
1917	73,367	1,274,600	59,808,734	5,198,904

There is no import duty on quebracho logs coming to this country but prior to October 3, 1913, there was a small duty imposed on the extract.

In 1912 the price of logs at South American ports was from $14 to $20 per long ton and for extract $80 to $85 per long ton. In 1915 the price of the extract had risen to $115 per long ton.

MANGROVE BARK

Mangrove bark has come into great prominence in the tanning industry of this country. In the year 1915, 20,041 lb. were imported at a value of $565,805, which represented a greater value than that of any other imported tanning material except quebracho. The Census of 1909 gives a consumption of $1,401,008 lb. of mangrove bark. Within the past decade it is represented as increasing very materially.

Mangrove bark formerly came principally from Portuguese East Africa, Madagascar, and the East Indies. Within recent years, however, large quantities have come from Venezuela and Colombia.

Most of the mangrove bark consists of the so-called red mangrove, *Rhizophora mangle*, *Linn*. This tree covers great areas of tidal swamp throughout the tropical regions of both the eastern and western hemispheres. Other varieties of rhizophora named black mangrove, of *Avicennia nitida* and white mangrove *Avicennia tomentosa* also produce bark of commercial importance in the tanning industry. Throughout the tropical regions, coasts, and river swamps of South America and Central America, the mangrove occurs in great abundance. All of the above three species of mangrove are also found in the swamps of southern Florida, but have not been developed on account of the excessive cost of cutting, transporting and delivering the product to market. The industry is being exploited especially in Colombia and Brazil, and to a lesser extent in the Guianas, Venezuela, and Trinidad.

The yield varies considerably with the various regions. Altogether this variation is said to be from 5 to 45 per cent. The older the tree, however, the greater is said to be the tannin content. The mangrove cut and placed on the market in large commercial quantities usually produces a yield of tannin of from 22 to 33 per cent. The leaves of the mangrove also contain merchantable quantities of tannin and are frequently used in the tanneries of southern Brazil, particularly in Santos and Cartagena.

The bark is exceedingly hard and heavy. When used locally the bark is employed directly by the tannery, and not used for extraction purposes. The methods for the extraction of tannin from mangrove bark have not been perfected to the same extent as for quebracho. Up to the present time, the process of extraction is somewhat similar to that employed for quebracho, but it is more difficult, and it is likely that the process will be still further developed in the future. It is said that extract from the mangrove forests of Africa contains from 60 to 70 per cent of tannin, whereas that produced in the Colombian factories contains about 48 to 50 per cent of tannin.

The use of mangrove bark began in Europe in 1804, and it has only recently begun to enter this country on a large scale. It is generally regarded by the tanneries as one of the cheapest forms of tannin and this accounts largely for its general acceptance and its increasing use. Mangrove tannin is seldom used alone as it has the reputation of imparting an undesirable color to leather. In France, a mixture of one-third mangrove bark, about two-fifths hemlock, and the remainder of oak or mimosa bark, is commonly used.

Owing to the various resources of mangrove forests found along the tidal shores of the tropics in nearly all parts of the world, this material constitutes a great asset for the future of the tanning industry. Its habit of growth renders it somewhat difficult to cut and transport to market, but improved methods are being constantly devised whereby it can be successfully produced. No estimates have been made of the quantities available, but they are believed to be very extensive; certainly sufficient to last several hundred years at the present rate of consumption. Mangrove is said to constitute the greatest single source of tannin supplies for the future requirements of the world.

MYROBALAN[1] NUTS

"Myrobalans" is the trade name applied to several species of Indian trees of the *Terminalia* genus. The most common and the one which constitutes the great source of this supply is the *Terminalia chebula*, which is a tree usually from 40 to 60 ft. in total height, which is cultivated in various districts of India, both for the timber as well as for the value of the nuts. The latter are harvested by the natives, placed in storage houses where the fruit shrivels up into irregular and wrinkled forms. The nuts in good condition should be hard and firm and should be completely free from moisture as their absorptive properties are very great. The tannin content of these nuts varies from 30 to 40 per cent, and is found chiefly in the outer layer.

India exported 73,355 tons in 1910. In the year 1909 this country used 18,000 tons, valued at $30.00 a ton, and 1,000,000 lb. of myrobalan extract, valued at $37,500. In 1915, 18,417,434 lb. of myrobalan nuts, valued at $198,000 were imported.

Used alone, myrobalans yield a light yellow tannin. The tannin penetrates the skins rapidly and produces a spongy leather so that the best effect is secured when blended with quebracho or hemlock bark. Mixed with these materials, myrobalans add weight, substance, and firmness as well as a fast color to the leather. It is used especially by tanners of calf, goat, and sheep skins. It can be used with harness and sole leather as well.

DIVI-DIVI

Divi-divi is the trade name applied to the seed pods of a small tree indigenous in the West Indies, Mexico, Venezuela and northern Brazil. Its scientific name is *Cæsalpinia coriaria*.

The pods are about 3 in. long and ¾ in. broad and very thin. On drying, they curl up. They contain from 40 to 45 per cent of tannin. They are commonly exported in their natural state in bags containing about 110 lb. of pods.

It is a very cheap form of tannin, and its use is not very extensive in this country. In 1918 this country imported 15,739,331 lb. valued

[1] This is also spelled *myrobolan*.

at $274,891. A closely allied species from Chile called algarobilla (*Cæsalpinia brevifolia*) is very rich in tannin. In 1915 the port of Curaçao, West Indies, shipped 500 tons of divi-divi to the United States.

Divi-divi is shipped principally from the ports of Caracas and Maracaibo and brought about 1.6 cents per pound at these ports in 1914.

Divi-divi has been used for over one hundred years but chiefly by the Germans. In use it is usually blended with certain tanbarks or other extracts. It readily adapts itself to separation into the extract form.

IMPORTED SUMACH

Sicilian sumach (*Rhus coriaria*), as it is known in tanning circles, contains from 20 to 35 per cent of tannin and is regarded as a valuable tanning agent in this country, where the importation has increased within recent years up to 1916.

It grows chiefly in Sicily and southern Italy, where it is extensively cultivated although it is found in other sections of the Mediterranean basin as well. In the year 1916 this country imported 17,454,996 lb. valued at $472,590. Owing to the war, its importation decreased during 1917 and 1918.

Sumach tannin is used principally for tanning fine leathers such as glove and book leathers and, as a mordant, to fix the basic aniline dyes.

VALONIA

Valonia is the usual commerical name given to the acorn of the Turkish oak (*Quercus ægilops*), which grows chiefly in Asia Minor and to a less extent in the Grecian Archipelago. It is sometimes called, according to its origin, Smyrna valonia and Greek valonia.

In 1915, this country imported 6,352,190 lb. of valonia valued at $88,061 and only 244,000 lb. in 1909.

These acorn cups may contain up to 45 per cent tannin. The tannin is readily derived in the form of an extract. It is seldom used alone as it has an injurious effect on the leather, but excellent results are obtained when used with other tanning materials. It is in great demand in normal times in Austria and Russia for the tanning of fine leathers in those countries.

OTHER FOREIGN TANNING MATERIALS

Gambier is used for both tanning and dyeing purposes. It comes to this country from Singapore and in 1914, 16,450,000 lb. costing $625,000 were consumed for both these purposes. Gambier usually contains from 35 to 40 per cent of pyrogallic tannin and comes from two species, namely *Uncaria gambier* and *U. acida*. It produces a brown tannin which is generally used in connection with other tanning agents.

Kino is an astringent gum used in tanning and dyeing and for medicines. It is derived from African or Gambia kino, which may yield up to 75 per cent of tannin. Its imports to this country are not reported separately in the customs statistics. The name is also applied to a number of tropical and sub-tropical plants.

Wattle or mimosa is the trade name applied to several acacias of Australia, South Africa and Tasmania. The black wattle is the *Acacia natalitia* and it is also found in commercial quantities in the *Acacia pycnantha*. Both barks are very rich in tannin.

Cutch (*Acacia catechu*) is imported in large quantities, but is used chiefly for dyeing purposes. It is occasionally used for tanning leathers in connection with the dyeing operation.

There are many other vegetable products among the barks, leaves, twigs, roots, wood, fruit, etc., which are used occasionally as tanning agents, but none has assumed any commercial importance as yet in this country. Among them may be mentioned Mexican sumach, cascalote, several oaks (bark), etc., which have varying percentages of tannin.

IMPORTS

The following table shows the amount and value of the imports of tanning materials to the United States for the years 1914–1918, inclusive:

QUANTITY AND VALUE OF CRUDE TANNING MATERIALS AND TANNING EXTRACTS IMPORTED TO THE UNITED STATES FOR 1914 TO 1918, INCLUSIVE

QUANTITY

	1914.	1915.	1916.	1917.	1918.
Tanning materials, crude:					
Quebracho wood, tons..	73,956	54,955	106,864	73,367	45,440
Mangrove bark, tons...	7,689	8,096	21,186	10,565	3,529
Sumach, pounds.......	10,770,400	13,165,182	21,542,390	11,637,023	14,046,662
Gambier, pounds......	14,936,129	14,169,490	12,819,859	10,133,625	8,964,832
Tanning extracts:					
Quebracho, pounds....	93,329,087	120,450,283	81,501,952	59,808,734	101,523,282
All others............	6,028,383	6,191,232	5,471,251	2,500,854	4,573,925

VALUE

	1914.	1915.	1916.	1917.	1918.
Tanning materials, crude:					
Quebracho wood, tons..	$900,880	$753,981	$1,598,465	$1,274,660	$718,567
Mangrove bark, tons...	196,891	218,952	582,922	299,897	72,956
Sumach, pounds.......	258,736	323,448	555,276	365,173	467,663
Gambier, pounds......	571,067	542,200	928,924	859,873	955,352
All others............	468,230	370,133	668,166	792,064	496,070
Tanning extracts:					
Quebracho, pounds....	2,543,302	3,676,749	5,432,468	5,198,904	4,917,212
All others, pounds.....	198,973	202,675	382,880	152,619	219,993

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CHAPTER IV

VENEERS

GENERAL

VENEERS are thin slices or sheets of wood. They were at first only made from beautifully grained and handsomely figured woods which, owing to their extreme cost, were seldom used in the form of solid boards.

The veneer industry has increased in importance in great strides within the past quarter of a century. It is generally considered a phase of 19th-century industrialism, but historically veneers were used even in early Roman times. Pliny, the younger, records how the Romans went to Greece to buy great tables with veneered tops in the manufacture of which the Grecians had attained great proficiency. It is said that the wealthy Romans paid very high prices for these tables faced with veneer of rare Eastern and tropical woods. Pliny does not record how these veneers were made or what species were used and the industry was practically a lost art until the early part of the last century.

The principal reason why veneers have not come into more common use until the last twenty to thirty years is the great wealth and comparative cheapness of native species, including an excellent selection of cabinet woods. With the gradual depletion of our timber supply, especially of the more valuable woods, it is a natural consequence that much of our high-grade furniture, interior finish, doors, etc., should be made with the veneer face, and the centers or cores composed of mediocre woods or low-grade stock. This situation, of course, contributes to the more efficient utilization of our timber supplies, since the best woods or best quality of our more valuable woods can be reserved for the exterior faces and the interiors made up of the cheaper woods and lower grades.

Until comparatively recent years veneers found their principal use for fine furniture and cabinet work. Within the past decade the demands for veneers have increased remarkably and most of our veneers are not used now for strictly veneer purposes in the original sense, but are utilized for a great variety of comparatively new uses, such, for example, as built-up stock, berry and fruit baskets, cheese boxes, crates and packing boxes, drawer bottoms, trunk stock, mirror backing, panels, etc.

The veneer industry has consequently come into a position as parent organization to a large number of subsidiary wood-working and using industries which are dependent upon it for the source of their working material.

Methods of Making Veneers.

The modern use of fine-faced veneers in cabinet work is said to have been started by Sir Ishambard Brunel at the Chatham Dock Yards, England, in 1799. Here was also the first steam sawmill used in England. A shop was equipped in 1805 in Battersea, England, and veneers were made from mahogany and rosewood. It is said that the first circular veneer saw was invented in 1805 which cut veneers as thin as $\frac{1}{16}$ of an inch. Soon after veneers were also made by slicing, which is the forerunner of the present methods of cutting and slicing veneers. It was not until 1896 that the rotary method of cutting veneers came into commercial importance.

At the present time the following methods are used in making veneers:

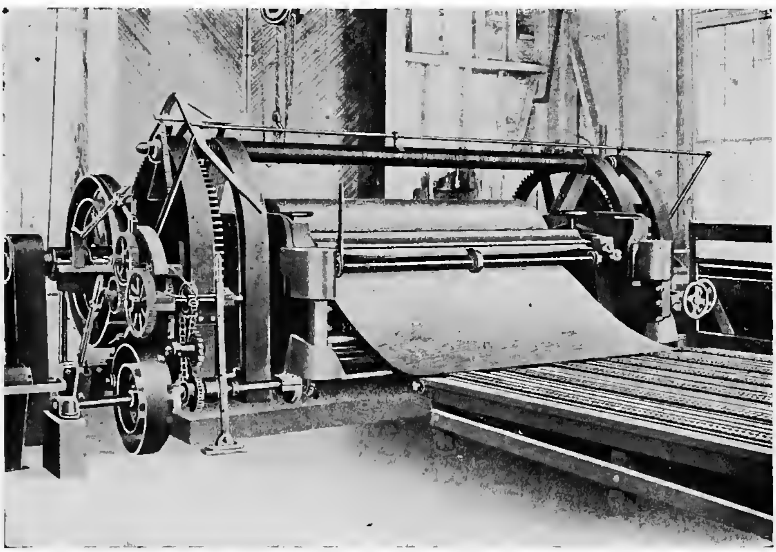
1. The rotary cut process, which consists of turning a log on a heavy lathe against a stationary knife, is the method by which about 90 per cent of all of our veneers are made. Continuous sheets of veneer are cut off down to a 6- to 10-in. core. Generally speaking, our lowest priced veneers are made by this process as it is a very cheap method of manufacture. Since it is a rotary process, cutting with the rings of annual growth, it does not bring out the quarter grain or figure of the wood as well as the other processes by which cuts can be made along the medullary rays. Most of the native black walnut and Circassian walnut veneers are made by the rotary method. Walnut stumps and burls are also cut by this method in connection with a stay log. More waste is occasioned by this process than the others, due to the core left after cutting and the large amount of waste in clipping and trimming.

2. The slicing process, which consists of rapidly moving a flitch of wood vertically downward against a cutting knife, is the method by which much of our quarter-cut oak veneers are made. Mahogany, Spanish cedar, rosewood and other foreign woods showing a pleasing figure on the quarter grain are commonly sliced by this method. This method is least wasteful of the raw material of the three processes.

3. Sawed veneers are considered most valuable because this process tears the wood fiber less than the other processes and they can be worked

up and finished to better advantage. Our most valuable mahogany and other foreign woods, especially those presenting a fine figure when cut on the quarter, are sawed. The method consists of moving a flitch of wood on a carriage against a circular saw which cuts a kerf of about $\frac{1}{20}$ of an inch. It is consequently a very wasteful process. Most of our sawed veneers are about $\frac{1}{20}$ of an inch in thickness.

Details of the manufacture of veneers by each of these processes are taken up later.



From Coe Manufacturing Company.

FIG. 17.—Rotary veneer machine in operation. A continuous sheet is cut off by revolving the log against a sharp stationary knife.

Qualifications Desired in Veneer Woods.

The veneers desired for facing table tops, fine furniture, cabinet work and similar uses demand a pleasing grain and figure. Other than this, however, the qualifications desired in veneer woods are not so particular. They may be summed up as follows:

1. Veneer woods should be reasonably low in price because the ultimate products for which veneers are largely used, such as berry and fruit baskets, crating, cooperage, novelties, packing boxes, cheese boxes, etc., bring a comparatively low price on the market.

2. The woods must be available and readily accessible. There must be sufficient quantities to make a uniform product.

3. The particular species should grow to a comparatively large size and must be symmetrical in shape.

4. The species in common demand must be reasonably free from defects such as various forms of checks, shake, frost cracks, rot, pitch streaks, " cat faces," etc.

5. The grain and fiber of the woods should be of such a nature that it readily adapts itself to manufacture. This, however, is of comparatively little importance as practically any wood can be made into veneers. Some, however, lend themselves to certain processes of manufacture better than others.

Woods Used.

Although red gum is pre-eminently the most important wood used for veneer, nearly all of the commercially important species used for lumber and other forest products in this country are used to some extent for this purpose. Altogether 37 separate native species and 13 foreign woods were manufactured into veneers according to the figures of the Census Bureau for 1911, which are the latest available statistics.

With the advent of the heavy demand for veneers about 1900, red gum took its place as the leading veneer wood and for the past decade it has furnished about one-third of all the veneers cut in the country by all processes. It is now used for some of the most expensive veneers as well as the most ordinary lines of usage. When cut on the quarter grain it offers a most pleasing figure and grain, and it has entered very prominently into the market for high-grade cabinet and finishing veneers.

Over 136,000,000 bd. ft. of red gum logs are used every year for veneers. Owing to the extensive available stands of red gum in the lower Mississippi Valley, its low-priced stumpage, the tall, large symmetrical stem which is ordinarily free from defects, and its comparatively soft, even and attractive grain, it meets very satisfactorily the requirements for a desirable veneer wood. It is likely that it will hold its commanding position for a long time to come. Red gum is largely produced in Arkansas. Missouri and the other states in the lower Mississippi Valley also contribute to its production. Veneer logs of this species bring from $9.00 to $14.00 delivered at the mill, per thousand board feet.

White oak is next in importance as a veneer wood, and it comprised 9 per cent of the total amount of veneer produced in 1911, when over 41,000,000 bd. ft. of white oak were used for this purpose. Probably 75 to 80 per cent of all sawed veneers and nearly this percentage of sliced veneers are of quartered oak. It is estimated that approximately two-thirds of all white-oak veneers are manufactured either by the slicing or sawing process. Quartered white oak has, for a long time, been a standard veneer, especially for table tops and general cabinet and furniture purposes. It is chiefly manufactured in Indiana. Logs of this species bring from $25.00 to $50.00 delivered at the mill, per thousand board feet.

Yellow pine veneers are next in order of importance. Over 35,000,000 bd. ft. were used in 1911 for the inexpensive lines of usage. They make excellent berry, fruit and vegetable baskets and packages and they are also used for slack cooperage, crates and boxes and core material. Its use for door and interior finish panels is on the rapid increase. When stained it presents a most attractive finish. Yellow pine is cut almost entirely by the rotary process in the South, where logs bring from $8.00 to $12.00 or more per thousand board feet, delivered at the mill.

Hard maple is the most important wood used for veneer in the Northern States, where it is used for both the inexpensive lines of usage as well as for the finest of finishing purposes. The well-known bird's-eye and curly maple have always held a position of high esteem in the trade. Maple veneers are chiefly made by the rotary process in Michigan, Wisconsin and New York, where log prices range from $16.00 to $23.00 per thousand board feet, at the mill.

Cottonwood makes an excellent veneer because of its soft, light and even-textured wood, which brings it into special demand for many purposes. It cuts very smoothly and evenly on the rotary lathes and along with basswood is one of the few woods which do not require any preliminary steaming or boiling to soften the fiber before cutting. Practically all cottonwood veneer is made by the rotary process in the lower Mississippi Valley states. Owing to its limited amount in the remaining forests its importance as a veneer wood in the future is not bright. Present prices of $13.00 to $20.00 per thousand board feet obtain at the mill for cottonwood logs.

Yellow poplar is one of the most desirable veneer woods available on account of its soft, even fiber, pleasing grain, freedom from defects and large symmetrical sizes. However, its wider use is precluded by its comparative scarcity and high price on the market. It yields a very high grade of crossbanding or core stock and it is commonly used for this purpose in high-grade panel, finish and cabinet work. In fact, yellow poplar and chestnut are our two most highly regarded core woods. Poplar veneers are principally made in Kentucky, Tennessee, North Carolina and West Virginia. Log prices vary from $18.00 to $30.00 per thousand board feet or more at the veneer mill.

Basswood is in strong demand for door and panel purposes, but it is very limited in its available supply. Birch is commonly used in the North for all kinds of veneers. Curly birch brings excellent prices. Elm is cut almost entirely for cheese boxes and for hoops and crates. Chestnut, especially the " sound wormy " variety, is widely used in built-up stock.

Other woods frequently used for veneers are Douglas fir, which is coming into well-merited prominence, together with western yellow pine, on the Pacific coast. Tupelo, beech, ash, red oak, cypress, sycamore, white pine, spruce and many others are also used.

Mahogany, Circassian walnut, Spanish cedar, the native black walnut and cherry and a few other valuable foreign woods such as rosewood, satinwood, English and Japanese oak, vermilion, padouk, etc., are usually made by the slicing or sawing process. Altogether they do not comprise more than 18,000,000 to 20,000,000 bd. ft. annually. Much of the black walnut and some of the mahogany is cut by the rotary process. More walnut is used for veneers than for any other purpose. About 5,000,000 ft. each of mahogany, black walnut and Spanish cedar logs are annually made into veneers. Mahogany logs are worth from $120 to $160, black walnut from $75 to $150 and Spanish cedar from $100 to $135 per thousand board feet in the log, delivered at the mills.

Annual Production and Values.

As mentioned above, over 500,000,000 bd. ft. of forest material, in the form of logs and flitches, are annually manufactured into veneer in the United States. It is estimated that there are over 1000 firms now engaged in the industry scattered over 35 states. In 1905 only 181,000,000 bd. ft. of logs were manufactured into veneers, and yet there is a general feeling in the industry that the demands for the output of the mills in their present capacity are far from stabilized. It is likely that over 1,000,000,000 ft. of logs will be annually consumed for veneers in this country within a few years.

Veneers may be cut in any thickness from $\frac{1}{500}$ up to $\frac{1}{2}$ an inch or more. For commercial purposes, thicknesses of less than $\frac{1}{201}$ of an inch or more than $\frac{1}{4}$ in. are seldom cut. Spanish cedar for cigar boxes are the thinnest veneers found on the market.

Rotary cut veneers are commonly cut from $\frac{1}{40}$ to $\frac{1}{8}$ in. in thickness, but those from $\frac{1}{20}$ to $\frac{1}{24}$ in. constitute the largest amount. Sawed veneers are usually cut $\frac{1}{20}$ of an inch in thickness. Sliced veneers are often cut from $\frac{1}{60}$ to $\frac{1}{20}$ of an inch.

The relation between the contents of a log in board feet and the square feet of veneers produced depends obviously on the method of cutting, the thickness of the veneer, the soundness of the log and the care in clipping and drying the product. These factors vary with almost every mill, so it is exceedingly difficult to standardize the amount of veneers of a given thickness to be expected from a thousand board feet log scale by a given process.

In a rotary veneer mill in Michigan where 16-ft. logs ran about twelve to the thousand by the Doyle rule and a 6- to 7-in. core was ordinarily left, 1000 bd. ft. of No. 1 logs yielded about 10,000 sq. ft. of $\frac{1}{15}$ in. stock, or about 13,000 sq. ft. of $\frac{1}{29}$-in. stock, on an average.

Veneers are sold by the square foot, surface measurement, the price varying with the species, the thickness of veneer, the character of the grain (curly, bird's-eye, quartered, crotch, etc.) and method of cutting, drying, etc. The following list was obtained at a large mill dealing in some of the better grades of veneers. The prices are given, wholesale, delivered in New York State for the year 1917. Prices have advanced very materially since the fall of 1918.

Wood.	Method of Cutting.	Thickness.	Price per Square Foot, Cents.
Plain mahogany	Sawed	1/16	3–3½
Striped or fancy mahogany	Sawed	1/28	6–8
Crotch mahogany	Sawed	1/28	8–12
Circassian walnut	Sawed	1/28	6–10
Red gum	Rotary cut	1/20	1½–2
Quartered red gum	Sliced	1/28	3–4
Black walnut	Rotary cut	1/20	2½–5
Red birch	Rotary cut	1/20	1–1½
Plain white oak	Rotary cut	1/20	1½
Quartered white oak	Sliced	1/20	2
Quartered white oak	Sawed	1/20	2½

ROTARY CUT VENEERS

Rotary veneer mills are located with reference to a continuous supply of raw material in the form of logs and along some railroad offering facilities for shipment of the product to market. Veneer mills may be located in connection with furniture or cabinet factories, door mills, cheese-box factories, basket mills, etc., or they may be independent of them and sell the bundled product to the various subsidiary industries which consume it. Few mills are supplied by the company's own logging operations. Logs are customarily purchased in carload lots from logging operations or from wood lots in the vicinity. As only the better class of logs are used, logging companies frequently set aside their veneer logs until they have a sufficient supply for a special shipment. There are no universally adopted rules for grading logs accepted at veneer mills. Individual mills have their own rules and uniformity in them is now being considered in the industry.

As the logs are unloaded at the plant they are left in an open yard just outside the mill and rolled in as needed. A few of the largest mills have storage ponds similar to those in use in connection with saw mills. The advance supply kept on hand is often so large that serious deterioration takes place due to checks, rot and insect attack. Seasoning is not necessary; in fact, green logs are preferred.

The machinery and equipment usually found in the modern rotary veneer plant consists of a drag-saw or cut-off saw to cut the logs into desired lengths, a vat for boiling or steaming, the rotary veneer machine or lathe, a clipper to trim the veneer into the desired sizes, conveyors, a wringer, a die cutter, a dryer and a knife grinder. When built-up stock is made, power or hand presses and glue-room equipment are added.

The following is a brief description of the usual method followed:

The logs come in even lengths up to 16 to 20 ft. long, and must be cut down to from 38- to 52-in. logs, which are the lengths usually used on the veneer lathe, or to 6, 7, 8, 9 or 10 ft. in length depending upon the width of veneer desired. They are rolled into the mill by hand or by the use of heavy cranes, or on a log hoist when a mill pond is used for storage purposes.

The cut-off saw, either of the drag, horizontal band or circular type, cuts the logs into the desired bolt lengths, which are conveyed to the steaming or boiling vats in order to soften the fibers for cutting. In the former, live steam is turned into the pits but no pressure applied. Boiling is the favored method because it heats the logs more evenly and the logs remain in good condition for cutting for hours, whereas steamed logs should be cut immediately after heating or they become hard and brash.

There has been no determination and common acceptance of the length of time or degree of temperature to be followed in boiling. Many mills fill the pits each morning with sufficient bolts for the next day's run and leave them there overnight. The usual size pit will hold from 600 to 1000 ft. board measure of bolts. Heat is applied by means of steam pipes.

The degree of heat and length of the boiling period should be governed by the hardness of the wood, its degree of dryness, porosity, toughness of the fiber, size of logs, etc., but little attention has apparently been paid to these matters.

In practice, the following periods of boiling are commonly used: From one to two days or up to forty-eight hours for the oaks, fifteen to eighteen hours for yellow poplar, from twelve to twenty-four hours for red and black gum, from twenty-four to thirty-six hours for elm, ash, birch and maple, Douglas fir and western pine. Temperatures of from

Photograph by Nelson C. Brown

FIG. 18.—A rotary veneer machine showing the lugs on which the log is turned and the veneer knife immediately back of the man. Photograph taken in a California veneer mill cutting western pine (*Pinus ponderosa*).

160° to 220° F. are maintained. If oak is boiled too long it becomes so hard that it is very difficult to cut it. Yellow poplar when over-boiled produces a rough veneer, showing that the fibers have been crushed too much rather than being cut sharply. Cottonwood and basswood do not require boiling.

After boiling, the bark is removed. This is done by splitting the bark lengthwise. The bark then drops off easily after being loosened in the boiling process.

The bolts are taken over to the veneer lathe, which has two large drive wheels and a spindle with chucks to hold the log in position. The machines are graded by the length of the knives, which are usually made in the following lengths: 24, 30, 50, 60, 65, 76, 90 and 124 in. They are $6\frac{1}{2}$ in. wide, $\frac{5}{8}$ in. thick and made of the finest cutting steel. The logs are centered on the chucks and cutting is done by revolving them against the stationary knife, the veneer coming over in long continuous sheets. An automatic geared device feeds the knife toward the log so that at each revolution it approaches the log nearer by the thickness of the veneer. The knife is usually sharpened after every thirty-five to forty hours of cutting. It must be changed more frequently with thick than with thinner veneers. It must be very sharp and uniformly so or a poor grade of veneer results. The shafts which hold the logs can be regulated to hold a short or a long log. Generally 24 to 28 revolutions are made per minute except on the very largest logs and continuous sheets are cut off down to a core of from 6 to 10 in.

As the veneer comes from the cutting lathe it is conveyed to the clipper, a machine which trims off defective portions and cuts the veneer to the desired sizes. This consists of a sharp knife from 5 to 10 ft. in length, worked by steam or foot power, extending across the conveyor table. The knife descends directly to the veneer and clips it in rectangular sections. A straight edge on one side insures a right angle in clipping.

In some mills, a wringer located back of the clipper eliminates any superfluous water in the veneer. A die-stamping machine is sometimes used to stamp out chair or drawer bottoms, covers, berry-box patterns or tapered peach-basket staves, etc. This machine will make from 20 to 30 strokes per minute and will stamp out from 52,000 to 400,000 pieces per day depending upon the thickness of the stock turned out.

Next the veneer goes through an automatic dryer. It is necessary to dry it artificially, as it warps, twists, checks and curls very badly when air dried. Although several types of dryers are on the market one of the most common types is described as follows: The veneer is slowly passed on revolving rolls through a long roller dryer which is steam heated and from which the moist air is carried off in hot blasts. One of the larger driers is 130 ft. long, 12 ft. wide and 5 rolls high. From fifteen to forty-five minutes are required for passing through the rolls, depending upon the thickness and kind of wood and the veneer is thoroughly dry when taken out. For example, in one mill it required forty minutes for $\frac{1}{8}$ in. veneer to pass through while with $\frac{1}{20}$-in. stock only twenty minutes were required. Five tiers of 1-in. steam pipes, 44 pipes in each tier are used and temperatures of from 200° to 260° F. are maintained. The drier box is covered with sheet iron and asbestos.

From the drier the sheets of veneer go to the glue room or to the bundling room, from which they are shipped.

The cost of manufacturing rotary cut veneers varies considerably. The chief factors which influence this cost are the size of the mill, labor charges, efficiency of the operation, thickness of veneers produced, kinds of woods used, type of machinery and equipment, etc. Costs are figured on the basis of 1000 sq. ft. of surface measurement. The cost may ordinarily be found within the following figures:

	Cost per Thousand Square Feet
Labor and superintendency....	$ .75–1.35
Power...	.20– .75
Overhead, including depreciation, interest, taxes, insurance.........................	.50–1.20
	$1.45–3.30

These figures are exclusive of the cost of logs, selling and office charges.

SLICED VENEERS

Although the least important of the three methods of making veneers, from the standpoint of production, and, therefore, of little comparative importance, the slicing process of veneer manufacture has taken material strides within the past decade or so. It is likely that it may surpass the sawing process in production. Slicing machines are almost always found in use in the same mills where veneer saws are used. The cost of making sliced veneers is considerably less than by the sawing process and there is much waste of material in the latter method due to saw kerf.

White oak is the principal wood used in slicing veneers and practically all of it is in the form of quartered flitches that have been cut out in sawmills. Quartered sycamore, red gum and red oak and some mahogany, Circassian walnut and Spanish cedar, together with a few other foreign woods are also cut. Only the finer furniture, cabinet and finish veneers are manufactured by this and the sawing procees. Indiana is the center of production of sliced veneers.

The slicing process aside from the actual cutting follows the same general methods as the rotary process, except that flitches instead of logs are used and steaming is customarily used instead of boiling, especially when mahogany and Spanish cedar are used. In some mills, the flitches are first steamed for a few hours and then soaked in hot water for about twelve hours before slicing. The question of the best preliminary method to be followed in softening the fibers for slicing is still an open one.

The present slicer in common use is a very ingenious mechanical device and has been evolved as a result of much experimentation. Several different types are on the market but the same general principle is followed in all. The accompanying illustration shows the general features of the machine. The flitches are fastened against the dog plate in a heavily constructed steel stay log, by means of screw dogs placed at

FIG. 19.—A veneer-slicing machine in operation, cutting Circassian walnut veneers. Note the veneer flitch fastened above. This is dropped vertically against a sharp knife. The men are engaged in piling the sliced veneers as they emerge at the base of the machine.

intervals of about 1 ft. The dogs hold the flitch in place both on the top and bottom. In slicing, the flitch is moved downward against a stationary knife which slices off a veneer of the desired thickness at each stroke. When the flitch moves upward, the knife automatically recedes sufficiently to clear the upward motion and then advances in a position to slice another sheet. Thus the flitch moves upward and downward in the same vertical plane, the knife being moved forward and backward at each stroke to cut each new slice until the flitch is largely used up.

As each slice is removed, it falls through the knife slots onto a platform. Two men, one at either end, pile them up in the same relative position as they appeared in the flitch. They are usually kept together and sold in this fashion.

The drawbacks to this process are: 1. It is a slow method of manufacture and 2, the veneer has only one face side and is not reversible. Mills using one machine have a daily capacity of about 50,000 to 80,000 sq. ft.

Sliced veneers are dried in many different ways but the most accepted procedure is the roller dryer as explained in connection with the rotary process. The old-fashioned hot room is occasionally employed as well as suspension in long sheets from the ceiling, but unsatisfactory results are generally the rule. Owing to the fact that veneers from one flitch are kept and sold together, they are seldom trimmed on the clipper, as explained in connection with rotary cut veneers.

SAWED VENEERS

Veneers were first made by hand sawing, the process being very laborious and expensive. They were only made of rare woods of highly attractive figure and consequently their use was very limited. For a long time sawing was the only process used. Now only the highest grade finish and cabinet veneers are sawed. It is a very simple method of manufacture, but it is the most wasteful of the three methods and the most expensive as well.

Sawed veneers are usually cut $\frac{1}{20}$ in. in thickness and a kerf of equal thickness is made. This means that as much wood is wasted as is ultimately used. They are preferred, however, to sliced or rotary cut veneers because in the case of the latter two the wood fibers are crushed by the knives, and the thinner the veneer the more serious is likely to be the result. On the other hand, with sawed veneers, the fibers are torn, but those only which come into contact with the saw. Consequently sawed veneers are stronger and are less likely to show up defects after being used for some time. It is also said that sawed veneer more closely resembles solid wood than any other kind. One great advantage in favor of sawed veneer is that it is reversible and either side may be used as the face.

It is estimated that at least 75 per cent of all sawed veneers are made of quartered white oak. In general, the same woods are used for both the sliced and sawed veneers. Considerable mahogany of the finest grades and special figure and grain such as ribbon mahogany as well as a limited amount of Circassian walnut, vermilion, Spanish cedar, teak, rosewood, and other expensive woods are sawed into veneers which bring exceptionally high prices as compared with the rotary cut veneers. Most of the high-priced foreign woods which do not show an especially pleasing grain on the quarter are cut, however, by the rotary method, by using a stay log for flitches, crotches, burls, etc. About 10,000 sq. ft. of sawed veneer $\frac{1}{20}$ in. in thickness can be cut from 1000 bd. ft. of flitch material.

In the manufacturing process flitches are usually used, and they are preferred in the green state. No preliminary steaming or boiling is prac-

Fig. 20.—Making sawed veneers. Many of the finest veneers are made by this method.

ticed to prepare the flitches for sawing. The flitches are either cut at the veneer mill or purchased from some sawmill, and kept in a covered shed preparatory to manufacture to prevent undue checking. As wanted, they are conveyed to the mill and mounted on a stay log by screw dogs on a vertical saw carriage. In the most up-to-date mills, the feed is automatic, the carriage being set up nearer the saw after each cut, to correspond with the desired thickness of veneer. The sawed sheets fall on the platform and are stacked up in the same position as they were found in the flitch. They are kept together and sold in this way the same as described in connection with sliced veneers. Drying is practiced in the same manner as that followed with sliced veneers.

BUILT-UP STOCK

The manufacture of built-up stock made of 3-, 5- or 7-ply material has really become a separate industry of great magnitude within comparatively recent years. Its demands on veneer as its raw material have increased very rapidly and explain to some extent the greatly increased production of rotary cut veneers. Plants turning out various forms of

Photograph by U. S. Forest Service.

FIG. 21.—Sheets of veneered heading used for barrels. These are piled for cooling after drying and are then taken to the glueing room. Poplar Bluff, Missouri.

built-up material may be found in connection with rotary veneer mills or in operation entirely independent of the veneer factory.

The principal fields of usefulness for built-up[1] or laminated stock are the following: panels, doors, aeroplanes, furniture, trunk stock, interior finish and many articles of both a utilitarian and an ornamental nature. It is even coming to be a strong competitor of lumber for many of its common

[1] The U. S. Forest Service laboratory at Madison, Wis., has made great strides during the war in the perfection of built-up stock and glues used in aeroplanes and hydroplanes.

lines of usage. By using successive layers of veneer, with the grain of each board running at right angles to the grain of the board adjoining it, many advantages over equal grades of lumber are claimed for it, the chief among them being the following:

(*a*) It is comparatively free from such common disagreeable effects such as warping, checking, twisting out of shape, etc., in the presence of changing temperature and atmospheric moisture.

(*b*) It is stronger for general purposes.

(*c*) It is relatively light in weight.

(*d*) Its low comparative cost.

(*e*) Its efficient use of wood, in that the core or crossbanding may be made of cheaper woods or those containing minor defects.

When making 3-ply stock, glue is applied only to both sides of the core or center ply. The back of the panel or other built-up stock is first laid on a truck, then the glued core is laid down and finally the top or face side, the direction of the grain of the core always running at right angles to that of the top and bottom pieces. The same principle is followed out in making 5-ply or 7-ply stock.

The glue is applied hot and as soon as a truck load is completed it is moved at once to the press. Both animal and vegetable glues are commonly used by the manufacturers of built-up stock, furniture, etc. More animal glue is undoubtedly used, however, than vegetable glue. Each individual operator, however, decides this for himself, and the question will be an open one for some time to come.

Many kinds of veneer presses have been developed, and at many of the mills home-made or locally contrived devices have been found in common use. The old hand screw press has been determined to be very efficient and is still in common use in some of our most modern and progressive plants. However, the hydraulic press is probably used to a greater extent at this time than any other.

As soon as a load is placed in the press a pressure of from 100 to 200 lb. per square inch is exerted, depending upon the nature of the work, the thickness of the built-up stock, species involved, etc. As soon as the maximum load is applied, retaining clamps are placed on and the whole set is removed from the press to make way for another set. The clamps are customarily left on for varying periods up to ten to twenty-five hours. In a large veneer plant in Wisconsin using mixed hardwoods native to the state, the clamps were retained for from twenty to twenty-five hours. In a large veneer mill in northern California which cuts western yellow pine by the rotary process, 36 courses of 3-ply stock were left in the clamps for from eight to twenty-four hours under a pressure of 125 lb. per square inch. It was said that eight hours was sufficient, but that for convenience they were released the day following and new courses were placed in the clamps. As a matter of fact, convenience in organization is the determinant factor in this time element. Leaving courses in clamps longer than the required time does not injure the stock.

After release from pressure the panel or other built-up stock is trimmed to even off the edges. It is then sanded or scraped and shipped to destination.

UTILIZATION OF VENEERS

There has never been any attempt at an accurate compilation of figures or statistics showing how our various kinds of veneers are used in this country. The different uses that have come into existence for veneers have broadened very greatly within the last few years. At the present time it is estimated that more than one-half of our veneer logs is cut into veneers for purposes other than the original use of veneers which was to cover less valuable woods especially when the figure and grain of the veneer woods were to be brought out to best advantage, as exemplified in furniture, cabinet work and similar lines of usage.

At the present time the cheaper veneers are most in demand especially for such materials as shipping containers, boxes, fruit and berry baskets, etc.

The following list shows the approximate order in which our veneers are used. A few years ago it was estimated by the Census Bureau that, under average conditions, 6 sq. ft. of surface veneers were produced from each board foot as measured in the log. When veneers are sliced each board foot should produce 12 sq. ft. of surface veneer if cut $\frac{1}{12}$ of an inch in thickness. Six square feet, however, is a good average because of the great amount of waste occasioned in the manufacture of veneers, especially in the form of cores, trimming, and loss in the form of defects, checks, etc. Using 6 sq. ft. of surface veneer as an average from each board foot, an annual consumption of 500,000,000 bd. ft. of logs would yield 3,000,000,000 surface feet of veneers annually consumed in this country. The following table has been made up as a result of visits made to a large number of veneer mills and data secured from men engaged in the industry. The most important fields for the utilization of veneers are taken up in the order of quantity consumed:

1. Furniture, including tables of all kinds, beds, dressers and other

bedroom furniture, cabinets, pianos and other musical instruments, book cases, etc. Veneers were originally used entirely for furniture purposes and it still constitutes the principal demand for veneers, and particularly those made from quartered oak and red gum, mahogany, black walnut, Circassian walnut, cherry, hard maple, birch, etc.

2. Doors and door panels. There are many veneer mills in this country which operate entirely for the production of veneer and veneer

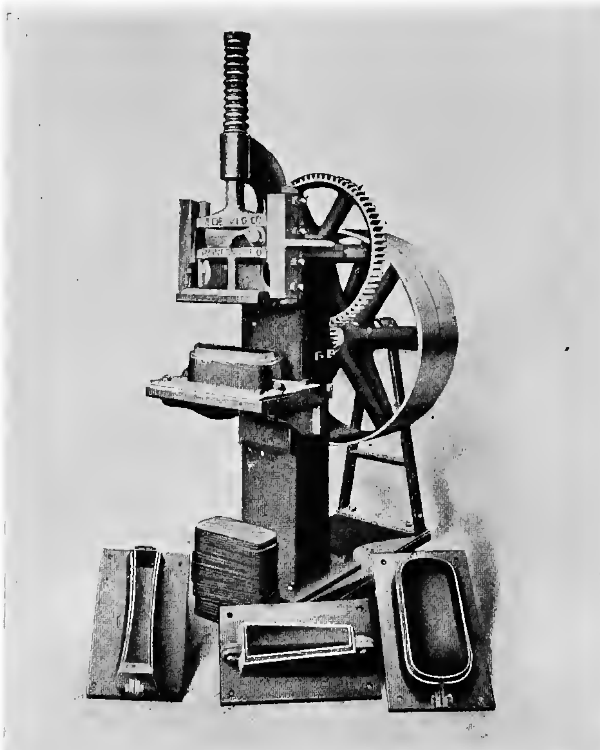


FIG. 22.—A hollow-die stamping machine used for making fruit-basket tops, novelties, etc.

core stock used for the production of doors and door panels. The largest door factory in this country, in fact, depends upon its veneer mill for a good share of the material that goes into its product. Veneers intended for use in door panels as well as for door stiles, rails and muntins are usually cut into $\frac{3}{16}$ in. thickness. The species used are oak, red gum, birch, Douglas fir, western pine, and Southern yellow pine.

3. Shipping containers, including packing boxes, cheese boxes, crating materials, veneer barrels, etc. It is very likely that in the future

a large share of our packing boxes, slack barrels and all of our cigar boxes will be made from veneer stock. Cigar boxes were formerly made entirely of Spanish cedar but, owing to the high cost of this material, the cheaper cigar boxes are made of veneer sliced to $\frac{1}{100}$ and $\frac{1}{120}$ of an inch in thickness and glued upon a basswood, yellow poplar or tupelo gum core. Veneers used for packing boxes, crates, etc., are cut in thicknesses of from $\frac{3}{16}$ to $\frac{3}{8}$ in. The species used are yellow pine, red gum, cottonwood, spruce, basswood and chestnut.

4. Fruit containers, including such products as berry cups, berry and fruit baskets and many forms of vegetable boxes. In some sections of the country, peaches, apples, potatoes, grapes and all forms of berries and vegetables are shipped in containers made entirely out of veneer material. Basket veneers are customarily cut to $\frac{1}{16}$ in. The principal species used are yellow pine, tupelo, elm, maple, basswood, oak and red gum.

5. Drawer bottoms, chair seats and mirror backing, which are usually classed together in the manufacture of veneers. This has opened up a new trend in the veneer trade and it is likely that the demand for these materials will increase very considerably in the future. They are cut in thicknesses of from $\frac{1}{12}$ to $\frac{3}{8}$ in. Yellow poplar, hard maple, red gum, cottonwood, birch and tupelo are the principal species used for these purposes.

6. Novelties and sporting goods. There is a great variety of novelties and articles made in the sporting goods factories which demand considerable quantities of veneers.

7. Miscellaneous, including such articles as automobile tops, egg cases, wooden dishes, hoops, hampers, toys, trunks and a great number of other uses which could be mentioned.

UTILIZATION OF WASTE

There is a great amount of waste occasioned in the manufacture of veneers before the product is ultimately used in one way or another. The following table is a rough estimate of the amount of waste that is to be expected under average conditions. Since rotary cut veneers make up 90 per cent of all the veneers turned out in the country, most of this table is based upon the manufacture and use of this particular kind. There is very little waste incurred in the manufacture of sliced and sawed veneers with the exception of the saw kerf lost in connection with the latter.

	Per Cent
Trimming, including the cutting off of defective ends and trimming around defects, knots, etc.	5.5
Loss through checks and cracks which occur in the logs before manufactured	6
Loss through damaged sap or in cutting around sap to bring out the best color	3.2
Loss in cores, which vary in diameter from 6 to 12 in. depending upon the size of the log	5.6
Loss through breakage	5
Loss through imperfect drying	4
Miscellaneous losses	4.7
Total	34.0

Miscellaneous waste includes kerf in sawed veneers, carelessness in handling, mis-cut veneer, etc. Most of the logs used for rotary cut veneers are shaved down to a diameter of 6 in. In all cases they are cut down to the spindle chucks which vary directly with the size of the log.

It is likely, therefore, that about one-third of all of the raw material intended to be manufactured into veneers and which is brought to the mills from the woods, is lost during the process of manufacture, of treating or of shipping. There is a distinct tendency to reduce this amount every year.

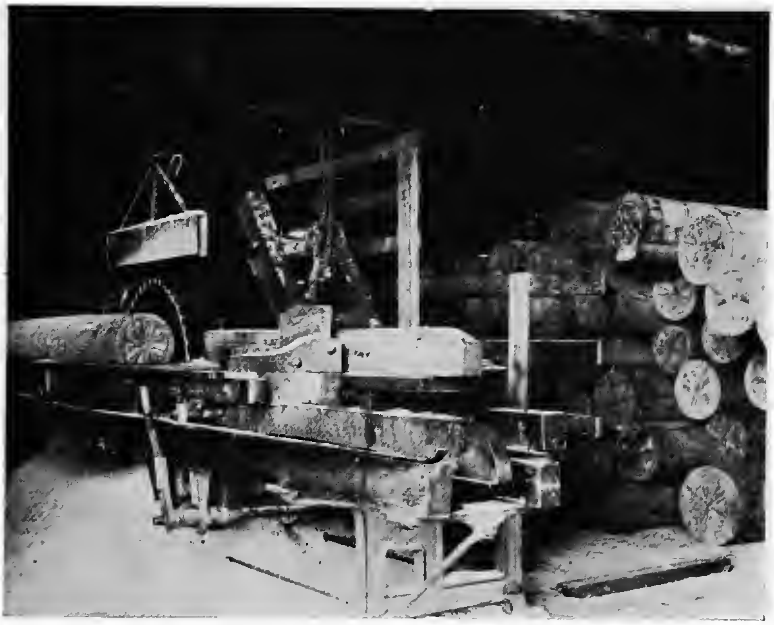
Practically all of the trimmings and defective veneers are utilized for fuel purposes in the power plant or are burned up in a waste burner or carted away locally for fuel purposes in the homes of laborers about the mill.

There have been developed, however, many uses for the core material left as a result of manufacture by the rotary cut process. At first these cores were used almost entirely for fuel purposes. Later, the larger cores were cut into crating material, boxes, shooks and smaller pieces of lumber. It is estimated that more cores are cut into boxes, lumber, crating stock, etc., than for any other purpose.

Yellow poplar, basswood, and cottonwood cores are frequently shipped to excelsior mills, as these woods make excellent excelsior. Cores of the heavier hardwoods are very often utilized by construction companies, for rollers for moving houses, machinery, etc.

Oak and pine cores have been in great demand for mine rollers and for general mine timbers, especially in mining regions such as the Pennsylvania coal region and the mines of southern Illinois, Indiana, Missouri and Alabama.

Some of the cores of the more valuable species are reinserted in special lathes, and veneers are cut off down to a 3-in. core, which is then used for a variety of purposes. Black walnut and Circassian walnut are very frequently sold to manufacturers of shotguns, pistols, rifles, etc., for gun stocks.



Photograph by Nelson C. Brown.

Fig. 23.—Sawing up the cores left after making rotary veneers at the Weed Lumber Co., Weed, California. They are used for box boards and crating stock.

Other miscellaneous uses for cores are fence posts, bowling pins (in the case of hard maple), heading for slack cooperage, cheese boxes and heading and bottoms for fruit and vegetable baskets.

GRADING RULES

Rules for the measurement and inspection of quartered oak veneer, sawed and sliced:

Measurement.

Tape measure shall be the standard measurement in all thicknesses, and the width shall be taped midway of the flitch.

In computing the feet in a flitch the actual length of the flitch shall be used.

Multiply the width in feet and inches as shown by the tape by the length of the flitch to obtain the number of square feet the flitch contains.

In determining the width of a bevel flitch, the average width of the sheets, shall be the width of the flitch.

In computing defects, the flitch shall be taken as a unit. The percentage of defects allowed in each grade as herein stated is figured on the total square feet contained in a flitch.

Cutting.

The term "cutting," as used in these rules, means a "piece of veneer" free from defects.

Figure.

All flitches must show 90 per cent of figure in the aggregate.

Grades.

There shall be two grades of veneer, standard and medium.

Standard Grade.

All flitches in which the defects do not exceed 10 per cent of the total feet in the flitch shall be measured full.

Flitches containing defects not to exceed 20 per cent of the total feet in the flitch may be cut in measurement 10 per cent of the total feet in the flitch to raise the veneer to this grade.

In estimating defects, no cutting to be considered less than 6 in. wide by 24 in. long.

Bright sap shall not be considered a defect. Widths shall be 6 in. to 12 in.

Lengths shall be 4 ft. and over, not over 5 per cent to be under 7 ft.

Medium Grade.

Flitches shall cut two-thirds clear, no cutting to be less than 5 in. wide by 18 in. long.

Bright sap shall not be considered a defect.

Widths shall be 5 in. and not over 10 in.

Lengths shall be 4 ft. and over, not over 5 per cent to be under 7 ft.

Note.

Any other specification for veneer, other than these rules, shall be a matter of special contract between buyer and seller.

Inspection and grading rules for rotary cut ash, basswood, birch, beech, elm, maple, chestnut, cottonwood gum, poplar, sycamore and oak:

No. 1 Faces or Face Stock.

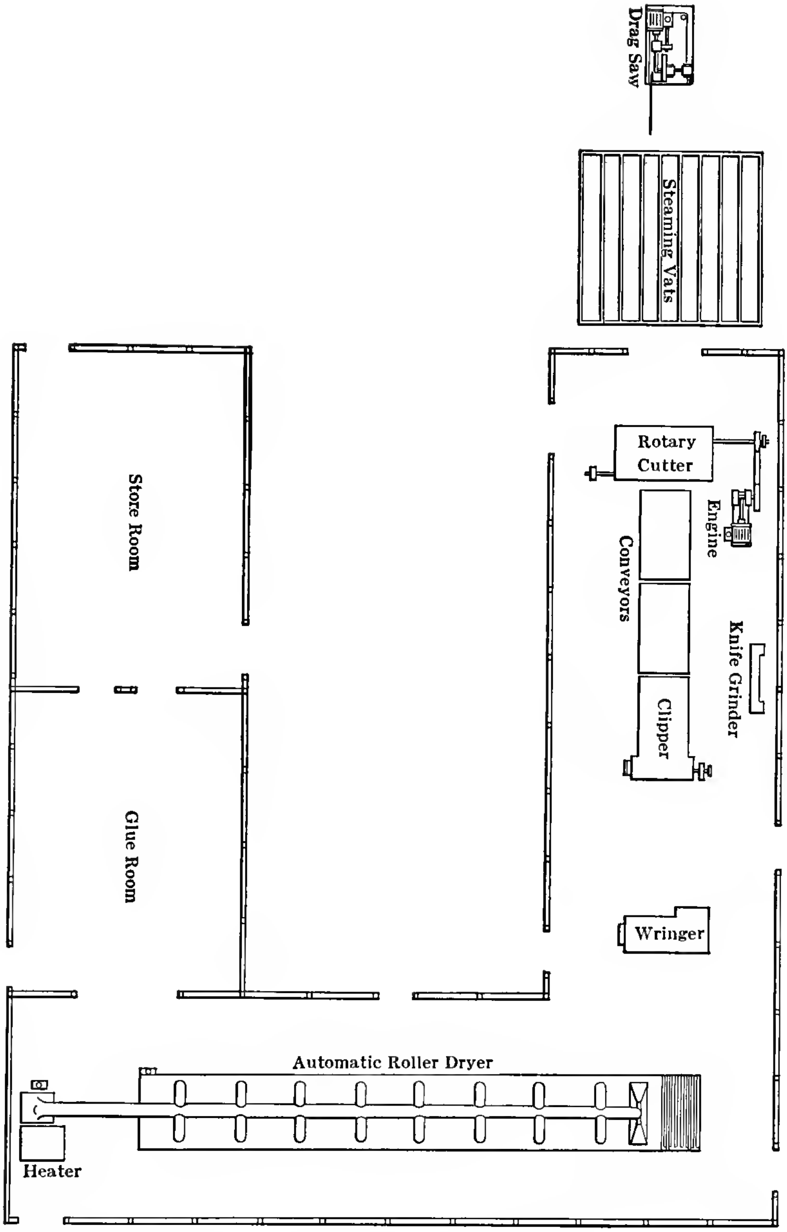
Stock of any thickness, free from knots, shall admit sap, splits that close, and slight discolorations.

Select Faces or Face Stock.

Stock of any thickness of the same grade as face stock, except that it shall be selected as to color.

No. 2 Faces or Face Stock.

Stock of any thickness shall admit sound knots, splits that close and log run color.



From Coe Manufacturing Co.

FIG. 24.—The "U" plan of veneer mill.

Backs or Backing Stock.

Stock of any thickness shall admit sound knots, pin-worm holes, discoloration, firm doty spots and open splits and checks, not to exceed $\frac{1}{16}$ in. in width.

Draw-bottom Stock.

Stock of any thickness shall admit sound knots, closed splits, pinworm holes and log run color.

Center Stock.

Stock of any thickness shall admit sound knots, pinworm holes, discoloration, firm doty spots and open splits and checks not to exceed $\frac{1}{16}$ in. in width.

Flitch Stock.

Stock of any thickness, of random widths and lengths, 10 in., wider, the sheets to be kept in consecutive order as they are cut from the flitch. The stock is to be at least two-thirds No. 1 faces.

Log Run Stock.

Stock of any thickness, random widths and lengths, as the logs will make 6 in. wider, not less than 75 per cent to be 12 in. and wider. Not less than 50 per cent shall be No. 1 face stock, and the remainder shall be suitable for center and backing stock.

Cross-banding.

Stock not thicker than $\frac{1}{16}$ in., cut to dimension sizes, shall admit sound knots, splits that close, pinwork holes, firm doty spots and log run color.

Dimension Stock.

All dimension sized stock, unless otherwise particularly specified, shall be machine cut to exact lengths and may be a trifle full as to width.

Surface dimensions shall be stated as follows: first, width across the grain, and last, length with the grain.

Box Grades.

Stock shall be 24 in. and under in width, any thickness; shall be machine sized tc dimension as required by the buyers, but seller shall have the privilege of shipping not to exceed 25 per cent narrow cuttings, 5 in. and over in width.

No less than 75 per cent of each shipment shall work without waste in sound cuttings, and the remaining 25 per cent shall work as good as three-quarter to sound cuttings.

The grade to sound cuttings shall admit of sound knots, discoloration, pinworm holes and splits or checks not more than $\frac{1}{8}$-in. in width.

Notes.

Stock of all grades must be cut solid, dried, so that it will not mold or damage in transit, and sufficiently flat to straighten under the press, dry, without splitting.

Any specification not covered by these rules shall be a matter of special contract between buyer and seller.

Inspection and grading rules for rotary cut walnut and cherry.

Dimension Faces.

Consist of stock that shall admit of not over $\frac{1}{2}$-in. sap along the edge, splits that close and small tight knots.

Random.

Consists of stock of sundry lengths, 3 ft. and up, and sundry widths, 6 in. and up, and will admit of same defects as dimension faces.

Flitches.

Consist of stock cut sundry lengths, 4 ft. and up, and sundry widths, 6 in. and up; the sheets are kept in consecutive order as they are cut from the flitch; shall admit of not over 50 per cent sap in any one sheet, splits and heart knots where the sheets will cut 50 per cent faces.

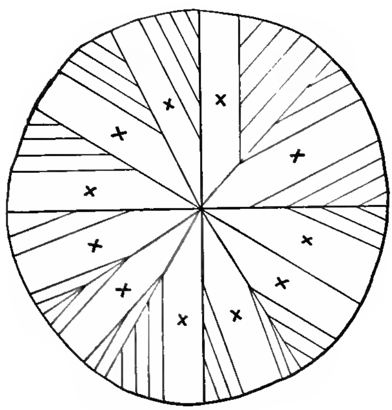


FIG. 25.—Diagram illustrating the utilization of a log for quartered flitches, marked (X) used for sawed and sliced veneers. The other cuts are used for lumber. The log is first quartered, then each quarter is dogged and turned on the carriage.

Log Run.

Consists of stock of such widths and lengths as the log will make, 6 in. and up wide; not over 25 per cent to be under 12 in. wide, not under 50 per cent faces, and the remainder can be defective, as the log may turn out.

Backs.

Consist of stock of all thicknesses cut to required sizes not suitable for faces but reasonably sound, and shall admit of same.

Backing.

Consists of stock of random widths and lengths suitable for backing only.

Note.

In specifying dimensions always name thickness first, next the width across the grain, and, last, the length.

All of the above rules have been officially adopted by the National Veneer and Panel Manufacturers' Association.

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CHAPTER V

SLACK COOPERAGE

GENERAL

COOPERAGE is the art of making vessels, or containers, of pieces of wood bound together by hoops. The industry is a very ancient art, as early historical records show that various forms of cooperage were in common use among the Romans at the beginning of the Christian era and even in early Biblical times.

Slack cooperage is made up of three forms of wood: Staves, heading and hoops. Each of these forms is commonly made at separate plants, although in many of the larger cooperage establishments both staves and heading are made in one plant. The manufacture of hoops is quite distinct, however, and it really constitutes a separate industry. Tight cooperage is distinguished from slack cooperage in its ability to contain liquids.

Although a large percentage of slack cooperage products refers to barrels, it is also inclusive of such containers as tubs, buckets, pails, kegs, churns, firkins, etc. There are many grades of slack cooperage barrels; the finest product has tongued and grooved staves and is used for the shipment of flour and sugar; semi-tight cooperage stock, which is classified with slack cooperage, is used for making vessels required for butter, lard, paste, paint, mince-meat, etc., while cheaper grades of slack cooperage are used for the shipment of apples and various forms of agricultural products such as vegetables, fruits, etc. Still cheaper and more roughly constructed slack cooperage barrels are utilized for the shipment of hardware, crockery, rosin, etc.

A good portion of our slack barrels is utilized for the shipment of cement (an equivalent of over 100,000,000 barrels of cement are produced annually), flour, sugar, apples and vegetables. Other commodities shipped in slack barrels are various chemicals, meal, crackers, starch, salt, cranberries, candy, tobacco, dried fish, lime, powder, and many other materials.

ANNUAL PRODUCTION

In spite of competition from boxes, crates, paper containers, cartons, etc., the production of slack cooperage stock has increased in the last decade. Statistics gathered by the U. S. Census Bureau vary in their amount from year to year, but there has been a general tendency to increase production.

In 1911, 1182 mills reported the production of 1,328,968,000 staves; 106,407,000 sets of heading, and 353,215,000 hoops. Expressed in the terms of the ordinary sized barrel and figuring one set of heading, 15

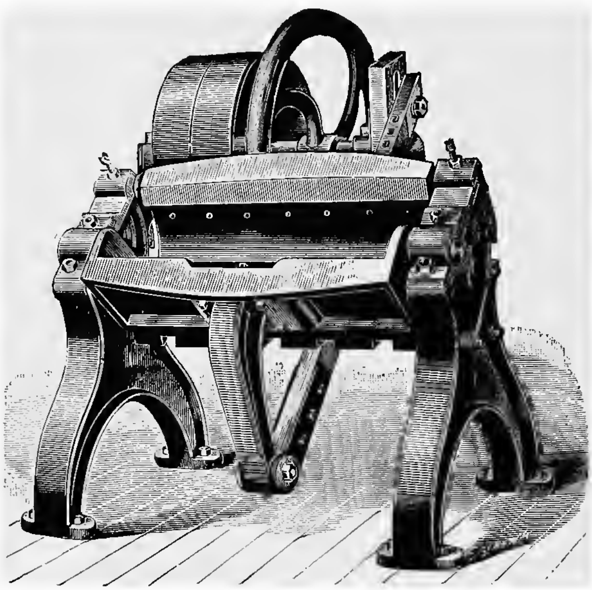


FIG. 26.—Stave Cutter. This makes 165 strokes per minute and has a daily capacity of 30,000 staves.

staves and 6 hoops to the barrel, the production would be sufficient staves for over 88,000,000 barrels; the heading would complete over 106,000,000 barrels and the hoops would be sufficient for over 58,000,000 barrels. These apparent discrepancies in production are accounted for by the fact that large numbers of second-hand barrels or portions of them are used over again. The wooden hoop is also being rapidly displaced by the steel and iron hoops.

The production of staves is centralized in Arkansas and Missouri, which together produce annually over 400,000,000 staves. Pennsylvania, Virginia and Maine are the next three states in order. The manufacture of heading is also centralized in Arkansas, which produces annually over 15,000,000 sets of heading. Michigan, Pennsylvania, Wisconsin and Virginia follow in order. The manufacture of hoops is centralized in Ohio, where over 106,000,000 hoops are made annually. Indiana, Michigan, Arkansas and Missouri follow in order. A few decades ago the industry was of greatest importance in the Ohio Valley and Lake states, but with the rapid depletion of the timber supply in those regions and the consequent rise in timber values, the industry has shifted to a large extent to the lower Mississippi Valley, where the cheaper and more abundant red gum and yellow pine are available.

SLACK COOPERAGE VERSUS OTHER FORMS OF SHIPPING CONTAINERS

The wide variation in the production of slack cooperage stock from year to year is not surprising when so many outside influences acting upon the industry and its output are taken into consideration. The larger proportion of slack barrels is used for marketing agricultural products. The prospect of an increase or decrease in the staple crops and the resultant effect upon the industry will naturally pay the makers of slack cooperage stock to gauge their output accordingly. The competition of cheaper classes of packages, moreover, has a direct bearing upon this situation. Within recent years, associations of apple growers and others have made official decisions which have an important influence on the output of slack barrels. The veneer barrel undoubtedly has made important inroads in the old style of manufacture of slack barrels. There has also been a growing tendency to market commodities in smaller containers such as cloth and paper bags, which are more easily handled as well as being more easily marketed. It is estimated that seven-eighths of all the flour made in this country is put up in cotton, jute and paper sacks and but one-eighth in wooden containers. This is to be expected since cotton and jute bags, counting four to the barrel, cost from 5 to 6 cents each and paper sacks even less, while wooden barrels commonly cost from 37 to 45 cents or more, each. Other commodities sold in sacks to a relatively less extent are sugar, salt, cement, plaster, etc. Another important competitor of the slack barrel, the carton package, is used for crackers, starch, cranberries and various fruits and agricultural products.

The increased demand for slack barrels in other lines than the above, however, has probably more than offset this effect of the competitive packages. For example, the rapid growth of the Portland cement industry has vastly increased the demand for wooden barrels. In many states apple growing is becoming a leading occupation, whereas a few years ago it was comparatively unimportant. The barrel has always been the foremost container for marketing apples, but since the Apple Growers' Congress in 1909 declared in favor of the barrel over the box for the standard shipping package, the demand for barrels has had a decided impetus. Again, the more recent movement for better protection of foodstuffs and commodities in transit and marketing has called special attention to the excellent qualities of the wooden package. Many other outstanding advantages of the wooden barrel are economy in storage, convenience in handling, less liability to loss in transit, better protection from insects and rodents and from exposure to atmospheric conditions, comparative cheapness and availability for secondary use.

LAWS GOVERNING THE INDUSTRY

Numerous attempts have been made to secure greater uniformity in the specifications and holding capacity of barrels, especially those used for agricultural products. Much progress has recently been made in this direction.

The United States Government has prescribed standard barrels for apples by an act of Congress in 1912 of which the dimensions without distention of its parts are as follows:

Length of stave—28½ in.
Diameter of head—17⅛ in.
Distance between heads—26 in.
Circumference of bilge—64 in.

This represents practically 7056 cu. in.

The statutes of the various states provide for the dimension of barrels and casks used for various commodities. Section 188 of the Agricultural Law of the State of New York requires that the capacity of fruit barrels shall equal 108 qt., 12½ pk. or 6720 cu. in. dry measure, and shall be of dimensions as follows:

Diameter—17½ in.
Length of stave—28½ in.
Bilge not less than 64 in. outside measurement.

If the barrel is made straight up and down or without any bilge it shall contain the same number of cubic inches as described in the foregoing. Anyone manufacturing barrels for use in the sale of apples, pears or any other fruit, must brand such barrels upon each end and upon the side with conspicuous letters " short barrel."

The legal fruit barrel in the State of Indiana shall contain not less than 12 pk. 96 qt. or 6451 cu. in.

The State of Wisconsin provides that the barrel shall contain 31.5 gal. and a hogshead 2 bbl. A barrel of flour measured by the hundred weight shall contain 196 lb.; a barrel of potatoes, 172 lb.; a barrel of unslacked lime, 200 lb.; a barrel of apples or pears usually represents a quantity equal to 100 lb. of grain or dry measure.

QUALIFICATIONS FOR SLACK COOPERAGE STOCK

Almost any species may be used for slack cooperage. Since slack barrels must compete with other forms of containers and packages, such as sacks, paper and cloth bags, fiber board boxes, wooden boxes and crates, cartons, etc., the primary requisite in considering stock for the manufacture of slack barrels is its comparative cheapness. Aside from this, it should be light in weight to reduce shipping charges and the wood should be easily worked. Woods which are soft and of uniform grain and texture, therefore, are much preferred to those which are hard, heavy and coarse.

Woods which dry quickly, steam well and retain their form when bent, are also in high demand for slack cooperage stock. Woods which are light in color are in especial demand for heading purposes. Basswood is generally considered our best heading wood on account of its light color together with its other admirable qualities, such as excellent workability, lightness in weight, freedom from resin, etc. Woods which do not contain oils, resins or discoloring materials or other substances likely to taint or sour substances brought into contact with them make very desirable heading and stave material.

For the manufacture of hoops, woods which are primarily tough, durable and exceedingly strong are required. Species likely to warp are not considered satisfactory, especially if the retainer is to be used for certain commodities.

WOODS USED

Until about 1890 practically the only wood used in the manufacture of slack cooperage was oak, and a large portion of this was white oak. The rapid rise in the value of oak, however, caused the cooperage trade to change to other less valuable but still abundant woods. Elm became the leading wood used for slack barrels and it became known commercially as the " patent elm stave." Until about 1900 and since 1890 elm was the leading wood used in this country for hoops and for staves and heading as well. The increasing demands for slack cooperage stock rapidly exhausted the available elm, however, and a change was soon made to other woods. About 1900 red gum began to appear upon the market for slack barrels, and since 1907 it has been the leading wood used for staves. With the decrease in the use of elm came the increased use of beech, birch and maple, particularly in the Lake States, where these woods had not been cut when the more valuable white pine was removed from the Michigan and Wisconsin forests. These came into such common usage that the trade name "hardwood staves" came to be

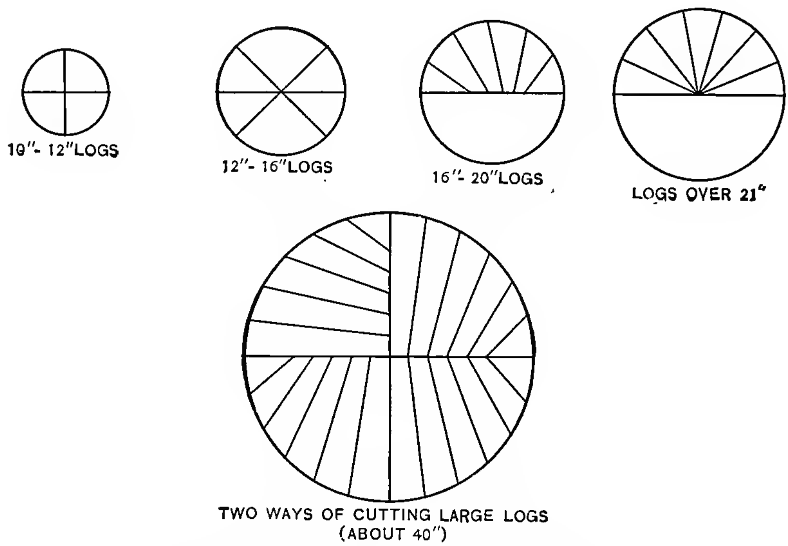


FIG. 27.—Method of cutting logs of various diameters into stave bolts.

applied to these woods, which are now used for the highest grades of slack barrels, namely, for the flour and sugar trade.

Red gum has been the leading stave wood for the past several years and it is likely that it will hold this place for some time to come. It has also been the leading heading wood next to pine for the past few years. Red gum staves and heading are shipped to every part of the country and large quantities are now exported to European and South American markets. In the South, red gum is practically the only wood used for molasses and sugar barrels and is used very largely for shipment of rosin as well. The available supply of red gum is comparatively large and this fact, together with the even texture and strength of its wood are important factors in making red gum our leading slack cooperage wood.

Pine is the leading heading wood expressed in terms of quantity used and is second only to red gum as our leading slack cooperage wood. By pine is meant both the Southern yellow pine and the white and red pine of the North. Because of its lightness and easiness with which it is worked, pine is regarded as highly desirable for certain purposes. However, yellow pine, on account of its highly resinous nature, is likely to discolor or impart a disagreeable odor or flavor to the contents. Staves from yellow pine, therefore, constitute a much cheaper grade and are used largely for the shipment of cement, lime, rosin and produce barrels. White and red pine make a much higher grade stave and heading. They are used largely for paint and fish pails and for the shipment of jelly, candy and apples and for ice cream freezers.

Beech is excelled in use only by red gum and pine. Its wide use is due to its extensive range in the Lake States and Northeast, comparative cheapness and high value as a stave wood. In the trade it is usually classed with birch and maple which, together, are called hardwood staves. They now represent the highest grades manufactured in slack cooperage industry and have the leading place for the shipment of flour, sugar and other commodities which demand a clean wood free from any disagreeable odors or discoloration.

On account of its great toughness and tensile strength, elm is our leading hoop wood. In fact, it constitutes about 90 per cent of all the hoops made. The only other woods that make high-grade hoops are hickory and ash but these woods are now valued so highly that they are not found, to a large extent, in the market as hoop material. Elm makes an excellent stave, but its comparative scarcity has precluded its common use for this purpose.

Chestnut is the next wood most commonly found in the manufacture of slack staves. It is also used for heading to some extent. Within recent years chestnut has risen very rapidly in importance as a stave wood. Its easy workability and lightness in weight for use as a shipping container contribute to its broad usefulness. Its manufacture, however, is principally localized in Pennsylvania and Virginia, where it is chiefly used for cement, lime, fruit and vegetable barrels.

About fifteen other woods are commonly used for slack cooperage stock including staves and heading. The leading woods among these are spruce, ash, oak, tupelo, cottonwood and basswood.

MANUFACTURE OF SLACK COOPERAGE STOCK

The manufacture of the three forms of slack cooperage stock, staves, heading and hoops is usually found in separate mills. The assembling of this stock into the finished barrels is almost always practiced in still another shop. Staves and heading are sometimes manufactured together in the larger plants where a division of the raw material may be

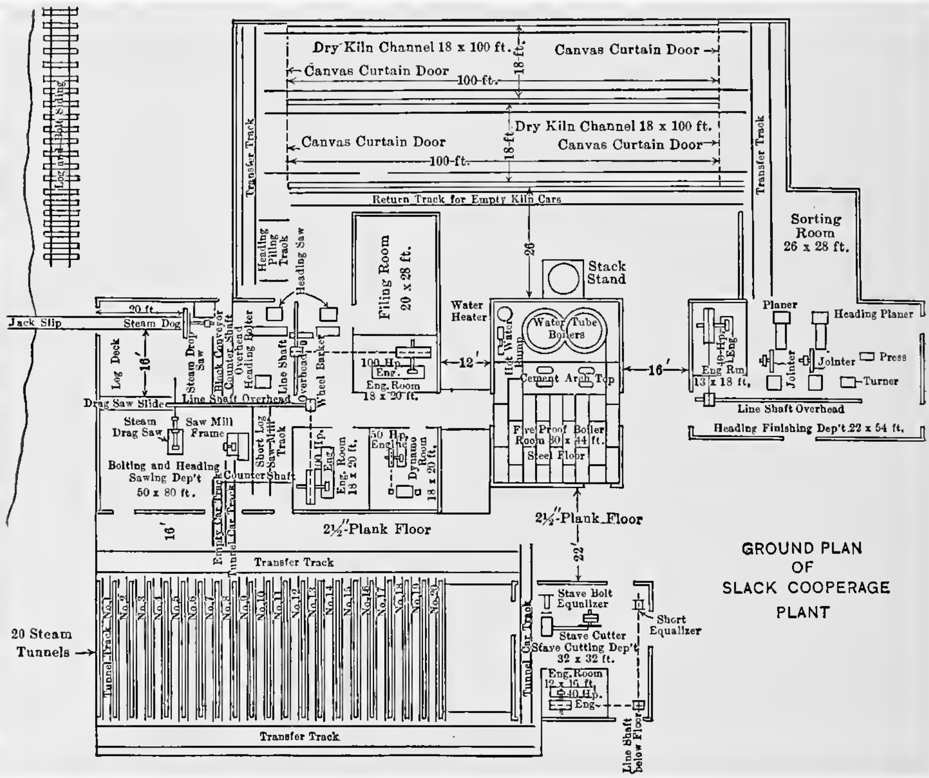


FIG. 28.

advantageously made, the poorer material going into heading, the better going into staves. This is done because the staves are thinner than the heading and they must later withstand the strain of bending over the bilge when assembled into the barrel.

Mills are located first with reference to a sufficient supply of raw material, either independently or in connection with a logging operation or sawmill. Location on a common carrier affording good transportation facilities and on a stream for a mill pond are desirable.

The raw material is preferred in the green state as it is manufactured much more readily and is delivered to the mill in the form of logs or bolts. They are accepted down to 8 in. at the small end at some of the plants. A mill pond to clean the logs, thaw frozen logs in winter, serve for storage purposes and to soften the wood for slicing and sawing is in common practice. A log hoist serves to elevate the logs to the main floor, from which point the material gravitates to constantly lower elevations.

In some mills the logs are rolled on to a deck; in others they are taken directly to a cut-off saw. In either case, they are inspected and designated for their proper use, the better grade of logs going into staves or hoops, while those containing crooks, knots, checks, and other defects are set aside for heading. Following this inspection they are bolted into the proper length by a drag saw or drop circular saw. The former is used in mills where large logs are the rule and the latter for mills in which the run of logs is small. In one large mill, all bolts for staves are cut into 32-in. lengths, while those for headings are cut into 22-in. lengths.

From this point in the process of manufacture the bolts are conducted on transfer chains or other carriers to the different parts of the mill.

Manufacture of Staves.

The larger bolts designated for staves are quartered or halved, depending upon their size, and, if necessary, cut in smaller flitches sufficiently large to yield staves 4 to 5 in. in width. Formerly stave bolts were rived with a maul and wedge, but this method is so wasteful that saws are almost universally used at the present time for this purpose.

The flitches or bolts are next put through a process to soften the fiber sufficiently to shear into staves. Steaming has been found to be the best method. Well-steamed wood shears about one-third more easily than green or wet wood and yields a brighter and much smoother stave. Wood that is not sufficiently steamed will produce rough, uneven staves that are likely to stain, whereas over-steaming deadens the fiber and, therefore, impairs its life and strength. Elm, cottonwood, soft maple and basswood require much less steaming than gum, beech, hard maple, birch and sycamore. In a mill cutting staves of the last four-named species, the wood was subjected to steaming for twenty-four hours under a pressure of from 100 to 110 lb. In some mills boiling the bolts for seven hours is practiced instead of steaming. There is a difference of opinion as to whether boiling or the use of live or exhaust steam is best, but steaming is the most common practice.

The usual procedure is to load the bolts on cars 55 by 53 in. in size, which are rolled into steam tunnels about 45 ft. in length. The tunnels may be constructed either of wood or concrete. One mill has 15 of these tunnels arranged side by side with a capacity of 9 cars, or a total capacity of 135 cars, which contain the equivalent of about 100,000 staves $28\frac{1}{2}$ inches in length.

From the steam boxes the bolts go to the stave bolt equalizer, located conveniently to the stave cutter (to the left of it and about 3 ft. from it). The bolts are first peeled of all bark. The equalizer cuts off both ends of the bolt to insure the desired length and make them smooth and square.

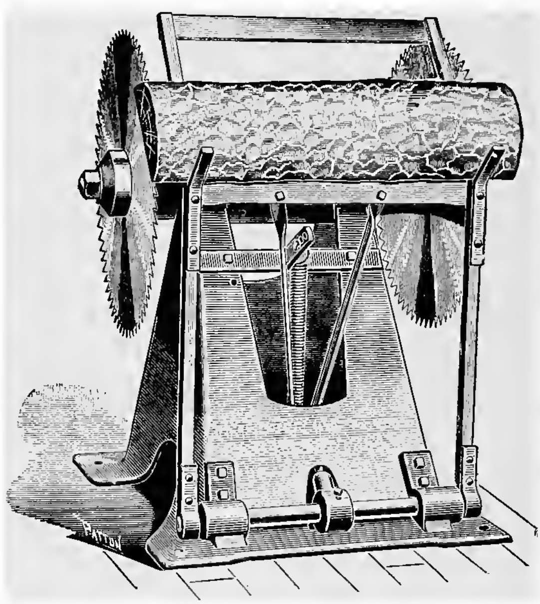
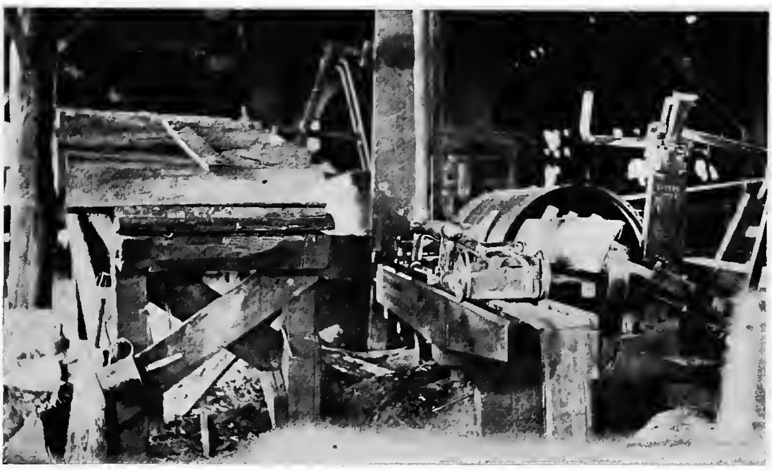


FIG. 29.—The Trevor stave bolt equalizer.

It is provided with two circular cut-off saws about 32 in. in diameter, of 11-gauge, having 64 teeth and run at a speed of about 1800 R.P.M. Each equalizer can turn out enough bolts for 50,000 staves daily.

Next the bolts are cut into staves on a stave-cutter. This machine has a knife usually 36 in. long and $6\frac{1}{2}$ in. wide, with a face ground to a circle of 20 in. The bolts fit in a tumbler and at each stroke against the knife a stave of any desired width is sliced off. The speed of the machine is regulated as fast as the operator can feed it, 150 to 170 strokes per minute being the usual practice. With even, straight bolts the work is much easier than with split or uneven pieces. This work demands the constant and most careful attention of the operator since the cut should be made on the quarter-grain in so far as possible in order to produce the strongest stave. It should always be of even thickness and smooth. This work is of such exacting nature combined with the danger of cutting one's fingers that stave cutters are usually required to work every other hour, or altogether only five hours on duty in a ten-hour day. One stave-cutting machine will turn out about 30,000 to 60,000 staves in a ten-hour day.

In working up the softwoods into staves, such as white and yellow pines, hemlock, spruce, tamarack, etc., the steaming process is not



Photograph by U. S. Forest Service.

FIG. 30.—Barrel stave saw and stave bolts ready to be sawn at mill of Mt. Olive Stave Co., Batesville, Independence Co., Arkansas. Both slack and tight staves are made on this type of saw.

resorted to. These woods, particularly the Southern pines, seem to be so shattered in the steaming and cutting process that the staves check and splinter up very seriously upon drying. The usual practice with these woods, therefore, is to cut them on a cylinder stave saw which is shown in the accompanying illustration. The speed of these saws is usually maintained at about 1800 R.P.M. The cylinder or drum saw is most commonly found in the South.

As soon as the staves are made on the drum saw or the stave cutter, they are received by a helper who loads them on carts, cars or sleighs, according to the season and location of the mill, and are transported to the dry shed for seasoning. Four to six staves are laid on top of one another, the curved sides fitting into each other. The ends of another similar bundle rest on the ends of other bundles and thus the piling continues making a sort of crib work construction. The piles are separated by a space varying from 14 to 24 in.

Seasoning is usually carried on in open-air sheds about 20 ft. wide and 100 to 150 ft. in length. The piles should be elevated about 10 to 16 in. from the ground and every opportunity offered to facilitate the drying out of the staves. The seasoning of hardwood staves requires from one to three months, depending upon the time of year. It is estimated that beech, birch and maple staves $28\frac{1}{2}$ in. in length should weigh about 1 lb. apiece when properly dried.

Just before the staves are shipped to the cooperage shop where the staves, heading and hoops are assembled into barrels, they are jointed. The jointing machine is brought to the staves in the dry sheds and operated there either by hand or power. The hand jointer is the more common form in use at the present time. The function of the jointer is to shape the staves so that the finished barrel will have the required bilge. Staves with a three-quarter bilge joint means that the ends of the staves are $\frac{3}{4}$ in. narrower than the center. It is very important that a careful man and one who understands grades is employed on the jointing machine. Current opinion in the trade now favors the bevel as against the square joint. At each downward stroke of the knife, narrow strips called listings are removed. Each stave jointer has an average capacity of about 10,000 staves in a ten-hour day.

For the purposes of shipping, staves are bundled in a stave press which is very similar to a shingle, excelsior or hay press in principle. Several different types are on the market. Staves are packed with alternating wide and narrow ones, and so arranged that about 200 in. in total width, are in one bundle. This is estimated on the basis of 50 staves to the bundle and that the width of the average stave is about 4 in. This method of packing is standard throughout the slack cooperage industry.

The crew of the stave department in a typical cooperage mill making both heading and staves of the Northern hardwoods is as follows. This mill runs eleven months in the year, during which it manufactures about 25,000,000 staves and 600,000 to 800,000 sets of heading:

2 men who load bolts.
2 men in feeding steam tunnel
1 man in pulling tunnel.
2 bark peelers.

3 equalizers—these men work one hour on and one-half hour off.
4 stave cutters—these men only work every other hour.
2 stave cullers.
2 loaders—on trucks that take them to the dry sheds.
2 drivers—to transport the trucks to the yards.
8 pilers in the yard.
4 stave jointers.

Stavers get $3.00 to $3.25 per day. Common labor received $1.75 per day of ten hours before the war.

Manufacture of Heading.

After the bolts designated for heading stock are cut off in proper lengths (22 in. for sugar barrel heads) by the main cut-off saw, they are first rossed to remove the bark and any accumulated sand, grit, etc. One man can remove the bark fast enough to keep two heading saws busy, when sawing 24,000 to 30,000 pieces of heading boards per day. Then each bolt is transferred on live rolls to the heading saw, the largest bolts being quartered or halved. One large mill observes the rule that bolts 12 in. and over in diameter must be halved; those over 16 in. are quartered.

The heading saw is also called an upright pendulous-swing saw. The larger this saw with greater rim speed, the greater will be the ease in cutting and, therefore, its capacity. The hardness and character of the wood sawed will govern, of course, the gauge and number of teeth in the saw. With beech, maple, birch, sycamore and oak a 56-in. saw with 80 teeth, 15 gauge at the rim and 6 gauge at the eye running 1500 R.P.M. will give the best results. With red gum, cottonwood, and basswood, a 50-in. saw with 64 teeth, 15 gauge on the rim and 10 gauge at the eye and running 1500 R.P.M. gives the most satisfactory results. A horizontal hand-feed heading saw is also used to some extent and has certain advantages.

The heading saw usually cuts the heading stock about $\frac{7}{10}$ of an inch in thickness. When surfaced and kiln dried it makes heading $\frac{7}{16}$ or $\frac{1}{2}$ in. in thickness. Surfacing is usually done only on one side.

The boards are then stacked on trucks which hold from 4500 to 5000 pieces and conveyed to the dry shed where they are left from ten to thirty days with stickers between the layers.

From the dry shed the heading boards are rolled on trucks into the dry kilns, of which there are many types. One mill which turns out 3500 to 4000 sets of heading per day has two channels in its dry kiln which are each 100 ft. by 18 ft. in dimension. Until within recent years, air drying was resorted to entirely to properly season the heading boards. Kiln drying has the advantages of saving in time and the control of the dry condition of the boards. Softwoods may be kiln dried directly from the heading saw and planer, but hardwoods should first be air dried for from ten to thirty days, depending upon the kind of wood and the season.

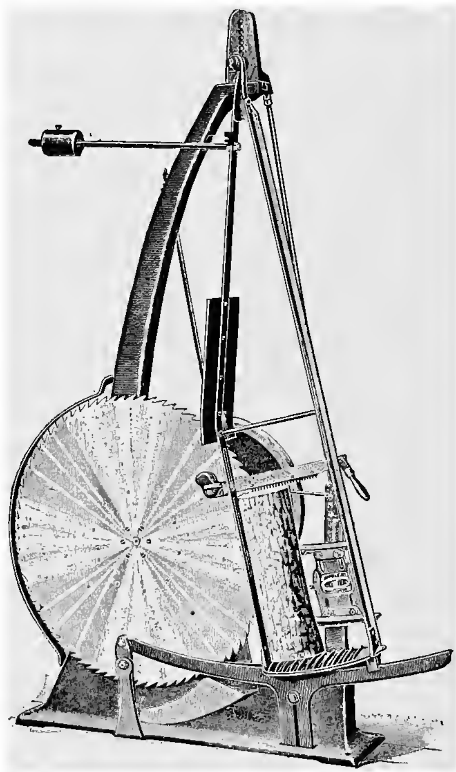


FIG. 31.—Heading sawing machine.

In a heading mill, which turns out from 2500 to 4000 sets of beech, birch and maple heading per day, there are two dry kilns 128 ft. long, 18 ft. wide and 10 ft. in height. Each kiln has a capacity of 20 cars, each of which holds from 4500 to 5000 pieces. Every effort is made to dry all the boards, which are separated by stickers, at the same rate, to prevent warping, checking and case-hardening. Many plants use a series of steam pipes to secure and regulate the proper amount of heat and a forced draft over the cars is provided by a large fan. At one mill, at the wet end of the kiln (where the highest humidity is maintained) the temperature is maintained from 90° to 130° F. At the dry end the temperature may be 150° or over.

The period of kiln-drying is about ten days for Northern hardwoods, during which the heading blanks slowly pass from the wet to the dry end of the kiln as fresh material is put in and the dried boards are conveyed to the heading mill. Although kiln-drying is in common practice, at some mills the heading stock is merely air dried in a shed.

Within the heading mill are the three machines—the jointer, the heading turner and the heading press or baler. In some mills the heading boards are planed before they reach the jointer. The heading room should have ample space for the various operations and should be well above the level of the ground in order easily to carry out the refuse to the boiler room and to load the baled heading on the cars with the least effort.

As the trucks containing the dry boards are unloaded from the dry kiln, the heading pieces are jointed. This consists of removing any bark or rough or uneven edges and making them smooth and even, so there will be a tight joint or " fit " when the heading pieces are placed together to form the barrel head. This is done either by a saw or a large rotary wheel provided with knives against which the boards are shoved by the jointer until a smooth edge is secured. Experience in the trade, however, has shown that a 5-ft. wheel jointer running 650 R.P.M. and with a 21-in. knife, will give the best satisfaction. An operator well versed in the work can joint 3500 to 4000 sets of heading in a day of ten hours. The heading board should be held firmly and evenly against the jointer to make the best joint. The edge should also be along the grain in so far as possible. If these precautions are not observed the joint is likely to be shattered or rough or uneven. There is a strong tendency to cause unnecessary waste which only an experienced man can avoid to best advantage.

The pieces next go to the matchers, of whom there are usually two, to keep one jointer and one heading turner busy. These men assemble the heading pieces into sizes approximately of the same diameter as the finished barrel head. From five to six pieces are used for sugar-barrel heading $19\frac{1}{8}$ in. in diameter. Assuming that the heading turner properly centers the pieces, an allowance of 1 in. is usually made for trimming. The " goosenecks " or " bats " left after trimming are a good guide to the matchers as to unnecessary waste in matching up boards for the heading turner. The boards are stacked up to a convenient height on a bench near the heading turner and as he finishes one pile another is moved up close to avoid loss of time. Piles of about 20 sets are customary.

The heading turner is probably the most interesting machine in a cooperage mill. Its function is to circle a finished barrel heading with a beveled edge out of each course of heading boards. The jointed and matched boards are placed into a form or clamp which holds the pieces firmly together; the operator, with a foot lever, releases the turner and the boards are swiftly revolved against a combination saw and knife. The saw which is concave in shape cuts the boards in a circle on a bevel

FIG. 32.—First step in assembling a barrel.

while the knife cuts the other bevel to meet it. Immediately the heading is turned, the machine automatically throws itself out of gear, discharges the heading pieces and assumes a position ready to receive another course. The speed of the turner saw is about 5000 R.P.M. In some mills the operator works only every other hour.

As each head is made, it drops down a chute with the waste to a pick-up or assembly man. He sets aside the waste and assembles the boards into regular piles. When enough sets have been piled up, they are carried or sent on live rolls to the baler. It is customary to pack 20 sets (40 heading) to the bundle which are baled with 3 wire ties of 11 gauge wire and loaded directly into the freight cars.

The manufacture of heading does not require skilled labor of any particular or exacting nature. A mill having a capacity of about 4000 sets of heading in a ten-hour day, but actually turning out about 3500 sets per day, has the following crew in the heading mill alone. About 100 h.p. was required to drive the heading machinery.

2 men or boys called " tads " to take the boards from the dry-kiln trucks and place them within convenient reach of the jointers.
2 jointers to feed the jointing machines.
2 matchers to put those boards together that will fit and make the proper width for a head.
2 turners—these men only work every other hour.
1 pick-up or assembly man to put the pieces together after coming from the heading turner.
1 baler who takes the assembled heads and fastens them with wire into bundles of 20 sets each.
1 boy who picks up the " goosenecks " and ties them together.
1 general utility man to assist anyone who becomes overrushed with work, look after breakdowns, clean-up congested parts of the mill, assist in loading baled heading, etc.
1 plant foreman.

MANUFACTURE OF HOOPS

Elm has always been the leading hoop wood on account of its toughness, strength, and ability to retain these qualities when steamed or boiled and bent. It makes up practically all of the material used for hoops, although oak, hickory, ash, birch, and maple are occasionally used. In the far South, pine, cypress and red and black gum are sometimes used, but the total amount is almost negligibl ecompared to elm. Wooden hoops are not as important a forest product as formerly, due to heavy competition from wire and flat steel and iron hoops, which are gradually displacing the wooden variety.

Hoops are generally made in separate mills which move from place to place as the scattering local supply of elm and other species are exhausted. Green timber which is sound and straight-grained and free from knots, shakes and other defects is the best material. It is generally felt that second growth rock elm makes a very poor and unsatisfactory hoop.

The standard barrel hoop should be $1\frac{3}{8}$ in. wide, 4 to 7 ft. long and with one edge about twice as thick as the other. Usually the thicker edge is $\frac{5}{16}$ in. wide and the other $\frac{3}{16}$ in. in width. Both edges are rounded. On finishing the hoops, one end is pointed while the other is "lapped" or thinned down to a fine edge like a wedge.

There are two methods of manufacturing coiled hoops and although certain variations in the two processes may be found in different parts of the country, they may be described as follows:

Sawed Hoops.

The timber for hoops is sawed into planks at a sawmill. They are ripped on a self-feed gang rip-saw into hoop bars $1\frac{7}{16}$ by $\frac{11}{16}$ in. in cross-section, each bar being large enough to turn out two hoops. The length may vary from 4 to 7 ft., depending upon the size of barrels they are intended for. Rip saws 16 in. in diameter and running at a speed of 3000 R.P.M. have proven to give excellent satisfaction.

The other machinery required for the manufacture of sawed hoops includes a combined planer and a jointer or lapper, and in addition a coiler. A great improvement over the old method is found in the Trautman sawed hoop machine which saws the hoop bar in two and planes, points and laps the hoop in one complete operation. The process is, briefly, as follows: One end of the bar is pointed by a revolving cutter head and is then started through the feed rolls. A saw placed at the necessary angle to produce the proper bevel, divides the bar into two hoops while a planer surfaces the opposite sides of the hoops. As they pass out, each hoop is lapped. Two operators are sufficient to run the machine, which has a rated capacity of 15,000 hoops per day. The Kettenring machine is another in common use.

The hoops are conveyed to a boiling vat or tank made of wood, which is about 7 ft. long, 5 ft. wide and 3 ft. deep. Here they are softened in the hot water which is heated by exhaust steam. They are then taken to the coiling machines.

Cut Hoops.

The timber is sawed into planks of the same width as the hoop and cross-cut into the desired length. In the cutting process, the following machines are required—a hoop cutter, a lapper or jointer, a hoop planer and a coiler. Before cutting the planks are steamed or boiled. For a long time there was some discussion as to whether steaming or boiling was better, but there is a general opinion among manufacturers that boiling is more efficient and cheaper in the end.

The size of the vat depends upon the capacity of the mill. For a plant with a capacity of 40,000 to 50,000 hoops per ten-hour day the vat should be about 45 to 60 ft. in length, 8 to 10 ft. wide, and 5 to 7 ft. deep and made of concrete or yellow pine. Some plants boil their hoop plank standing on end, as they claim that best results are secured when each plank is separated from the others, which is difficult or impossible when the planks are laid flat in the horizontal tanks.

The heat applied and length of boiling depend upon the condition of the stock. All that is required is to soften up the fibers so they will cut easily.

While still hot the planks are taken to the hoop cutter, which should be adjusted to cut the hoops slightly thicker than the finished size to allow for planing. Hoop-cutting machines are usually run at a speed of 200 R.P.M. and have a capacity of 60,000 to 75,000 cut and beveled hoops in ten hours. Next the hoops are planed in special machines that dress three hoops at a time and have a capacity of 30,000 to 35,000 hoops per day of ten hours. They are then pointed and lapped on other special machines and sent to the coiling machine.

As to the relative advantages of cut and sawed hoops there has been much discussion. Many more hoops can be made from a given amount of timber by the cut process than by the sawed process for the reason that with cut hoops there is no loss in sawdust. It is estimated, for example, that 1000 bd. ft. of elm logs will make 4000 cut hoops as against 3000 sawed hoops. Hoop-cutting machines will turn out from 40,000 to 60,000 hoops per day as against 15,000 sawed hoops per day. However, the machinery used in sawing hoops is much more portable than the other, it requires much less capital and skill for equipment and maintenance and the sawed hoop is generally considered in the trade to be superior. The last argument seems to be true, because in the cutting process the knife is inclined to shatter the wood in forcing its way through the fibers which results in materially weakening the hoop.

The hoop-coiling machine is an ingenious device to coil the hoops while still hot from the vat whether made by the cutting or sawing process. Several makes have a capacity of from 15,000 to 20,000 or more per day. If the hoops are not hot when coiled, there will be much breakage and splintering in consequence. After coiling the hoops are carefully stacked in an open air shed and thoroughly dried before shipment. Coiled elm hoops are made in many dimensions, varying in finished lengths from 3 ft. 6 in. to 8 ft. 6 in.

ASSEMBLING

The assembling of the various parts of slack cooperage into the finished barrel is accomplished in shops at or near the point where the barrel is filled with its contents. For example, sugar refineries, flour and cement mills, fruit and other storage warehouses usually have shops in connection with them where great quantities of staves, heading and hoops are brought in carload lots and assembled into the barrel of the desired size.

Formerly small cooperage shops were commonly found where barrels were largely assembled by hand, but the tendency in the business is to centralize the assembling of barrels in large shops where recently improved machinery is introduced to turn out great quantities of barrels at a lower cost.

The process of putting together the barrels generally consists of the following distinct operations:

1. Putting the required number of staves together in a form. This operation is commonly called " raising " or " setting up."

2. Heating over a stove or patent heater to dry out the wood, increase the flexibility of the staves and make a closer fit.

3. Bending or forcing the staves together in a bending press or by means of a windlass and rope. This operation is often called windlassing.

4. Crozing, which consists of making a groove in which the heading fits.

5. Chiming or chamfering down the ends of the staves on a bevel from the groove to the end.

The following is a brief description of the process of making apple barrels as carried out in the old-fashioned cooperage shop. The cooper sets up, on an average, 16 staves inside a wooden hoop 64 in. in circumference, inside measurement, on a platform in front of his work bench. The ends of the barrel are then drawn together by placing a rope over the end of the barrel and drawing it tight by means of a foot lever and pulley. A small regulation hoop is placed over each end as the staves are drawn together. The cooper then places the barrel over a small coal stove or heater and a metal cover or hood is let down over the barrel to retain the heat. Here it is left until it begins to steam or smoke. Meanwhile the cooper starts the assembling of a new barrel as just described. The heated barrel is taken back to the work bench where the quarter hoops and second hoops are fitted on, the ends of the staves are pounded to even them off and planed. Next the croze or groove is made followed by the chiming operation. The heads are set in the groove at each end and the first hoops are fitted on and nailed. When used immediately one head is left off until filled with apples or other contents.

In the average small cooperage plant, coopers are paid from 5 to 8 cents apiece for the work of assembling the parts. A good cooper will average 80 barrels a day. Exceptional coopers will put out from 90 to 100 apple barrels in a day. These barrels sell at the shop for from 35 to 43 cents or more per barrel, depending upon size, quality and local demand.

In the larger and more modern cooperage shops, instead of one cooper doing the whole operation several men are employed and each man tends a machine or looks after only one particular task. Very little hand work is done. The staves are first put together in a " raiser " by means of which one man will " raise " from 75 to 100 barrels in one hour. The other ends of the staves are cramped together by a windlass, an ingenious mechanical device operated either by power or by hand. The barrel is rolled down an incline to the heater, where it remains for about thirty seconds and goes on to the hoopers and trimmers, who fit the hoops, trim up the ends of the staves and another machine in one revolving motion cuts the bevel and groove in the staves, noted above as the chime and the croze. There is a continuous progressive movement of the barrel from the first to the last operation with the minimum loss of time and effort. From the crozer the barrel goes to the " header," who stands it on a metal base, the heads are put into position and the " rebutter " forces the last hoops into place. The barrel is then ready for shipment.

UTILIZATION OF WASTE

The slack cooperage industry offers many opportunities for saving woods waste. After logging has progressed over an area, the remaining small trees, tops (crooked and otherwise) and defective logs are often worked up into heading and staves, particularly the former. On many operations, all 4-ft. bolts down to 8 in. in diameter at the small end are taken for slack stock.

At some of the larger hardwood sawmills, defective ends, slabs and the smallest logs are sent over to a heading mill erected in connection with the sawmill.

The manufacture itself of heading, staves and hoops necessitates the loss of considerable wood. In the making of staves and hoops, it is estimated that from 40 to 50 per cent of the contents of logs are lost in the process. The loss in the manufacture of heading is even much greater, the waste commonly reaching 60 or 70 per cent of the original logs or bolts. A good portion of this waste is frequently unpreventable. The chief sources of waste are as follows:

1. Severely checked logs and bolts resulting from too long exposure in the woods or in the yard. Green material brought directly from the woods and used immediately makes the best stock.

2. Logs suitable only for heading are cut up into stave lengths or multiples thereof and later found to be only useful for heading. This results from careless or incompetent inspection of the raw material.

3. Logs are frequently bolted into lengths suitable for making a certain sized heading or staves and later used for shorter staves or smaller heading. In the making of many thousand staves and sets of heading daily the loss in trimming, due to this carelessness, may determine to a considerable degree the character of the profits. In some mills heading bolts are cut 21 in. long when only $17\frac{1}{8}$ or smaller heading will be circled out of them. Bolts for 32-in. staves are often cut into $28\frac{1}{2}$-in. staves, etc.

4. Faulty or careless manufacture, such as in handling the stock, useless waste in jointing both staves and heading, and in bolting and quartering the stock are common sources of waste. Only too often careless methods of piling staves for seasoning result in a serious loss.

Although considerable loss is occasioned in the manufacture of slack-barrel stock, up-to-date plants utilize practically all of the waste material. The sawdust and some of the smaller pieces go to the furnaces in the power plant, the ashes being sold for fertilizer. Some of the larger material is utilized for trunk slats, crate stock, furniture parts, chair rungs, toy stock, etc. The principal forms of waste occurring in the process of manufacture aside from those mentioned above, are as follows:

(*a*) "Goosenecks," the waste from the heading turner.

(*b*) "Listings," narrow strips removed by the stave jointer.

(*c*) Corner wood—odd corners left after staves are made from the stave bolts.

(*d*) Culled staves and blockwood consisting of culls from heading material.

One of the largest cooperage mills in the country sends all of its waste wood to a wood distillation plant for which $2.75 is secured per cord f.o.b. cars at the cooperage mill.

EQUIVALENTS

There are no universally adopted figures of the number of hoops, staves and heading of given sizes that may be cut from 1000 bd. ft. of logs or from a cord of bolts. However, the following equivalents are accepted by a large number of companies:

For an average run of logs, about 2400 staves 30 in. in length and 4 in. in width may be cut from 1000 bd. ft. of logs measured by the Doyle rule. It is said that in Arkansas 1 cord of bolts 32 in. in length measured with the bark will yield 1000 staves or without bark 1200 staves. Bolts of this length are usually stacked 4 ft. and 12 ft. long, which makes the standard cord of 128 cu. ft.

When the dry thickness of heading is $\frac{7}{16}$ in. and $19\frac{1}{8}$ in. in diameter, 1000 bd. ft. of logs, Doyle rule, will yield 2000 pieces of heading, or about 400 sets.

Measured by the same rule, 1000 bd. ft. will yield 4000 cut hoops or 3000 sawed hoops.

STOCK WEIGHTS

The following is a list of weights adopted by the National Slack Cooperage Manufacturers' Association in 1915. The heading is kiln-dried; the staves are thoroughly air-dried, and the hoops are in the usual air-dried condition for shipment.

Staves

	Weight Per Thousand Pieces
Elm, North of the Ohio River.	
$28\frac{1}{2}$ in. staves, cut 5 to $1\frac{7}{8}$ in., avg. 4 in. wide	780 lb.
30 in. staves, cut 5 to $1\frac{7}{8}$ in., avg. 4 in. wide	830 lb.
32 in. staves, cut 5 to $1\frac{7}{8}$ in., avg. 4 in. wide	885 lb.
34 in. staves, cut 5 to $1\frac{7}{8}$ in., avg. 4 in. wide	945 lb.
33 in. staves, cut 5 to $1\frac{7}{8}$ in., avg. 4 in. wide	915 lb.
$28\frac{1}{2}$ in. staves, cut 6 to 2 in., avg. 4 in. wide	680 lb.
Elm, South of the Ohio River.	
$28\frac{1}{2}$ in. staves, cut 5 to $1\frac{7}{8}$ in., avg. 4 in. wide	800 lb.
30 in. staves, cut 5 to $1\frac{7}{8}$ in., avg. 4 in wide	840 lb.
32 in. staves, cut 5 to $1\frac{7}{8}$ in., avg. 4 in. wide	925 lb.
34 in. staves, cut 5 to $1\frac{7}{8}$ in., avg. 4 in. wide	1000 lb.
$28\frac{1}{2}$ in. staves, cut 6 to 2 in., avg. 4 in. wide	700 lb.
Gum, Mixed Staves.	
$28\frac{1}{2}$ in. staves, cut 6 to 2 in., avg. 4 in. wide	700 lb.

Hardwood Staves (beech, birch, maple).	Weight Per Thousand Pieces
$28\frac{1}{2}$ in. staves, cut 6 to $2\frac{1}{8}$ in., avg. 4 in. wide	950 lb.
30 in. staves, cut 6 to $2\frac{1}{8}$ in., avg. 4 in. wide	1000 lb.

Cottonwood Staves.

$28\frac{1}{2}$ in. staves, cut 5 to $1\frac{15}{16}$ in., avg. 4 in. wide	650 lb.

Gum Staves.

$23\frac{1}{2}$ in. staves, cut 5 to $1\frac{15}{16}$ in., avg. 4 in. wide	600 lb.
$28\frac{1}{2}$ in. staves, cut 5 to $1\frac{15}{16}$ in., avg. 4 in. wide	800 lb.
30 in. staves, cut 5 to $1\frac{15}{16}$ in., avg. 4 in. wide	840 lb.
32 in. staves, cut 5 to $1\frac{15}{16}$ in., avg. 4 in. wide	925 lb.
34 in. staves, cut 5 to $1\frac{15}{16}$ in., avg. 4 in. wide	1000 lb.
36 in. staves, cut 5 to 2 in., avg. 4 in. wide	1100 lb.
40 in. staves, cut 5 to $2\frac{1}{16}$ in., avg. 4 in. wide	1200 lb.
$23\frac{1}{2}$ in. staves, cut 6 to 2 in., avg. $3\frac{1}{2}$ in. wide	500 lb.
24 in. staves, cut 6 to 2 in., avg. $3\frac{1}{2}$ in. wide	525 lb.

Elm Hoops

3 ft. 8 in. hoops, $\frac{4}{16}\times\frac{2}{16}\times1\frac{1}{4}$ in	275 lb.
4 ft. hoops, $\frac{4}{16}\times\frac{2}{16}\times1\frac{1}{4}$ in	300 lb.
4 ft. 4 in. hoops, $\frac{4}{16}\times\frac{2}{15}\times1\frac{1}{4}$ in	350 lb.
5 ft. hoops, $\frac{4}{16}\times\frac{2}{15}\times1\frac{1}{4}$ in	400 lb.
5 ft. 6 in. hoops, $\frac{5}{16}\times\frac{3}{16}\times1\frac{3}{8}$ in	460 ft.
6 ft. hoops, $\frac{5}{16}\times\frac{3}{16}\times1\frac{3}{8}$ in	500 lb.
6 ft. 6 in. hoops, $\frac{5}{16}\times\frac{3}{16}\times1\frac{3}{8}$ in	545 lb.
6 ft. 8 in. hoops, $\frac{5}{16}\times\frac{3}{16}\times1\frac{3}{8}$ in	570 lb.
7 ft. hoops, $\frac{5}{16}\times\frac{3}{16}\times1\frac{3}{8}$ in	600 lb.
7 ft. 8 in. hoops, $\frac{5}{16}\times\frac{3}{16}\times1\frac{3}{8}$ in	650 lb.
8 ft. hoops, $\frac{5}{16}\times\frac{3}{16}\times1\frac{3}{8}$ in	700 lb.

Heading

Gum.	Weight Per 100 Sets
$15\frac{1}{2}$ in. heads, $\frac{1}{2}$ in. thick	360 lb.
$17\frac{1}{8}$ in. heads, $\frac{1}{2}$ in. thick	435 lb.
$18\frac{1}{2}$ in. heads, $\frac{1}{2}$ in. thick	500 lb.
$19\frac{1}{8}$ in. heads, $\frac{1}{2}$ in. thick	550 lb.
20 in. heads, $\frac{1}{2}$ in. thick	600 lb.
21 in. heads, $\frac{1}{2}$ in. thick	650 lb.
$22\frac{5}{8}$ in. heads, $\frac{1}{2}$ in. thick	725 lb.
$23\frac{5}{8}$ in. heads $\frac{1}{2}$ in. thick	825 lb.
24 in. heads, $\frac{1}{2}$ in. thick	875 lb.

Cottonwood.

$19\frac{1}{8}$ in. heads, $\frac{1}{2}$ in. thick	450 lb.

Basswood.

	Weight Per 100 Sets
14½ in. heads, ½ in. thick	240 lb.
15 in. heads, ½ in. thick	250 lb.
15½ in. heads, ½ in. thick	260 lb.
16½ in. heads, ½ in. thick	300 lb.
17⅛ in. heads, ½ in. thick	340 lb.
19⅛ in. heads, ½ in. thick	400 lb.

Hardwood (beech, birch, maple).

14½ in. heads, 7/16 in. thick	310 lb.
15 in. heads, 7/16 in. thick	340 lb.
15½ in. heads, 7/16 in. thick	360 lb.
16 in. heads, 7/16 in. thick	400 lb.
16½ in. heads, 7/16 in. thick	440 lb.
17⅛ in. heads, 7/16 in. thick	500 lb.
18½ in. heads, 7/16 in. thick	600 lb.
19⅛ in. heads, 7/16 in. thick	675 lb.
20 in. heads, ½ in. thick	750 lb.
21 in. heads, ½ in. thick	800 lb.
22 in. heads, ½ in. thick	900 lb.
23 in. heads, ½ in. thick	970 lb.
23⅝ in. heads, ½ in. thick	1030 lb.
24 in. heads, ½ in. thick	1100 lb.

Yellow Pine.

9 in. heads	110 lb.
9¼ in. heads	125 lb.
9½ in. heads	135 lb.
10¼ in. heads	150 lb.
11¼ in. heads	180 lb.
12 in. heads	200 lb.
12½ in. heads	220 lb.
13 in. heads	240 lb.
13½ in. heads	260 lb.
14 in. heads	280 lb.
14½ in. heads	300 lb.
15 in. heads	320 lb.
15½ in. heads	345 lb.
16 in. heads	370 lb.
16½ in. heads	395 lb.
17 in. heads	420 lb.
17⅛ in. heads	435 lb.
18 in. heads	475 lb.
18⅛ in. heads	485 lb.
18½ in. heads	500 lb.
19 in. heads	530 lb.
19½ in. heads	540 lb.

	Weight Per 100 Sets
$19\frac{1}{2}$ in. heads	550 lb.
20 in. heads	610 lb.
21 in. heads	675 lb.
$21\frac{1}{2}$ in. heads	710 lb.
22 in heads	755 lb.
23 in. heads	840 lb.
$23\frac{5}{8}$ in. heads	890 lb.
24 in. heads	930 lb.

GRADING RULES

The following grading rules were adopted by the National Slack Cooperage Manufacturers' Association on May 14, 1915.

Staves.

1. Elm and gum staves $28\frac{1}{2}$ in. and longer shall be cut five staves to $1\frac{7}{8}$ in. in thickness.

2. Cottonwood and basswood staves $21\frac{1}{2}$ in. and longer shall be cut five staves to $1\frac{15}{16}$ in. in thickness.

3. Elm, gum, cottonwood and basswood staves 24 in. and shorter shall be cut six staves to 2 in. in thickness.

4. Hardwood staves, oak, beech, and maple $28\frac{1}{2}$ in. and longer shall be cut six staves to $2\frac{1}{8}$ in. in thickness.

5. Hardwood staves, oak, beech and maple, 24 in. and shorter, shall be cut six staves to 2 in. in thickness.

6. White ash staves shall be cut five staves to $2\frac{1}{8}$ in. in thickness.

7. No. 1 staves shall be of uniform thickness, free from knots, slanting shakes, dozy wood, badly stained with black and blue mildew, or other defects making stave unfit for use in a No. 1 barrel.

8. Meal barrel staves shall be free of slanting shakes over $1\frac{1}{2}$ in. long, knot holes and unsound knots (but sound knots not over $\frac{3}{4}$ in. in diameter shall be allowed), and shall consist of good, sound, workable staves. Moderate stain, mildew or discoloration no defect.

9. Mill run staves shall consist of the run of the knife, made from regular run of stave logs, and shall contain 40 per cent or more of No. 1 staves. All dead culls out.

10. No. 2 staves shall, unless otherwise specified, contain the meal barrel grade and be free from dead culls. Mildew and stain no defect.

11. Standard bilge on staves, unless otherwise specified, shall be as follows: 18 in. to 22 in. in length both inclusive, $\frac{1}{2}$ in. bilge; 23 in. to $28\frac{1}{2}$ in. in length, both inclusive, $\frac{5}{8}$-in. bilge; 30 in. in length, $\frac{3}{4}$-in. bilge; 32 in. and 34 in. in length, $\frac{5}{8}$-in. bilge.

12. Standard quarter shall be 9 in. for flour barrels and $8\frac{1}{2}$ in. for sugar barrels.

13. No. 1 staves longer than 24 in. shall not be less than 2 in. nor exceed $5\frac{1}{2}$ in. in width, measuring across the bilge. No. 2 staves of same lengths may be from 2 in. to 6 in. in width.

14. All barrel staves $28\frac{1}{2}$ in. and longer to average in measurement, after being jointed, 4 in. per stave or 4000 in. per thousand staves.

15. Half barrel staves, 23 in., $23\frac{1}{2}$ in. or 24 in., $3\frac{1}{2}$ in. to the stave, or 175 in. to the bundle of 50 staves.

16. Keg staves to measure 160 in. to the bundle of 50 staves.

17. All staves shall be thoroughly air dried before jointing and shall be measured across the center of the bilge. Unless otherwise specified, it will be presumed that staves are to be air dried.

18. No. 1 white ash staves shall be of uniform thickness, smoothly cut, free from knots, slanting shakes, dozy timber, worm holes, stains or mold of any kind which makes the stave unfit for use in the manufacture of No. 1 butter tubs and to average not less than 85 per cent white.

19. No. 2 ash staves—same specifications as No. 2 gum and elm.

20. All ash staves shall be jointed with $\frac{5}{8}$-in. bilge unless otherwise specified.

21. Mill run apple barrel staves, unless otherwise specified, shall be cut six staves to 2 in. in thickness and shall consist of the run of the mill from the regular run of stave logs. An average of not less than 60 per cent of the staves in each bundle to be bright on the outside. At least 40 per cent of all staves to be No. 1. Mold on No. 1 staves no defect. All mill run apple barrel staves, unless otherwise specified, shall be jointed with $\frac{9}{16}$-in. bilge.

22. Cement barrel and all other staves not specifically mentioned should be sold according to the local custom or by special agreement. Same will apply as well to bilge of such staves.

Dead Cull Staves.

23. Dead cull staves are staves containing knotholes of over 1 in. in diameter; staves with large, coarse knots or badly cross-grained near quarter preventing staves being tressed in barrels; staves under $\frac{1}{2}$-in. thick; staves with bad slanting shake exceeding 6 in. in length, or with rot that seriously impairs strength.

Hoops.

24. Standard dimensions of coiled elm hoops, 5 ft. 6 in. and longer, to be, when finished and seasoned, $\frac{5}{16}\times\frac{3}{16}\times1\frac{3}{8}$ in.

25. Dimensions of keg hoops, 5 ft. and shorter, may be $\frac{4}{16}\times\frac{2}{16}\times1\frac{1}{4}$ in., or standard dimensions, as provided in Section 24.

26. No. 1 hoops shall be of good sound timber, up to specifications, well finished and free from broken and other defective hoops, in the coil in excess of 3 per cent of hoops over 5 ft. in length, 5 per cent of 5-ft. hoops and 8 per cent of hoops less than 5 ft. long, which are unfit for use on a barrel, and to be dry when shipped.

Heading.

27. No. 1 basswood, cottonwood or tupelo gum heading shall be manufactured from good, sound timber, thoroughly kiln-dried, turned true to size, and shall be $\frac{1}{2}$ in. thickness after being dressed on one side, and free from all defects making it unfit for use in No. 1 barrels. Stain or discoloration or under side no defect. To be jointed straight unless otherwise specified.

28. No. 1 hardwood and red gum heading shall be of the same specifications as in Paragraph 27, excepting that the thickness after being dressed shall be $\frac{7}{16}$ in.

29. Mill-run heading shall consist of the run of the saw from the regular run of the heading bolts or logs, without any previous culling to select out the better grade,

well manufactured of standard thickness and kiln dried. All dead culls out and to contain not less than 50 per cent No. 1 pieces or cants.

30. Pine heading, all sizes over $12\frac{1}{2}$ in. in diameter to $16\frac{1}{2}$ in. inclusive, shall be $\frac{7}{16}$ in. in thickness after being dressed on one side; larger sizes shall be $\frac{1}{2}$ in. in thickness after being dressed on one side. Specifications otherwise to be the same as provided in Paragraphs 27 to 36, both inclusive, except as to thickness.

31. No. 2 heading shall be manufactured from heading blanks culled in the process of manufacturing No. 1 heading and shall be workable free from dead culls.

32. All heading to be well bundled, 15 sets to the bundle, sizes $14\frac{1}{8}$ in. to $19\frac{3}{4}$ in., inclusive; 2 wires to the bundle, sizes under $19\frac{1}{8}$ in.; 3 wires to the bundle, sizes $19\frac{1}{8}$ and over. Number of pieces to the head not to exceed the following:

33. No. 1 and M. R. grades, above $13\frac{1}{2}$ in. and to $17\frac{1}{8}$ in., inclusive, three and four pieces, at least 50 per cent to be three piece, or less.

34. No. 1 and M. R. grades, 18 to $19\frac{1}{2}$ in., inclusive, three-, four- and five-piece, at least 50 per cent to be four-piece, or less.

35. Heading that contains knotholes of over 1 in. diameter, bad slanting shakes, rotten timber or other defects that make it unworkable, shall be considered as dead culls.

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CHAPTER VI

TIGHT COOPERAGE

GENERAL

TIGHT cooperage refers to barrels and containers made of staves and heading for liquid contents. As contrasted, therefore, with manufacturing methods and woods used for slack cooperage barrels, a much more carefully manufactured article must be produced and it must be made of woods which are practically impermeable in their wood structure. On account of its impermeable nature together with the fact that it does not tend to discolor or lend a disagreeable odor to the contents, its hardness, workability, excellent seasoning qualities, etc., white oak is preeminently our best tight cooperage wood. In the early days of tight cooperage manufacture, white oak constituted the only wood used. This species also contributed a large portion of the raw material used for slack cooperage purposes.

Outside of the fact that white oak meets the requirements for tight barrels better than any other wood, only the best quality of white oak can be used. Ordinarily trees less than 18 in. in diameter at $4\frac{1}{2}$ ft. above the ground are seldom used. In addition to this minimum size, the trees must be straight-grained and sound and comparatively free from knots, rot, shake, or other defects.

Where the seasoning of contents is involved, such, for example, as in the case of wines, whisky, beer and other spirituous liquors, the wood composing both staves and heading must be only of an excellent grade of white oak. When tight barrels are used for purposes where the seasoning of the contained liquid is not involved, such, for example, as mineral oils, lard, chemicals, pork, turpentine, molasses, syrup, etc., a limited amount of other species such as red oak, red gum, white ash, and a few other species have come into use. Owing to the curvature of the staves which are largely sawed now it is very important that these be of more impermeable wood than the heading. However, all woods which are used as substitutes for white oak are paraffined or otherwise coated on the interior to protect them against leakage. Red oak is much more susceptible to leakage than white oak owing to its open pores. (In white oak the pores are closed by means of tyloses.) There is a growing tendency to use more and more substitute woods in the cheaper grades of tight cooperage staves and heading. This condition, moreover, is being aggravated by the growing scarcity of high-grade white oak stock, the increasing demands for white oak for tight cooperage barrels and the consequent rise in prices.

Photograph by U. S. Forest Service.

FIG. 33.—This shows a method sometimes employed in riving sections of white oak logs into stave bolts. Houston Co., Tennessee.

Where the seasoning and aging of the contained beverages are involved, as mentioned above, all white oak barrels are charred on the inside to an average depth of $\frac{1}{8}$ to $\frac{1}{3}$ of an inch. This has been universally the custom for a long time, especially with whisky barrels.

The pure food laws passed by Congress and the increase in petroleum and turpentine production greatly stimulated the demand for tight barrels. As soon as these laws went into effect, there was a very strong demand upon the distillers and others for considerable quantity of bonded goods resulting in an increased demand for raw materials for staves and heading. The great increase in the production of petroleum and, to some extent, of cotton seed oil and turpentine, have also tended to enlarge the demand upon white oak and other species used for these barrels. The prohibition laws have not materially decreased the output of tight cooperage stock because the demand for oil staves and heading has increased to such a large extent.

SPECIAL FEATURES

Altogether the tight cooperage industry is distinguished by the following outstanding features:

1. The steadily increasing demands for stave and heading stock attended by the rapidly rising stumpage values and prices demanded for the product.

2. Great waste in the production and manufacture of both staves and heading. In the early days, staves were almost entirely rived in order to insure straight grain in the finished stave. At the present time, only a small portion of our tight staves are bucked, and split, and hewed, and these are turned out almost entirely for foreign consumption. They bring unusually high prices compared to the sawed staves. It is estimated that from 50 to 70 per cent of the raw material as it stands in the woods is lost in the manufacture of staves even under the present methods pursued in the industry and from 40 to 60 per cent of the raw material is lost in the manufacture of heading. Only trees above 16 in. in diameter at breast height can be used and the heart of the largest trees up to a diameter of from 4 to 8 in. is usually left in the woods together with all sap wood, tops, cross grain and knotty or otherwise defective material. Only rarely is material less than 12 in. in diameter at the top taken, thus leaving a long, clear top frequently in the woods. This top is sometimes utilized for ties or for wagon and chair stock.

3. There is a very heavy drain upon one species which lends itself most admirably for the purpose of tight cooperage stock and for which there are no apparent satisfactory substitutes. It is estimated that from 12 to 16 per cent of all oak cut for lumber and all other purposes goes into tight cooperage stock.

4. Production by means of small portable mills, which are frequently moved from place to place near the source of supply, and long hauls of the rough product to the nearest railroad point or shipping wharf along the river. Some companies own from 20 to 40 or more of these small port-

able mills, which are scattered over the white oak regions of Arkansas, Tennessee, Mississippi, Missouri and other states from five to twenty-five or more miles from the nearest shipping point.

5. The industry is highly specialized in that few local mills or plants make more than two kinds of staves or heading for the market. The manufacture of beer and ale staves constitutes a separate branch of the industry.

SPECIES USED

White oak comprises from 75 to 85 per cent of all the material used for tight cooperage staves and from 65 to 70 per cent of all the material used for heading.

Other species used for staves are red oak, red gum and ash. Ash makes up about 75 per cent or more of all of the heading used in pork barrels. Red oak constitutes about 14 per cent of all the material used for tight cooperage heading. Other species used for heading purposes in order are red gum, white pine, white ash, basswood and cypress. Other species occasionally used which are coming into greater prominence from year to year, are beech, birch, chestnut, Douglas fir, hard maple and spruce.

Most of the white oak is the true white oak (*Quercus alba*). Some of it is post oak (*Q. minor*) and some of the other white oaks, such as overcup oak (*Q. acuminata*) bur oak (*Q. macrocarpa*) and swamp white oak (*Q. platanoides*) are used to a limited extent. There is very little difference in the character of the wood produced by these various white oaks and they are usually accepted without discrimination by the manufacturers and purchasers of stumpage under the single head of white oak.

The highest grade of staves are called Bourbon staves, which are known as " whiskies " in the trade. These barrels are made entirely, that is, including both staves and heading, of white oak. The grade of tight staves which brings the next highest price on the market are the spirit and wine staves, which are colloquially known as " wines " in the trade. These also are made entirely of white oak. The next grade are the oils and tierces, which are known as " oils " and which are largely made up of white oak, but red oak and red gum are used to some extent. The least expensive staves are those used in pork barrels and are called " porks." White ash furnishes a large amount of material for these barrels and white oak is also used to a large extent as well as red oak, red gum, Douglas fir, birch and hard maple.

Although these four kinds of staves constitute the large majority of staves turned out for tight cooperage, there are also a large number of other specialized products, such, for example, as beer barrels and special barrels for the West Indian liquor trade, for claret, turpentine, molasses, tank staves and other special sizes such as half beer barrels, quarter barrels, sixth barrels, eighth barrels, ale hogsheads, etc.

In order of quantity, oil and tierce staves come first. Next, in order, are the "wines," then the "whiskies," the "porks," etc. With the advent of prohibition, there has been a decrease in the production of wines and whiskies and a great increase in the making of oil barrels.

ANNUAL PRODUCTION

It is estimated that at the present time between 450,000,000 and 500,000,000 staves are annually produced together with about 40,000,000 sets of heading for the tight-cooperage industry.

According to the latest available government statistics[1] published for the year 1911, there were over 357,000,000 staves produced during that year and over 30,000,000 sets of heading. Although the production of both staves and heading are distributed over 25 different states, nearly one-third of all staves were produced in Arkansas where more than twice as many were cut than in the state next in order of production. Other important states producing staves are Tennessee, West Virginia, Mississippi and Kentucky. New Hampshire is classified as an important tight cooperage state, but this produces chiefly white pine stock for fish and pickle buckets, mince-meat pails, etc. Sometimes these are classified with the slack cooperage stock.

Arkansas furnishes 40 per cent of the heading and nearly three times more than Tennessee, its nearest competitor. Other important states producing heading are Mississippi, Kentucky, Missouri and Louisiana.

It is apparent, therefore, that the industry is centralized in Arkansas and a few other states bordering on the Mississippi River south of the mouth of the Ohio River.

As contrasted with the production of 1911, in 1905 there were produced only about 241,000,000 staves and about 13,000,000 sets of heading, nearly all of which was made up of white oak.

About 25 per cent of our tight cooperage stock is exported under normal conditions, New Orleans being the principal exporting center. Hewed staves are manufactured almost entirely for the foreign market, most of the work being done by expert foreign laborers. Most of the exported material goes to Europe, and France is the leading nation which

[1] U. S. Bureau of the Census and U. S. Forest Service.

imports American tight cooperage stock. Most of the exported material is used for the wine trade.

About 87 per cent of the staves manufactured in 1911 were sawed. About 94 per cent of the heading was sawed. Others were bucked and split or hewed. There are about 500 active establishments producing tight cooperage staves and heading in this country.

VALUE OF PRODUCTS

In 1909 the value of tight staves produced was estimated to be $9,201,964; or an average of $24.26 per thousand for the 379,000,000 staves produced in that year. In the same year there were 20,691,000 sets of heading produced having a total value of $3,716,000. In addition to this there were 16,547,000 beer and ale staves produced for which no available figures are obtainable regarding value. More recent data relating to total production and values are not available, but market quotations show a tremendous increase in prices. For instance, early in 1915 Bourbon staves were selling in the Ozark region for $52 per thousand f.o.b. car, while, in December, 1916, this grade brought $77. In 1916 the number of finished barrels produced for malt liquors amounted to 58,634,000. Their output has not varied greatly during the past ten years. Since the average price of a barrel was about $2 f.o.b. central markets, in 1917, the total value of finished high-grade stock produced annually amounts to over $177,000,000.[1]

WOODS OPERATIONS

In contrast with the general policy followed in the slack cooperage industry where the logs and bolts or other raw material are brought to the mill, in the tight cooperage industry it is the general custom to use small portable mills, which are set up in the woods near the source of the raw material and are frequently moved about from place to place. This means a much shorter haul of the bolts, which are the form of the raw material used customarily in the manufacture of tight cooperage stock.

Formerly a good share of the tight staves were rived, but this method was so very wasteful and the supply of raw material became relatively so limited that most of the tight cooperage staves are now split into bolts and then sawed into staves at small portable mills located at convenient accessible points throughout the forest. Beer staves and a very few whisky and wine staves are still split out. It is also the custom to rive isolated timber more commonly than accessible timber because there is

[1] From data supplied by the U. S. Forest Service.

less waste material to be hauled in with rived staves and, therefore, the haul can be done cheaper. In Germany, the proper bilge of rived staves is secured by hewing, whereas bending is secured in the United States in a finishing plant by end pressure.

Stumpage.

Within recent years, stumpage values in Arkansas have averaged from $2.50 to $5.50 or more per thousand board feet, depending upon (*a*) quality and size of the trees; (*b*) location, that is, the topography and its relation to the nearest available haul-roads; (*c*) accessibility or distance to the mill or shipping point. The nature of the haul-road, including its grade and the character of its surface, have a strong bearing on the value of stumpage.

Only the best white oaks are taken. They must be tall, straight, cylindrical, free from large limbs for a good height and at least 16 in. in diameter at breast height. Under average conditions, only about 500 to 1000 bd. ft. of desirable white oak material are found per acre in the Arkansas forests.

Stumpage is higher for good stave stock than for heading because better quality is demanded for stave stock, and it is possible to use a greater portion of the tree with heading on account of the bolts being shorter. Sometimes the same tree is used for both stave and heading bolts, but with the majority of operations the work is limited to either the cutting out of one or the other product. Very commonly the defects are not visible until the tree has been opened up, so that there is a large amount of waste attendant upon most of these operations. There is, of course, a great deal more waste with rived staves than with sawed staves because the former must be of absolutely straight-grained material. There is also much more waste with whisky staves than in the case of "oils." "Oils," on the other hand, require considerably more waste than pork staves.

It is the general practice in purchasing stumpage to pay for only the scale of the quartered sections which come up to grade. Stumpage is paid for on the basis of per thousand board feet, bolt scale. There is considerable agitation now in the Forest Service to pay for stumpage on the basis of cubical contents regardless of board measure actually used.

Rived Staves.

Only the finest white oak timber is selected for rived staves, as it must be wholly free from defects and, in addition, it must be straight-grained in order to split out properly.

The white oaks are felled and sawed by cross-cut saws into blocks which are 2 in. longer than the intended staves. The sap line is demarked with a pencil and inside the sap line with the help of a pattern showing the cross-section of the staves, as many staves as possible are pencil marked. By the use of axes, wedges and wooden mauls, the block is then halved, quartered and split out along the pencil marks. Staves are split out along the medullary rays in order to insure the greatest impermeability. The core of at least 4 in. in diameter containing the small limb stubs is usually thrown away. The rough staves are inspected, sorted and piled in a hollow square or "hog-pen fashion" for air drying. As a rule, woodsmen do this work by contract, supplying their own tools. The rough staves after being thoroughly air dried are run through the stave bucker, by which three-quarters of all the rived staves are made in the United States. This machine dresses and planes both sides of the stave to proper curvature and thickness. A rack forces the rough staves through the narrow space left between two knives which are fastened in a rocking frame. The knives are either straight or curved to correspond to the periphery of the barrel. Sometimes the staves are run through a stave dresser instead of through the bucker. The dresser carries knives on two cutter heads, dressing and shaping the staves on both sides to proper thickness and leaving either an abrupt or gradual shoulder. Rived staves finished in this way are much less permeable than staves cut out on the circular drum saw, because the latter does not always follow the grain of the wood.

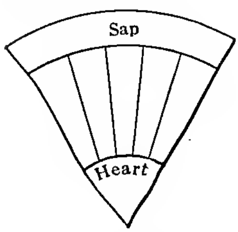


FIG. 34.—Diagram showing method of riving staves from a white oak log. Both the sap and heart are commonly wasted.

Logging and Delivering Bolts.

In logging bolts for sawed staves, woodsmen fell the trees and cross-cut them into bolts which vary in length from 18 to 38 in. Those for heading are usually 22 in. long while those for staves are 37 to 38 in. long, depending upon the economy of waste. A 30-in. bolt is the minimum length for staves. The cutters go up the tree trunk as far as the grades justify, being limited only by size and the number of limbs and defects that may be present.

The operating season is customarily a year long. Bolts are halved and quartered on the ground with a wedge, wooden maul or sledge hammer. The bolt makers, as a rule, work by contract by the piece, \$2.00 to \$2.75 per cord being paid for felling the timber, making the bolts and removing the bark which is done in the same operation. They are immediately graded and all bolts taken which will make pork or oil staves or better.

Bolts are then hauled in immediately to the mill and sawed before seasoning. They may be ricked or stacked at the mill for from ten to

Photograph by U. S. Forest Service.

FIG. 35.—White oak butt cut for stave bolts from which twelve bolts were obtained. The four interior sections are called heart bolts and the exterior sections sap bolts. Very often both the sapwood and heart of a log are cut away and wasted, leaving only a comparatively small portion to be utilized. Giles Co., Tennessee.

thirty days. On these hauls, country roads are usually very poor and rather rough. On "rough going" bolts are seldom hauled more than three miles. Hauling is done the year round by four-wheeled wagons and teams, one-third to one-half a cord usually making up a load. The common practice is to let out the hauling by contract to farmers and local owners of teams. The cost ordinarily runs about \$2.25 per cord for a

$1\frac{1}{4}$-mile haul; \$2.50 for a $1\frac{1}{2}$-mile haul and \$2.75 for a $1\frac{3}{4}$-mile haul under average conditions of road, surface, etc.

The following is a summary of the logging costs on a typical operation in Arkansas.

	Cost per Cord.
Road work during operation amounting to \$500 which is pro-rated among 1756 cords..	.28
Felling and bolt making by contract	2.50
Brush disposal including lopping and piling on National Forest sales.	.50
Bolt haul, including snaking	2.75
Total cost per cord	\$6.03

The cost of bolts, therefore, stacked on the mill yard in terms of thousand staves and on the basis of 500 staves equaling 1 cord of bolts would be \$12.06 per thousand staves.

Equivalents.

Although there is considerable variation in equivalents in this industry, the following are generally accepted. There are 80 to 100 bolts of 34-in. staves in a cord of bolts. A cord of bolts is equivalent to about 850 ft., board measure, bolt scale according to the U. S. Forest Service, scale of Scribner Decimal C. which allows for cull timber. There are 1000 staves, 34 to 36 in. long in 2 cords of bolts or in 1700 ft., board measure, of bolts by the Scribner Decimal C. scale. Therefore, 1000 ft., board measure, will produce about 588 staves, 34 to 36 in. long.

In some localities it is said that it requires eight 18-in. white oaks to average 1000 half-barrel beer staves.

It requires 1000 ft., board measure, by the Decimal C. scale to produce from 300 to 350 tight barrel heads.

The average width of the standard stave is recognized as $4\frac{1}{2}$ in. It requires from 18 to 21 standard staves to make a whisky barrel which is 81 in. in diameter, outside dimensions.

On a representative sale involving 412,800 bd. ft. by the Scribner Decimal C. scale on the Arkansas National Forest, the following check of equivalents was determined: The above amount made 502 cords of 36-in. bolts and sawed out 256,000 staves, of which 8 per cent or 20,520 staves were culls, 48 per cent or 122,710 staves were Bourbon, and 44 per cent or 113,270 staves were wines and oils. One cord of bolts, therefore, made 511 staves of all grades and represented an equivalant of 822 bd. ft.

Photograph by U. S. Forest Service.

FIG. 36.—Equalizer in operation at a tight stave mill in Tennessee. This machine trims off the length of the bolts to an exact size.

MANUFACTURE OF STAVES AND HEADING

Manufacturing establishments for making staves and heading from bolts are placed in the forest on locations advantageously situated with reference to water, yarding facilities and bolt haul. Since the moving and setting up of a mill from place to place ordinarily costs about $200, the mill is moved to the timber, so to speak, to obviate long, costly hauls. In hauling bolts, considerable waste is being transported in the form of saw kerf, listings and odds and ends.

Many mills operate as a rule under one company. The usual practice is to have separate mills for staves and headings; the mills being frequently located now from 10 to 20 miles from the nearest points of shipment on the railroad. This in itself is evidence of the rapidly decreasing supply of white oak timber, the most accessible stumpage having been cut off sometime ago. There should be at least 2,000,000 staves available to be cut from each mill set. Mills should not be moved more frequently than once a year, for economical production.

The mill equipment for staves usually costs about $2500 to $5000 with an average of about $3300 aside from horses, tools, harness and necessary buildings, which are roughly constructed affairs. The men working both at these mills and in the woods usually live in tents which are easily transported from place to place.

As soon as convenient after the bolts are hauled in from the woods, they are equalized to finish them to a uniform length the same as in the finished stave, by the use of a swinging frame operating against two cut-off saws. They then go to the circular drum saw shown in the illustration,[1] where staves are cut to the desired bevel or curvature $\frac{3}{4}$ of an inch

Photograph by U. S. Forest Service.

FIG. 37.—A split stave emerging between the bucker knives. The waste shavings are held by the operator on each side of the stave. This illustrates one of the wasteful processes involved in the production of tight cooperage stock.

thick for wine staves and $\frac{7}{8}$ of an inch for whisky staves. The stave saw consists of a hollow steel cylinder having the diameter of the barrels to be made and carrying saw teeth at one end. It usually saws staves on a 23-in. circle and up to 36-in. in length. The carriage pushes the bolts against this cylinder. A stave holder runs into the cylinder and removes the sawed staves. The speed of this saw is about 1500 R.P.M. The capacity of one of these drum saws and consequently of the plant runs between 8000 and 12,000 staves per day.

The staves are then stacked in a mill yard and air dried in hollow square fashion for from 2 to 6 months prior to the long haul to the railroad. From 400 to 500 staves are hauled per load. Staves are graded

[1] See foregoing chapter on slack cooperage.

both at the mill and also at the railroad where they are usually inspected by the purchaser.

These stave mills do not run regularly and the annual output is commonly only about 900,000 to 1,200,000 staves, although it may be as high as 2,000,000 staves.

Photograph by U. S. Forest Service.

FIG. 38.—Stave jointers or listing machines in operation at a tight stave mill in Arkansas, the center of production of both tight and slack cooperage stock.

The following table shows the men required in one of these stave mills, the daily wage paid and the milling cost per thousand staves:

COST OF MANUFACTURING TIGHT STAVES

	Daily Wage.	Milling Cost per M Staves.
1 Filer	$3.50	.35
1 Sawyer	2.50	.25
1 Side sawyer	2.00	.20
2 Listers at $2 or 20 cents per M	4.00	.40
1 Equalizer	2.00	.20
1 Fireman and engineer	2.00	.20
1 Yardman wheeling bolts (or with mule and dolly)	2.00	20
1 Stacker	2.00	20
1 Stave catcher	1.75	.17
1 Grader	1.75	.17
1 Dust and slab boy	1.50	.155
1 Cut-off man	1.75	.175
1 Watchman	1.75	.175
2 Mules ($1.50 per day)	....	.155
		$3.00

The following is an estimate of the kind and cost of equipment of a typical stave mill before the war:

Machinery and Equipment	Cost (Set-up) including Freight, Hauling, and Setting-up
1 boiler and setting, 40 h.p.	$700
1 engine complete	400
pulleys and shafting	200
1 sharpener for barrel saw	50
1 bolt equalizer	90
1 stave lister	325
2 equalizer saws	35
1 24-in. barrel stave saw	550
1 extra cylinder	225
blow pipes for sawdust, etc.	125
1 drive belt	75
3 trucks	100
Miscellaneous—tools, extra parts, pipes, fittings, wheelbarrows, grindstone and supplies	400
Total	$3275

This equipment is capable of turning out about 8000–12,000 whisky staves per day of ten hours.

The cost of staves per thousand on the stave mill yard may be estimated as follows:

	Cost per M Staves
Stumpage at $4.00 per thousand board feet	$7.00
Logging cost; felling, bolt making, road making and hauling	12.06
Milling costs	3.00
General expense	.91
Insurance and taxes	.62
Total cost	$23.59

In addition to these costs, the stave haul to the railroad averages from $6.00 to $9.00, depending upon distance, character of haul, finish of timber, labor, etc. Inspection, grading and loading costs about 75 cents per thousand staves.

The total cost, therefore, delivered at the shipping point runs between $28 and $33 per thousand staves.

On many of these operations, an estimate that 60 per cent of the staves are sufficiently good for "wines" and 40 per cent for "oils" is made. The former bring about $50 per thousand and the latter $25 per thousand. The selling price runs, therefore, about $40 per thousand staves, leaving a profit of from $7.00 to $12.00 on each thousand staves marketed.

Photograph by U. S. Forest Service.

FIG. 39.—About 1,000,000 tight cooperage staves piled for seasoning in Quitman Co., Mississippi.

Heading mills are operated along the same lines as described for tight staves, and the stock is always sawed in 1-in. thicknesses from bolts cut about 2 in. longer than the diameter of the finished heading. The machines commonly used in these small portable heading mills are a heading bolter, a heading saw, a heading jointer and doweler, a heading planer and a heading rounder together with a baler or baling press.

In the manufacture of heading, the same general method is followed as described in the chapter on slack cooperage heading except that the machinery is much more specialized and expensive. The power required at one of these portable heading mills is about 25 to 30 h.p. It is estimated that at each location of the mill about 200,000 sets of heading are turned out. About 8000 to 10,000 headings are completed per day of ten hours.

Most of the heading turned out for tight barrels is doweled to insure a tighter fit and to prevent loosening of the joints in any way. These dowels are customarily $\frac{5}{16}$ of an inch in diameter. Many plants have

FIG. 40.—Stave jointer in operation in a large cooperage assembling plant.

their own machines to make dowel pins. One machine in common use splits the material into proper thickness for the pins, then forces it through the dies and delivers the pins separate from the waste. The machine makes 3 pins at a stroke and will turn out several bushels of about 5000 pins each, in a day of ten hours.

The final finishing of staves and heading, including dressing, dry-kilning, bending, packing, etc., is accomplished at large plants which are chiefly centralized in large centers within or contiguous to the producing regions such as Memphis, Louisville, Peoria, St. Louis and other points on the lower Ohio and Mississippi Rivers.

Bending was formerly accomplished by steaming and drying on a form. It is now done almost entirely by end pressure on a stave-bending machine and held in shape by iron holders called "span dogs," which are released when the staves are assembled in the finished container. Bending is used for beer staves and those intended for packages of considerable bilge. Otherwise there would be a serious loss from breakage in windlassing when the unbent staves are forced together for the upper truss hoop.

ASSEMBLING

As a rule the assembling of tight cooperage stock into barrels, kegs, etc., is done at or near the plant where the contents are put into them, as was found to be the case in connection with the assembling of slack cooperage stock. It is true, however, that more tight barrels are made and shipped from large central cooperage plants to points of destination where they are to be filled than in the case of slack barrels. This is notably true in the case of turpentine barrels and to some extent with beer kegs, whisky barrels and others.

The assembling of tight cooperage stock demands the greatest care and skill for the apparent reasons that (*a*) the finished barrel must be sufficiently tight to prevent leakage, (*b*) the vessel must withstand transportation to great distances together with considerable rough handling, and (*c*) the barrel must often resist great internal pressure from fermenting liquors.

The machinery, therefore, must be of the most elaborate, exacting and specialized design. Special types of assembling machinery have recently been invented and placed on the market which are vast improvements over the old hand cooper or even the machinery in use ten and twenty years ago. Most of them are great labor-saving devices.

The machinery usually found in a modern up-to-date tight cooperage shop consists of the following: A setting-up form with necessary truss hoops, a power windlass, a heater, a trusser, a crozer, a head-setting form, a lathe, a thin hoop driver, a heading-up machine, a bung borer and a barrel tester. When the steel hoops are made in the plant it is essential to have, in addition, a hole-punching machine, a riveter and a hoop flarer.

In many of the plants the stock is brought in in bundles, enough staves (usually 18) in one bundle for one barrel. First the staves are set up in a form by a "raiser" or "setter up," who sends them directly to the steamers, where they are heated or steamed for from three to five minutes to increase the flexibility of the staves. Then they are "windlassed " by power which consists of throwing a wire rope over the loose ends and drawing them together until the head truss hoop can be thrown over them. The power is then released and the barrel rolled or conveyed to the trusser after leveling the staves by slamming the barrel on end on the floor. When steamed, the barrels, after windlassing, are sometimes sent to the heaters to dry them out. The function of the trusser is to force the hoops well down on the barrel. The barrel next goes to the crozing machine which crozes, chimes and howels the staves in one oper-

Fig. 41.—Method of heating the staves preliminary to placing them in a power windlass for final assembling.

ation, finishing both ends at the same time. To accomplish this, the three tools are placed in one head, which, revolving at high speed inside of the package insures a uniform thickness and depth of chime. Meanwhile stationary cutters level the barrel. The bung hole is then bored and the barrel goes to the heading-up machine, where the heading is inserted by releasing the head truss hoops. Many of the tight barrels are inserted in a lathe and turned at a rate of from 100 to 150 R.P.M. against a smoothing plane to give them a better finish. The barrels then go to the thin hooper, where the steel hoops are driven down in final shape. The last operation consists of testing the permeability of the vessels, after which all cracks or leaks are repaired and it is inspected and stored until needed.

In finishing tight cooperage barrels, flat steel or iron hoops are used almost entirely, as they are stronger and less liable to breakage and damage than wooden hoops. They are, however, much more expensive than the wooden hoops.

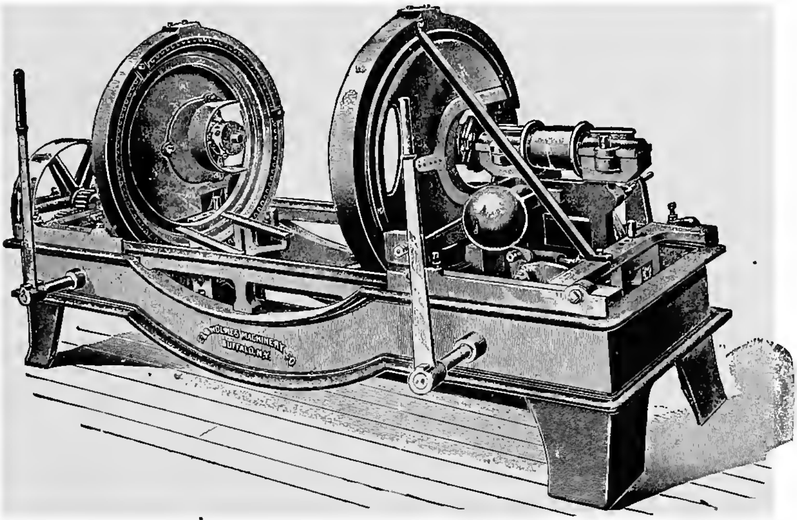


FIG. 42.—Machine for chamfering, howeling and crozing tight barrels.

Many of the tight-barrel plants assemble from 300 to 1000 or more packages per day of ten hours. In a plant turning out from 500 to 800 barrels formed of 34-in. staves and $20\frac{1}{2}$-in. heading the following labor was employed. All of the men excepting the foreman received ordinary day wages running from $1.75 to $2.25 per day before the war:

1 man to bring in the bundles of staves.
1 man raising and setting up the staves.
1 man to steam the barrels and to operate the windlass to bring the staves together with the top hoop.
1 man looking after the stoves or heaters.
1 man to level up the barrels.
1 man to run the trusser.
1 man to croze the barrels.
1 man to bore bung holes.
1 man operating the heading-up machine.
1 man at the thin hooper.
1 man testing barrels.
1 man making hoops.
1 man inspecting and repairing barrels.
1 foreman.

STANDARD SPECIFICATIONS AND RULES

These rules govern the sales and arbitrations dealing with the marketing of tight cooperage stock and have been adopted by the National Coopers' Association, 1916.

Bucked Bourbon Barrel Staves.

Shall be equalized, 34, 35 or $35\frac{1}{2}$ in. long, as agreed, to be, when thoroughly kiln-dried, $\frac{7}{8}$ in. thick, and to average in width when close jointed, free of sap, not exceeding 21 staves to the barrel, and to be free of seed or worm holes of any kind, cat faces or checks, and crooks inside or outside. (A twist, not varying to exceed $\frac{3}{4}$-in. from a straight line shall be allowed.) Crooks with hollow to back of stave, not exceeding $\frac{1}{2}$ in. in variation to 12 in. in length, shall be allowed. Reverse crooks not admitted. Sound streaks that do not go through stave will be admitted, provided they are on inside of stave and over 6 in. from ends.

(See notes I., II., IV., and V., following.)

Bucked Alcohol and Whisky Barrel Staves.

Same specifications as bucked Bourbon staves, except length is to be 33 or 34 in., and thickness $\frac{3}{4}$ in. after being thoroughly kiln-dried.

(See notes I., II., IV., and V., following.)

Sawed Alcohol, Bourbon and Rye Whisky Barrel Staves.

Shall be sawed with the grain from straight-grain bolts, and equalized 33 or 34, 35 or 36 in. long, as agreed, to be evenly sawed and of uniform thickness throughout, and when thoroughly kiln-dried to be full $\frac{3}{4}$, $\frac{7}{8}$ or 1 in. thick, respectively, when planed on inside or outside; and full $\frac{13}{16}$, $\frac{15}{16}$ and $1\frac{1}{32}$ in. thick, respectively, when not planed. To average in width when close jointed, free of sap, not exceeding 21 staves to the barrel, and to be free of seed or worm holes of any kind, cat faces or checks. Sound streaks that do not go through staves will be admitted, provided they are on inside of stave and over 6 in. from ends. The grain of the stave must be such that a straight line, drawn at right angles, across the thickness at the ends of a stave must pass through not less than three lines of grain at any one place.

(See notes I., II., IV., and V., following.)

Bucked or Sawed Half Whisky and Alcohol Staves.

Same specifications as above, length 26 to 30 in., as agreed, thickness $\frac{11}{16}$ or $\frac{3}{4}$ in., as agreed, and to average in width when close jointed and free of sap not less than 19 staves to a half-barrel.

(See notes I., II., IV., and V., following.)

Sawed Wine Barrel Staves.

Shall be sawed with the grain from straight grain bolts and equalized, 34 in. long, and to be, when kiln-dried and planed on both sides, $\frac{11}{16}$ in. thick, and when planed on one side to be $\frac{3}{4}$ in. scant thick; to average in width when close jointed, not exceeding 21 staves to the barrel. Slight defects not showing through on both sides admissible.

(See notes I., II., IV., and V., following.)

Red Oak Oil Barrel or Tierce Staves.

Shall be equalized, 34, 35 or 36 in. long, as agreed, and to be, when thoroughly dry, $\frac{3}{4}$-in. thick, evenly sawed and of uniform thickness throughout; to average in width when close jointed, including sound sap, not exceeding 22 staves to the standard barrel. To be free from seed holes, cat faces which show through on both sides, and rotten sap.

(See notes following.)

Turpentine Barrel Staves.

Shall be equalized, 34 in. long, and to be, when thoroughly kiln-dried and planed, not less than $\frac{3}{4}$-in. thick, evenly sawed, and of uniform thickness throughout; to average in width when close jointed, including sound sap, not exceeding 22 staves to the standard barrel.

To be free from seed holes, cat faces, rotten sap, wood want or proof.

(Notes I., IV. and V.; also note II. as to length only.)

Cuban Tierce Staves.

Shall be equalized, 36 in. long, and, when thoroughly dry, to measure 1 in. thick, otherwise to grade same as $\frac{3}{4}$-in. oil or tierce; to average in width, when close jointed, including sap, not exceeding 21 staves to a barrel.

(See notes following.)

Pork Staves.

Shall be equalized, 30 in. long, and, when thoroughly dry, to measure $\frac{5}{8}$ in. thick, evenly sawed and of uniform thickness throughout; to average in width, when close jointed, including sound sap, not exceeding 19 staves to the barrel. To be free from seed holes, cat faces, wind shakes and rotten sap. Slight defects not showing through on both sides of staves admissible.

(See notes following.)

Notes.

NOTE I. All staves must be evenly equalized, so as to be square on the ends.

NOTE II. Variations in staves. All staves must not be less than the standard measurement herein stated, but if $\frac{1}{8}$ in. shorter or longer, or $\frac{1}{16}$ in. over or under specifications in thickness on one edge, will not affect the grade.

NOTE III. Worm holes. Sound worm holes in sawed oil tierce, or pork staves not exceeding two in a straight line across the width of the staves within 12 in. of the center, not more than five worm holes in any one stave, and 10 per cent of the number of staves in carload will be admitted.

NOTE IV. All staves must have a proper circle; no flat staves will be accepted.

NOTE V. When not otherwise agreed, all staves over 30 in. in length shall be settled for on an average width basis of $4\frac{1}{2}$ in., and all staves 26 to 30 in. in length, on an average width basis of $4\frac{1}{4}$ in.

NOTE VI. Unless otherwise specified by the buyer, all oil barrel staves averaging 18 to 31 in. shall be jointed with a $\frac{3}{4}$-in. bilge, and for each stave in excess of 18 staves the bilge shall be reduced $\frac{1}{16}$ of an inch.

(Note that this does not prevent parties contracting for staves on basis of any other width if they prefer. These specifications are to apply where there is no specific agreement.)

EXPORTS

The exports of staves from this country are shown in the following table. They are practically all tight barrel staves used largely in the wine trade of Europe:

STAVES FROM THE UNITED STATES

Year Ending June 30th.	Number of Staves.	Value in Dollars.
1914	77,150,535	$5,852,230
1915	39,297,268	2,481,592
1916	57,537,610	3,529,181
1917	61,469,225	3,921,882
1918	63,207,351	3,724,895

These staves go principally to Canada, France, Italy, Spain, Holland and England.

CHAPTER VII

NAVAL STORES

GENERAL

THE naval stores industry is one of the most important of all forest industries, excepting lumbering, measured in terms of the value of its products. It is also one of the oldest of the forest industries in this country. The value of the products turpentine and rosin, in 1910, was over $35,000,000. The industry has been closely identified with the economic development of the South. The earlier colonists depended to a large degree on the products of the industry for their livelihood, particularly in North Carolina and South Carolina. The primary products of the earlier development of the industry, pitch and tar, were among the first exports from this country and were extensively used in wooden sailing vessels; hence the name naval stores. This name is still applied to the present products of the industry, which are confined to turpentine and rosin.

The production of naval stores is a waning industry, due to the rapid depletion of the virgin timber supply and the failure to perpetuate the industry either by providing for the reproduction of the forests or by conservative methods of tapping, which would at least continue to an appreciable extent the life of the industry. Until about 1890, lumbermen considered timber bled for turpentine unfit for manufacturing into lumber and literally billions of board feet of valuable timber have been allowed to go to waste by windfall, insects and fire, especially in Georgia and the Carolinas, after the bleeding process had been completed.

Until the introduction of various forms of cups in which to collect the resinous exudation from the trees, the method of boxing has been practically the same for the past two hundred years.

The gummy exudation from the tree is called crude turpentine or resin, and the final products of the industry as marketed are called spirits of turpentine or turpentine, which is the distillate of the resin, while the residue after distillation is called rosin.

The question of the effect of turpentining on the strength and durability of lumber and timbers has long been a debated subject. Investigations have proven that it has practically no deleterious effect of this kind; in fact, bled timber is more durable than " round " or unbled timber, owing to the increased presence of resin. However, on account of the discrimination in the lumber grading rules against excessively resinous lumber and the fact that the wood back of the faces on turpentined timber

Photograph by U. S. Forest Service.

FIG. 43.—Cutting a " box " in the base of a longleaf pine for the collection of resin as it exudes after each chipping.

is generally heavily filled with resin to a depth of $\frac{1}{2}$ to $1\frac{1}{2}$ in., the proportion of high-grade lumber contained in " round " or unbled timber is somewhat greater than that cut from turpentined or bled timber. This condition is minimized to a large extent by slabbing a butt log containing a turpentined " face " at the saw-mill, in order to remove all of the wood having a high resin content.

SOURCE OF PRODUCTS

The naval stores industry is confined to eight states of the southeast, bordering the Atlantic and Gulf of Mexico from North Carolina to Texas, inclusive. Probably at least 90 per cent of the total products is derived at present from the longleaf yellow pine (*Pinus palustris*). Cuban or slash pine (*Pinus heterophylla*) is also tapped. Other Southern pines such as the loblolly and shortleaf pines yield a resinous exudation when tapped, but there is not a sufficient quantity of resin available to make their exploitation for this purpose commercially profitable. Western yellow pine may be developed in the future in the southwest, California and in Oregon, and experiments have demonstrated that the resinous flow is sufficient to justify commercial development. However, there are many practical and commercial difficulties in the way of present development, particularly the labor question and a market for the products.

Resin is stored in resin ducts which are peculiarly large and abundant in longleaf and Cuban pines. The resin ducts form in the region of the cambium layer. When exposed by a cut or chipping streak the exudation of their resinous secretion is permitted. Each cut stimulates the formation and development of other resin ducts above the incision or cut and an area of from 2 to 3 in. above the cut is affected in this way.

Experiments have shown that over 67 per cent of the total resin flow after each exposure or chipping occurs within the first twenty-four hours. Oxidation and crystallization of the resin at the mouths of the resin ducts causes them to be clogged, so it is necessary to make fresh cuts from time to time to renew the flow by opening new ducts. Chipping is consequently done every week. At the expiration of this period practically all flow from the previous cut has ceased. If the weather suddenly turns cold it is likely to retard or even completely stop the flow of resin.

ANNUAL PRODUCTION

North and South Carolina were formerly and for a long time the most important centers of production of naval stores. When the virgin longleaf timber of these states was largely bled for turpentine, Georgia became the center of production. For the past two decades, Florida has been the great producing center of naval stores. The largest areas of forest still untapped are in Florida. The only other large areas of virgin forests still remaining unbled for turpentine and rosin are to be found in Mississippi, Louisiana and Texas.

According to Veitch, the following is an estimate of the production of turpentine and rosin for the calendar year 1918:

PRODUCTION OF TURPENTINE AND ROSIN FOR 1918

State.	Turpentine, Barrels.	Rosin Round Barrels.	No. of Operations (Reported).
Florida	104,478	321,511	349
Georgia	54,192	170,884	373
Louisiana	52,636	155,402	38
Alabama	33,076	105,029	145
Mississippi	31,217	92,149	40
Texas	23,086	67,552	8
North Carolina	554	1,981	17
South Carolina	429	1,438	17
Totals	299,668	915,946	987

There has been a great decrease in the production of turpentine and rosin during the recent years. There was a serious drop in production from 1917 to 1918. The industry is on the wane due to the rapid exhaustion of the available timber supplies of the South.

More than 50 per cent of the total amount of products are exported. The high peak in the value of the exports of naval stores was reached in 1912, when $26,754,987 worth were exported. In 1917 only $15,581,208 worth of naval stores were exported. This country is the great source of the world's supply of turpentine and rosin. In normal times the products were chiefly sent to Germany, the United Kingdom, the Netherlands and Canada. The war has seriously interfered with the exports of naval stores from this country.

The peak in the production of turpentine was reached in 1900, when 38,488,000 gal. were produced, and the greatest quantity of rosin was produced in 1908, when 4,288,000 barrels were placed on the market. For the five-year period up to 1914 the average annual production was 31,800,000 gal. of turpentine and 3,700,000 barrels of rosin. The following table shows the quantity and value of turpentine and rosin produced according to the Census Bureau figures, from the years 1900 to 1913:

NUMBER OF ESTABLISHMENTS AND QUANTITY AND VALUE OF TURPENTINE AND ROSIN PRODUCED—UNITED STATES

(Figures taken from reports of the Bureau of the Census)

Year.	Number of Establishments.	Turpentine.		Rosin.		Combined Value of Turpentine and Rosin.
		Gallons.	Value.	Barrels.	Value.	
[1] 1913	....	32,000,000	....	3,815,000	no data	no data
[1] 1912	....	34,000,000	....	4,000,000		
[1] 1911	....	31,900,000	....	3,800,000		
1910	....	27,750,000	$17,680,000	3,651,000	$18,255,000	$35,935,000
1909	1,585	28,941,000	12,654,000	3,258,000	12,577,000	25,231,000
1908	1,696	36,589,000	14,112,000	4,288,000	17,795,000	31,907,000
1907	1,629	34,181,000	18,283,000	3,999,000	17,317,000	35,600,000
1904	1,287	30,687,000	15,170,000	3,508,000	8,726,000	23,896,000
1900	1,503	38,488,000	14,960,000	2,563,000	5,129,000	20,090,000

[1] According to "Naval Stores Review" of Apr. 4, 1914.

The following table shows the quantity and value of turpentine and rosin exported from this country for the various years from 1860 to 1913:

QUANTITY AND VALUE OF SPIRITS OF TURPENTINE AND ROSIN EXPORTED, 1860–1913

(Figures from the Bureau of the Census)

Year Ending June 30th.	Turpentine.		Rosin.	
	Gallons.	Value.	Barrels.	Value.
1913	21,039,597	$8,794,656	2,806,046	$17,359,145
1912	19,599,241	10,069,135	2,474,460	16,462,850
1911	14,817,751	10,768,202	2,189,607	14,067,335
1910	15,587,737	8,780,236	2,144,318	9,753,488
1909	17,502,028	7,018,058	2,170,177	8,004,838
1908	19,532,583	10,146,151	2,712,732	11,395,126
1905	15,894,813	8,902,101	2,310,275	7,069,084
1903	16,378,787	8,014,322	2,396,498	4,817,205
1900	18,090,582	8,554,922	2,369,118	3,796,367
1890	11,248,920	4,590,931	[1] 1,601,377	[1] 2,762,373
1880	7,091,200	2,132,154	[1] 1,040,345	[1] 2,368,180
1870	3,246,697	1,357,302	[1] 583,316	[1] 1,776,625
1860	4,072,023	1,916,289	[1] 770,652	[1] 1,818,238

[1] Turpentine included with rosin.

WOODS OPERATION

For many years the unit of woods operation has been the "crop," which consists of an orchard of 10,500 boxes or faces. The area included within the crop varies considerably with the density of the stand, the size of the individual trees and the intensity of the boxing (number of boxes per tree). This number has been determined upon as a result of experience—it being found to be the most convenient in laying out a turpentine operation, collecting the products, supervision, etc. Subdivisions of the crop are called "drifts," which may follow topographic or other natural or artificial divisions.

Boxing.

After laying out the crop, the trees are boxed during the winter according to the old-fashioned system. This consists of chopping a cavity or "box" about 3 to 4 in. wide, 6 to 7 in. deep and 12 in. long near the base

Photograph by U. S. Forest Service.

FIG. 44.—"Cornering" a box to provide a smooth surface over which the resin is guided into the box. Photograph taken at Statesboro, Georgia.

of the tree. This cavity will hold about $1\frac{1}{2}$ qt. and is designed to catch the resin as it exudes from the surface, called the face, which is chipped periodically. The top edge of the box is generally from 5 to 12 in. from the ground. There may be from one to four or more boxes on every tree; depending upon its size.

Cornering.

Cornering consists of removing a triangular-shaped chip above each corner of the box. It is done to provide a smooth surface over which the resinous exudation may flow into the box and to expose two diagonal lines to guide the initial chipping. It is shown in the accompanying illustration.

Chipping.

This operation consists of re-exposing the cambium layer by cutting it periodically with a chipper or hack. This streak or chipping is done

Photograph by U. S. Forest Service.

FIG. 45.—Chipping the fourth streak above a virgin box near Ocilla, Georgia. Chipping is usually done every week to induce new resin flow from March to October.

every week during the warm season, generally from March to late in October, depending upon the season. The number of chippings per season may vary from 28 to 40, and the average is about 32. The operation of chipping is shown in the accompanying illustration. For high faces, up to 8 ft., a long hack sometimes called a " puller " is used. A 5 to 7 lb. weight on the end of the hack facilitates the work of cutting the streak, which is made by a sharp U-shaped blade made in three sizes (usually about 1 in. across the curvature). The gash is about $\frac{1}{2}$ to $1\frac{1}{2}$ in. in depth. Two cuts, forming a V at an angle of 90 to 100°, form the streak. Chipping continues through four seasons, at the end of which a height of about 7 to 8 ft. is attained. Shallow chipping has been found to yield better results and it is said that a depth of $\frac{1}{2}$ in. is the best. Narrow chipping, around $\frac{1}{2}$ in. in width, is also best. The present method is about 1 in. or more. This reduces the length of time the tree can be tapped. It is possible to improve the present methods vastly. An experienced laborer will chip from 8000 to 10,500 faces per week.

Dipping.

Dipping consists of removing the resin or gum from the box. A dipper with a long-handled, trowel-shaped blade is used. The gum is emptied into a small wooden bucket which the worker carries from tree to tree. Dipping is done every three to five weeks, depending upon the season and condition of the trees. Operators generally estimated that dipping is done from seven to eight times a season. Resin barrels, placed at convenient points through the drifts by a wagon, are used for collecting the gum as the buckets are filled. As these barrels are filled they are taken directly by wagon to the turpentine stills. One still will take care of the products of from 20 to 25 crops of 10,500 boxes each.

Scraping.

Owing to the gummy and sticky nature of the resin, considerable quantities of it adhere to the face and never reach the box at the base of the tree. Obviously, this condition is enhanced the higher the chipping occurs up the tree. Cold weather also affects it. This gum is scraped from the face at the end of each season by means of special tools called "scrapers" and it is caught at the base of the tree in a wooden receptacle called a "scrape box." The "scrape" yields very inferior products compared to the "dip." It is estimated that only 45 to 60 per cent of the normal quantity of turpentine is secured from the scrape and it produces a rosin of dark color and consequently of low grade. It generally contains many impurities, such as pieces of wood, leaves, twigs, bark, bugs, etc.

After the turpentine season is over the ground about the base of each tree is raked over for a distance of 3 to 4 or more feet to guard against fires. Inflammable material such as pine needles, particles of gum, sticks, etc., are removed by this raking. The pine woods are then set fire, generally speaking, to improve the grazing, keep down the brush, which would interfere with the turpentining operation, sand to prevent forest fires from starting from some accidental or intentional cause. When the woods burn in this way, after raking, there is little likelihood of fires getting into the highly inflammable boxes and doing irreparable damage

Photograph by U. S. Forest Service.

FIG. 46.—" Dipping " the resin from the old-fashioned box. This method is very wasteful compared to the cup systems.

by burning out the boxes and resulting in the felling of the tree by windfall.

CUP AND GUTTER OR APRON SYSTEMS

Owing to the serious losses resulting from the wasteful process of turpentining by the old box system and the growing scarcity of virgin longleaf pine forests still untapped in the South and the consequent need for more conservative methods of tapping the trees, several processes were introduced from time to time which provided a substitute for the box as a method of collecting the resin. It is said that the first substitute was patented in 1868.

In 1894 W. W. Ashe introduced the French cup and gutter system, which had proved to be such a success in the maritime pine forests in the Landes region of southwest France. Dr. C. H. Herty, however, is generally credited with the successful introduction and commercial applica-

Photograph by U. S. Forest Service.

FIG. 47.—Correct position of the Herty cup and gutters. This shows the condition of the face at the end of the first season after about thirty-five chippings have been made.

tion of the cup and gutter systems in this country, and the Herty cup is now widely used throughout the South. Only within the past two decades, however, has this great improvement been generally adopted. The first large commercial use of the cup system was in 1904. It is said that at the present time as many cups are in use as boxes and on all new forests tapped, probably 75 to 80 per cent of all the trees are equipped with cups, which have demonstrated a saving of 20 per cent in value of products over the old wasteful box method of turpentining.

The principle of the cup and gutter systems lies in the substitution of two gutters or an apron and a cup for the box. The gutters or apron is used to guide the crude turpentine, as it exudes from the tree into a clay or galvanized iron receptacle, which is either hung from a zinc nail or the apron itself. The gutters or aprons can be elevated from time to time. This obviates the necessity of the gum or resin flowing over such a long-exposed face to the box; consequently the amount of scrape is reduced and both a greater quantity and higher quality of product are secured.

The gutters are generally 2 in. wide and 6 to 12 in. long and are bent into the shape of an obtuse angle. The gutters are inserted in slits made by a broadaxe, one projecting about 2 in. beyond the lower end of the other in order to conduct all the resin into the cup, which is suspended from a nail. Both clay and galvanized iron cups holding 1, 1½ and 2 qt. are commonly used. The position of the cup and gutters is shown in the accompanying illustration.

In the case of the aprons, a flat piece of galvanized iron, nearly rectangular in shape and with one edge concave in order to conform with the shape of the tree, is inserted in a slit made with a broadaxe having a concave edge. The slit is almost horizontal and slopes slightly downward.

The cup or receptacle used with this form is generally hung directly from the apron. As in the case of the other form of cup, it may be either of clay or galvanized iron, but it is generally made of the latter material. In shape it is rectangular, about 12 in. long, 3 in. wide and about 3 in. deep, and is smaller in both length and width at the bottom than at the top. The illustration shows the position, shape and method of use of this form.

There are several other forms and adaptations of the forms described above and new variations are introduced to the industry nearly every year.

In all cases, the cups are removed at the end of each season and are elevated together with the aprons or gutters to new positions higher on the tree at the beginning of each season.

The advantages of the cup systems over the old box system may be summarized as follows:

1. The yield of turpentine is considerably greater and the value of the rosin much higher. This is explained by the fact that the cups are raised

each year and, therefore, there is more and cleaner resin and much less "scrape" which yields an inferior grade of rosin.

2. The danger from fire is greatly decreased. Formerly ground fires could easily get into the box cut in the base of the tree and would either ruin the face for further turpentining or completely burn away the base of the tree. The tree would then deteriorate and be unfit for lumber by the time logging operations could move it to the sawmill.

Photograph by U. S. Forest Service.

FIG. 48.—Method of collecting resin with the McKoy cup. A single apron is used to conduct the resin from the face to the cup. This is moved up the tree after each season's operations. Walton County, Florida.

3. The use of cups does not injure the vitality of the tree as does the boxes. Often after severe boxing windfall results. The following Table[1] shows a comparison of the number of dead trees and those blown down

[1] From the Naval Stores Industry, by Schorger and Betts, U. S. Dept. of Agric., Forest Service, Bulletin No. 229, page 26.

by the storm under the two systems in one season. It is conclusive evidence in favor of the cup system over the boxing method:

	Trees Blown Down.		Dead Trees.	
	Boxed.	Cupped.	Boxed.	Cupped.
After 16 chippings	5	1	2	1
After 32 chippings	8	3	35	16

Specifications for turpentining recommended by Schorger and Betts are as follows:

1. No trees under 10 in. in diameter shall be tapped; minimum diameter to carry two faces, 16 in.; no tree shall carry more than two faces.

Photograph by Nelson C. Brown.

Fig. 49.—Western yellow pine tapped for naval stores products. Experimental area on Coconino National Forest, Arizona.

2. The faces on trees from 10 to 16 in. in diameter shall not exceed 12 in. in width, and the faces on trees above 16 in. in diameter shall not exceed 14 in. in width.

3. The height of the face shall not be increased by more than 16 in. each year the tree is tapped.

4. Each streak shall not exceed a width of ½ in. or a depth of ½ in., the depth being measured from the dividing line between the wood and the bark.

5. Before the chipping season opens the rough outer bark shall be scraped off over the entire surface to be chipped for each season, care being taken not to penetrate the living bark.

Photograph by U. S. Forest Service.

FIG. 50.—Tools and utensils used in the naval stores industry. From left to right, broadaxe used to cut slit for apron, cup and apron in place, hack used in chipping, broadaxe used in making "face," maul, and on right foreground cup and apron. Photograph taken on experimental area in western yellow pine timber on Sierra National Forest, California.

6. During the winter a space of at least 2½ ft. shall be raked free of debris about each tapped tree.

DISTILLATION

As the resin is collected in buckets and then in barrels in the forest, it is transported on wagons to the still, located at a place convenient to several (20 to 25) crops and generally on a railroad, to facilitate the marketing of the products—spirits of turpentine and rosin. Copper stills have only been used since 1834. Prior to that time iron retorts were used and they were exceedingly crude and wasteful and produced a very inferior product.

The equipment and housing of a modern turpentine distilling plant usually consists of the following:

1 still house—a roughly constructed open shed containing the copper still, loading platform and " worm " for condensing the vapors.

1 storage shed, separate from the still, for storing the turpentine. It generally houses, as well, the kettle for heating the glue used in coating the inside of the turpentine barrels.

1 cooperage shed for making rosin barrels.

1 rosin screen and rosin barrel platform.

Photograph by U. S. Forest Service.

FIG. 51.—Turpentine still at Clinton, Sampson Co., North Carolina.

The capacity of the stills is generally from 15 to 20 barrels, but may be as high as 40 barrels.

The barrels of crude gum are dumped into the still after removing the still head and gooseneck. The residue of gum, sticking to the inside of the barrels, is removed by introducing live steam or by allowing them to drain slowly. With " virgin " dip or the new fresh gum, the still is only filled to three-quarters its capacity, while with ordinary dip only about one-half the still is filled and with old scrape only about one-third the still is filled. This is done because of the danger of boiling up into the still head and the consequent fire hazard, which must be carefully watched in all still operations.

After charging, the fire is started underneath the still. In the case of "scrape," several pails of water are added. The process of distillation requires about 2 to $2\frac{1}{2}$ hours. The operator or "stiller" watches his charge very closely and he can gauge the distillation by the sounds emitted from the still and by the relative proportions of water and turpentine in the distillate. When needed, additional quantities of water are run into the still, especially when distilling old dip and scrape. The operator can determine the end of the distilling process by the small proportion of turpentine in the distillate. It is never attempted to remove all of the turpentine because a better grade of rosin is secured in this way. The fire is then put out and the residue is skimmed to remove the waste and foreign material such as chips, bark, needles, etc., which collect on the surface. Sometimes skimming is done during the distilling process.

After skimming, the hot residue is allowed to run out an aperture at the base of the still and through a short pipe and a set of three or four screens into a large metal vat. The screens are placed, one above the other and are of 6- to 8-, 14-, 32- and 60-in. mesh from top to bottom. A piece of cotton cloth is generally placed on top of the lowest screen.

After cooling in the vat for a period up to an hour, depending upon its temperature, it is dipped out into slack barrels which hold about 450 lb. Upon cooling, it hardens in about twenty to twenty-five hours into rosin and is ready for shipment to market. Rosin is graded according to its color. Virgin dip yields the lightest colored and best rosin, called "W. W." or "water white," whereas the scrape yields the darkest and least valuable rosin. The following are the grades of rosin, in order of quality: WW, WG, N, M, K, I, H,G, F, E, D, B.

As the distillate comes from the copper condenser or worm, it is collected in a barrel, the turpentine rising by gravity to the top. Near the top a spout permits the turpentine to run off into a second barrel, from which it is dipped into barrels of 50 gal. capacity and shipped to market.

Savannah is the great naval stores market in this country, both for domestic and foreign consumption. Owing to the large foreign trade developed and its proximity to the Georgia and Carolina turpentine orchards, it has for a long time held a pre-eminent position and Savannah quotations are recognized as the standard in the industry.

The Savannah Board of Trade has been very active in developing the industry along proper lines. As a result of some dispute and to improve the standards of containers for naval stores, this Board issued in 1911 letters of instruction to the operators of stills, as follows:

Turpentine Barrels.

All barrels, whether new or second hand, should be kept absolutely protected from the elements, and not allowed to remain subject to rain and sunshine at way stations and river landings. Glue will not take on damp staves. Every barrel should be glued twice before being filled. Use only the best quality of glue, as it is the cheapest in the end. Before gluing, see that your pot is absolutely clean. Put into this 20 lb. of good glue and 5 gal. of water, and allow it to soak overnight. On the following morning apply sufficient heat to melt up to a temperature not exceeding 160° F. Under no condition whatever must glue be allowed to boil, as this causes decomposition to set in, which causes the bad smell usually noticed around glue sheds, and renders it utterly worthless. This amount of prepared glue will be sufficient for 20 barrels. After gluing, barrels should be taken off the trough and stood on the head for about one-half hour, after which time they should be reversed, so that the surplus glue will run down equally on both heads. The barrels should then be well and thoroughly driven, and, after standing for twenty-four hours should be given a second coat of glue, using the exact formula as before. They are then ready to be filled in forty-eight hours, and if treated in this way there should be no turning except for broken staves.

Rosin.

Rule No. 9 of the Savannah Board of Trade says in part: "Rosin barrels to be in merchantable order must have two good heads, not exceeding $1\frac{1}{2}$ in. in thickness, staves not to exceed 1 in. in thickness; the top well-lined." Too much stress, therefore, cannot be placed on the absolute necessity of carrying out this rule to the very letter, especially regarding the thickness of staves and heading, for rule No. 10 specifically instructs the inspector to make a proper deduction in weight in all rosin when the staves and headings are more than the prescribed thickness in rule No. 9. In such cases, therefore, the operator will lose, as in addition to having the deductions made, for which he receives nothing, he must pay the full amount of freight to the railroad. Operators must see that every barrel is well coopered before shipment; see that all four hoops are nailed on the barrels, and the heads cut to fit close, and a good lining hoop as prescribed by rule No. 9 is in place. Staves must be properly equalized. Staves should be 40 in. long, and barrels built on a 22-in. stress hoop, which gives a well-shaped and easily handled barrel.

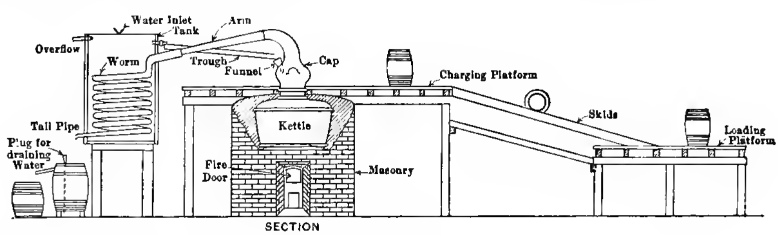
YIELDS

The Census Bureau of 1909 shows the following yields of turpentine per crop of 10,500 boxes for each of the principal states in the South producing naval stores:

YIELD OF TURPENTINE PER CROP BY STATES

State	Yield of Turpentine per Crop of 10,500 Boxes. Barrels
Alabama	35.6
Florida	29.8
Georgia	26.5
Louisiana	44.7
Mississippi	34.5
Texas	43.5

The larger yields shown in the above table from the forests of Louisiana and Texas are undoubtedly explained by the fact that the timber in those states is much larger than the timber now being bled in the other states. Consequently, the yield would naturally be much larger per crop.



From Schorger and Betts.

FIG. 52.—Diagrammatic cross-section of a turpentine still. The barrels of resin are brought in from the forest and, after unloading on the platform on the right, are emptied into the kettle on removal of the cap. The turpentine is collected in the barrel at the right.

A crop will generally yield from 29 to 46 barrels of turpentine and from 163 to 234 barrels of rosin, depending upon the year of tapping. It is obvious that the yield of turpentine will be much greater during the first year of tapping and the same is true of the yield of rosin. Considerable depends upon the method of tapping, that is, by the box or the cup system.

The yield of crude turpentine or rosin is generally about 8 to 12 lb. per box, or about 20 to 25 lb. from a tree of average size where two faces are exposed.

One barrel of average crude turpentine will yield about 5 gal. of spirits of turpentine and from 60 to 65 per cent of its bulk in rosin.

The bleeding of the first year produces a fine, light-colored rosin and this grows darker from year to year until at the end of the fourth year the scrape at the end of the season yields the poorest grade of rosin.

The following tables show a comparison of yields of turpentine and rosin from bleeding by both the cup and box system:[1]

SPIRITS OF TURPENTINE FROM HALF CROPS, SEASONS 1902–1904, GEORGIA

Year.	Cups.			Boxes.			Excess from Cupped Half Crop.	Net Price per Gallon at Time of Operation.	Value of Excess from Cupped Half Crop.
	Dip.	Scrape.	Total.	Dip.	Scrape.	Total.			
	Gal.	Gal.	Gal.	Gal.	Gal.	Gal.	Gal.	Cents.	
First	1385.3	205.0	1590.3	1134.7	153.7	1288.4	301.9	40	$120.76
Second	1103.5	165.0	1268.5	705.2	226.6	931.8	336.7	45	151.52
Third	781.3	136.0	917.3	536.1	190.5	726.6	190.7	45	85.82
Total	3270.1	506.0	3776.1	2376.0	570.8	2946.8	829.3	....	$358.10

NET SALES OF ROSIN FROM HALF CROPS, SEASONS 1902–1904, GEORGIA

Year.	Cups.			Boxes.			Value of Excess from Cupped Half Crop
	Dip.	Scrape.	Total.	Dip.	Scrape.	Total.	
First	$401.72	$47.72	$449.44	$328.40	$35.53	$363.93	$85.51
Second	286.88	58.24	345.12	132.42	84.08	216.50	128.62
Third	212.60	61.65	274.25	124.76	79.70	204.46	69.79
Total	$901.20	$167.61	$1068.81	$585.58	$199.31	$784.89	$283.92

UTILIZATION OF PRODUCTS

Turpentine.

Probably the greatest quantity of turpentine is used for paints and varnishes. It has the power of thinning out these materials by its action as a solvent, as well as by its power of oxidation and evaporation.

It is widely used in the cloth-printing industry, especially for woolens and cottons and it is extensively in demand as a solvent for rubber, gutta percha and like substances.

Turpentine is also used in a great variety of chemicals, medicines and, in a number of industries, for many specialized purposes.

[1] From The Naval Stores Industry by Schorger and Betts, U. S. Department of Agriculture, Bulletin No. 229, page 23.

The following table[1] shows the high and low prices, per gallon, at Savannah for turpentine for eleven years.

PRICES OF TURPENTINE—PER GALLON

Year.	High.	Low.
1917–18	$ .49½	$.36
1916–17	.54	.35½
1915–16	.56	.36
1914–15	.47	.40¾
1913–14	.48½	.35
1912–13	.48	.35
1911–12	1.02	.44¼
1910–11	1.07	.55¼
1909–10	.60¾	.35½
1908–09	.50½	.35
1907–08	.69	.40

Rosin.

The greatest single utility of rosin is in the manufacture of soap. It is combined with caustic soda and potash to form the various kinds of soap. It is also in great demand as a rosin sizing in the manufacture of paper. It gives certain kinds of paper a stiff coating or surface, making them adaptable for printing and writing purposes. Without this sizing it would be impossible for certain papers to take colors, inks, etc.

"Brewer's pitch," made of rosin and a small admixture of turpentine, was widely used to coat the interiors of barrels and other containers of beer and malted liquors. This coating gives the liquors a better taste and renders the barrels easy to clean.

Rosin is also in great demand for a wide variety of manufacturing enterprises, particularly in the making of linoleum, sealing wax, oilcloth, special flooring compounds and coverings, various kinds of inks, roofing materials, lubricating compounds, and a great variety of chemicals too numerous to mention.

An important use for rosin is for resin driers, which are extensively used in the drying of oil paints and varnishes. Rosin soaps are combined with metallic salts to form metallic resinates, which are known in the trade as " Japan driers."

Rosin is distilled into rosin oils which are produced under several different trade names. These oils are used in the manufacture of several greases and specialty lubricants, as well as solvents.

[1] From the Naval Stores Review, Savannah, Ga., June 7, 1919, p. 10.

The following table [1] shows the range of prices from high to low for rosin in the Savannah market:

ROSIN MARKET PRICES AT SAVANNAH.

High and low prices per barrel for four-year period.

Grade.	1914–15.		1915–16.		1916–17.		1917–18.	
	High.	Low.	High.	Low.	High.	Low.	High.	Low.
Water white	$7.50	$5.50	$7.50	$5.50	$7.32½	$5.20	$7.75	$5.90
Window glass	6.25	5.40	7.25	5.35	7.10	5.05	7.65	5.75
N	6.00	5.00	7.00	4.70	7.02½	4.75	7.55	5.75
M	5.30	3.95	6.50	3.95	6.75	4.50	7.10	5.75
K	4.55¾	3.20	6.15	3.25	6.62½	4.20	6.95	5.20
I	4.35	3.05	5.90	3.10	6.50	4.20	6.70	5.15
H	4.35	3.05	5.90	3.05	6.50	4.10	6.65	5.15
G	4.20	3.05	5.90	3.05	6.45	4.10	6.60	5.10
F	4.15	3.05	5.90	3.00	6.40	3.95	6.60	5.05
E	4.02½	3.02½	5.85	2.95	6.35	3.90	6.60	5.05
D	4.05	3.00	5.85	2.85	6.35	3.85	6.60	5.02½
B	4.00	2.90	5.85	2.70	6.35	3.75	6.60	5.00

FRENCH METHODS

Turpentine and rosin are produced in large commercial quantities in various European countries, particularly France, Spain and Russia, but the total production in all Europe is exceedingly small by comparison with that in this country.

The industry has been highly developed in France, where it is centralized in the Landes, a region of about 2,000,000 acres in southwest France from Bordeaux to the Spanish frontier. The forests of the Landes are composed of almost pure maritime pine (*Pinus maritima*) and, in the period before the great war, the value of the yield of naval stores products was greater than the value of the timber when cut.

The maritime pine trees are much smaller than the longleaf pine of the South, since most of the trees are planted and are cut when from sixty to seventy-five years of age. Many of these trees are continually bled for turpentine from fifteen years of age until they are cut.

The French turpentine operators chip the trees by slicing off a new shaving each time the resin flow is to be renewed. The face is only about 3½ in. wide instead of 12 to 14 in. in this country. Chipping is done every eight days, and during the first season the height of chipping is only carried about 24 in. up the tree. The depth of chipping is only

[1] From the Naval Stores Review, Savannah, Ga., June 7, 1919, pp. 24–27.

about $\frac{1}{2}$ in. and is done with a concave gouge instead of a semi-round or circular hack as in this country.

A single zinc apron or gutter is used to guide the resin into an earthenware cup hung below it. The apron is inserted in a slit made by a chisel specially designed for the purpose. The cup contains about 1 qt. and is supported by a nail at the base and the apron at the top. The aprons and cups are raised each year. Only two faces are generally permitted

Photograph by Nelson C. Brown.

Fig. 53.—Method of tapping maritime pine near Arres in the Landes region of France. A narrow "face" is chipped and the apron and cup moved up each year. Trees are frequently bled for thirty years or more. The faces heal over and are changed to different parts of the trunk.

on each tree at one time. Chipping is done up to 12 to 15 ft. in height or more. The worker uses stilts to chip at the higher levels.

After bleeding, these narrow faces heal over so that the face can be moved to different parts of the tree from time to time and the tapping continued for a period of thirty to forty years or more. This is in sharp contrast to the practice in this country, where the period of tapping seldom exceeds four years.

Distillation follows the same general lines as those described for this country, but there are several preparatory measures such as clarification and steaming and distillation by steam is used as well as direct distillation.

It is unsatisfactory to compare the yields of maritime and longleaf pines because of the different sized trees, different methods of bleeding, chipping, etc. However, it may be said that the resin content of the longleaf pine is much greater for similar sized trees than is the case with the maritime pine.

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CHAPTER VIII

HARDWOOD DISTILLATION [1]

HISTORY

Introduction.

The heating or carbonizing of wood for the purpose of manufacturing charcoal has been in practice as long as history is recorded. It is believed that it is as old as civilization itself. In the manufacture of charcoal by the old process, the wood is heated to such temperatures that it is carbonized while the gases that pass off in the form of dense, heavy, black smoke have given rise to the modern processes of distilling wood.

Altogether two distinct branches of the industry have been developed in this country. The most important branch is devoted to the utilization of the denser and heavier hardwoods and seeks the recovery of the following commercial products—wood alcohol, acetate of lime, and charcoal. In addition the minor products are wood tar and wood gas, both of which are at the present time usually utilized as fuel in the heating process. Only those hardwoods that are comparatively free from an excessive content of gums, tannins, resins, etc., are desirable. The so-called Northern hardwoods, such as maple, birch and beech, are considered the most desirable. Hickory and oak are also considered of almost equal value.

The other branch of the wood-distillation industry requires resinous woods, and the objective products are, on the other hand, turpentine, tar, wood oils, and charcoal. The southern longleaf pine is the best wood for this kind of distillation and, up to the present time, has been practically the only one used for this purpose.

Early Practices.

The first record of the distillation of wood on a commercial scale in this country was in 1830, when James Ward began the manufacture of pyroligneous acid at North Adams, Mass. This is the raw liquor

[1] This chapter is largely taken from The Hardwood Distillation Industry in New York, by the author, bulletin of the New York State College of Forestry, Syracuse, New York, 1916.

distilled from the condensed vapors that pass off in heating the wood. So far as can be learned from records, it was not until 1850 that the distillation of wood for the production of volatile products and semi-refined products was begun. According to the most authentic records the first successful wood distillation plant in this country was established in New York State in 1850, when John H. Turnbull, of Turnbull & Co., Scotland, who had for some time been connected with the industry, came to this country and erected at Milburn, Broome Co., New York (now Conklin on the Delaware, Lackawanna & Western

Photograph by Nelson C. Brown

Fig. 54.—Beech, birch and hard maple cut in 50-in. lengths for conversion by dry distillation into wood alcohol, acetate of lime and charcoal. This wood is always seasoned about one year before it is used.

Railroad) a small chemical plant. The copper and steel castings were brought from Scotland. There were eight cast-iron retorts, 42 in. in diameter and about 8 ft. long, and the necessary copper stills, copper log condensers, etc. A number of men experienced in the industry were brought over by Turnbull from Scotland and many of these men and their sons became managers of plants which soon after sprang up in southern and southeastern New York.

The retorts were charged each twelve hours with wood cut in 8 ft.

lengths. The vapor was condensed in a copper log condenser and the liquid recovered was pumped into settling tanks, from which it was drawn to the copper stills for distillation. The settled tar was drawn off from these settling tanks each day, and spread, with a ladle, over the charcoal, which was burned under the retorts, the copper and lime stills, and the pans—all distillation being accomplished by this direct method. Little or no effort was made to save the wood spirit, the main object being to produce acetate of lime, for which a high price was obtained both in the home and Scotch markets.

The methods followed in operating the plant demanded a large amount of hand labor, and sturdy men of experience were needed to carry the work forward. These men with their families came from time to time from Scotland. In a short time Milburn became known as the Scotch Settlement, and it was famous for the number of trained men who, after getting their experience here, were called upon to take charge of distillation plants not only in New York, but in Pennsylvania, Michigan, Canada and other centers as well.

About 1865 (or soon after), a Mr. Pollock, a chemist, of Morrisania, New York, began refining wood spirit in a small way. The market developed rapidly. Shortly after the Burcey Column was introduced to the crude plants, thereby adding to the power of the stills to recover wood spirit of 82 per cent test. The production of wood spirit being greatly increased, it became desirable to install a central refining station, and the Burcey Chemical Co., with a refinery at Binghamton, New York, resulted. A refinery was also started in Brockton, Mass., in 1877.

For a long time the sale of charcoal was limited, the greater part being consumed as fuel in the plants. Slowly the market developed, until to-day practically the entire output is shipped, hard and soft coal taking its place under the boiler and retorts, and live steam being used in the stills (now fitted with coils), and in the pans, which have steam jackets at the bottom.

At the present time plant operation is along efficient lines. Old-time methods have been discontinued, and the manual labor is now greatly reduced. In the woods there is also a notable improvement. Cord wood is now, to some extent, cut from the limbs and refuse tree trunks, after the lumberman has taken out the best timber in the shape of logs. Thus the danger of fire is reduced and the ground, which, otherwise would be covered with scattered brush, is free for new seedlings to take root without delay, or the stumps left to sprout up with a new wood crop.

UTILIZATION OF WOOD IN THE INDUSTRY

Favorable Conditions.

The Northern hardwood forests, chiefly in Michigan, Pennsylvania, New York and Wisconsin, are very fortunately located for engaging in the wood-distillation industry. There are three very necessary conditions for successful operation, namely: (1) a plentiful and, therefore, a relatively cheap wood supply; (2) comparatively near a good fuel supply, such as natural gas and coal;[1] (3) reasonably accessible to a market for the products of the industry. The only desirable condition that is not generally present is that of large iron furnaces where the charcoal can be utilized to the best advantage. In Wisconsin and Michigan, however, are large iron furnaces which have been largely responsible for the development of large distillation plants in those states.

Desirable Species.

Woods that are hard and heavy are the most suitable for the wood-distillation industry, especially those that are, in addition to the above qualifications, free from tarry and resinous products. As a rule, heartwood is considered much more desirable than sapwood and there is an almost uniform opinion among manufacturers to the effect that hard maple is considered best and that beech and birch follow in order. Chestnut contains too much tannin for successful production of distillates. Ash, oak and hickory are considered almost as good as the so-called northern hardwoods, namely beech, birch and hard maple. Cherry and elm contain too much tarry material and, consequently, the distillate results in an excessive amount of wood tar which has very little commercial value and, in addition, there is an insufficient yield of alcohol and acetate of lime. Basswood, popple, cottonwood and the soft woods or conifers are entirely too soft and light. The conifers such as spruce, white pine, balsam, fir, hemlock, etc., are undesirable on account of the resinous nature of their wood and their light weight. Other native species found in the Northern hardwood forests do not grow in sufficient quantities to make them of any importance for use in the industry

Stumpage Values.

The value of the timber on the stump varies considerably. On large logging operations where the tops, limbs, defective trees and brashy material are utilized, practically no stumpage value is used,

[1] This is especially true of plants located in Pennsylvania and New York.

because the utilization of this material is considered as salvage. On most of the New York and Pennsylvania operations steep, rocky hillsides, covered by the desirable hardwoods, are anywhere from one-half mile to several miles from the plant or shipping point. Stumpage on these operations, particularly in Delaware County, which is the center of the industry in New York State, runs about 75 cents per cord. Altogether they vary between 25 cents to $1.00 per cord. There is a general tendency for stumpage values to rise. This has been especially true during the past decade. Since the European War broke out, the stumpage values have been inflated to a considerable extent above these figures.

Cutting and Delivering to the Factory.

Cutting is done by choppers who, in many sections, look upon getting out the annual cord-wood supply in the winter as a lucrative means of winter employment. The trees are cut up in 50-in. lengths and hauled on sleds when snow is on the ground or on wagons directly to the acid plant. Hauls up to 8 to 10 miles are fairly frequent.

For cutting and stacking, the usual figure is about $1.25 to $1.40 per cord. Cutting is usually done by contract and where the wood is favorably sized and located for chopping and the ground fairly level, cutting and stacking can be done as low as $1.00 to $1.10 per cord by experienced choppers. The maximum figure is about $1.50 per cord. The cost of hauling varies with the distance and the character of the ground and the road over which the load is hauled. One and one-half to two cords are usually considered the maximum load under the most favorable conditions. The total cost of wood delivered at the commercial plants is about $4.00 per cord. Estimates obtained from all the New York plants show that the average value of cordwood delivered at the plants in 1916 was $4.06 per cord. The maximum cost was estimated to be $5.00 per cord at one plant. At another plant, the cost was estimated to be $3.25 per cord which was the minimum estimated cost in the State.

Seasoning and Weights.

In all cases the wood must be seasoned for at least one year before being used in the ovens or retorts. If used green, the high-moisture content is excessive and too much heat is required to derive the product. At many of the plants it is estimated that before seasoning, the average cord of mixed beech, birch and maple weighs in the neighborhood of 6200 lb. After seasoning the average cord weighs about 3800 lb. The wood is used in the process with the bark on. All forms of limb and body wood down to 2 in. in diameter are utilized. When over 8 in. in diameter, the wood is commonly split. Body wood is much preferred to limb wood because the latter contains too much sapwood and, consequently, more moisture. As mentioned previously, yields from heartwood are much greater than those from sapwood.

Opportunities for Utilization of Sawmill and Woods Waste.

Some of the most successful plants in this country are operated where woods waste consisting of tops, limbs, crooked trees, defective logs and broken material in the woods can be utilized to advantage. Haul roads,

Photograph by Nelson C. Brown.

Fig. 55.—General view of the Maryland Wood Products Co. plant at Maryland, Otsego Co., New York. The trucks loaded with hard maple, beech and birch on the left are ready to be moved into the retorts in the oven house.

skidways and railroads maintained and operated for the purpose of getting out logs can be utilized to excellent advantage in getting out the other material for distillation purposes, and under these conditions the wood can be delivered at the factory at a very low comparative cost. This is the method usually followed in connection with large distillation plants in Michigan and Wisconsin and is also followed to some extent in the Adirondacks. Where the larger logs are utilized for lumber, the material that would otherwise be wasted is used for wood distillation purposes. This feature constitutes an important contribution to the cause of forest conservation. The removal of all of this material from the forest also means that the fire danger is greatly lessened.

The larger refuse from the manufacture of lumber in sawmills is used to advantage in the largest plants in this country in Michigan. It is believed that this form of utilization of sawmill waste will come into greater prominence in the industry in the future. Only the larger forms of sawmill waste, such as slabs, edgings, trimmings, and similar material can be utilized to commercial advantage. The sawdust, shavings and similar material usually cut up by the slasher cannot be utilized profitably except as fuel, but experiments are now being undertaken which may permit of the utilization of sawdust and shavings for distillation within a short time or as soon as some promising experiments can be perfected on a commercial basis.

Management of Timber Lands.

Several of the wood distillation companies in New York and Pennsylvania own tracts as large as 50,000 acres each or lease tracts nearly as large. These are managed on a permanent basis and carefully protected from the annual fire hazard during the dangerous dry seasons. These companies are practicing one of the best forms of forestry because they utilize the products of the forest most completely, the maximum growth of the forest is stimulated, and forest fires, the greatest enemy of the forest, in so far as practicable, are eliminated. The rougher and more mountainous portions of the forest are admirably suited to forest culture on account of the steep, rocky hillsides which contain many springs and seepage flows, thus permitting the most rapid growth of timber and stimulating the sprouting capacity in all of the larger trees. The cutting is usually done in the winter time. The following spring the stumps sprout up thriftily and vigorously to a height of from 5 to 10 ft. the first year. After a period of from twenty to thirty years the stand is cut over and the same process is repeated. In one section, four different age classes of timber were noted where average yields of one cord per acre per year had been obtained after the original forests were cut over. These tracts are in much better condition than they would be under ordinary conditions of lumbering because the forest is renewed both from sprout and from seed. The vigor of the forest is, therefore, maintained, forest fires are kept out and all of the available wood product is utilized. It would be a highly desirable situation if all forest industries could be run on the same basis.

Statistics of Wood Consumption.

For a long time New York was the leader in the consumption of wood in the hardwood distillation industry. In the early nineties, however, the industry spread into Pennsylvania and the greatest consumption at present is found in Michigan where, although there are comparatively few plants, the total consumption of wood exceeds that of any other state. From an investigation carried on in the spring of 1916, the New York State College of Forestry has determined that the annual consumption of hardwood for the industry in New York at that time was 192,330 cords. The daily capacity as reported by these plants was 643½ cords. These figures have been compiled as a result of both the daily and annual capacities of the twenty-five plants in the state, as estimated by the plants themselves. The latest available statistics as compiled by the Bureau of Census at Washington, D. C., for the consumption of hardwoods in New York State in this industry was for 1911, for which year it was announced that 132,400 cords were consumed.

The largest plant in the state in the spring of 1916 consumed 80 cords per day. This was an 8-oven plant located in Delaware County. The smallest plant in the state was one consuming only 12 cords per day in Sullivan County. This was an old cylinder retort plant containing 8 pairs of retorts. The average daily capacity of the individual New York plant is 25.74 cords and the average annual capacity is 7691 cords.

As a rule the oven retort plants are much larger in daily capacity than the round retort plants. The smallest oven retort plant is a 2-oven affair consuming 16 cords per day with an 80-cord plant per day the largest. The smallest round retort plant also consumes 12 cords per day with the largest one consuming 30 cords per day.

The latest available statistics of wood consumption in the hardwood distillation industry in the United States were for 1911, when it was reported that 1,058,955 cords were consumed. Of this amount Michigan with 13 plants led with 396,916 cords; Pennsylvania was second with 50 plants consuming 364,539 cords and New York third with 25 plants consuming 132,400 cords. Seventeen other plants scattered in 11 different states, chiefly in the northeast, reported a consumption of 165,100 cords.

It is very likely that with the stimulation of high prices for products of the wood distillation industry, due to the European War, the total consumption in the whole country in hardwood distillation amounts to at least 1,200,000 cords, although this is a very rough estimate. The following table shows the statistics of wood consumption for the United

States as compiled by the U. S. Bureau of Census from the years 1900 to 1911:

Year.	Number of Establishments.	Number of Cords of Hardwood Consumed.
1890	53	600,000 [1]
1900	93	800,000 [1]
1907	100	1,210,771
1908	101	878,632
1909	116	1,149,847
1910	117	1,257,917
1911	105	1,058,055

[1] Estimated.

This table shows how the consumption of the wood in the industry dropped off after the enactment of the Federal Law in 1907 which resulted in the serious drop of prices obtained for the crude wood alcohol.

DEVELOPMENTS IN THE INDUSTRY

Up to nearly 1860 practically all of the acetate of lime used in the dye business in this country had been imported from Europe. Acetate of lime was the principal product sought after in wood distillation in the early developments of the industry. The distillate was not utilized for wood alcohol or for any other purpose than for lime acetate, and the charcoal was used, when convenient, for fuel for manufacturing pig iron and for other purposes. Acetate of lime was commonly used even in the wet condition before it had been thoroughly dried out. In the early days of the industry it brought as high as 18 cents a pound even in the wet condition. In October, 1916, dry gray acetate of lime brought $3\frac{1}{2}$ cents a pound whereas in the fall of 1914 it was bringing only $1\frac{1}{2}$ cents a pound. In the spring of 1916 it brought 7 cents per pound. During 1917 and 1918 the price dropped back to between $1\frac{1}{2}$ and $2\frac{1}{2}$ cents per pound.

Mr. Patterson was one of the first men to establish a plant in New York, located at Kirkwood, near Binghamton. Mr. Thomas Keery entered the business with him at Keeryville, between Cadosia and Apex in Delaware County, and this firm has been in the business ever since. At that time the brown acetate of lime was full of tar and not nearly equal to the present refined product. The charcoal and alcohol were usually allowed to go practically to waste. Enormous prices were obtained for acetate of lime, so that interest was greatly stimulated in the industry.

About 1885 the raw form of wood alcohol was developed and an attempt was made to sell it to the hat manufacturing industries at Danbury, Conn. This was one of the very first large fields for the use of wood alcohol and it brought high prices. Formerly grain alcohol had been used to stiffen hats and the use of wood alcohol rapidly came into common practice. At first as high as 70 cents a gallon was paid for this wood alcohol.

Charcoal developed as the price of acetate went down. Acetate of lime was used to fix the color in dyes. particularly in Fall River, Mass.

FIG. 56.—General view of hardwood distillation plant at Betula, Pennsylvania. On the left is the wood yard, in the center the oven house and still house and on the right, the charcoal storage warehouse. Immediately to the right of the oven house are the two sets of cooling ovens.

Gradually a big influx of wood distillation plants came in and the prices gradually dropped. Around 1885 to 1900 there were a great many small capacity plants and most of them followed very rough and crude methods. All of them used the cylinder retort process. These plants, however, were gradually replaced by the larger modern plants using the long oven instead of the old retort. There is now a much smaller number of plants than formerly, but on the other hand there is a much greater annual consumption of wood in the industry, due to the economy in plant operation with the advent of the oven in the early nineties.

Up to 1900 the industry was almost wholly centralized in the state of New York. At that time a few plants were started in Pennsylvania. just over the border from the southern tier of counties in New York. About 1902 to 1906 the industry was further developed in Michigan, where the largest wood distillation plants, some of them utilizing as much as 110 to 200 cords of wood per day, are now located. Ideal conditions are present for the successful manufacture of wood distillation products in Michigan because of the availability of the raw material in connection with hardwood, saw and planing mills, together with the fact that iron furnaces are maintained in connection with them where the charcoal can be used to the best economical advantage. In addition, the raw material is secured from the waste of sawmills and logging operations, and one of the principal products can be utilized on the ground without excessive shipping rates.

Before 1907 wood alcohol had been bringing from 38 to 40 cents per gallon wholesale for the crude product, that is, the 82 per cent crude alcohol. When the Federal Internal Revenue Department removed the tariff on grain alcohol, which took effect September 1, 1907, the price of crude wood alcohol dropped to about 16 cents per gallon and gradually came back to 26 cents. The approximate price in 1916 was 45 cents per gallon, and in March, 1917, was 65 cents, a price stimulated largely by the European War conditions. Before the war in 1914, the price was about 25 cents to 28 cents per gallon of crude 82 per cent alcohol.

PROCESSES OF MANUFACTURE

Within the past fifty years the developments in the processes of manufacture followed in hardwood distillation have been remarkable. The history of the industry represents an evolution from the old wasteful charcoal pits. To recover the condensable gases lost in making charcoal by the old pit process, brick kilns were used. This was a very crude process, but represented a great step in advance. Next came the round iron retorts placed in " batteries " of two each in long bricked-up rows, and within comparatively recent years the steel oven which is a great labor- and time-saving device. The following are brief descriptions of these three processes which followed each other in rapid chronological order:

Brick Kilns.

The brick kilns supplanted the old charcoal pit as a means of manufacturing charcoal when the iron industry in this country assumed large proportions. Brick was substituted for the open-air or clay-covered pit because manufacture was simplified, the loss of carbonization was minimized and burning, therefore, could be carried on with greater safety. However, a good portion of the vapors are lost with the brick kilns, as they are with the old open-air pit, since the yield is only about 40 per cent to 50 per cent of the yield from the oven process. These brick kilns are made with a circular base, with holes in the base for drafts of air regulated by special doors and the vapors are drawn off by exhausters through wooden ducts. This practice was followed especially in Pennsylvania and in Wisconsin, where an abundant supply of the desirable hardwoods was found in a location near blast furnaces where pig iron was produced. Pig iron, manufactured by the use of charcoal, is considered far superior to that made by coke. The pig iron made with charcoal commonly brings about $5.00 a ton more than that manufactured with coke. The brick kilns were usually built to hold 50 to 90 cords each and were charged and discharged by hand. The complete manufacture of charcoal by the brick kilns, including charging and discharging, required from fifteen to twenty-five days. The heating necessary to distill the wood is supplied by the combustion of part of the charge within the apparatus, in the same way that charcoal is made in the open-air pit. The yield of charcoal by this method is somewhat below that manufactured in the retorts or ovens and is generally considered inferior in grade. The brick kiln is desirable only when the chief product is charcoal and transportation facilities are not available or the market is too distant for the other products of wood distillation, such as wood alcohol and acetate of lime. Where other forms of fuel, such as natural gas and coal, are out of the question and the manufacture of charcoal is desired, it is also commonly used.

Most of the brick kilns were in operation in Michigan and Wisconsin, where charcoal was in great demand in connection with iron furnaces.

Iron Retorts.

The iron retort followed the brick kiln and was the first device invented whereby the vapors from the carbonization of wood are collected on an efficient basis and distilled in the form of pyroligneous acid and later refined into wood alcohol, acetate of lime, etc. The yields, however, are much lower on account of slow firing. These retorts were small cylindrical vessels originally of cast iron and later steel cylinders 50 in. in diameter by 9 ft. in length. They were placed horizontally in pairs, and batteries of 10 to 15 pairs were common in long brick rows in the earlier plants. Each retort was sufficiently large to hold about five-eighths of a cord of wood. Heating was provided externally by a fire box located underneath the retort. For fuel, coal, charcoal, wood gas, wood oil, wood tar, and wood itself, have been used. The retorts are built and discharged from the single door in front which can be fastened tightly and sealed with clay to prevent the entrance of oxygen after the heating process is started. Along the top of these rows of retorts the surface is bricked over and serves as a drying floor for the acetate of lime. A run, that is the period from the first charging of the retort to the removal of the charcoal after the process, usually requires from twenty-two to twenty-four hours.

Oven Retorts.

The small round retort is now being rapidly replaced in the larger and more progressive plants by the large rectangular retort or oven retort. This is also known as an oven. Until about 1900 a large number of these round retort plants were in operation, but about 1895 the oven retort came in, which provides for loading and unloading the retort by the use of cars which are run directly into the chamber. This resulted in a considerable saving of labor charges so that all of the new plants now being constructed are introducing the ovens. In several of the states there are not as many plants active now as there were twenty years ago, but there is a vastly larger amount of wood being consumed per plant, due to the fact that the oven retorts can consume as high as 10 to 12 cords in a single oven, whereas the old round retort held only about $\frac{5}{8}$ to 1 cord of wood.

The modern hardwood distillation plant, therefore, is usually the oven retort plant. This was a decided advance in the manufacture of wood distillation products. As noted above, it is largely a labor-saving device and, although the initial cost is considerably greater the operating charge per cord is so much smaller than with the round retort that it is being universally introduced. The ovens are rectangular in cross-section and may be anywhere from 25 to 56 ft. in length. The common form is an oven 52 ft. in length, 8 ft. 4 in. in height and 6 ft. 3 in. in width. These ovens are usually arranged in pairs similar to the process followed with the round retort. The cars, each loaded with about 2 cords of wood, are run in on standard or narrow gauge tracks directly into the ovens.

They are heated in a manner similar to the round retorts, that is, by means of a fire box underneath, although there may be fire boxes at one or both ends, and the fuel in the Pennsylvania and southern New York regions is usually either coal or natural gas. In the Delaware County section the fuel consists of coal from the Scranton region. The vapors pass out from one or two large openings at the side or at the end and are condensed through a large copper condenser. The process of distillation requires from twenty-two to twenty-four hours with the oven retorts, and when the doors are unsealed and opened a cable is attached to the first

Photograph by Nelson C. Brown.

FIG. 57.—The wood distillation plant of the Cobbs-Mitchell-Co. at Cadillac, Michigan, showing the oven house, the first and second sets of 52-ft. cooling ovens and on the left the trucks of charcoal which have just been released from the second cooling ovens. This plant has a capacity of 96 cords per day. Hardwood sawmill and woods waste is used.

car and they are drawn from the ovens directly into the first cooling oven, which is of the same type of construction and shape as the heating oven. The capacities of the oven plants vary with the number and size of the ovens. There are some oven plants that now consume as high as 200 cords a day in the Lake States. The largest plant in New York State has eight ovens; it consumes 80 cords of wood per day and has an annual capacity of 24,000 cords.

Whereas the charcoal is emptied from the round retorts into round containers, sealed tightly to cause the slow cooling of the charcoal without admission of oxygen, the charcoal, after the heating process is completed in the oven retorts, is left in the cars and drawn into the first cooling oven and left for twenty-four hours. This is of the same type and construction as the charring oven. The cars containing charcoal are then drawn into second coolers, where they remain for twenty-four hours; then left in the open air forty-eight hours, so that there is a period of ninety-six hours which elapses between the time of the completion of the heating process and the time when the charcoal is loaded on the cars. It

Photograph by Nelson C. Brown.

FIG. 58.—Alley between first and second sets of cooling ovens, showing the character of doors and method of banking around the base. The trucks of charcoal are retained in each of these ovens about twenty-four hours.

must remain on the freight cars at least twelve hours before shipment, so that 108 hours elapse to the time of final shipment. This precaution is taken to prevent fire, which otherwise sometimes causes the loss of charcoal and cars in transit.

Distillation.

Although many changes have been introduced in the manner in which the wood is heated for distillation purposes, very few changes have been made within the last twenty years in the refining of the crude distillate.

In the modern oven retort operation the process requires from twenty-three to twenty-six hours for completion. When the wood is rolled in trucks into the ovens, the doors are hermetically sealed and the fires are started underneath. In from one to two hours the wood is sufficiently heated up so that water distillation takes place. This distillate contains about 2 per cent acid. Then the green gas comes free for about five to six hours.

It is considered desirable to heat up the wood gradually and also to let it cool off gradually at the end of the process. The exothermic process, that is, that part of the process in which the wood fibers break down under the intense heat, does not take place until the temperature is run up to about 300° F. In about six hours after closing the doors the temperature attains an average of about 450° F. It is then maintained between 450 and 600° F. Temperatures of over 600° F. are considered undesirable. After about six hours of heating the pyroligneous acid begins to flow, and the best average is maintained up to about the eighteenth hour. An operator can determine from the color of the pyroligneous acid whether there is too much heat maintained, and if the wood fibers have broken down sufficiently. At the end of the heating process, the distillate forms tar to a large extent. After the eighteenth hour the latent heat in the oven settings is sufficient to complete the process to the end, but the heat is gradually decreased until the charcoal is withdrawn.

As the gases and vapors pass out through the nozzle of the oven, they are condensed into a yellowish green, ill-smelling liquor called pyroligneous acid. A copper run takes this condensate to the raw liquor "sump," a tank in the ground and so placed that the liquor will run into it by gravity. Meanwhile, the "fixed" or non-condensible gas is trapped and taken off at the outlet of the condenser and used for fuel underneath the boilers or ovens or perhaps both. A simple gooseneck is used to trap off the gas.

The pyroligneous acid is next pumped from the "sump" in the ground to a series of wooden settling tubs, of which there should be at least five in number. These tubs are usually from 5 to 8 ft. in diameter and 6 to 8 ft. in height. The purpose of these tubs is to settle the tar and heavy oils. The heavy tar is taken to a wood tar still equipped with a copper condenser. This tar still is of wooden construction because the tar would "eat up" the copper in about a year. The residue remaining in the tar still is utilized together with residue from primary stills as boiler fuel.

The pyroligneous acid is then run by gravity to the primary steam-heated copper stills equipped with automatic feed in order to supply the still continuously. The residue or boiled tar, which gradually fills up in the still from the bottom, is distilled by itself and run off at intervals of a few days or whenever the deposit reduces the flow of distillate from the still. During this process, which is known as " tarring down," the distillate is run into a separate tank and the light oils which rise to the top are drawn off. The acid liquor is then piped to storage tanks or tubs with the regular run from this still. These copper stills are made in any size which will give them the most flexible operation, that is, the size is determined by the question of economy in operation in labor cost. This, in turn, depends upon the capacity of the plant in cords of wood. The vapors from the copper still are conveyed through a large copper neck to an all copper tubular condenser encased in a steel water jacket. The flow of distillate from these condensers is piped to storage tubs.

From the storage tubs the acid liquor goes to the liming or neutralizing tubs. These are wooden tubs 12 ft. to 14 ft. in diameter about 4 ft. high, and provided with an agitator operated by a shaft and bevel gear from the top. The liquor is neutralized by adding slaked lime, a small quantity at a time. The proper quantity of lime is commonly determined by the color of the liquor, which changes at the neutral point between an acid and alkaline substance to a wine color, followed by a straw color and the appearance of beads on the surface.

From the neutralizing tubs the liquor is pumped or forced by means of a steam ejector to the " lime lee " stills. These stills are constructed of steel plate, the heat being applied by copper steam coils. The alcohol vapors pass off through an iron or copper neck, and are condensed in a copper condenser, and piped to storage tanks.

When the alcohol has been distilled off in the lime lee stills, the residue or acetate solution is forced by steam or air pressure to a settling pan located over carbonizing ovens. After the impurities settle and are drawn off the acetate liquor is run into a large shallow steam-jacketed steel pan, and boiled down to the consistency of mortar; it is then shoveled out and spread on brick, steel or concrete kiln floors over the ovens and thoroughly turned and dried; it is then shoveled into sacks for shipment as acetate of lime.

The alcohol liquor from the lime lee still is drawn from the storage tanks previously mentioned into a steel alcohol still provided with copper steam coils, and distilled off through a copper fractionating column consisting of a series of baffling plates having a tubular water-cooled separator at the top. By this process the lower proof products are thrown back for further distillation, while the more volatile vapors pass over through a condenser, the distillate being sold to the refineries as finished crude alcohol of 82 per cent proof.

PLANT EQUIPMENT

The equipment of a modern hardwood distillation plant demands a comparatively large initial investment. They are usually located with reference to a large available supply of hardwoods which can be brought to the factory at a comparatively low cost per cord. From 10 to 40 acres are usually required for the plant and its adjoining storage yards and trackage facilities. The modern plant has from 2 to 8 oven retorts which are usually 52 ft. long and housed in a retort house; open space for two sets of cooling ovens; a shed for the cooling and shipping of charcoal, and the still house and power plant, which are usually separate from the retort house. Most of the modern wood distillation plants in New York cost from $50,000 to $500,000 for the initial investment.

Before the European War it was usually estimated that a complete plant aside from timber lands and the wood-yard would cost $2000 per cord of daily capacity. Since the war this average has risen to $2500 per cord. However, this may vary between about $2000 and $3000 per cord, depending upon the degree of completeness, cost of transportation, labor costs, character of the machinery and materials installed, etc. This means that an 8-oven plant with approximately an 80-cord daily capacity will cost in the neighborhood of $200,000. Using these same figures, the smallest modern oven plant with only 2 ovens, and with a daily capacity of 20 cords, will cost in the neighborhood of $50,000.

A plant with seven 25-ft. ovens built about 1902 cost in the neighborhood of $125,000 fully equipped.

The following is a brief description of the principal features of equipment that are usually found in the hardwood distillation plants:

Storage Yards.

The storage yards should be in the close vicinity of the retort house and connected with it by standard gauge tracks running through the stacks of piled cordwood. The storage yards should consist of between 5 and 20 acres, depending upon the capacity of the plant, and should be slightly raised in elevation above the retort house so that the loaded cars can be rolled easily into the ovens as needed.

Inasmuch as the wood must be seasoned for between one and two years, it is necessary to have a large, convenient and well-located wood yard so that there should be at least six months' seasoned supply on hand all the time.

At a 35-cord capacity plant it is planned to have 10,000 cords of wood as an advance supply continually on hand.

The wood is usually cut in 50-in. lengths and stacked in long piles up to 12 ft. in height on either side of the standard guage tracks from which the unseasoned wood is unloaded from freight cars. In other cases parallel roadways are left open for the wagons to unload directly from the woods. Parallel tracks between these roadways are then provided to load the wood cars for the ovens after seasoning. In cylindrical retort plants the wood is commonly rolled in on wheelbarrows or open trucks and loaded by hand.

Retort House.

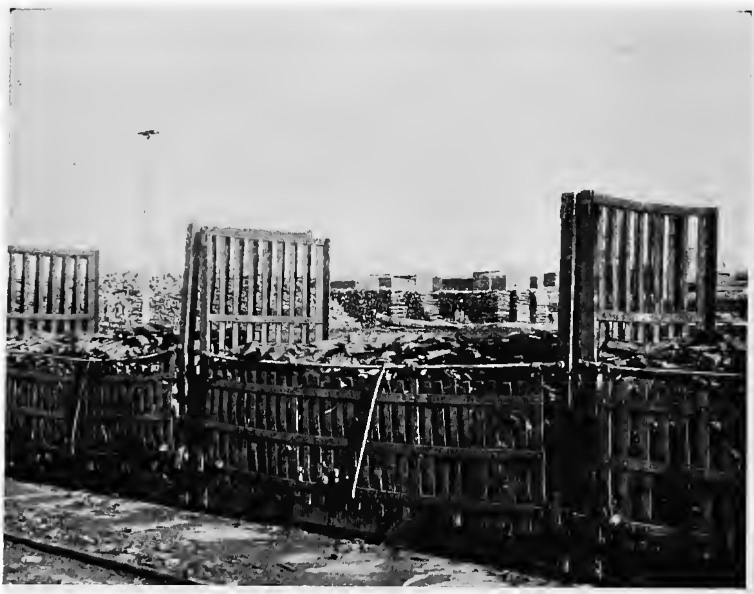
The retort house is the largest building in the plant. It houses the cylindrical retorts or oven retorts and, in some cases, the stills and appliances for treating the pyroligneous acid as well. However, in the most modern plants, the still house is a separate building.

The principal requisite of a retort house is that it should be of fireproof construction on account of the very inflammable nature of charcoal and wood alcohol. One retort house at a plant having a daily capacity of 38 cords is 60 ft. in width by 240 ft. long, 20 ft. high to the eaves and 40 ft. to the peak of the roof. Steel beams and supports are used throughout with sheet-iron roof and siding. Other retort houses are either built of stone or brick in order to reduce the fire hazard and, therefore, obtain low insurance rates. Many plants are poorly arranged because of their enlargements from rather modest beginnings, and no definite plan seems to have been followed in the arrangement of the plant.

Trackage and Cars.

The tracks are usually standard gauge with the rails from 40 to 75 lb. in weight, and are so arranged as to bring the wood from the storage yards to the retort house and then to conduct the cars loaded with charcoal through the two sets of cooling ovens and out to the charcoal shed, where the charcoal is loaded on freight cars. The most modern plants have the progressive arrangement, that is, the loaded cars come from the storage yards directly to the retort house; follow through in one continuous direction to the first cooling oven and then to the second and on out to the charcoal sheds, where the charcoal is shipped. The return tracks take the empty cars back to the storage yards, where they are reloaded and the same process followed out.

The cars are all of steel construction and hold from 2 to 2½ cords of 50-in. wood. A 50- to 54-ft. oven will hold four of these cars in one charge. A 25-ft. oven will hold two cars. They are built in different sizes, but the usual style of car is 52 in. wide, 6 ft. 6 in. high and 12 ft. 6 in. long with four small wheels. They first came into use about 1895 and have proven to be a great success.



Photograph by Nelson C. Brown

FIG. 59.—Cars or trucks loaded with charcoal after heating in ovens. Each truck contains about 2 cords of 50-in. billets of beech, birch and maple wood. Photograph taken at the Cummer-Diggins plant, Cadillac, Michigan.

The cars cost from $80 to $140 apiece, f.o.b. at Warren, Pa. They last indefinitely according to most of the operators, so that there is very little depreciation charge on them. Both sides of the car are detachable to facilitate the loading and emptying of the cars.

Retorts.

The old iron retort was a cylindrical vessel holding about five-eighths of a cord. The standard size was 50 in. in diameter by 9 ft. in length. Cordwood 48 in. in length was used instead of the 50 in. length commonly used in the oven retorts. The retorts are set in brickwork in pairs, each pair forming a battery and heated directly from beneath. They are charged and discharged from a single door in front which can be hermetically sealed. Considerable labor is involved in the charging and discharging of these retorts, and the ovens with the cars running directly into them on tracks are a great improvement. With the invention of the ovens in the early nineties very few of the old, round retorts were installed. In fact, all of the new plants being installed are equipped with the long oven retorts.

Ovens.

The oven or oven retort is a vast improvement over the round retort, the chief advantages being that a large amount of wood can be distilled at one time and considerable labor is saved in charging and discharging the ovens, the loaded wood cars being run directly in from one end on tracks and hauled out by means of a cable on the other end to the first cooling oven.

These ovens in cross-section are 6 ft. 3 in. wide and 8 ft. 4 in. high. In length they vary from 25 ft. to 50 ft., although the usual length used at the present time is a 52-ft. oven which holds 4 cars. These ovens are usually installed in batteries, that is, 2 ovens being placed close together and called a battery. In Michigan there are as many as 7 to 10 batteries in a single plant. The largest New York plant contains 8 ovens and is located at Corbett in Delaware County. Altogether in New York State there are 46 ovens distributed over 10 plants.

These ovens have air-tight doors on one or both ends, depending upon whether the charcoal is to be taken out in the same direction as it entered or sent out through the progressive form of trackage arrangement. The ovens are of steel, usually three-eighths of an inch in thickness, while the bottoms and backs are of $\frac{1}{2}$-in. material. The oven is sustained by means of angle irons riveted perpendicularly on the sides and on one side near the top are riveted cast-iron nozzles, usually two in number, which are attached to the condensers. In the heating process it is said that the 52-ft. oven will expand 4 in. in length due to the tremendous heat applied during distillation. These ovens last only from three to twelve years, so that the depreciation charge is very high.

The 52-ft. oven costs about $1800 apiece and approximately an equal amount is required to install and set it up ready for operation.

Cooling Ovens.

In every oven retort plant the charcoal is gradually cooled by being run into cooling ovens located immediately in front of the retort house in the open air. The first cooling oven is about 8 to 10 ft. from the charring oven and the second cooling oven about an equal distance beyond the first cooling oven. The accompanying photographs show the arrangement of the cooling ovens in relation to the retort house. The cooling ovens appear to be the same in size, shape and construction as are the ovens themselves. However, the sides are only of $\frac{3}{16}$-in. steel and usually there are doors at both ends. There are no bottoms to these cooling ovens as they rest directly on the ground. Dirt is piled around the base to prevent the admission of air.

The cars with the heated charcoal, after the distilling process, are rolled directly into the first cooling oven. As soon as the air is admitted on the opening of the doors, the charcoal bursts in flame and as soon as possible after the cars are rolled into the cooling oven the doors are hermetically sealed, so that the charcoal will cool slowly. The charcoal is left for twenty-four hours in the first cooling oven, twenty-four hours in the second cooling oven, then is left at least forty-eight hours in an open shed or in the open air, and after being loaded on the freight cars it is left standing for at least twelve hours before shipping. This means a total of one hundred and eight hours from the time of heating to the time of leaving the yard. A government regulation prescribes this procedure because " punky " knots hold fire for a long time in the charcoal and it is necessary that these extreme precautions be taken to prevent burning of the cars.

In some of the plants, an outlet pipe is used near the top of the cooling oven to permit the escape of the acid fumes. It is claimed by some that this saves the eating of the iron by these fumes.

Still House.

The provision for re-distilling the pyroligneous liquor is usually housed in the old plants along with the cylindrical retorts, but in the more modern oven plants the apparatus is placed in a separate fireproof building, usually in close proximity to the power-house or in connection with it.

The equipment of the still house consists principally of the settling tubs, neutralizing tubs, storage tubs, steam pans, copper and iron stills, condensers, fractionating column, etc., required for the three principal distillations previously described. Although the equipment in some small details may vary in each plant, the general process of separating the acetate of lime and the wood alcohol, as well as the wood tar, is the same as was in common practice about twenty years ago.

For each separate plant, however, individual plans are drawn up to meet the requirements of local conditions. Altogether it is estimated that the equipment of the still house costs between $430 and $500 per cord of daily capacity. In the description of processes of manufacture, the function of the various equipment in the still house is described.

FIG. 60.—Interior of the still house at a hardwood distillation plant in Pennsylvania.

The following is the usual equipment used or recommended for a hardwood distillation plant consuming 30 cords of wood per day:

Retort condensers including tubs and outlet connections, number and size depending upon style of retort or oven installed.

Copper liquor run for conducting raw liquor from condenser outlets to storage tub.

Copper gas main and connection for conducting wood gas from condenser outlets to boiler for fuel.

5 wooden settling tubs for raw liquor from storage tank above mentioned.

1 copper still complete with copper steam coils, neck and condenser for first distillation of raw liquor. Wooden storage tubs for liquor from copper still.

Wooden liming tub with power agitator for neutralizing liquor from storage tubs above mentioned.

1 iron lime lee still fitted with copper steam coils and condenser (an iron neck may be used on this still).

1 or 2 steel storage ranks for lime lee liquor.

1 steel alcohol still with copper steam coils, column, separator and condenser for producing 82 per cent crude alcohol from lime lee liquor above mentioned.

Steel storage tank and one large steel shipping tank for raw liquor. The residue from lime lee stills (acetate of lime) would be piped to the open steel settling tank and then to steam pan. The acetate of lime would then be shoveled from steam pan to drying floor on top of ovens if possible in order to utilize waste heat from ovens.

The use of a small wooden tar still with copper neck and condenser for distilling raw tar from settlers which contain a considerable quantity of alcohol is also recommended.

For refining the crude alcohol further one would require one steel still with copper steam coils, refining column, separator and condenser for first distillation; one steel still with copper steam coils, column of different type than used in first distillation including separator and cooler for second distillation. The alcohol in first and second distillation is treated with caustic soda. A steel tank graduated in inches or gallons should be provided for caustic soda storage and charging stills.

2 steel storage tanks would be required for each still each tank having the capacity equal to still.

An all: copper still with copper steam coils, refining column of special type, including separator, cooler, hydrometer jar, necks, etc., complete would be required for third distillation. The alcohol would be treated with sulphuric acid in this distillation. Suitable storage and shipping tanks which may be of steel to be provided for finished goods.

This latter outfit would produce commercial refined alcohol of 95 per cent to 97 per cent purity.

Drying Floor.

The drying floor is a flat, level space surfaced with cement or concrete usually placed over the ovens. The heat of the ovens furnishes the necessary temperature to dry out the acetate of lime. After being dried it is bagged up and shipped directly in freight cars.

Charcoal House.

The charcoal house is usually an open-constructed affair slightly elevated above the level of the oven house, so that the cars containing charcoal can be unloaded directly into box cars or into charcoal bins. The trucks containing charcoal must be left either in the open air or standing in the charcoal house at least forty-eight hours before the charcoal can be dumped into the box cars. Most of the charcoal is shipped in the loose state. Sometimes it is separated into as many as five grades, the finer product being bagged and shipped in sacks containing 25 or 50 lb. each. In all cases the charcoal house is well removed from the oven house to decrease the danger from fire. It is also well protected by means of hose, water pails, fire extinguishers, etc., to minimize the fire hazard.

Cost of Plant and Equipment.

As outlined before, the initial cost of a modern complete wood distillation plant is very large. It is estimated that, under present market conditions, an investment of $2500 should be provided for each cord of capacity. That is, if a plant is so designed to be of 50 cords capacity, the initial investment required would probably be about $125,000.

Before the great European War, it was generally estimated that a complete plant would cost about $2000 per cord of capacity. The difference in the above estimates is due to the fact that the cost of iron, steel, copper and other materials used in the manufacture of wood distillates has risen tremendously as a result of the competition to better conditions in this country, together with a demand for supplies from European countries.

The old-fashioned cylindrical retort plant is much less expensive for the initial expense, but the heavy charges due to labor result in excessive operating charges. A 24-round retort plant, that is, one containing a battery of 12 pairs with each pair of retorts holding about $1\frac{3}{8}$ cords, costs $75,000 for the entire plant.

When it is figured that the modern plant costs $2500 per cord of capacity, it is estimated that one-third of this charge is for building, while the apparatus costs about two-thirds.

PLANT OPERATION

The following are the principal features of plant operation. Each is briefly described, giving the principal commercial features involved, such as costs, per cord charges, and other commercial features involved in the operation of a wood distillation plant.

Altogether there are six forms of fuel commonly used in the hardwood distillation industry. They are as follows: Coal, natural gas, charcoal, wood, wood tar and wood gas. Altogether coal is most commonly used. In the district centering around Olean, New York, many of the plants use natural gas. Most of the plants in the Olean district, however, are just over the New York line in Pennsylvania. Both hard and soft coal are commonly used for the purposes of direct heating and the production of steam. Practically all plants use the wood tar and wood gas, which are products of the distillation process, directly under the ovens or retorts or under the boilers.

The estimates regarding the cost of fuel vary considerably. Altogether estimates were received from $1.15 to $2.00 per cord. The cost will naturally vary with the kind of fuel used, the distance from source of supply, efficiency of boilers and steam pipes and other correlated factors. In one of the larger plants of the state which has seven 25-ft. ovens, it was estimated that 300 bu. of charcoal, 300 gal. of wood tar and all of the available wood gas were used for each charge of seven ovens. At a prominent plant in New York it was estimated that 300 lb. of soft bituminous coal were used for the distillation of 1 cord of wood. In an oven containing 10 cords, therefore, this would require 3000 lb. of soft coal for one charge. It is estimated that the fuel value of wood tar is at least twice as much as that of coal for a given weight

Labor.

Labor is a very important item in the cost of production. Altogether the labor is unskilled at all of the plants with the exception of the plant superintendent or manager, and, in the case of the largest plants, there is a chemist or expert engineer employed who receives more than the ordinary day wages. There is a distinct tendency to raise wages at the various plants. During 1916 these varied between $1.50 per day to $1.60 at one plant up to $2.00 per day at others. All plants, of course, run night and day, but there is a very small force engaged in the work during the night time. At most of the plants there is a given piece of work to be done each day and when this is completed the men are free for the rest of the time. For instance, in the wood yard, the day's work may consist of loading so many cars of wood. When this particular work is completed, the men are through for the day.

Altogether the larger the plant the greater is the economy in labor, The greatest saving in labor in the development of the industry has been the change from the old round retort plant to the modern oven plant. Owing to the fact that the trucks are pulled in and out of the oven by means of a power cable, there is a great saving in labor over the old round retort plants where the retorts had to be loaded and discharged by hand.

At a 4-oven plant having a capacity of 40 cords per day, there were the following employees:

2 firemen at the boilers.
2 men in the still house.

2 firemen for the ovens.
4 men in the dry kiln.
4 men to charge and draw trucks or cars.
1 extra man about the piping.
2 men in the wood yard handling wood.
1 foreman.

This makes a total of 18 men on the 24-hour shift, that is, there are 13 men on during the day and 5 during the night. This list does not include the teamsters used in drawing the wood from the chopping area to the storage yards.

At a 2-oven plant there were 12 men employed beside the superintendent. All of these men were common labor paid in 1916 at the rate of $1.50 per day. The firemen were on eight-hour shifts and all others were on ten-hour shifts. The following shows the number of men required on this particular operation:

2 still house men, 1 on the night and the other on the day shift.
2 kiln men, 1 on the night and 1 on the day shift.
3 firemen in eight-hour shifts each.
3 oven men to load wood on cars or coal screener.
3 extra handy men.

The labor cost per cord varies very much. In two plants the costs were $1.15 and $1.18 per cord, respectively. At other plants the labor cost is sometimes as high as $1.50 to $1.70 per cord. The labor charge is considerably higher, of course, in the cylindrical retort plants than in the oven plants due to the reasons given above.

Depreciation Charges.

Owing to the intense heat required to distill the wood, and the acid nature of the products, depreciation charges on the ovens, retorts, cars and distilling apparatus are very heavy. Ovens usually last only from three to twelve years. The coolers last much longer as a rule, and the wood cars last from twelve to twenty years. Altogether a depreciation charge of from 50 cents to $1.00 per cord is customary at most of the plants. However, the usual charge is likely to be nearer $1.00 than the lower figure.

The life of the copper apparatus is about ten to twelve years and there is considerable salvage on old copper.

Cost of Operation.

The cost of operation depends on a large number of factors, the chief of which are the charges for wood, fuel and labor. Transportation charges for material such as fuel, supplies, etc., are also an important consideration.

It is very difficult to say what the average costs of operation should be. They are usually figured or based on the charges per cord. At the various plants, the method of cost computation varies considerably, so that it is very difficult to compare one with another. The degree of efficiency also varies considerably, so it is very difficult in this respect to compare them. At an oven retort plant that has been run for several years, the costs per cord in 1916 were figured as follows:

Wood	$4.00
Labor	1.50
Fuel	1.77
Lime	.19
Supplies, oils, etc	.32
General expenses	.51
Depreciation	.58
Insurance	.08
Taxes	.22
Total	$9.17

The above computation was based on a month's run and a very careful record was kept of all costs. There were 16 men employed at this factory, not including the men engaged in cutting and hauling the wood, nor the office force. The standard wage scale was $1.60 per day and the factory was located in the region in which a plentiful supply of wood could be obtained.

At another oven plant the following costs were observed. These are also given per cord of wood:

Wood	$4.00
Fuel	1.50
Labor	2.00
Depreciation, etc	1.00
Marketing	1.47
Total	$9.97

Yields.

The yield of products at hardwood distillation plants varies considerably. The yield at any particular plant depends upon the following factors:

1. Temperature, that is, the maximum and minimum temperatures used during the exothermic process.

2. The rapidity of heating. Too rapid heating will cause a much smaller and lower grade of product. Usually about ten hours is the time required to get wood up to the highest temperatures. If heating is done too rapidly the color of the pyroligneous acid is much darker and the yields are consequently much lower.

3. The species of wood. There is a general consensus of opinion among the New York plants that maple is the best wood with beech next and birch third. Oak and hickory are also desirable species, but if there is too much soft maple, basswood, poplar, gray birch or other inferior species, the yields will be lowered.

4. The condition of the wood. It is generally assumed that the dryer and more thoroughly the wood is seasoned, the better will be the product. It is also true that heartwood yields much larger and better products than sapwood, and body wood is much more desirable than limb wood.

5. Efficiency of the plant. This is determined by the character of the machinery and equipment, arrangement of the apparatus and many other factors connected with the efficiency of an operation.

The products of hardwood distillation are as follows: Wood alcohol, acetate of lime, charcoal, wood tar and wood gas. The latter two are practically always used as fuel under the boilers or retorts.

From an investigation of the 25 plants in New York State it was determined that an average yield of 42.7 bu. of charcoal are obtained per cord of wood from all of the plants. There was a maximum yield of 50 bu. of charcoal per cord and a minimum yield of 38 bu.

The average estimated yield of acetate of lime was 199.47 lb. per cord of wood. The minimum was 171 lb. and the maximum 220 lb.

In wood alcohol the average yield was 9.9 gal. of 82 per cent wood alcohol per cord of wood. The minimum was 8 gal. and the maximum 11 gal. per cord.

It is estimated that between 23 and 28 gal. of wood tar are secured per cord with an average of about 25 gal. It is estimated that about 11,500 cu. ft. of gas are secured per cord of wood.

These figures are based upon the individual estimates of the various wood distillation plants of the state. Altogether much better yields are secured from the oven plants than from the cylindrical retort plants.

Value of Products.

One of the greatest drawbacks to engaging in the wood distillation business has been the great fluctuation in the price levels for all of the principal products, namely, acetate of lime, wood alcohol and charcoal.

In the early days of the industry charcoal was the principal product, and it brought from 10 to 20 cents a bushel or more. Then acetate of lime became the principal product sought after and finally the wood alcohol. Before the Federal legislation, the profits were excellent and attractive, but since 1907 and up to the outbreak of the great European War on August 1, 1914, price levels were very uncertain and several of the concerns were driven out of business.

Up to the time of this war the prices obtained for acetate of lime varied between $1.25 to $2.00 per hundred pounds. Since August 1, 1914, the following price levels have been obtained:

August to October, 1914	$1.50 per 100 lb.
November, 1914	1.75 per 100 lb.
December, 1914	2.00 per 100 lb.
January, 1915	2.00 per 100 lb.
February to May, 1915	2.50 per 100 lb.
June to August, 1915	3.50 per 100 lb.
September to October, 1915	4.00 per 100 lb.
November to December, 1915	5.00 per 100 lb.
January, 1916	6.00 per 100 lb.
February to August, 1916	7.00 per 100 lb.
September, 1916	5.00 per 100 lb.
October, 1916	3.50 per 100 lb.

In regard to wood alcohol, the prices have also fluctuated considerably. Quotations varied between 30 cents and 45 cents per gal. for the crude 82 per cent alcohol. Since the outbreak of the war, however, the use of both wood alcohol and acetate of lime have been greatly stimulated for their use in the manufacture of certain war munitions and the prices have steadily advanced.

During the year 1914 the market price of 82 per cent crude wood alcohol was 25 cents per gallon delivered to the refineries in tank cars and the price of 95 per cent refined delivered to buyers in free wooden barrels to points east of the Mississippi River, 45 cents per gallon for 1 to 10 bbl. lots and a small discount in carloads. Prices held at these figures until October, 1915, when the price of 95 per cent refined good alcohol began to advance first to 50 cents, later to 55 cents, then on

February of 1916 to 65 cents and on October 1, 1916, to 70 cents. These advances were made possible by the rapid increase in the price of denatured alcohol, this material now being 60 cents per gallon. There is every indication that the price of both alcohols has gone sufficiently high for some time to come. In the spring of 1916, 97 per cent refined alcohol brought 70 cents per gallon. Methyl acetone was worth 90 to 95 cents per gallon and pure methyl or columbian methanol was worth $1.00 a gallon.

With the increased use of both acetate of lime and wood alcohol, the demand for charcoal has not kept pace with these other two products, and consequently prices have suffered very materially. In 1917 charcoal was only bringing around 5 to 6 cents per bushel. In 1914 it was bringing 7 cents a bushel wholesale at the acid factory. The estimated production of charcoal in this country before the war broke out was about 5,000,000 bu. a month and the iron furnaces took by far the greatest proportion of this.

Practically all of the products of the wood distillation industry are sold wholesale in carload lots at the factory. The wood alcohol is shipped in tank cars or in tight barrels. Charcoal is shipped in sacks and the acetate of lime is also shipped in sacks or bags. Up to the present time no regular market has been developed either for the wood gas or wood tar. Both of these are usually now consumed as fuel underneath the retorts. It is very likely that some time in the future a definite market will be developed for the utilization of wood oils and wood tar. It can be made into creosote, but the process is so expensive that this form cannot compete successfully with coal-tar creosotes.

The following table shows a comparison of values of products per cord under conditions prevailing in 1914, and those occurring in 1916. This table is based upon the average of yields of acetate of lime, wood alcohol and charcoal per cord. The values are those described before. The table shows that the operators were receiving more than twice as much for their products under market conditions in the spring of 1916 as they did under those prevailing before the war:

	Yield per Cord.	Value per Unit, 1916.	Value per Cord, 1916.	Value per Unit, 1914.	Value per Cord, 1914.
Acetate of lime.....	199.47 lbs.	$.07	$13.97	$1.7	$3.39
Wood alcohol......	9.9 gals.	.37	3.66	.25	2.48
Charcoal..........	47.7 bu.	.6	2.86	.7	3.34
			$20.49		$9.21

UTILIZATION OF PRODUCTS

The utilization of the products of the hardwood distillation industry has been a great problem, especially since the Federal law of 1907 went into effect. The greatest money return is received from disposal of the acetate of lime, and the prices received for this product have undergone great fluctuation.

Altogether there are three primary products derived from the process, namely, the raw pyroligneous acid, the wood gas and the charcoal which remains as a residue from the distillation of the wood. The secondary

FIG. 61.—Acetate of lime drying over the retorts in the oven house at a large plant at Betula, Pennsylvania.

products as a result of the separation of the tar from the pyroligneous acid and the further distillation of the pyroligneous acid are, first, wood tar, second, acetate of lime, and third, wood alcohol.

The utilization of the five derived products of this industry, therefore, are described as follows: Acetate of lime, wood alcohol, charcoal, wood tar and wood gas.

Acetate of Lime.

It is estimated that approximately 100,000 long tons of acetate of lime are produced every year in this country. Under normal conditions, that is, before August, 1914, only about 75,000 long tons were produced.

Under normal conditions the export and domestic consumption of acetate of lime about equaled each other. Now this product is chiefly consumed in this country.

Probably 75 per cent of the acetate of lime produced in this country is used as the raw material for the acetic acid industry. More recently, there has been a heavy demand for the use of acetate of lime as a source of acetone. About 100 lb. of 80 per cent acetate of lime are equivalent to 50 to 60 lb. of refined acetic acid or 20 lb. of acetone. Acetic acid is used chiefly for the manufacture of white lead acetone in the textile and leather industries and in a great variety of other commercial manufactures. One of the most important present uses is in the manufacture of cordite and lyddite, two high explosives. Acetone is also used largely as a solvent for the cutting of gun cotton and in the manufacture of smokeless powder.

In many of the European countries, acetic acid or wood vinegar is a common product on the market. However, the manufacture of wood vinegar from acetic acid is prohibited in this country.

Wood Alcohol.

It is estimated that between 10,000,000 and 11,000,000 gal. of wood alcohol are produced every year in this country. Its greatest single use is as a solvent. Probably 90 per cent of all the wood alcohol used is for this purpose in one way or another. Its greatest consumption is probably in the paint and varnish industry, in which about 35 to 50 per cent is utilized.

Practically no wood alcohol is used in the raw 82 per cent state. It is all refined to a higher state of purity before being utilized. One concern refines a good share of the total product of the country.

Wood alcohol is used very largely in aniline dye factories to make colors, especially greens, purples and light blues. It is also used in the manufacture of formaldehyde, photographic films and in stiffening hats.

Refined wood alcohol of high purity or methyl alcohol, that is, of 99 to 100 per cent purity, is sold under a great variety of trade names, such as columbian methanol, colonial methyl, diamond methyl, etc. As an extraction agent wood alcohol is used in the manufacture of smokeless powder, nitrocellulose and other explosives. Gun cotton, for example, is freed from cellulose nitrates by extraction with wood alcohol.

Other common uses are as follows: As fuel, as an illuminant, as a denaturant and in various chemical and medicinal preparations.

Charcoal.

Until about 1905 the great market for charcoal was in the reduction of iron ores. Important methods of steel production within recent years, however, have gradually eliminated the strong demand for charcoal for this particular purpose. Charcoal iron or Swedish iron, as it is often called in the trade, is still in demand for certain specialized uses, especially for high-grade steel used for tools, instruments, car wheels, etc. Pig iron reduced with charcoal commonly brings $5.00 a ton more than coke iron. A single blast furnace uses between 10,000 and 12,000 bu. of charcoal a day. Where there are from 5 to 10 blasting furnaces at a single ore-reduction plant, it is easily seen that the consumption of charcoal may be very large. A great many of the hardwood distillation plants in Michigan and Wisconsin have ore-reducing plants in connection with them. These are the conditions under which the greatest economy in charcoal utilization is practiced. Much of the charcoal for these plants, however, is made by the open-pit or bee-hive kiln as well as by the oven plants. An investigation carried on by the U. S. Forest Service showed the consumption of charcoal in this country to be as follows: 76 per cent went to blast furnaces; 19.5 per cent is utilized in domestic uses; 1.9 per cent is used for chemical purposes; 1.03 per cent is used for powder mills and the remainder went to smelters, railroads, etc. However, replies from only 60 per cent of the plants were received, so that it is not likely that a large number of plants throughout New York and Pennsylvania are properly represented by this estimate.

Charcoal from the New York plants is probably used in a greater variety of ways than from those in other states. There is no question but that the major portion of charcoal produced in this country is still used in blast furnaces and for the manufacture of gunpowder.

One New York plant screens it and ships it in five different grades. When the charcoal is shipped, it is screened to remove the finer pieces. This is ground up in some cases and pressed into briquettes and used for fuel. Other common uses for charcoal are for medicinal purposes, for poultry and cattle food, in chemical manufacture and for fuel in a great variety of ways.

Wood Tar.

At the present time practically all of the wood tar is used for fuel under the ovens or boilers. Throughout the country it is estimated that between 30,000,000 and 40,000,000 gal. of wood tar are used in this way. In some cases, prices of between 4 and 8½ cents have been received per gallon for the use of this material in chemical manufactures, but its use is very limited. It is believed that sometime in the future a method will be found for using this wood tar as a basis of creosote on a commercial scale. A good share of our creosote at the present time is made from coal tar and a large part of it is imported. There is no question that sometime in the future this material will be used for the preservation of wooden material, such as ties, poles, mine timber, etc.

Wood Gas.

Wood gas is used entirely as a fuel underneath the ovens at the present time. In some localities in Germany and Austria wood gas has been used for illuminating purposes, and it is very possible that at some time in the future this may be used for a much more economical purpose than as a fuel underneath the ovens. This, however, is looking a long way in advance and it is probable that for some time at least it will continue to serve the purpose of fuel along with the wood tar and coal or other fuel brought in to supply the necessary amount of heat.

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CHAPTER IX

SOFTWOOD DISTILLATION

GENERAL

THE distillation of softwoods in this country is an outgrowth of the hardwood distillation industry as developed in its earlier days in New York and Pennsylvania.[1] Owing to the radically different kind of woods available in the South, consisting largely of pines of a highly resinous nature, a different process than that evolved for the dense hardwoods of the North was found necessary.

The distillation of softwoods has not developed to the extent that has been the case with the northern hardwoods. Two distinct methods of distillation have been evolved, namely, destructive or dry distillation and steam distillation with its later development called the extraction or solvent process. The industry is still in its infancy, however, since no standard method of production has been generally adopted as has been the case with the hardwood distillation industry, and each plant follows a method which is usually quite different from that of the others.

There are great possibilities in this industry, however, for the utilization of wood products which otherwise are wasted. At a meeting of the American Society of Chemical Engineers in Baltimore in 1916, Mr. Arthur D. Little expressed a very apt viewpoint of the industry:

> When the real work of wood waste utilization has once begun and attention of chemical engineers and financial men has been drawn more generally to the huge potential values now ignorantly thrown away, we may expect the rapid development of these by-product industries and an initiation of many new ones to the great enrichment of the South and in somewhat less degree that of the Northwest.

The crude beginnings of softwood distillation were not in common use in the South until about 1885, but it was not until about 1905 that any marked improvements had been made in solving even some of the elementary problems in the industry. At the present time there is a vast

[1] See Chapter on Hardwood Distillation. For details regarding Process of Dry Distillation, also consult same chapter.

amount of work and an unusually large opportunity for the skilled wood chemist and engineer to develop a satisfactory solution to the many problems. The material collected and made available up to the present time on the industry illustrates what not to do rather than what should be followed. The industry is characterized by a great number of commercial failures due to fluctuations in market conditions and mistakes in both chemical and commercial aspects.

The first improvement in the industry was the introduction of iron retorts to replace the open-air charcoal pit. This improvement made possible the recovery of turpentine, a little of the pine oils, considerable tar oil, creosote oil, pitch and pyroligneous acid in addition to the tar and charcoal which were the only products of the old-fashioned charcoal pits. The quality of these products was exceedingly poor and there was but little demand for them during the earlier days of the industry. The turpentine was of exceedingly poor quality but could be further refined at some expense. The tar product was in less favor than the product from the kilns and could be marketed only at a rather low price. The market for charcoal was also poor and considerable quantities of it were used to fire the retorts. The gas product was also used directly for fuel. The pitch, if no market existed, was disposed of in accordance with the ingenuity of the producer. It was sold in the solution of tar oils or creosote oils or even sold as tar. The solutions gradually grew to a large number and were marketed as oils, paints, insecticides, disinfectants, medicinal products, etc., under a large variety of trade names.

Many improvements have been made in the retort process within the past two or three decades, until at the present time a high grade of turpentine and tars much superior to the kiln tars are produced. Practically the only commercial success has been attained by the manufacturer who has developed a special ability to market his products, particularly the oils, as specialties under established trade names. This practice tended to decrease the keen competition which heretofore had been very destructive to the successful marketing of the products. The production of acetate of lime from the pyroligneous acid is a still more recent development and was made possible through the increased demand for acetones. During the war acetate of lime commanded a price as high as 7 cents per pound and its production was greatly stimulated. After the war, the price, however, dropped to about 2 cents per pound.

Up to a comparatively recent date it is doubtful whether the greater measure of success is to be attributed to the chemical engineer in charge of the individual plant or the ability of the manufacturer as a business man to anticipate the demand and to develop a special market for his products, which are sold to a large extent as specialties. At the present time there is a gradually increasing belief among chemical engineers that the destructive method of distillation is wrong to a large extent in its fundamental principles. This belief has caused the development of many new processes. However, the plants operating by the destructive method have been and are still operating on a commercial basis, whereas, those based upon the distillation of steam and, to a less extent, those using extraction by solvent baths, have largely failed to survive the fluctuating market conditions. Many of the failures are no doubt due to the lack of real knowledge of the possibilities of each system followed, a lack of knowledge of the market possibilities and the failure to keep accurate cost data.

With the development of the softwood distillation industry, there has been a gradual sorting out of the species which can be profitably utilized on a commerical scale. The principal requirement is that the wood be sufficiently rich in resin and that there be as much " lightwood " as possible. Lightwood generally consists of stumps and logs after the bark and sapwood have rotted off and is characterized by high resin content. Longleaf pine is the most satisfactory species used and is the same tree which is tapped for rosin and spirits of turpentine as described in the Chapter on Naval Stores. Cuban (*Pinus heterophylla*) and shortleaf (*Pinus echinata*) pines are also used, but only to a limited extent. Several experimental and commercial plants have been constructed to utilize Norway pine in the Lake States and Douglas fir and western yellow pine and larch in the West. These have generally proven unsatisfactory, however, for general commercial development because the low average resin content, the comparatively high cost of obtaining the raw material, and the fluctuations in the values for the products did not permit a sufficient latitude for profitable development. Many of the experiments on these woods have been tried out with specially selected specimens and although these experiments have in some cases proven that the products could be extracted on a commercially profitable basis, in actual practice on large operations it has been impossible to secure a sufficient quantity of wood of equally high resinous or " fatty " constituents.

DESTRUCTIVE DISTILLATION

The destructive distillation of resinous woods is carried out at the present time chiefly in the South along the South Atlantic and Gulf

Coasts. In this region there is a comparatively plentiful and cheap supply of raw material, such as longleaf, Cuban and shortleaf pines. The process briefly consists of heating the wood in retorts in the absence of air and the condensation of the gaseous products as has been described in connection with the hardwood distillation industry.

Retorts of cylindrical shape containing from one to four cords are used. They are usually placed in horizontal fashion in rows or batteries over a bricked-up furnace. The fire-box may be arranged to heat either one or two retorts. The wood is charged and drawn from doors at either one or both ends of the retort. Within the past few years, cars loaded with wood and run directly into long ovens, as has been described in the case of the hardwood distillation industry, have been used to a limited extent.

Photograph by U. S. Forest Service.

Fig. 62.—General view of destructive distillation plant of the Pine Products Co., in Georgia. This plant uses longleaf yellow pine. The retorts are loaded with the wood shown in the foreground. In the rear are the stills, settling and storage tanks, etc.

The distillation process usually requires about twenty-four hours as is true of the hardwoods. The furnace fires are then drawn and the charcoal allowed to cool for twenty-four hours. The gases are condensed through copper condensers and the usual products are, aside from charcoal and the non-condensing gases, light oils, tar and pyroligneous acid. The yields are generally about 7–10 gal. of refined wood turpentine, $1\frac{1}{2}$ gal. of pine oil, 50 gal. of tar, and 800 to 900 lb. of charcoal per cord of fat pine weighing about 4000 lb. Light oils and tar are very complex and are usually separated into a variety of products depending upon the current market conditions. Very little has been done commercially in this field, however, and a great opportunity exists for further investigation and research. The light oils are obtained in two fractions, the one containing turpentine being condensed from a low temperature in separate tanks. In some plants the volatile products are mixed in one condenser. The pyroligneous acid contains the same ingredients as has been described in the case of hardwoods, but in such small amounts that it is not commercially profitable to refine it further, and it is usually allowed to run to waste. The tar is refined to produce oils and a good grade of retort tar may be sold in its original state. The turpentine is of good color, but has a characteristic odor, and is considered somewhat inferior to the spirits of turpentine secured by tapping the trees as described in the Chapter on Naval Stores.

It is impossible to state the average costs involved or to even approximate an estimate of the number of men employed, kinds of equipment used, etc., because each plant differs from the other and the standardization in this industry is probably less than can be found in almost any other. Lightwood is generally secured at about \$3.00 to \$4.75 per cord f.o.b. plant.

At one of the most important dry distillation plants in the Southeast the following production was secured. This is based on a six-months' run in which 8690 cords of longleaf pine were utilized. Each cord (128 cu. ft.) of lightwood weighed between 3500 and 4000 lb.

PRODUCTION BY THE DRY DISTILLATION SYSTEM

Products.	Number of Gallons per Cord of Wood.
Turpentine	7
Pine oil	2
Tar oils	32
Tar and pitch	41
Total	82

In addition to the above products, 39 bu. of charcoal were secured from each cord, on an average.

The prices secured for the products of dry distillation are shown as follows: They are given f.o.b. plant for the month of May for both 1914 and 1919.

PRICES OF DRY DISTILLATION PRODUCTS

Products.	Unit.	Value May, 1914.	Value May, 1919.
Turpentine	Gallon	$.33	$.60
Pine oil	Gallon	.30	.65
Tar oils, refined	Gallon	.18	.35
Tar oils, crude	Gallon	.12	.24
Tar	Barrel	8.00	12.00
Pitch	Pound	.015	.03
Charcoal	Bushel	.09	.17
Pyroligneous acid	Gallon	.02	.02

The cost of production at one prominent plant in the South was estimated to be about $15.00 per cord in 1914 and since that date the cost gradually increased up to about $30.00 per cord or an advance of 100 per cent. At this plant good lightwood was secured for $3.50 per cord in 1914 whereas $7.50 was paid per cord in 1919. The wood is always paid for on the basis of weight, it being obvious that the heaviest dry wood contains the most fatty constituents. The depreciation charges on these plants are exceedingly heavy because the expensive metal retorts burn out in about four to five years. Taxes, labor, repairs, supplies and equipment as well as the cost of wood have advanced in price considerably since 1914.

STEAM DISTILLATION AND EXTRACTION

The introduction of steam distillation and extraction has been much more recent than distillation by the destructive process.

The woods used for this branch of the industry are the same as have been described for the destructive process. The wood is "hogged" or reduced to small chips as in the case of reducing the wood for making paper pulp by the sulphite process. In some plants sawdust is also used. In the steaming process the chips are placed in vertical or horizontal retorts which are equipped with steam coils so that the wood can be reduced by live steam. The chips are steamed for three to four hours from low-pressure boilers, during which time the turpentine and pine oils are largely removed. The steam and oil fibers pass into a condenser and then into a separator, the oils and crude turpentine rising to the top and it is thus easily removed. After steaming, the chips are subjected to a vacuum to dry them.

In the extraction or solvent process a solvent such as naphtha, benzol, gasoline, etc., is admitted to the retort and heated to boiling temperature by the steam coils. This solvent removes the rosin from the wood. The extracted chips after being freed of rosin as well as the petroleum solvents are discharged through a trap in the bottom of the retort and sent to the boiler house, where they are used for fuel for power and steam.

The products, therefore, of this form of distillation are crude turpentine, a yellow oil consisting of wood turpentine, and pine oil. This crude turpentine, if properly refined, produces a colorless uniform quality fluid which is very similar to the standard spirits of turpentine. The rosin, however, is of comparatively low grade and does not command the same price as that derived from the tapping of the trees.

The length of time required for the extraction by steam distillation is ordinarily about twelve hours. One plant in the South which has a capacity of 20 cords for each charge requires from 12 to 20 men to operate and the initial cost of equipment is said to be from $1000 to $3000 per cord of capacity. The yields vary directly with the character of the wood used. In one plant from a continuous run of 711 cords there were secured an average of 815 lb. of rosin, 11 lb. of turpentine and 4 gal. of pine oil per cord. By the spring of 1919, practically all the plants using the steam process had gone out of existence.

The so-called bath process is a form of steam distillation. A non-volatile pitch or rosin is heated to the boiling-point and circulated through the wood in the retorts. The turpentine and oils in the wood are liberated by this heat and mixture with the bath. The oils and turpentine are recovered separately and the bath used again. This process has not developed under market conditions which would thoroughly justify its general commercial use; the alkali process or one similar to it has been very optimistically spoken of and by some it is predicted that it will ultimately solve the problems of softwood distillation. The process combines the recovery of the resinous parts of the wood with the production of wood pulp. In the disintegration through the cooking for pulp the volatile oils are liberated and recovered from the digester. The rosin may be recovered as sizing or as rosin oils. The process is still in the earlier stages of development but appears to have an important prospect for the future. Palmer, in his "Distillation of Resinous Woods," has shown the following experimental yields from the various kinds of wood used in both the destructive and steam distillation processes based upon an average cord of raw wood material weighing about 4000 lb.:

Distillation Method.	Species.	Turpentine, Gallons.	Pine Oils, Gallons.	Rosin, Pounds.	Tar, Gallons.	Charcoal, Bushels.
Destructive distillation	Southern pine	(Ref.) 7–12	50–75	....	40–60	25–35
	Douglas fir	(Crude) 1–2	0.75	....	....	27
Steam distillation and extraction	Southern pine	(Ref.) 10–15	1–5	500–600		
	Norway pine	8	2	350–450		
	Douglas fir	1½	½	70–80		
	Western yellow pine	12	3	Not determined		
	Western yellow pine (mill waste)	(Crude) 1½		Not determined		
Steam distillation......	Mill waste	(Ref.) 2–4	½			

UTILIZATION OF PRODUCTS

The wood turpentine secured from the destructive process of softwood distillation is generally classed in the markets as inferior to gum turpentine chiefly because of its peculiar odor. The wood turpentine derived from steam distillation is of more uniform quality and better flavored than the product from destructive distillation. Both are sold at a small discount below the price secured for gum turpentine and are used mostly in the paint industry for varnishes and paints, particularly for paints used on exterior portions of structures.

Tar oils are the combination of heavy oils from the tar and heavy oils from the crude turpentine. These are chiefly used as disinfectants, paint driers and a great variety of chemical and medicinal commodities. The lighter oils contain the wood tar creosote.

The principal use of the tar oils is for flotation oils used in the recovery of copper, zinc and silver.

The tar after removal of the light and heavy oils is used largely in the shipping and building industries.

Charcoal is used in the same way as hardwood charcoal, that is, in iron furnaces in the manufacture of gunpowder, as a filtrant and purifier, and for chicken and stock food, etc. It is also widely used as a fuel in the distillation plants themselves and for domestic purposes in the localities where it is produced.

Rosin is refined and used in many industries, especially in the production of linoleums, varnishes, soaps, printing inks, foundry work, and for sizing in the manufacture of paper.

The pyroligneous acid is usually sold in crude form as a disinfectant and to the dye trade for special dyeing purposes. If the market conditions justify, it may be further refined for manufacture into wood alcohol and acetate of lime as described in connection with the hardwood distillation industry.

FUTURE OF INDUSTRY

The present conditions obtaining in the softwood distillation industry do not hold out a large measure of promise for the future. With but one or two principal products the manufacturer is largely at the mercy of the market, which has fluctuated very widely in the past. A plan whereby the production of distillates will not be the entire purpose of the manufacturer should accrue to the benefit of the industry at large. After a careful survey of successes and failures up to the present time, experts interested in the improvement of the industry are generally agreed that this principle is a sound one. According to John E. Teeple, in a given 5000 lb. of rich fat lightwood stumps, there is about 20 per cent or 1000 lb. of rosin, 40 gal. of turpentine and pine oil, and 750 lb. of water. This leaves about 3000 lb. of wood fiber. By destructive distillation of the above sample the manufacturer may derive all of the turpentine, but only a small portion of the pine oils before the disintegration of the rosin and wood. These oils are valuable and no satisfactory method exists at the present time of extracting them from the decomposed products.

It is believed that a combination of the softwood distillation industry and the paper industry can be brought about to profitable commercial advantage. The present method of steam distillation leaves the fiber of the residue unchanged. It is possible to operate these plants successfully if the minimum price for turpentine is not less than 50 cents per gallon and for rosin $5.00 per barrel. At the introduction of the solvent method it was believed that prices would not reach the minimum levels again, but in January, 1916, rosin was selling at $3.00 per barrel and turpentine at only 38 cents per gallon.

The 3000 lb. of fiber mentioned in Teeple's experiment contains a certain proportion of bark, but may make about 1500 lb. of wood pulp. This pulp is not satisfactory to use in the manufacture of white papers, but experiments conducted by the U. S. Forest Service have indicated that it will produce an excellent quality of kraft paper. A combination of a process removing all of the distillate products from the wood and another making use of the 3000 lb. of wood fiber for pulp should be the most satisfactory and profitable utilization of the original material. The solution of this problem, therefore, is very likely to be the combination of distillation with paper-making under the direction of competent business men and chemical engineers.

A factor which will be very important in the solution of the problems of the industry along these lines is the possibility of clearing land in the South. A plant may be so located that it can secure sufficient raw material from the surrounding region, the land may be cleared for agriculture and thus enhance its value, and a paper pulp factory established to operate in connection with the distillation plant.

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CHAPTER X

CHARCOAL

GENERAL

CHARCOAL is charred wood as the result of partial or incomplete combustion. Its manufacture in the past consisted usually in carbonizing wood in open-air pits. The wood is usually placed in large piles of various forms and charred, or it may be the residue from the distillation of wood in closed retorts. For many centuries charcoal has been used as the principal domestic fuel, particularly in countries like Italy, Spain and France, where there is a shortage of coal. During the middle and latter parts of the past century its production was greatly stimulated for use in the reduction of iron ores.

The production of charcoal by the old open-air pit method reached its height of importance long ago in this country. It has been for many centuries and is still of great importance in Europe where, in many countries, charcoal serves the purpose as the principal domestic fuel, both for heating and for cook'ng. It is also extensively used in various arts and industries.

The manufacture of charcoal is practiced principally in regions of abundant forest resources. Owing to the fact that charcoal can be transported with ease on account of its lightness in weight—wood, a heavy form of fuel, can be made readily available for the market by conversion to approximately one-half its original volume and one-quarter its original air-dry weight.

The manufacture of charcoal by the open-pit method is a very wasteful operation, because the volatile products which pass off in the process of conversion are not recovered. Principally because of this fact combined with the demand for the volatile products of wood such as wood alcohol, acetate of lime, etc., the distillation of wood in ovens and in closed retorts has made great progress and has discouraged the making of charcoal by the open-pit process.

The old-fashioned method of manufacture is still very important in the rather remote districts in the heavily forested sections of Sweden, Austria and France. In this country, only in restricted sections of the hardwood forests of the East and in the softwood regions of western Montana and isolated portions of the West and South, are the old charcoal pits in operation. They are used to a limited extent near iron ore reduction plants, and in comparatively inaccessible districts where good hardwoods are abundant and cheap and the market is near enough to attract its manufacture.

According to the census of 1909, the production of charcoal in this country amounted to 39,017,247 bu., valued at $2,351,644, or an average value of about $.06 per bu. The census of 1880 shows a consumption of 74,008,972 bu., valued at $5,276,736, or an average value of $.071 per bushel. In 1870 there were said to be 3473 charcoal operations in this country. The reported production of 1909 was made in wood distillation plants, very little being made by the old crude charcoal pit methods, and none of which was reported in the census statistics, whereas the production in 1880 was made largely in open-air pits or beehive retorts, and over 94 per cent of it was used in the manufacture of iron.

With improved methods in the reduction of iron ore, and the greater use of coke for the same purpose as that formerly supplied by charcoal, the demand for the latter has gradually decreased. One of the principal problems at present adduced by the operators of wood distillation plants [1] is the difficulty encountered in the profitable sale of their charcoal. In some sections it became a drug on the market prior to our entrance in the war, and the prices for it decreased to an exceedingly low level.

In Europe the conversion of stumps, tops, branches and other wood waste after logging as well as saw-mill refuse, such as slabs, edgings, etc., into charcoal, is a common sight in all of the forested sections. Where the market for charcoal is attractive, the making of this by-product is an important means of complete and efficient utilization of the forest product.

WOODS USED AND YIELDS

The yields of charcoal depend upon the method and rate of burning, the degree of heat, the kind, character and condition of the wood, etc. Woods of high specific gravity yield the most and best charcoal. Consequently such woods of great density as hickory, hard maple, beech, birch, and the oaks are regarded as the best kinds of wood for making high-grade charcoal. The lighter weight hardwoods and the softwoods

[1] See Chapter on Hardwood Distillation.

produce both less charcoal and a product of lower quality for general utility purposes. For certain specialized purposes in metallurgical work, however, a charcoal derived from mixed hardwoods and softwoods is sometimes preferred. Charcoal made from willow and other light-weight woods has been in great demand for the manufacture of certain forms of explosives, filtering purposes and disinfectants. Experiments have shown that the volume of charcoal is only about 50 per cent to 60 per cent of that of the original air-dry wood, and the weight only about 19 per cent to 25 per cent of the original weight of wood used.

Photograph by U. S. Forest Service.

FIG. 63.—A charcoal pit near Elk Neck, Cecil Co., Maryland, ready to be covered with grass, leaves, etc., and soil preparatory to burning. Beech, birch, maple, hickory and the oaks make the best charcoal because of their great density.

On a large operation in Virginia where pits containing about 35 cords of white and red-oak wood were used, an average of about 30 bu. to the cord were secured. In southern Pennsylvania where a mixture of oaks and yellow pine were used in open-air pits, a yield of 30 bu. was secured. It is generally regarded that this is an average yield when the better hardwoods and more dense soft woods are used.

The yields from the beehive and other forms of prepared kilns are obviously much greater, because of the increased efficiency in operation. An investigation of the yields of 25 hardwood distillation plants in New

York disclosed the average yield of 42.7 bushels of charcoal per cord of wood, which consisted largely of beech, birch and maple.[1]

Experiments have shown that the number of pounds of dry charcoal per bushel varies from 32.89 for shellbark hickory, to 27.26 for beech, 21.10 for white oak and 17.52 for longleaf pine. The same experiments demonstrated that the weight of charcoal produced per cord of air-dry wood also varied considerably. A cord of shellbark hickory produced 1172 lb., beech, 635 lb; white oak, 825 lb, and longleaf pine, 585 lb.

The table on page 239 shows the yields from a variety of American woods, together with their specific gravity, weight of wood, and a number of other related facts.[2] The specific gravities do not agree with those commonly accepted at the present time, but the correlated facts are interesting.

In Europe, where the industry has been most highly developed, investigations carried on by Bergil disclosed the following yields, expressed in percentages of weight and volume. The species mentioned are very similar in properties and characteristics to those of similar name in the American forests.

YIELD OF VARIOUS EUROPEAN SPECIES IN CHARCOAL DERIVED BY THE OPEN-PIT METHOD

Species.	Yield.	
	Percentage of Original Weight.	Percentage of Original Volume.
Beech and oak, quartered wood	20–22	52–56
Birch, quartered wood	20–21	65–68
Pine (*Pinus maritima* and *P. sylvestris*) quartered wood	22–25	60–64
Norway spruce (*Picea excelsa*), quartered wood	23–26	65–75
Norway spruce, stump wood	21–25	50–65
Norway spruce, edgings and mill waste	20–24	42–50
Mixed hardwood and softwood, mill waste (oak, birch, beech, pine and spruce)	19–22	38–48

PROCESSES USED

The process of manufacture of charcoal by the open-pit method consists generally of the following operation: Billets of wood from 2 to 4 ft. or more in length and from 2 to 6 in. in diameter, are piled on end in a conical form. There may be from 10 to 35 cords or more to the pile, and

[1] See the "Hardward Distillation Industry in New York," by Nelson C. Brown, New York State College of Forestry, Syracuse, New York, 1916.

[2] Taken from experiments by Marcus Ball, Philadelphia.

Common and Botanical Names.	Specific Gravity of Dry Wood.	Avoidupois Pounds of Dry Wood in 1 Cord.	Product of Charcoal, from 100 Parts of Dry Wood, by Weight.	Specific Gravities of Dry Coal.	Pounds of Dry Coal in 1 Bu.	Pounds of Charcoal from 1 Cord of Dry Wood.	Bushels of Charcoal from 1 Cord of Dry Wood.	Time 10° of Heat were Maintained in the Room by the Combustion of 1 Lb. of Each Article. H.	M.	Value of Specified Quantities of Each Article Compared with Shell-bark Hickory as the Standard.
White ash (*Fraxinus americana*)	.772	3450	25.74	.547	28.78	888	31	6	40	77
Beech (*Fagus americana*)	.724	3236	19.62	.518	27.26	635	23	6		65
Black birch (*Betula nigra*)	.697	3115	19.40	.428	22.52	604	27	6		63
Chestnut (*Castanea dentata*)	.522	2333	25.29	.379	19.94	590	30	6	40	52
White elm (*Ulmus americana*)	.580	2592	24.85	.357	18.79	644	34	6	40	58
Sour gum or tupelo (*Nyssa sylvatica*)	.703	3142	22.16	.400	21.05	696	33	6	20	67
Sweet or red gum (*Liquidambar styraciflua*)	.634	2834	19.69	.413	21.73	558	26	6		57
Shell-bark hickory (*Hicoria alba*)	1.000	4469	26.22	.625	32.89	1172	36	6	40	100
Hard maple (*Acer saccharum*)	.644	2878	21.43	.431	22.68	617	27	6	10	60
Soft maple (*Acer rubra*)	.597	2668	20.64	.370	19.47	551	28	6		54
Chestnut oak (*Quercus prinus*)	.885	3955	22.76	.481	25.31	900	36	6	30	86
White oak (*Quercus alba*)	.855	3821	21.62	.401	21.10	826	39	6	20	81
Pin oak (*Quercus palustris*)	.747	3339	22.22	.436	22.94	742	32	6	20	71
Red oak (*Quercus rubra*)	.728	3254	22.43	.400	21.05	630	30	6	20	69
Yellow oak (*Quercus velutina*)	.653	2919	21.60	.295	15.52	631	41	6	10	60
Yellow pine (*Pinus palustris*)	.551	2463	23.75	.333	17.52	585	33	6	30	54
Pitch pine (*Pinus rigida*)	.426	1904	26.76	.298	15.68	510	33	6	40	43
White pine (*Pinus strobus*)	.418	1868	24.35	.293	15.42	455	30	6	40	42
Yellow poplar (*Liriodendron tulipifera*)	.563	2516	21.81	.383	20.15	549	27	6	10	52
Sycamore (*Platanus occidentalis*)	.535	2391	23.60	.374	19.68	564	29	6	30	52

the form may vary from a regular cone to an obtuse cone or a truncated cone. Openings are left at the base to serve as a draft, together with a central shaft to carry off the smoke running vertically through the middle of the pile.

The sticks of wood are piled compactly together. The pile is first covered with grass, leaves, moss, branches, or needles, etc., depending upon the best available material, to a depth of from 3 to 5 in., and then with soil and turf to a depth of from 2 to 5 in. in addition. It is then

FIG. 64.—A charcoal pit in the process of burning. An " explosion " has occurred and the burners are determining the extent of the cavity. The latter is filled with small pieces of wood which are held in readiness for this purpose. The framework in the exterior is used to hold the dirt in place. Photograph taken in Deerlodge National Forest, Montana. The wood used is lodgepole pine (*Pinus murrayana*.)

ignited by means of a torch at the base of the central flue, and the whole pile gradually chars upward and outward, great care being exercised not to burn the pile too rapidly, or to permit flames to burst out. The admission of only sufficient air to cause partial combustion is a most important feature of the burning process. The time required for burning depends upon the kind of wood and its size and dryness, the method of piling, size of pile, the temperature and weather, and the character of the ground, etc.

In Montana the average-sized charcoal pit is about 40 ft. in diameter at the base, about 30 ft. across the top, and the pile usually assumes the shape of a truncated cone. This pit will yield about 2000 bu. of charcoal, and before burning, contains about 55 cords of lodgepole pine. Some pits in the lodgepole pine forest contain as high as 65 to 70 cords each. It requires about twenty-one days and nights of average weather conditions to complete the carbonization of an average pit of 55 cords. On these piles the wood is first covered with pine needles or grass or hay, and then covered with dirt and sod.

In Sweden and Austria charcoal pits containing up to 80 cords of wood each are common; in the Austrian Tyrol there are piles frequently containing up to 60 cords, while those in France, Spain and Italy contain only from 10 to 30 to 40 cords, or even less. In Austria there are several beech forests, which can be profitably utilized only by conversion of the wood into the form of charcoal, on account of the inaccessibility of these forests and the difficulty in transportation in the raw wood state.

Mathey states that the time required for burning charcoal pits depends largely upon the volume of wood involved. Under average conditions, the following number of days are required for burning different sized pits:[1]

TIME REQUIRED FOR BURNING OAK AND BEECH CHARCOAL BY THE OPEN-PIT METHOD

Number of Days.	Volume of Wood, Steres.	Volume of Wood, Cords (Approximately).
2-3	7-8	2-2⅓
4-6	10-15	3-4
6-8	20-30	6-8
12-15	40-60	12-16
28-30	100-200	27½-55

It is claimed by experienced charcoal burners that new locations of pits do not give as good results as when old places are used. The accessibility and convenience to the wood supply generally governs the question of moving to new ground. The space chosen for burning should satisfy the following conditions:

1. It should require little work in clearing and preparation.
2. It should be accessible and convenient to the wood supply, as well as affording good means of transporting the product to market.
3. It should be near and convenient to a water supply.
4. It should be well protected from the wind.

[1] See "Traité d'Exploitation Commerciale des Bois," by A. Mathey, Vol. II, p. 40.

5. Its location should be on soil which is rather dry and soft, and preferably clay or calcareous soil.

Special kilns or ovens have been devised and have been used in connection with or near large iron furnaces. They did not seek at first the recovery of the volatile products of wood, but were the medium or step between the crude old-fashioned open-air charcoal pit and the modern wood distillation plant. They have largely gone out of existence at the present time, owing to the much greater profits to be derived by the construction and operation of the distillation plant. They were usually of conical shape, about 24 ft. in diameter, about 25 to 30 ft. in height

Photograph by U. S. Forest Service

FIG. 65.—Type of brick beehive kiln used for making charcoal for iron furnaces in northern New York. Photograph taken at Wolf Pond, Franklin Co., New York. These had a capacity of about 40 cords each.

and had a capacity of about 40 cords of wood. They were commonly called " beehive " ovens. They were lined with fire brick up to 10 to 12 ft. on the inside, and were plastered on both inside and outside. Air holes were provided around the base of the kiln and at the top was an iron door which could be raised and lowered as desired.

Another form of rectangular shape, about 40 ft. long, 16 ft. wide and 15 ft. high, usually held about 80 cords of wood at one charge, and produced about 3000 bu. of charcoal at one time.

The yield by both these forms is usually from 37 to 46 bu. of charcoal per cord of wood. The time required for filling, burning and emptying the charge in the case of the larger kiln of rectangular shape is about four weeks and for the smaller one about three weeks.

About three weeks are required for the operation on the average outdoor pit containing about 25 to 30 cords of air-dry hardwoods. One man can usually tend two pits at a time if located close together. A crew of 5 or 6 men will look after 3 or 4 pits generally, while another crew chops, piles, transports the wood, and erects the piles, and bags and transports the charcoal to market.

The location of the pits of the open-air style can be changed from place to place, convenient to the source of wood supply, all that is necessary being the leveling and clearing of the space 40 to 75 ft. in diameter. In the case of the brick ovens or kilns, the wood must be transported much greater distances. Although the yield from the old-style pit is not as great as that from the beehive or rectangular oven, it is claimed that the charcoal made in the open pits is superior to that made in the ovens.

The conditions and the rate of burning in open-air pits depends upon the following factors:

1. The kind of wood. Dense hardwoods of high specific gravity are the best for making charcoal. The conifers are much inferior, dependent upon their weight. Heavy woods require much more time for burning. For the manufacture of certain kinds of charcoal iron, however, a mixture of hardwoods and soft woods is considered best.
2. The size of wood used including the length, thickness, regularity and straightness of the individual billets. Large pieces obviously require much longer time for burning than thin, slender pieces. The best size is billets 3 to 4 in. in diameter, or billets from 6 to 9 in. in diameter that have been quartered.
3. Condition of the wood. It should be well seasoned, but never doty or partially decayed or rotten. Wood free of knots and other defects makes much better charcoal than that containing large knots and frequent defects.
4. Condition of the ground. It should be perfectly dry, solid, level and free from draft. The latter is very important. In a loose, sandy or gravelly soil, air may be drawn in from underneath and, therefore, the draft may be beyond the control of the operators.
5. The time of year. The best time is from July to September or October, the wood having been cut the previous winter and

piled for seasoning during the spring and early summer months. Under good weather conditions the operator can watch it night and day with least difficulty, and the summer and fall months offer the best conditions. The danger from forest fires is always present then, but with care this is of little consequence.

6. The condition of the weather and temperature. This is of great importance. The action of the wind and temperature seriously affects the rate of burning, and must be watched with great care. In rainy and humid weather the drafts must be opened much more than in clear, dry or windy weather.

Photograph by Nelson C. Brown.

FIG. 66.—A forest of beech (*Fagus sylvatica*) cut clean for charcoal in one of the State Forests of Tuscany in central Italy. From 140 to 200 cubic meters of wood were produced per acre from this area. Note the piling of both stem and limbwood as well as the smallest branches. The stumps are also grubbed out and converted into charcoal.

In the forest of Camaldoli in central Italy, where the per capita consumption of charcoal is greater than in any other country, Dr. Ferrari made the following interesting determination[1] of the division of time required for the operation of charcoal making under average conditions, by the open-pit method. The wood used was red oak (*Quercus cerrus*)

[1] From "Prontuario del Forestale," by Dr. Egidio Ferrari. Milan, 1918.

cut from coppice forests twenty to twenty-five years of age. About 90 kgm. (198 lb.) of charcoal was secured per stere[1] of wood. The basis is the time required per man per stere of wood.

DIVISION OF TIME REQUIRED ON CHARCOAL OPERATIONS

Operation.	Hours per Man per Stere[1] of wood.
Cutting trees	5.60
Cutting wood to size	5.60
Preparation of the ground	.50
Hauling wood	4.80
Arranging the wood in pit	1.00
Covering the pit with dirt, etc	1.00
Burning	8.00
Extinction of fire, removal of cover and measuring charcoal	1.50
Total	28.00

[1] One stere = .276 cord or 1 cord (128 stacked cubic feet) = 3.63 steres.

Therefore, for a pit of 40 steres (about 11 cords) it would require one man 1120 hours or 2 men 560 hours for the complete operation. On a pit containing 200 steres (about 55 cords), it would require a crew of 10 men ($28 \times 200 \div 10$) 560 working hours, or $23\frac{1}{3}$ days of twenty-four hours each for the complete operation.

UTILIZATION AND PRICES

One of the most important uses of charcoal during the past few years was in the manufacture of gunpowder and explosives. It is also extensively used in metallurgical operations as a reducing agent. Its principal use from twenty to fifty years ago was for the production of charcoal or Swedish iron, but the introduction and wide use of coke and improvements in the methods of reducing iron ores have seriously diminished the demand for charcoal. It is widely used as a filtrant, for medicinal purposes, and for fuel.

In the copper smelters of Montana and Arizona charcoal is used in the smelters for testing the ore and for treating some ores.

Some of the larger iron furnaces use as much as 750,000 to 1,000,000 bu. or more annually. It requires from 50 to 65 bu. of charcoal to reduce a ton of ore. This is equivalent to about 126 to 144 bu. to the ton of iron. These figures were obtained in New York and New England blast furnaces.

More complete discussion of the utilization of charcoal is found in the chapter on Hardwood Distillation.

The price obtained for charcoal has been the determinant factor in the activity in the industry. For the past fifty years, the price, delivered at the nearest railroad station, or at the point of consumption, has varied between 4 and 8 cents per bushel. Before the great European war it was a "drug" on the markets at 4 to 6 cents per bushel, but with the impetus given to the demand for all forms of fuel within recent years, it

Photograph by Nelsan C. Brown.

FIG. 67.—A view of the yard of a saw mill at Vallombrosa, Italy, where mill waste, including slabs, edgings and trimmings were converted into charcoal. The three pits in the foreground are almost ready to burn. The production of charcoal was greatly stimulated during the war owing to the price of coal having risen from $10 to $15 up to $80 to $140 per ton. The manufacture of charcoal is one of the most important uses for wood in Italy. Each pile contains about 40 cubic meters of wood. Before the war charcoal brought about $2 per quintal of 220 lb. whereas in 1919 it brought about $8 for the same amount. These piles show the type of charcoal kiln commonly employed in Italy.

has risen to 7 and 8 cents per bushel and even much higher in places in the years 1917 to 1919. Owing to the stimulation in the hardwood distillation industry, however, during the war, the acid factories have increased their output of charcoal and the number of open-air pits have not greatly increased except in isolated forest regions where a special demand has arisen.

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CHAPTER XI

BOXES AND BOX SHOOKS[1]

GENERAL

THE manufacture of boxes, crating stock and shooks is one of the most important wood-using industries in this country. It is very closely associated with the lumber industry inasmuch as the raw material is usually supplied in the form of lumber.

About 12 to 15 per cent of the total annual lumber cut of this country, amounting to from 4,800,000,000 to 6,000,000,000 bd.-ft.[2], are consumed every year for boxes, box shooks, crates and fruit and vegetable packages.

In spite of the introduction of a number of other materials to take the place of the wooden container the consumption of lumber for boxes has been on the steady increase. Great quantities of boxes are annually consumed for the packing and shipment of canned goods and vegetables, milk, fish, apples and other fruits, and a great variety of other products. Over 20,000,000 boxes are used annually for oranges and lemons alone in California. In addition this state consumes large quantities of box shooks for the shipment of melons and other fruits and vegetables. Probably the greatest single use is for canned goods, which, together with the demand for boxes for apples and other products, explains the fact that over 50 per cent of the total number of box boards are manufactured in the eastern section including New England, New York, Pennsylvania, West Virginia, Virginia and North Carolina.

For a long time white pine has been the wood most prominently in demand for the manufacture of boxes. This has been true not only on account of its availability and relative cheapness, but because of its softness, workability and lightness in weight.

[1] This is the only lumber-using industry described in this book. Owing to its importance and its development as a large and distinct industry, it was deemed advisable to include the major statistics and some of the more important facts. It is treated very briefly, however, owing to the necessity for economy in space.

[2] The larger amount is based on an estimate by the National Association of Box Manufacturers.

Low grades of lumber are generally used for the manufacture of boxes because of their cheapness and because the defects, such as knots, can be readily cut out as in the use of shop grades of lumber for sash and doors, etc.

Within recent years certain forms of veneers have been used in the manufacture of boxes, but the total percentage does not constitute more than 5 to 10 per cent of the total amount of wood used by the industry.

QUALITIES DESIRED IN WOODS USED FOR BOXES

The qualities desired in woods used for boxes may be summarized as follows:

1. Lightness in weight. This is exceedingly important, because practically all boxes are used for the shipment of commodities and the question of weights is vital. Many varieties of woods, although available, are not used extensively because their weight prohibits their use.

2. Strength is of importance, but it has been determined that the use of more nails and strapping will greatly strengthen a box made of comparatively weak wood. Where great strength is required, as in the shipment of iron and steel products and other heavy commodities, hardwoods are employed.

3. Nail-holding power is obviously of considerable importance.

4. A smooth and attractive surface, preferably light in color, should be offered for printing and labeling.

5. Softness and workability are desirable qualities which are sometimes of determining influence in choosing the character of woods used for box purposes.

6. Sanitary qualities (odorless, tasteless, etc.) are needed for many food boxes.

The pines, especially white pine, Norway pine, Idaho white pine, western yellow pine (western soft pine, California white pine), California sugar pine, shortleaf,[1] and North Carolina pine, meet the above requirements to the best advantage. Other woods of light weight and of workable qualities which possess the other properties are red gum, spruce, cottonwood, hemlock and yellow poplar.

[1] Including the Arkansas and Gulf States shortleaf pine (*Pinus echinata*).

SPECIES USED AND ANNUAL CONSUMPTION

White pine formerly constituted a large share of the total amount of lumber consumed for box purposes in this country. About twenty-five years ago it is estimated that this species supplied from 50 to 60 per cent of all of the material consumed for boxes. At the present time, however, it furnishes only about 25 per cent of the total annual consumption. Nearly every species of wood of commercial importance in this country is now used for making box shooks and crating material. In many cases locally produced woods are used because of their availability and relatively low cost.

The use of yellow pine has advanced remarkably in the last few decades for the making of packing cases of all kinds and now constitutes from 20 to 23 per cent of the total amount of lumber used for boxes. A good share of the material classified as yellow pine is made of North Carolina pine and produced in the South Atlantic States from Maryland to South Carolina, inclusive. It is estimated that North Carolina pine constitutes about 70 per cent of the total amount of yellow pine used for boxes. Of the remaining 30 per cent a large share is made up of Arkansas and Gulf States shortleaf and loblolly pine and the remainder of longleaf, pitch and scrub pines.

Red gum has recently entered prominently into the box-board industry. It is somewhat harder, stronger, and holds the nail better than the so-called soft pines and is extensively used in the Central West and lower Mississippi Valley.

Of the total consumption of wood for the making of boxes eight kinds of wood constitute from 80 to 84 per cent of the whole. These include white pine, yellow pine, red gum, spruce, western yellow pine, cottonwood, hemlock, and yellow poplar in order of importance.

The principal states in the consumption of lumber for box shooks are Virginia, New York, Illinois, Massachusetts, California and Pennsylvania in order of importance. New York, Illinois and Massachusetts produce comparatively little lumber, but they are great manufacturing and industrial states and also produce commodities such as apples, canned goods of various kinds, and other foods which require wooden containers for shipment.

The following table [1] shows the annual consumption of lumber by

[1] This table has been compiled by J. C. Nellis from the various reports of the wood-using industries of each state carried on by the U. S. Forest Service in co-operation with the various state agencies.

kinds of wood together with the total lumber production for the year 1916:

BOXWOODS—CONSUMPTION BY BOX MANUFACTURERS AND TOTAL LUMBER PRODUCTION

Kind of Wood.	Quantity Used Annually by Box Manufacturers, 1912. Feet B. M.	Total Lumber Production,[1] 1916, Feet B. M.
White pine	1,131,969,940	2,600,000,000
Yellow pine (including North Carolina pine)	1,042,936,123	14,975,000,000
Red gum	401,735,390	850,000,000
Spruce	335,935,643	1,200,000,000
Western yellow pine	288,691,927	1,690,000,000
Cottonwood	210,819,509	200,000,000
Hemlock	203,526,091	2,350,000,000
Yellow poplar	165,116,737	575,000,000
Maple	96,831,648	975,000,000
Birch	90,787,900	450,000,000
Basswood	86,979,611	270,000,000
Beech	77,899,280	360,000,000
Tupelo	74,982,910	260,000,000
Elm	63,726,458	235,000,000
Oak	56,362,111	3,500,000,000
Balsam fir	40,173,700	125,000,000
Cypress	38,962,895	1,000,000,000
Chestnut	36,216,700	325,000,000
Sugar pine	24,686,000	169,250,000
Sycamore	16,451,693	40,000,000
Ash	10,507,308	210,000,000
Willow	10,004,600	1,610,000
Larch (including tamarack)	7,470,300	440,000,000
Douglas fir	7,349,840	5,416,000,000
Noble fir	6,653,500	Included in white fir
Magnolia	5,449,000	1,359,000
Buckeye	3,174,028	3,161,000
White fir	3,142,080	189,660,000
Cedar	2,512,150	425,000,000
Redwood	2,439,500	490,850,000
Red fir	1,328,330	Included in white fir
All other woods	3,150,278	280,361,000
Total	4,547,973,180	39,807,251,000

[1] Computed total production.

The following table[1] shows the consumption of box lumber by states together with the total lumber production of each state. In some of

[1] Compiled by J. C. Nellis.

these states the consumption of lumber for making boxes bears a prominent relation to the total lumber production.

BOX LUMBER CONSUMPTION AND TOTAL LUMBER PRODUCTION BY STATES

State.	Quantity Used Annually for Boxes, 1912. Feet B. M.	Total Lumber Production, 1916. Feet B. M.
Virginia	433,028,997	1,335,000,000
New York	390,057,650	400,000 000
Illinois	389,199,000	60,000,000
Massachusetts	353,405,350	219,000,000
California	309,406,285	1,420,000,000 [1]
Pennsylvania	276,587,094	750,000,000
Michigan	232,111,486	1,230,000,000
New Hampshire	200,209,596	385,000,000
Ohio	153,417,273	280,000,000
Maryland	144,309,000	90,771,000
Wisconsin	119,267,000	1,600,000,000
Kentucky	112,424,500	550,000,000
Missouri	111,765,699	260,000,000
Arkansas	110,822,000	1,910,000,000
Maine	108,889,400	935,000,000
New Jersey	102,605,205	40,000,000
Washington [2]	96,448,500	4,492,997,000
Indiana	85,267,160	280,000,000
Oregon [2]	78,939,000	2,221,854,000
Tennessee	77,979,510	732,000,000
Minnesota	77,854,600	1,145,000,000
North Carolina	76,525,000	2,100,000,000
Louisiana	56,004,500	4,200,000,000
Florida	53,469,000	1,425,000,000
Vermont	48,871,060	200,000,000
Mississippi	39,295,093	2,730,000,000
Texas	35,762,125	2,130,000,000
Iowa	31,340,476	20,000,000
Kansas	28,544,500	534,000
Arizona and New Mexico	28,035,000	184,878,000
Delaware	27,624,173	14,000,000
Connecticut	24,411,090	80,000,000
Georgia	24,373,409	1,000,000,000
West Virginia	23,837,000	1,220,000,000
Alabama	22,442,000	1,720,000,000
Rhode Island	15,951,200	18,000,000
South Carolina	13,960,000	820,000,000
Idaho	10,245,000	849,554,000
Nebraska	6,861,000	None
Montana	5,249,927	383,658,000
Colorado	4,734,000	77,578,000
Oklahoma	4,389,000	240,000,000
Nevada and Utah	1,517,000	9,383,000 [3]
District of Columbia	518,655	None
North and South Dakota	18,667	22,650,000 [4]
Wyoming	None	18,494,000
Total	4,547,973,180	39,807,251,000

[1] California and Nevada.

[2] 1914 Statistics on box lumber consumption are available:
Washington . . . . 106,307,980 feet B. M.
Oregon . . . . 72,299,344 " "

[3] Utah.

[4] South Dakota.

MANUFACTURE

The manufacture of boxes and shooks is usually an industry separate from the manufacture of lumber, although occasionally in the Southern States and very often in the Western States the shook factory is one department in a sawmill. It uses lumber of comparatively low grade which contains more or less knots and other defects. The upper grades which are free from these same defects are generally too expensive to be used by the box manufacturers.

The great problem in the industry is to cut up the lumber and remove the defects or have the knots removed in the center of the board with as little waste as possible and the minimum expenditure of power and labor. The waste in making boxes is generally from 15 to 30 per cent or more. If boxes were to be made with no knots or other defects it would result in the waste of from 60 to 80 per cent. The presence of a knot in the box does not interfere with its strength or usefulness provided they are not along the edges or in a position where they will be reached by nails.

Many different sizes and types of boxes are made, but they may be classified as nailed, lock-cornered and wire-bound boxes. The latter has come into the trade very prominently within recent years, but the nailed box is still the type most prominently used and probably constitutes 90 per cent of the total number of wooden boxes used in this country.

The conventional sizes of lumber manufactured by the saw-mills are necessarily accepted by the box manufacturers. The thicknesses, that is 1, $1\frac{1}{4}$, $1\frac{1}{2}$, $1\frac{3}{4}$, 2 in., etc., in the rough, are resawed in the box factory to $\frac{3}{8}$, $\frac{1}{2}$, and $\frac{5}{8}$-in. material, etc. The widths range between 3 and 12 in. and more but in some factories only stock widths in even inches, such as 4, 6, 8, 10 and 12 in. are made. The lengths of box shooks generally range anywhere from 12 in. up to 18 in. or more. For these purposes lumber is acceptable in almost any length from 6 ft. and up and in width from 3 in. and up. The box grades (No. 1 and 2 box) according to the White Pine Association of the Tonawandas, the No. 4 Common of the Northern Pine Manufacturers' Association, the No. 4 Common of the Western Pine Manufacturers' Association and the round edge or mill run grade of New England white pine are specially adapted to the manufacture of boxes. The box grade (No. 4) of the North Carolina Pine Association and the No. 2 Common grade of the Southern Pine Association and the Georgia-Florida Sawmill Association are also specially adapted for use in the manufacture of boxes.

The details of the methods and cost of manufacture vary so greatly that it is impossible to discuss this subject to any length without going into a great amount of detail. The following figures, however, will convey some impression of the costs involved in a box factory in the important box and shook manufacturing district of New England. At this box shook factory cutting about 12,000,000 bd.-ft. of white pine and spruce per year and employing about 120 men the following costs were determined. The lumber was received at the mill in round-edge or live-sawed stock. The boxes were used for canned vegetables, cereals, milk, paints and shoes, and a number of specifications were required to suit the individual requirements. The minimum size was a box 15 in. in length, 12 in. in width and 10 in. in depth, and the maximum size was 40 in. in length, 24 in. in width and 24 in. in depth. The average costs for the years 1914 and 1918 are given to show the rapid rise in charges due to the war and its activities:

COST OF MANUFACTURING BOX SHOOKS, NEW ENGLAND

Item.	Cost per Thousand Board-feet.	
	1914.	1918.
Labor	$4.46	$8.54
Overhead, including salaries, insurance, taxes, general repairs, depreciation, supplies, and various sundries	1.30	5.69
Lumber delivered f.o.b. mill	18.67	37.00
Total cost of production	24.43	51.23
10 per cent profit	2.44	5.12
Sale price	26.87	56.35

In the above figures, the waste figured at 20 per cent in this mill has been included in the cost of lumber. The waste includes loss by edging and trimming, but does not include waste of saw kerf, which is always included in the value of the lumber itself.

SIZES AND SPECIFICATIONS

As indicated above, there are so many different sizes and specifications used in the manufacture of boxes that it is impossible to go into this subject in any great detail.

Since one of the principal use for boxes is for canned goods the following standard specifications for canned goods boxes as adopted by the United States Food Administration and the Quartermaster Corps at Washington are given. These include the kinds of woods used, the sizes of cans which each box is designed to contain, the thickness and sizes of the individual shooks used in boxes and the number of nails. These specifications were based on years of experience followed by tests made at the U. S. Forest Products Laboratory and were adopted in 1917 by the National Association of Box Manufacturers, the National Canners' Association and the National Wholesale Grocers' Association.

STANDARD SPECIFICATIONS FOR CANNED FOOD BOXES

Domestic

Style A: Nailed Wooden Boxes.
Style B: Lock Corner Wooden Boxes.

Boxes must be well manufactured from lumber which is sound (free from decay or dote), and well seasoned. Boxes when stored after nailing should not be placed in a heated room. Lumber must be free from knot holes, loose or rotten knots greater than 1 in. in diameter. No knots will be permitted which will interfere with the proper nailing of the box.

The grouping of woods with the specifications following will govern:

Group 1

White pine	Basswood	White fir
Aspen	Cypress	Cedar
Spruce	Southern yellow pine	Redwood
Western yellow pine	Hemlock	Butternut
Cottonwood	Virginia and Carolina pine	Cucumber
Yellow poplar	Willow	Alpine fir
Balsam fir	Noble fir	Lodgepole pine
Chestnut	Magnolia	Douglas fir
Sugar pine	Buckeye	Larch

Boxes to Carry:

24 No. $2\frac{1}{2}$ cans;
24 No. 3 cans;
6 No. 8 cans;
6 No. 10 cans;

And other cans of approximately the same content.

NAILED CONSTRUCTION

Ends.

Not less than $\frac{5}{8}$ in. thick one or two pieces.[1] Two-piece ends, cleated or fastened with three corrugated fasteners. When one-piece sides are used the third corrugated fastener may be omitted.

[1] The thicknesses specified herein are to allow for an occasional unavoidable variation in manufacture, but that variation shall not exceed one sixty-fourth of an inch below the thicknesses specified.

Sides, Tops, and Bottoms.

Not less than $\frac{5}{16}$ in. thick,[1] not more than two pieces to each side or three pieces to each top or bottom and no piece less than 2 in. in width.

Nailing.

Seven nails to each nailing edge; 6d. standard cement-coated box nails.

LOCK-CORNER CONSTRUCTION

Not less than $\frac{5}{8}$ in. ends and $\frac{5}{16}$ in. sides, top and bottom,[1] all piecing tongued, grooved and glued, top and bottom nailed with not less than 14 6d. standard cement-coated box nails in each top and each bottom.

Boxes to Carry:

24 No. 1 cans;
48 No. 1 cans;
24 No. 2 cans;

And other cans of approximately the same content.

NAILED CONSTRUCTION

Ends.

Not less than $\frac{5}{8}$ in. thick,[1] one or two pieces. Two-piece ends cleated or fastened with two corrugated fasteners.

Sides, Tops and Bottoms.

Not less than $\frac{5}{16}$ in. thick,[1] not more than two pieces to each side or three pieces to each top or bottom, and no piece less than 2 in. in width.

Nailing.

Six nails to each nailing edge. 6d. standard cement-coated box nails.

LOCK-CORNER CONSTRUCTION

Not less than $\frac{7}{16}$-in. ends and sides, $\frac{5}{16}$-in. top and bottom; or $\frac{1}{2}$-in. ends and $\frac{5}{16}$-in. sides, top and bottom, all piecing tongued, grooved and glued; top and bottom nailed with not less than 12 4d. standard cement-coated box nails in each top and each bottom.

GROUP 2

White elm	Beech	Tupelo
Red gum	Oak	Maple, soft or silver
Sycamore	Hackberry	Birch
Pumpkin ash	Black ash	Rock elm
Hard maple	Black gum	White ash

Boxes to Carry:

24 No. $2\frac{1}{2}$ cans;
24 No. 3 cans;
6 No. 8 cans;
6 No. 10 cans;

And other cans of approximately the same content.

[1] The thicknesses specified herein are to allow for an occasional unavoidable variation in manufacture, but that variation shall not exceed one sixty-fourth of an inch below the thicknesses specified.

NAILED CONSTRUCTION

Ends.

Not less than $\frac{5}{8}$ in. thick,[1] one or two pieces. Two-piece ends cleated or fastened with two corrugated fasteners.

Sides, Tops, and Bottoms.

Not less than $\frac{5}{16}$ in. thick,[1] not more than two pieces to each side, or three pieces to each top or bottom, no piece less than 2 in. in width.

Except.

On the following woods: Hard maple, beech, oak, hackberry, birch, rock elm, white ash, the thickness will be not less than $\frac{1}{4}$ in.,[1] not more than two pieces to each side, or three pieces to each top or bottom and no piece less than 2 in. in width.

Veneer.

Red gum not less than $\frac{1}{4}$-in thick,[1] one-piece sides and tops, one and two-piece bottoms, no piece less than 2 in. in width.

Nailing.

Seven nails to each nailing edge, 4d. standard cement-coated box nails.

LOCK-CORNER CONSTRUCTION

Ends.

Not less than $\frac{1}{2}$ in. thick, $\frac{5}{16}$-in. sides, top, and bottom.[1] All piecing tongued, grooved, and glued, top and bottom nailed with not less than 14 4d. standard cement-coated box nails in each top and each bottom.

Boxes to Carry:

24 No. 1 cans;
48 No. 1 cans;
24 No. 2 cans;

And other cans of approximately the same content.

NAILED CONSTRUCTION

Ends.

Not less than $\frac{1}{2}$-in. thick,[1] one or two pieces Two-piece ends cleated or fastened with two corrugated fasteners.

Sides, Tops, and Bottoms.

Not less than $\frac{5}{16}$ in. thick,[1] not more than two pieces to each side, or three pieces to each top or bottom, no piece less than 2 in. in width.

Except.

On the following woods: Hard maple, beech, oak, white ash, birch, rock elm, hackberry, the thickness will be not less than $\frac{1}{4}$ in.,[1] not more than 2 pieces to each side or three pieces to each top or bottom, and no piece less than 2 in. in width.

Veneer.

Red gum not less than $\frac{1}{4}$ in. thick,[1] one-piece sides and tops, one- and two-piece bottoms, no piece less than 2 in. in width.

[1] The thicknesses specified herein are to allow for an occasional unavoidable variation in manufacture, but that variation shall not exceed one sixty-fourth of an inch below the thicknesses specified.

Nailing.

Six nails to each nailing edge, 4d. standard cement-coated box nails.

LOCK-CORNER CONSTRUCTION

Ends.

Not less than $\frac{1}{2}$ in. thick, $\frac{5}{16}$-in. sides, top and bottom.[1] All piecing tongued, grooved, and glued, top and bottom nailed with not less than 12 4d. standard cement-coated box nails in each top and each bottom.

SPECIAL INSTRUCTIONS

Size.

Allow only $\frac{1}{4}$ in. over exact length of contents. Allow only $\frac{1}{4}$-in over exact width of contents. Allow only $\frac{1}{8}$ in. over exact depth of contents.

Printing.

One end only, in one color.

Cleating.

Cleats $1\frac{1}{8}$ in. by $\frac{3}{8}$ in., or any other size cleat that has equally large cross-section, with six nails to each cleat driven through and clinched. No piece of end shall have less than two nails. Outside nails shall be driven as near the ends of cleats as is possible without splitting the cleat. Balance of nails shall be as evenly spaced as possible and no nail shall be driven in a joint.

Nailing.

Space nails as evenly as possible. No nail shall be driven into a joint. All nails shall be friven squarely into the center of the thickness of the end. Put not less than two nails in each end of any one piece of lumber.

Outside nails on the sides shall be driven just inside the end nails of the cleats.

Outside nails on the top and bottom shall be driven far enough inside to miss the side nails.

Sides, tops and bottoms shall be flush with the ends.

Tops and bottoms shall overlap sides.

Size of nails depends on woods used for ends.

NOTE

In Group 1, Sawed Lumber.

When one-piece sides and two-piece tops and bottoms are used, $\frac{1}{32}$-in thinner material permitted.

Style C: 4-One-Wooden Boxes—Wire Bound

SPECIFICATIONS

To carry canned foods and similar commodities weighing not to exceed 90 lb. net.

Boxes must be well manufactured from sound (free from decay or dote), well-seasoned thin boards and cleat lumber. Kiln-dried lumber by excessively high temperatures or low humidities, or below 6 per cent moisture must be avoided.

The thin boards must be free from knot holes, loose or rotten knots greater than

[1] The thicknesses specified herein are to allow for an occasional unavoidable variation in manufacture, but that variation shall not exceed one sixty-fourth of an inch below the thicknesses specified.

1 in. in diameter. Cleats must be free from knots and from excessive cross grain. No knots will be permitted which will interfere with proper nailing or stapling.

Boards.

Tops, bottoms, sides and ends not less than $\frac{1}{8}$ in. thick if gum, yellow pine or hardwood veneer; $\frac{5}{32}$ in. thick if western pine, spruce, or fir veneer; $\frac{5}{16}$ in. thick if resawed boards.

Cleats.

$\frac{13}{16} \times \frac{7}{8}$ in. or $\frac{3}{4} \times \frac{15}{16}$ in.

Wires.

16-gauge, not over 6 in. apart.

Staples.

Not over 2 in. apart, and not less than two staples in each end of each board.

Printing.

One end only, in one color.

Size.

Allow only $\frac{1}{8}$ in. over exact length of contents; allow only $\frac{1}{8}$ in. over exact width of contents; depth should be exact depth of contents, without any allowance.

Fastening Ends in Boxes.

The ends shall be firmly fastened to the inside of the side cleats with either 16-gauge staples with legs not less than $\frac{13}{16}$ in. long, or with two-penny cement-coated nails, both staples and nails having centers not in excess of 2 in. apart.

The following table shows the sizes of cans used in the canned food boxes and how they are packed in them. These are the sizes officially adopted by the United States Food Administration.

SIZES OF CANS AND HOW PACKED

Size.	Diameter, Inches.	Height, Inches.	Number in Case.	Arrangement.	Tiers.	Exact Width, Inches.	Exact Length, Inches.	Exact Height, Inches.	Weight of Cans and Contents, Pounds.	Principal Use.
No. 1..........	$2\frac{11}{16}$	4	24	3×4	2	$8\frac{1}{16}$	$10\frac{3}{4}$	8	22	Shrimp, oysters, soup, jam.
Do........	$2\frac{11}{16}$	4	48	4×6	2	$10\frac{3}{4}$	$16\frac{1}{8}$	8	44	Do.
No. 1 tall.......	$2\frac{11}{16}$	$4\frac{1}{4}$	24	3×4	2	$8\frac{1}{16}$	$10\frac{3}{4}$	$8\frac{1}{2}$	23	Do.
Do........	$2\frac{11}{16}$	$4\frac{1}{4}$	48	4×6	2	$10\frac{3}{4}$	$16\frac{1}{8}$	$8\frac{1}{2}$	45	Do.
Salmon, 1 lb....	3	$4\frac{5}{8}$	48	4×6	2	12	18	$9\frac{1}{4}$	60	Salmon, sliced fruit.
Milk, sweetened	$2\frac{15}{16}$	$3\frac{9}{16}$	48	4×6	2	$11\frac{3}{4}$	$17\frac{5}{8}$	$7\frac{1}{8}$	46	Sweetened condensed milk.
Milk, tall evaporated.	$2\frac{15}{16}$	$4\frac{5}{8}$	48	4×6	2	$11\frac{3}{4}$	$17\frac{5}{8}$	$9\frac{1}{4}$	57	Unsweetened evaporated milk.
No. 2..........	$3\frac{7}{16}$	$4\frac{9}{16}$	24	3×4	2	$10\frac{1}{8}$	$13\frac{1}{2}$	$9\frac{1}{8}$	36	Fruit, vegetables.
No. $2\frac{1}{2}$.........	4	$4\frac{11}{16}$	24	3×4	2	12	16	$9\frac{3}{8}$	52	Do.
No. 3..........	$4\frac{1}{4}$	$4\frac{7}{8}$	24	3×4	2	$12\frac{3}{4}$	17	$9\frac{3}{4}$	66	Do.
No. 10.........	$6\frac{3}{16}$	7	6	2×3	1	$12\frac{3}{8}$	$18\frac{9}{16}$	7	46	Do.

NOTE.—There are occasional slight variations from standard in can sizes, due to method of manu facture, and it is therefore advisable for manufacturers of solid fiber board and corrugated fiber con tainers to procure sample cans before filling orders.

Export Boxes.

The proper designing of boxes to carry American exports is now more important than ever because of the expansion in our foreign trade. Very stringent specifications for boxes to carry supplies to France during 1918 were adopted by the War Department and used to some extent commercially. However, the requirements of an export box may be summed up as: (1) proper size for convenient handling, all the way to destination; (2) *sound* lumber, heavy enough for the net weight, but no heavier, and cleats on all boxes weighing from 75 to 100 lb. and up; (3) end nails not over 2 in. apart; side nails 6 in. apart. Penny of nail = thickness of piece holding point of nail after driving expressed in eighths of an inch (plus one penny for softwoods); (4) strapping, generally around both ends 1 in. to 3 in. from inside of end and of about 250 lb. tensile strength for boxes 90 lb. gross and up to 850 lb. tensile strength for boxes up to 250 to 500 lb. gross. For waterproofing boxes, metal liners may be used and several paper manufacturers now make waterproof lining paper for boxes. Anti-rust and anti-tarnish paper, etc., can also be secured for packing valuable commodities.

EXPORT OF SHOOKS

This country is an important exporter of box shooks. The trade in these commodities has been developed largely to Cuba, Mexico, Brazil, Argentina, the West Indies, and England.

The following table shows the value of box shooks exported from the United States to all other countries for the years 1914 to 1918, inclusive:

EXPORTS OF BOX SHOOKS FOR YEARS ENDING JUNE 30

Year.	Value.
1914	$2,812,749
1915	2,327,220
1916	3,034,332
1917	4,386,175
1918	3,304,222

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War Department. Instruction Book for Export Packing of Engineer Material, Engineer Corps, 1919.

WENTLING, J. P. Woods Used for Packing Boxes in New England. U. S. Department of Agriculture, Forest Service Circular 78, 1907.

World Survey of Box Shook Industry as Reflected by Consular Reports. Timberman, December, 1914, and January to March, 1915.

Addenda. For miscellaneous data and recent information regarding the box industry, the following associations of box manufacturers should be consulted:

National Association of Box Manufacturers, Chicago.

Eastern Shook and Wooden Box Manufacturers' Association, Boston, Mass.

North Carolina Pine Box and Shook Manufacturers' Association, Baltimore.

Southeastern Box Manufacturers' Association, Atlanta, Ga.

Northwestern Shook Association, Chicago.

Box Department, West Coast Lumbermen's Association, Seattle, Wash.

Box Bureau, Western Pine Manufacturers' Association, Portland, Ore.

California Pine Box Distributors, San Francisco, Calif.

CHAPTER XII

CROSS TIES

GENERAL

With the rapid expansion in American railway development in the past fifty years there has been a great concurrent demand for cross ties. It is estimated that in 1880 about 35,000,000 new ties were used; in 1890 64,000,000 were used; in 1900 over 83,000,000; and, at the present time between 130,000,000 and 145,000,000 new ties are annually demanded both for renewals and for the construction of new track. One large railway system uses new ties at the rate of five every minute. Many of our larger railway systems use between 2,000,000 and 4,000,000 new ties every year. With a total railway mileage of 434,500 miles in this country and 2640 ties per mile, there are 1,147,080,000 ties constantly in use. The average life of untreated ties is only about five years and the average cost is estimated [1] at about 70 cents per tie.

Altogether the production and utilization of cross-tie material in this country are characterized by the following:

(*a*) Rapid rise in values, due largely to the growing scarcity of available material and especially of the most desirable species.

(*b*) Production by farmers and cutters, who work chiefly through the winter months and sell directly to the railroads or indirectly through tie jobbers. The source of material, therefore, is largely woodlots, small scattered holdings or larger tracts already cut over for saw logs.

(*c*) As a result of condition (*b*) most of our ties are hewn. The waste of raw material incurred in hewing ties is enormous. It amounts annually to about 285,000,000 cu. ft.

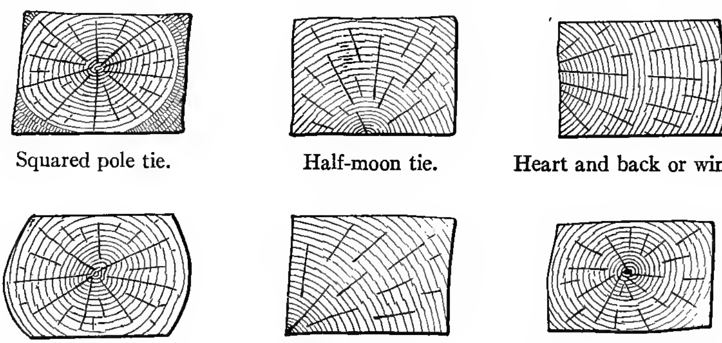
(*d*) Marked tendency to use treated ties, due to rise in price values of durable woods and availability of cheaper and non-durable woods which, when treated, give service equal or superior to the untreated durable woods.

[1] During 1917.

(*e*) Tendency to increase specifications of length, thickness and face of ties to meet the demands of heavier rolling stock, and more frequent traffic.

(*f*) Increased use of tie plates, screw spikes and other patent devices to prevent mechanical abrasion and give longer service.

As recently as 1895 white oak ties could be purchased for about 20 to 25 cents apiece. At that time, standard rails were 60 lb. in weight, axle loads about 15,000 lb., cars were of only 40,000-lb. capacity and comparatively few trains were operated. Now, white oak ties bring from 70 cents to $1.00 apiece or more depending upon point of delivery, and many inferior woods are being introduced and treated to prolong



Squared pole tie. Half-moon tie. Heart and back or wing tie.

Pole tie. Quartered tie. Boxed heart or rifle tie (containing no sap.)

FIG. 68.—Common forms of hewed cross ties with reference to their position in the log.

their life. The records of one important railroad show that the average price paid for ties (of several species) in 1904 was 50 cents, in 1909 57 cents, and in 1913, 70 cents apiece.

In 1915 the total mileage of railways including steam, electric and horse was 434,500. Of this amount, steam railways made up over 390,000 miles. In 1900 there were only 289,000 miles of trackage of all kinds of railways.

SPECIES USED

For a long time in the early days of railroad development, the timber growing adjacent to the tracks was depended upon for the cross-tie supply. Throughout the East, the oaks and preferably the white oak, were used extensively and constituted nearly all of the tie stock. With the development of the western extensions and transcontinental lines the demand increased in rapid strides and together with the decreasing supply of good oak, large numbers of ties were collected at central depots and shipped to points of consumption.

At the present time the oaks still lead in the quantity of ties consumed by the railroads, but a much greater variety of species is now used. In fact, practically every tree species in the country is used, at least to some extent, for cross-tie purposes. Most of the ties now cut are made and used in the tracks of the railroads running through the same region where

Photograph by U. S. Forest Service.

FIG. 69.—"Tie hacker" making ties from lodgepole pine in the Gallatin National Forest, Montana. After felling and limbing the tree, it is "scored" on each side with the axe as shown; then the "hacker," standing on the tree and working backward, "faces" the tree with a broadaxe from the butt to the limit of size suitable for making ties.

they are produced. The U. S. Railroad Administration has made this a requirement.

The latest available statistics are for 1915, but the most complete are those published by the Bureau of Census and the Forest Service for 1911. These show that in that year about 135,000,000 ties were used. Of these over 59,000,000, or about 44 per cent, were of oak and over 24,000,000 were of southern pine. The next, in order of quantity, were Douglas fir, cedar, chestnut, cypress, tamarack, hemlock, western pine and redwood. These ten kinds supplied 95 per cent of all ties used in 1911.

Other miscellaneous species are gum, maple, beech, spruce, birch, elm, white pine, lodgepole pine, eucalyptus, hackberry, hickory, sycamore and locust.

With the exception of western pine and hemlock, the first ten species are distinguished by their durability in contact with the soil. There is a strong tendency to increase the demand for such perishable woods as gum, beech, maple, birch, elm, etc., which, when treated with some preservative, last as long or longer than the more durable varieties such as oak, longleaf pine, cedar, chestnut, etc., when used in the untreated condition.

Between 8 and 15 per cent of the total number of ties used annually are for new track so that the demand for renewals or decayed or worn-out ties accounts for the large majority of new ties used.

Steam railroads use between 90 and 94 per cent of the ties. The electric roads use the same kinds as the steam railroads, but usually adopt smaller specifications and use " seconds " or those which fail to meet the specifications for No. 1 ties. The number of ties used on narrow gauge railways is negligible.

About 80 per cent of all ties are hewed; in fact it is recognized as the common method of producing ties except on the Pacific Coast, where over 60 per cent of the Douglas fir ties are sawed. Nearly 90 per cent of the oak ties are hewed.

About 40 per cent of all our ties are produced in the South, which is the center of production for southern pine gum and cypress ties. The central hardwood region, embracing the territory tributary to the Ohio river and Illinois and Missouri, produces about 22 per cent of all the ties. More oak ties come from this region than from any other. The Lake states of Michigan, Wisconsin and Minnesota produce most of the cedar, tamarack and hemlock ties. The North Atlantic region, including New England, New York, Pennsylvania, New Jersey and Maryland, produce most of the chestnut ties and considerable of oak. The Pacific Coast, including the states of Washington, Oregon and California, produce only about 6 per cent of the ties and these consist largely of Douglas fir sawed ties together with some western red cedar, western pine and redwood ties. The Rocky Mountain region produces only about 5 per cent of the ties and these consist largely of Douglas fir, western red cedar, western larch, lodgepole pine and western pine ties.

The principal species used for cross ties and the number of each are shown in the following table for several years as published by the U. S. Census Bureau and the Forest Service:

NUMBER OF CROSS TIES REPORTED PURCHASED, 1907 TO 1911 AND 1915, BY KINDS OF WOOD

Kind of Wood.	1915.	1911.	1910.	1909.	1908.	1907.
Oak	49,333,881	59,508,000	68,382,000	57,132,000	48,110,000	61,757,000
Southern pine	14,115,681	24,265,000	26,264,000	21,385,000	21,530,000	34,215,000
Douglas fir	6,950,910	11,253,000	11,629,000	9,067,000	7,988,000	14,525,000
Cedar	5,122,103	8,015,000	7,305,000	6,777,000	8,172,000	8,954,000
Chestnut	4,548,352	7,542,000	7,760,000	6,629,000	8,074,000	7,851,000
Cypress	4,478,612	5,857,000	5,396,000	4,589,000	3,457,000	6,780,000
Eastern tamarack	2,606,794	4,138,000	5,163,000	3,311,000	4,025,000	4,562,000
West'n yellow pine	1,402,836	2,696,000	4,612,000	6,797,000	3,093,000	5,019,000
Lodgepole pine	1,316,819					
Western larch	1,251,304					
Beech	1,173,490	1,109,000	798,000	195,000	192,000	52,000
Maple	1,069,547	1,189,000	773,000	158,000	151,000	
Hemlock	859,662	3,686,000	3,468,000	2,642,000	3,120,000	2,367,000
Redwood	563,685	1,820,000	2,165,000	2,088,000	871,000	2,032,000
Gum	485,466	1,293,000	1,621,000	378,000	262,000	15,000
Birch	465,815					
All other	1,361,694	2,682,000	2,895,000	2,603,000	3,421,000	5,574,000
All kinds	[1] 97,106,651	135,053,000	148,231,000	123,751,000	112,466,000	153,703,000

[1] Mileage of railroads reporting ties represent 78.46 per cent of total mileage. Mileage represented of former years not obtainable.

REQUIREMENTS OF A GOOD TIE

The selection of tie material to satisfy the various requirements of the railroads is of large importance. Altogether the following are the principal points which determine the desirability of any wood for use as cross ties:

1. Durability. This is of prime importance. It is estimated by various railway officials that the average tie of all species used by the railroads in this country does not last, untreated, more than five years. White oak ordinarily lasts from eight to ten years, untreated. The life of untreated ties will be discussed later.

2. Ability to resist impact. The crushing of ties by heavy rails and rolling stock, resulting in serious checking and splitting, precludes the use of soft woods such as cedar, redwood, cypress, etc., where the rolling stock is heavy and trains are frequent. The American Railway Engineering Association announced in 1907 that a maximum of 75 per cent of cedar ties used by one railroad failed because of mechanical destruction. Other railroads report failures of from 10 per cent to 75 per cent due to that cause rather than to decay.

3. Ability to resist spike pulling and lateral displacement of spikes. This is of such importance that many railroads are contemplating the use of screw spikes to replace the ordinary nail spike. Hard, dense woods, as oak, maple, beech, etc., are much superior to soft-fibered woods such as cedar, western pine, spruce, cypress, etc., for this purpose.

4. The wood must be of sufficient strength to withstand the strains due to center binding. Practically all woods used for ties meet this requirement. On weaker species, center binding will cause checking and splitting which may become serious and require renewal with new ties.

5. Available in sufficient quantities and reasonably inexpensive. Locust, mulberry, osage orange and other woods make excellent ties, but

Photograph by U. S. Forest Service.

FIG. 70.—"Peeler" or bark spud used in removing the bark after the tree trunk has been "faced" and before it is sawed or chopped into tie lengths.

do not grow in sufficient quantities. Walnut, hickory and cherry make good ties, but they are too valuable for this purpose. White oak has risen so rapidly in price that, although still fairly abundant, railroads are being forced to use inferior and cheaper woods after treatment with some preservative.

The above considerations apply largely to ties intended for use in the untreated condition. If the ties are to be treated, the principal requisite qualities are:

1. Strength.
2. Hardness.
3. Permeability.
4. Availability and inexpensiveness.

These will be at once apparent when reviewed in the light of the above discussion. Such species as the red oaks, hard maple, yellow birch, beech, red and black gum and elm meet these conditions to best advantage and all of them are now rapidly coming into common use for treatment. Maple and beech, untreated, last only about four years in the track, but when subjected to a treatment of 10 lb. of creosote per cubic foot, they should last from sixteen to twenty years or more, whereas such highly durable woods as redwood, cedar and cypress give a service in the track of only about ten to twelve years.

Since sapwood is generally more easily impregnated with chemical preservatives than heartwood, it is considered a desirable qualification to have an even distribution of sapwood entirely surrounding the heartwood when the ties are intended for treatment.

SAWED VERSUS HEWED TIES

There is a wide range of opinion among those experienced in the use of both sawed and hewed ties as to the relative advantages and disadvantages of each form. As noted before, about 80 per cent of all ties are hewed, and this form is almost universal in the East as contrasted with the Pacific Coast, where about 80 per cent of all ties produced are sawed.

Inasmuch as ties are generally produced from small holdings such as farmers' woodlots, scattered bodies not reached by a logging operation, and from tops and cull trees left after logging, there seems to be no disposition to change the method of making them. In fact, the proportion of hewed to sawed ties has remained about the same for the past decade or more. The introduction of wood preservation on an extended scale, however, has tended to increase the demand for a uniform sized tie and one which offers an even bearing surface for both tie plates and rails.

The principal points in favor of the hewed tie may be summarized as follows:

1. They shed water more readily than sawed ties and hence are likely to be more durable. This is obviously of little importance when the ties are to be treated.
2. Hewed ties are cut with a straight grain, hence they may have superior strength to sawed ties.
3. The railroad receives a larger volume of wood when buying hewed ties because sawed ties are always cut to fixed specifications, whereas in hewing the object is to keep above these fixed dimensions so that the volume of wood is likely to be much larger.

4. It is generally cheaper for the producer to hew the ties on the ground where the trees are felled rather than to indulge in an an expensive haul of slabwood which is generally wasted. In other words, it is usually cheaper to hew ties and haul them directly to market than to haul the logs to a sawmill and then load and haul the ties to the point of shipment. This presupposes a condition where a choice of method must be made. Sawed ties are usually made in a sawmill where the principal product is lumber, the ties being cut out of the knotty hearts of the logs.

As opposed to these arguments, the following points are sometimes adduced in favor of the sawed ties:

1. Hewing generally means the waste of a large amount of material. The waste is estimated by Zon in hewing loblolly pine at from 25 to 75 per cent of the available material. It is pointed out that as a rule only one tie is hewed from a 15-in. log that could be sawed into two ties. It is estimated by the Forest Service that 285,000,000 cu. ft. are wasted every year in hewing ties.
2. The sawed tie is cut to specific dimensions, so that in treating them the desired absorption of preservatives per cubic foot can be accurately determined. This cannot be followed accurately with hewed ties, each of which, in reality, has a different volume, and it is obvious that each tie cannot be measured before treatment.
3. More sawed than hewed ties can be loaded on a cylinder buggy for treatment so that the daily output of the preservation plant is increased and consequently the cost of treating per tie is decreased.
4. Tie plates and rails will find a more even and uniform bearing surface on sawed than on hewed ties. The latter must ordinarily be adzed before the plates and rails are spiked. This is usually offered as a serious objection, especially where tie plates are used.
5. The hewed tie contains much needless volume and weight and, therefore, is more expensive to handle and to transport.

SPECIFICATIONS AND PRICES

There has been a marked tendency to increase the size of the specifications of ties used by the larger railway systems to meet the demands of increased traffic and heavier rolling stock. Prices, as outlined above, have also steadily risen.

For a long time all standard gauge railroad ties were 8 ft. in length. In recent years many railroads have increased this to $8\frac{1}{2}$ ft. and some even to 9 ft. Formerly a thickness of 6 in. was prescribed for both sawed or hewed ties, but now many of the railroads require a thickness of $6\frac{1}{2}$ to 7 in. Pole ties, that is, those faced, either by hewing or sawing on two parallel sides, are now usually required to measure 7 to 8 in. on the face. Squared ties, or those hewed or sawed on all four sides, are now customarily 7 by 9 in. in cross-section, although some railroads still hold to the dimensions of 6 by 8 in., which were commonly in use a few years ago.

The following tabular statement shows the size specifications adopted by some of both the larger and smaller railway systems in the country, for the period before the entry of this country in the war:

RAILROAD TIE SPECIFICATIONS; COMPILED FROM SOME OF THE LEADING ROADS OF THE UNITED STATES

1916 SPECIFICATIONS

Railroad.	Species.	No. 1 Squared.			No. 1 Pole.			No. 2 Squared.			No. 2 Pole.		
		L	*T*	*F*	*L*	*T*	*F*	*L*	*T*	*F*	*L*	*T*	*F*
Baltimore & Ohio	White oak group	8.5	7	8	8.5	7	7	8.5	6	7	8.5	6	6
	Cherry	8.5	7	8	8.5	7	7	8.5	6	7	8.5	6	6
	Mulberry	8.5	7	8	8.5	7	7	8.5	6	7	8.5	6	6
	Black walnut	8.5	7	8	8.5	7	7	8.5	6	7	8.5	6	6
	Heart longleaf	8.5	7	9	8.5	7	6						
Boston & Albany	Heart yellow pine	8.5	7	9									
	Native chestnut	8.5	7	9	...	...	...	8.5	7	9			
	Native oak	8.5	7	9	...	...	...	8.5	7	9			
Boston & Maine	White oaks	8	7	9	8	7	7–12	8	6	8	8	6	5–12
	Chestnut	8	7	9	8	7	7–12	8	6	8	8	6	5–12
	Cedar (white)	8	7	9	8	7	7–12	8	6	8	8	6	5–12
	Red oak	...	...	...	...	...	...	8	6	8	8	6	5–12
Buffalo & Susquehanna	White oaks	8.5	8	7	8.5	7	7–12	8.5	7	6–8	8.5	7	6–8
	Chestnut	8.5	8	7	8.5	7	7–12	8.5	7	6–8	8.5	7	6–8
	Cedar	8.5	8	7	8.5	7	7–12	8.5	7	6–8	8.5	7	6–8
C., B. & Q.	White oaks	8	6	8	8	6–7	8	...	...	...	8	6–7	6–7
	Red oak	8	6	8	8	6–7	8	...	...	...	8	6–7	6–7
Delaware & Hudson	White oaks	8.5	7	9	8.5	7–8	6	8.5	6	8	8.5	6–7	5–6
	Chestnut	8.5	7	9	8.5	7–8	6	8.5	6	8	8.5	6–7	5–6
	Cherry	8.5	7	9	8.5	7–8	6	8.5	6	8	8.5	6–7	5–6
	Red oak	8.5	7	9	8.5	7–8	6	8.5	8	8	8.5	6–7	5–6
D., L. & W.	White oaks	8.5	7	8–12	8.5	7	7–12	8.5	6	7	8.5	6	6
	Chestnut	8.5	7	8–12	8.5	7	7–12	8.5	6	7	8.5	6	6
	Red oak	8.5	7	8–12	8.5	7	7–12	8.5	6	7	8.5	6	6
	Beech and birch	8.5	7	8–12	8.5	7	7–12	8.5	6	7	8.5	6	6
Great Northern	Tamarack	8.5	7	7	8.5	7	7	8.5	6	6			
	Douglas fir	8.5	7	7	8.5	7	7	8.5	6	6			
Lehigh & Hudson	White oaks	8.5	7	9	8.5	6–7	8–12						
	2d growth chestnut	8.5	7	9	8.5	6–7	8–12						
Lehigh Valley	Longleaf heart wood	8.5	7	9	...	...	...	8.5	7	8			

L = length in feet; T = thickness in inches; F = face in inches.

RAILROAD TIE SPECIFICATIONS; COMPILED FROM SOME OF THE LEADING ROADS OF THE UNITED STATES—*Continued*

1916 SPECIFICATIONS

Railroad.	Species.	No. 1 Squared.			No. 1 Pole.			No. 2 Squared.			No. 2 Pole.		
		L	*T*	*F*	*L*	*T*	*F*	*L*	*T*	*F*	*L*	*T*	*F*
Louisville & Nashville	Cypress	9	7	9	9	$6\frac{1}{2}$	$8\frac{1}{2}$	9	6	7.5			
	White oak	8.5	7	9	....			8–8′ 5″	7	9			
	Chestnut oak	8.5	7	9	....			8–8′ 5″	7	9			
	Red oak	8.5	7	9									
Michigan Central	White oaks	8.5	7	9	8.5	$6\frac{3}{4}$–$7\frac{1}{4}$	9	8.5	7	7	8.5	7	7
	Red oaks	8.5	7	9	8.5	$6\frac{3}{4}$–$7\frac{1}{4}$	9	8.5	7	7	8.5	7	7
N. Y., N. H. & H.	White oak	8.5	7	9	8.5	7	7–12	8	6	8	8	6	6–12
	Red oak	....			....			8	6	8	8	6	6–12
	Chestnut	8.5	7	9	8.5	7	7–12	8	6	8	8	6	6–12
	Cedar (white)	8.5	7	9	8.5	7	7–12	8	6	8	8	6	6–12
Northern Pacific	White oak	8	7	7	8	7	7	8	6–7	6			
	Tamarack	8	7	8	8	7	7	8	6–7	6			
	Douglas fir	8	7	8	8	7	7	8	6–7	6			
	Miscellaneous	8	7	8	8	7	7	8	6–7	6			
Pennsylvania	White oaks	8.5	7	8	8.5	7	7	8.5	7	7	8.5	7	6
	Black locust	8.5	7	8	8.5	7	7	8.5	7	7	8.5	7	6
	Black cherry	8.5	7	8	8.5	7	7	8.5	7	7	8.5	7	6
	Cypress	8.5	7	9	....			8.5	7	8			
	Longleaf pine	8.5	7	9	....			8.5	7	8			
	Chestnut	8.5	7	8	8.5	7	7	8.5	7	7	8.5	7	6
	Sassafras	8.5	7	8	8.5	7	7	8.5	7	7	8.5	7	6
	Red mulberry	....			....			8.5	7	7	8.5	7	6
	Red cake	....			....			8.5	7	7	8.5	7	6
	Beech	....			....			8.5	7	7	8.5	7	6
	Gums	....			....			8.5	7	7	8.5	7	6
	Shortleaf pine	....			....			8.5	7	8			
Wabash.....	White oaks	8	6	8									
	Red and black oaks	....			....			8	6	8			
Wisconsin & Northern	Hemlock	8	7	7	....			8	7	6			
	Tamarack	8	7	7	....			8	7	6			

L = length in feet; *T* = thickness in inches; *F* = face in inches.

The same general requirements governing the making and delivering of No. 1 ties along the railroad right of way were in effect by most of the leading systems. Although there may be minor differences, they may be summarized as follows:

1. All ties shall be made from live timber of good quality, straight and free from any rotten or loose knots, wind shakes, worm holes, checks or other injurious defects which impair the usefulness, strength or durability of the tie.
2. All ties must be cut from the stump between October 1st and April 1st and must be freed of all bark. Ties must be delivered at railroad not later than six months from date of felling.
3. All ties must have parallel faces, sawed or hewed smooth with the grain of the wood. When hewed, ties must be free from deep score hacks on the faces and all knots must be cut close and smooth.
4. All ties must be cut off square at the ends.
5. Ties delivered on right of way must
    (*a*) Not be piled closer than 10 ft. to the nearest track;
    (*b*) Be piled separately by species;
    (*c*) Not be over 12 layers high;

(*d*) Not interfere with view of approaching trains;
(*e*) Be ranked as required to season to best advantage.

In addition to the above, the species acceptable to the railroad are always specified. No. 2 and No. 3 ties are less rigid in their requirements, both in size and quality, than the above.

The following prices will give an idea of the values prevailing for cross ties announced by some of the railroads in their specifications:

The following prices were advertised by the Pennsylvania Railroad for certain divisions:

Species.	Grade 1.	Grade 2.	Grade 3.
White oak, black locust, black walnut, and black cherry ..	$.75	$.65	$.35
Chestnut, sassafras and red mulberry................	.55	.45	.20
Red oaks, honey locust, hickories and beech..........	50	.40	.20
Hard maples, sycamore, red gum, hackberry and ashes	.45	.35	.15
Soft maples, black gum, butternut, birches and elms...	.40	.30	.10

The Delaware, Lackawanna & Western Railroad paid the following prices in 1917:

Species.	Class A.	Class B.	Class C.
White oak..................................	$.80	$.70	$.55
Chestnut..................................	.55	.50	.35
Red oak..................................	.65	.60	.35

The Baltimore & Ohio Railroad paid the following prices in 1917:

Species.	Number 1.	Number 2.	Number 3.
White oaks, cherry, mulberry, black locust or black walnut..................................	$.65	$.50	$.25
Chestnut..................................	.45	.30	not taken

The only specifications that do not conform in general to the above "squared" and "pole" ties in this country are the rectangular ties adopted several years ago and still used by the Great Northern Railway. At Somers, in western Montana, these are sawed out of western larch and Douglas fir by special machinery. The ties are 8 ft. long, 12 in. across the upper face and 8 in. deep from the face to the lowest point of the angle. They contain approximately 40 bd. ft. each. The following are the advantages claimed for the Great Northern triangular tie:

1. It is a self-tamping tie. It embeds itself easily and firmly on the road bed and will not "crawl."
2. It gives an even 12-in. surface to the rail with its attendant advantages.
3. The ties are replaced more readily and, therefore, more cheaply.
4. More ties and lumber can be cut out of the various-sized trees than other accepted forms.

The following are the disadvantages of the triangular form:

1. It gives a less satisfactory bearing surface on the ballast.
2. The ties are likely to check and split off on the edges.
3. The spike must be driven in the exact center.

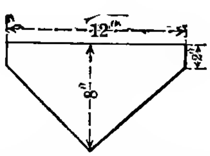


FIG. 71.—Triangular tie used by the Great Northern Railway.

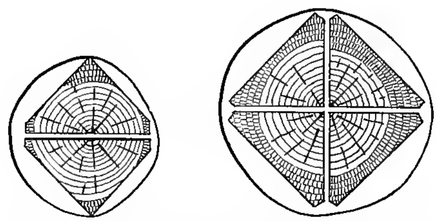


FIG. 72.—Method of sawing triangular ties from tie logs.

These ties cost the Great Northern about 56 cents apiece. There are 25 ties per thousand board feet and they were sold on the basis of $14.00 per thousand board feet for Douglas fir and Western larch ties in 1917.

The following specifications are those issued by the United States Railroad Administration under date of June 11, 1918:

UNITED STATES RAILROAD ADMINISTRAION

SPECIFICATIONS FOR CROSS TIES

Kinds of Wood.

Before manufacturing ties, producers should ascertain from the railroad to which they contemplate delivering them just which of the following kinds of wood suitable for cross ties will be accepted: Ash, beech, birch, catalpa, cedar, cherry, chestnut, cypress, elm, fir, gum, hackberry, hemlock, hickory, larch, locust, maple, mulberry, oak, pine, redwood, sassafras, spruce, sycamore, and walnut. Others will not be accepted unless specially ordered.

Quality.

All ties shall be free from any defects that may impair their strength or durability as cross ties, such as decay, splits, shakes, or large or numerous holes or knots.

Ties from needleleaved trees shall be of compact wood, with not less than one-third summerwood when averaging five or more rings of annual growth per inch, or with not less than one-half summerwood in fewer rings, measured along any radius from the pith to the top of the tie. Ties of coarse wood, with fewer rings or less summerwood, will be accepted when specially ordered.

Ties from needleleaved trees for use without preservative treatment shall not have sapwood more than 2 in. wide on the top of the tie between 20 in. and 40 in. from the middle, and will be designated as "heart" ties. Those with more sapwood will be designated as "sap" ties.

Manufacture.

Ties ought to be made from trees which have been felled not longer than one month.

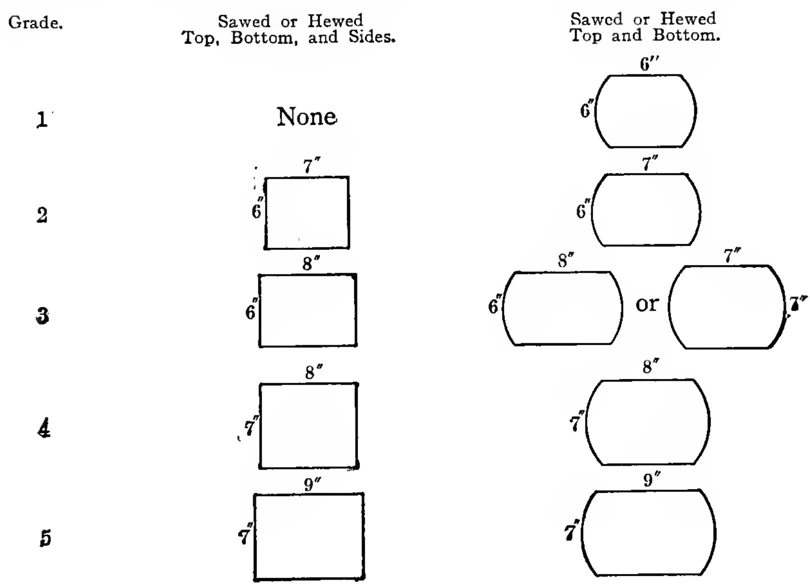
All ties shall be straight, well manufactured, cut square at the ends, have top and bottom parallel, and have bark entirely removed.

Dimensions.

Before manufacturing ties, producers should ascertain from the railroad to which they contemplate delivering them just which of the following lengths, shapes and sizes will be accepted.

All ties shall be 8 ft. or 8 ft. 6 in. long.

All ties shall measure as follows throughout both sections between 20 in and 40 in. from the middle of the tie:



The above are minimum dimensions. Ties over 1 in. more in thickness, over 3 in. more in width, or over 2 in. more in length will be degraded or rejected.

The top of the tie is the plane farthest from the pith of the tree, whether or not the pith is present in the tie.

Delivery.

All ties ought to be delivered to a railroad within one month after being made.

Ties delivered on the premises of the railroad shall be stacked not less than 10 ft. from the nearest rail of any track at suitable and convenient places; but not at public crossings, nor where they will interfere with the views of trainmen or of people approaching the railroad. Ties should be stacked in alternate layers of two and seven, the bottom layer to consist of two ties kept at least 6 in. above the ground. The second layer shall consist of seven ties laid crosswise of the first layer. When the ties are rectangular, the two outside ties of the layers of seven and the layers of two shall be laid on edge. The ties in layers of two shall be laid at the extreme ends of the ties in the layers of seven. No stack may be more than twelve layers high, and there shall be 5 ft. between stacks to facilitate inspection. Ties may be ranked like cordwood, in which case the owner shall rehandle them while inspection is being made. Ties which have stood on their ends on the ground will be rejected.

All ties at the owner's risk until accepted. All rejected ties shall be removed within one month after inspection.

Ties shall be piled as grouped below. Only the kinds of wood named in the same column may be piled together.

CLASS U—TIES WHICH MAY BE USED UNTREATED

Group Ua.	Group Ub.	Group Uc.	Group Ud.
Black Locust	" Heart " Pines	" Heart " Cedars	Catalpa
White Oaks	" Heart " Douglas Fir	" Heart " Cypress	Chestnut
Black Walnut		Redwood	Red Mulberry
			Sassafras

CLASS T—TIES WHICH SHOULD BE TREATED

Group Ta.	Group Tb.	Group Tc.	Group Td.
Ashes	" Sap " Cedars	Beech	Elms
Hickories	" Sap " Cypress	Birches	Hackberry
Honey Locust	" Sap " Douglas Fir	Cherry	Soft Maples
Red Oaks	Hemlocks	Gums	Spruces
	Larches	Hard Maples	Sycamore
	" Sap " Pines		White Walnut

Shipment.

Ties shall be separated in the car according to the above groups and sizes as far as practicable.

Approved, Washington, D. C., June 11, 1918.

JOHN SKELTON WILLIAMS,
Director of Finance and Purchases.

C. R. GRAY
Director of Operation.

The following prices were paid during the winter of 1919 by a prominent eastern railroad for the species as listed:

Sizes.		Grade.	Class U Woods. To be used Untreated.		Class T Woods for Treatment.		
Sawed or Hewed Top, Bottom, and Sides, Ins.	Sawed or Hewed Top or Bottom, Ins.	No.	UA	UD	TA	TC	TD
None	6×6	1	$.85	$.65	$.75	$.65	$.65
6×7	6×7	2	1.00	.75	.90	.75	.75
6×8	6×8 or 7×7	3	1.20	.95	1.10	.95	.95
7×8	7×8	4	1.35	1.10	1.25	1.10	1.10
7×9	7×9	5	1.50	1.25	1.40	1.25	1.25
Ties should be piled as grouped in classes.			Black Locust White Oaks Black Walnut	Catalpa Chestnut Red Mulberry Sassafras	Ashes Hickories Honey Locust Red Oaks	Beech Birches Cherry Gums Hard Maples	Elms Hackberry Soft Maples Spruces Sycamore White Walnut

The above are minimum dimensions. Ties over 1 in. more in thickness, over 3 in. more in width, or over 2 in. more in length will be degraded or rejected.

The top of the tie is the plane farthest from the pith of the tree, whether or not the pith is present in the tie.

MAKING AND DELIVERY TO MARKET

General.

The hewing of ties is done either by owners of small holdings, such as woodlots, or by contractors who buy stumpage by the acre or area or still more commonly by the tie. Throughout the country the work is usually done between October 1st and April 1st, both because many of the railroads require in their specifications that the timber be cut during that period and because other work is less active in the fall and winter. Then, too, hauling can usually be done more cheaply in the winter, especially with snow or the ground. On many of the larger logging operations, tie cutters follow up the work after the saw logs are removed and hew the ties from the remaining tops, smaller trees of insufficient size for saw logs and cull trees too defective, knotty or crooked to make good lumber. In the woodlots of the East and central hardwood region, many farmers look upon the getting out of a few hundred ties during the winter as a regular source of employment and income.

Stumpage.

As in the case in all timber values expressed as stumpage, the value of ties in the tree varies with their kind and quality, accessibility and difficulty of logging and transportation to market. The following stumpage values are those which prevailed prior to 1917:

In the prominent tie-producing sections of Kentucky and West Virginia, well-located white oak stumpage involving a haul of from 1 to 6 miles was worth from 10 to 20 cents per tie. Many sales have been made for about 16 cents or more. Southern yellow pine stumpage is worth from 6 to 14 cents with an average of about 10 cents.

Douglas fir and western larch stumpage brought from 4 to 10 cents per tie; western pine from 4 to 8 cents per tie.

Red oak and chestnut stumpage brought from 8 to 15 cents per tie, depending upon quality and location.

Hardwood ties, such as beech, birch, maple, elm and red gum were worth, on the stump, from 5 to 12 cents apiece.

Suitable Sized Timber for Hewing.

The best sized trees from which ties are made by hewing are those from 11 to 15 in. in diameter at breast height, although trees from 10 to 17 in. are customarily taken.

Lodgepole pine, as it grows throughout the northern Rocky Mountains, is naturally most suitable in size for hewing into ties since most of the merchantable stands of this timber contain from 75 to 200 trees, 10 to 16 in. in diameter. They are tall and straight and free from excessive taper.

Hewed ties seldom conform to the dimensions specified by the railroads, other than length. As a general rule, tie inspectors do not care how large the ties are, as long as they are at least large enough to meet the specifications. Therefore tie cutters prefer those trees which will yield No. 1 ties with the least effort on their part.

In investigating the average number of ties that can be cut from trees of different diameters, Zon has prepared the following table[1] as a result of measuring 996 loblolly pine and hardwood ties in eastern Texas:

Diameter Breast High.	Number of Trees Measured.	Average Number of Ties Cut from Each Diameter Class.
11	77	2.4
12	236	3.1
13	257	3.9
14	231	4.8
15	140	5.2
16	53	5.7
17	2	6.0

[1] See "Loblolly Pine in Eastern Texas," by R. Zon. Forest Service Bulletin No. 64, 1905, p. 36.

By counting the number of trees per acre of each diameter and multiplying this by the average number of ties per tree the yield of ties per acre can be easily derived.

In western yellow pine, suitable for hewing into ties in the Southwest, the average number of ties per tree is only 2.7, but here the trees do not grow to a very good height.

Tie hackers do not like trees of too small diameter because an insufficient number of No. 1 ties can be cut from them for the labor involved in felling, limbing, etc., whereas in trees of 16 in. or over in diameter the hewing is more difficult and the ties are difficult to handle on account of their large size.

The following table is interesting in that it shows the minimum diameter of logs from which the various-sized pole ties may be hewed together with the cubic feet contained in the pole tie that conforms to the exact specifications of 1917. They are given for some of our larger railroad systems. A length of 8 ft. is used for all.

Railroad.	Hewed Pole Ties.		Minimum Diameter of Log in Inches.	Cubic Feet in Tie.
	Face, Ins.	Thickness, Ins.		
C., B. & Q. (Burlington)	7.5	6.5	10	3.34
Union Pacific	6.5	7	9.6	3.38
Great Northern	7	7	9.9	3.48
Northern Pacific	8	7	10.6	3.73
Santa Fe	8	7	10.6	3.73
Chicago, Milwaukee & St. Paul	8	7	10.6	3.73
Oregon Short Line	8½	7	11.	3.97
Chicago & Northwestern	6.7	6	9	2.76

Number of Ties per Thousand Board Feet.

It is customary to use the converting factor of 30 ties per thousand board feet for the average standard gauge pole tie, cut 8 ft. long. This means, therefore, that the average tie contains 33⅓ board feet. It is very apparent from the above discussion and specifications that this factor is a variable one.

Sawed ties are usually cut to conform exactly with the specifications and are sold by the board feet as well as by the piece so that the converting factor is usually applied only to hewed pole ties. The number of board feet contained in each tie, therefore, depends upon the specifications and also upon how closely the tie hacker conforms to these given dimensions.

The following study by Koch in western Montana contains some valuable data on the average number of hewed ties per thousand board feet.[1] It was made on several small tie sales from National Forest timber.

NUMBER 1 TIES

Operator.	Number of Ties Cut.	Average Scale in Board Feet per Tie.	Total Scale in Board Feet.	Average Thickness, Ins.	Average Width, Ins.
1	712	24.705	17,590	8	13
2	284	26.055	7,400	8	13
3	155	28.839	4,470	9	12
4	402	32.040	12,880	9	13

Number of number 1 ties per thousand board-feet, 37.

NUMBER 2 TIES

Operator.	Number of Ties Cut.	Average Scale in Board-feet per Tie.	Total Scale in Board-feet.	Average Thickness, Ins.	Average Width, Ins.
1	111	10.495	11,165	7	8
2	5	14.000	70	8	9
3	19	15.263	290	8	9
4	68	14.264	970	8	9

Number of number 2 ties per thousand board-feet	81
Per cent of number 2 ties	$11\frac{1}{2}$
Average scale of number 1 and number 2 ties	25.5
Number of number 1 and number 2 ties per thousand board-feet	39

Koch concluded from this study that 40 ties should be considered equivalent to 1000 ft., board measure, instead of 30 as at present.

In a large tie sawmill cutting ties 7 in. thick by 8 in. wide and 8 ft. long, from a run of 148,311 logs which scaled 14,135,310 bd. ft. (about 10 logs per thousand), 419,199 ties were yielded in addition to about 15,687 cords of slabwood. It was determined, therefore, that from similar-sized logs, 30 ties and 1 cord of slabwood should be derived per thousand board feet.

As noted before, the Great Northern triangular tie contains 40 bd. ft. each so that there are only 25 ties of this size to the thousand board feet.

Hewing.

Hewing, generally speaking, refers to the operation of felling, limbing, scoring, facing and bucking the tree into tie lengths. It is sometimes called " making " ties.

The tie makers, also called " tie hacks," " hackers," etc., usually

[1] Number 1 ties were 8 ft. long, 7 in. thick, not less than 8 in. nor more than 12 in. in width. Number 2 ties were of the same length with a 7-in. face and 6 in. in thickness.

work by contract and are paid by the piece. Each man works alone and is assigned an area. His equipment consists of the following: One 4 to $4\frac{1}{2}$-lb. double bitted axe, one 12-in. 6 to 7-lb. broadaxe, one cross-cut saw, an iron wedge, a light sledge hammer, a bark spud, a measuring pole of the desired length and a bottle of kerosene to oil the saw. It is customary practice for each man to furnish his own tools.

Photograph by U. S. Forest Service.

FIG. 73.—Making ties in the hardwood forests of Decatur Co., Tennessee. The man on the left is hewing with the broadaxe; the other "scoring" with the axe.

In felling, care is taken to have any crooks or the largest diameter of the tree perpendicular to the ground in order to facilitate hewing. Small crooks are permitted by the railroads if the hewed surfaces are straight and parallel to each other. As soon as the tree is felled, the "tie hack," standing on the trunk, scores each face by chopping into the sides with an axe at an angle of about 45° with the direction of the tree and at intervals of from 4 to 8 in. The limbs are taken off with the axe as the tree is scored. After scoring, the two faces are hewed down to the desired width and smoothness with the broadaxe, the chopper standing on the tree and working backward with the grain. The tree is then peeled with a bark spud and bucked up into the desired tie lengths with the cross-cut saw. When faced on four sides, which is seldom done, the tree is turned, scored and hewed on the other two sides before barking and bucking. A few years ago softwood ties were sometimes chopped to length, but this is seldom done now.

The cost of hewing depends upon the following factors:

1. The ability and efficiency of the hacker or tie chopper.
2. The species and whether green or dead.
3. The condition and slope of the ground.
4. The run of timber; such as adaptable sizes, shape, length of bole, freedom from limbs and defects, and amount per acre, etc.
5. Specifications of ties.

An experienced and efficient tie hacker will make from 40 to 50 ties in favorably located and sized lodgepole pine and hemlock, from 35 to 40 in Douglas fir, western larch, western pine, cedar, loblolly and longleaf pines and other softwoods and from 20 to 35 in oak, chestnut and hardwoods. An average will run, in softwoods, between 20 and 35 and from 15 to 25 in hardwoods.

Contracts for hewing No. 1 ties range from 14 to 15 cents for difficult conditions down to 10 cents for good "chances" and from 11 to 8 cents for "seconds." The usual prices paid in Pennsylvania are 11 cents for chestnut and 13 cents for oak "firsts" and 8 and 10 cents respectively for "seconds." In the West, 14 cents is a customary price for hewing "first" and 9 cents for "seconds." A tie hack bends every effort to make all the "firsts" possible from every tree handled as it is current opinion among them that there is no money in making "seconds." Hewing No. 1 ties in West Virginia and Kentucky costs from 13 to 15 cents per tie. On a tie operation in northern New Mexico where the timber ran about 3 ties per tree, each man turned out about 20 ties on an average per day. In a ten-hour day the time was divided as follows: $1\frac{1}{4}$ hours felling, $3\frac{1}{2}$ hours limbing and scoring, 3 hours facing, 1 hour bucking into lengths and $1\frac{1}{4}$ hours peeling. On this basis the average cost of hewing was distributed as follows:

Operation	Cost per Tie
Felling	$.011
Scoring	.032
Facing	.027
Bucking	.009
Peeling	.011
	$ .090

At 20 ties per day this would mean a wage of $1.80 per day for the tie hacker. However, time lost in getting supplies, and during inspections, and wear and tear on tools, which the men supplied themselves, reduces this to some extent.

On some operations, expert workers frequently make from $3.50 to $4.00 per day or more out of which board costs them from 60 to 75 cents per day.

Skidding.

Skidding usually costs from 2 to 3 cents per tie. It is done by hand for short distances, but is more frequently done by a single horse or team taking from 2 to 6 ties per trip. On one operation where over 3000 ties

Photograph by U. S. Forest Service.

FIG. 74.—Hauling Douglas fir ties to the landing or chute with the "go-devil." From 10 to 15 ties or more can be hauled at one time by this method, depending upon the distance, slope and the "going."

were taken by hand to the haul road an average distance of $\frac{1}{4}$ mile, each man handled 136 ties per day, on an average, and the cost was 3 cents. Go-devils are sometimes used, especially on the longer skidding chances. One man can skid from 150 to 200 ties with one horse, a distance of $\frac{1}{8}$ mile, in the average day.

Hauling.

Hauling from the banking grounds to the railroad or stream is usually done by means of a wagon or sled. Winter hauling on snow with sleds is of course the cheapest. The cost is determined by:

1. The distance.
2. Condition of the road together with its grade.
3. Labor and horse charges.
4. Availability of snow for sleigh haul.

On an iced sleigh-haul road from 60 to 100 ties are commonly hauled. From 40 to 60 ties may be hauled on a wagon under the most favorable conditions but under ordinary circumstances from 30 to 40 ties are considered a good load.

The following shows the number of trips for various hauling distances figured on the basis of 40 ties per load and $6.00 per day for team and man:

Distance, Miles.	Number of Trips per Day.	Cost per Tie, Cents.
$\frac{1}{2}$	15	0.10
1	8	1.88
2	5	3.00
3	3	5.00
4–7	2	7.50
10–14	1	15.00

The price of hauling always includes piling at the railroad right of way, yard or along the stream, according to directions. Loading on the cars is usually done by the railroad company. If the contractor does this, there is a standard charge of 2 cents per tie for loading.

Other Forms of Transportation.

The cheapest method of transportation is driving, but good drivable streams are seldom available on tie operations. Ties can be driven cheaper than other forms of material because of their short length and small size compared to saw logs, poles, long timbers, etc. Driving can be practiced only in the spring, so that an interest charge of from 6 to 8 per cent must be added to the cost together with an allowance for loss. The cost of driving is very variable. The cost of putting ties in the stream and taking them out and piling costs about 2 cents apiece. Two men and one horse can take out and pile 600 ties per day. In one drive of about 90 miles, involving 300,000 ties, in the West, the cost per tie was $5\frac{1}{2}$ cents.

Fluming and chuting are practiced to a limited extent on some of the larger operations in the West, particularly with lodgepole pine, Douglas fir and western yellow pine.

On some of our navigable streams, ties are fastened together in large rafts or they are loaded on large barges and towed to destination. The average river barge on the Mississippi River or its tributaries holds between 7000 and 8000 ties each. In loading the cars from a barge or raft, a tie hoist is used. This usually consists of a cradle lowered and raised on an incline track from the water to the loading platform by means of a

Photograph by U. S. Forest Service.

FIG. 75.—Ties hauled from 1 to 3 miles by wagon to the landing at the flume. From 30 to 60 ties are hauled on each trip. Fluming and driving are common methods employed in bringing softwood ties to market in rough, mountainous regions. Photograph taken in western Montana.

gasoline engine. Before they are loaded on the cars from the ranks or cribs, they are inspected and branded by a railroad tie inspector and are spotted with paint.

Summary of Operating Costs.

The following table [1] shows the usual costs involved in and prices received for white oak and other hardwood ties based upon a number of operations in Kentucky, the center of the oak-producing region in 1917. The specifications used are 8-in. face, 7 in. in thickness and $8\frac{1}{2}$ ft. long.

[1] Data supplied by Mr. W. F. Goltra.

The "seconds" or No. 2 ties were those which failed to pass inspection as No. 1 ties:

	White and Chestnut Oak.		Red Oak.		Beech.	
	Firsts.	Seconds.	Firsts.	Seconds.	Firsts.	Seconds.
Stumpage	$.20	$.12	$.12	$ 10	$.10	$.08
Felling and hewing	.15	.10	.12	.08	.12	.08
Hauling to railroad (av. 10 miles)	.15	.10	.15	.12	.15	.12
Loading on cars	.02	.02	.02	.02	.02	.02
Totals	$.52	$.34	$.41	$.32	$.39	$.30
Prices received	.60	.40	.47	.37	.42	.32
Profit	$.08	$.06	$.06	$.05	$.03	$.02

The following data were supplied by the U. S. Forest Service from a tie chance on the Tongue River within the Bighorn National Forest in Wyoming, where 1,555,000 standard gauge hewed and sawed ties were taken out on a flume operation. Most of the timber was lodgepole pine and a very limited amount of Engelmann spruce. Most of the ties were hewed.

	Hewed Ties.	Sawed Ties.
Felling, bucking, limbing and hewing (for hewed ties)	$.122	$.031
Skidding	.050	.031
Hauling to flume, including cost of temporary roads	.040	.056
Brush disposal and cutting defective trees	.030	.024
Fluming or driving to mill	....	.016
Sawing	....	.055
Fluming 27 miles, driving to railroad and handling in yard	.035	.035
Depreciation of improvements and equipment	.047	.065
Maintenance of improvements and equipment	.010	.013
General and miscellaneous expenses	.017	.022
Totals	$.351	$.348

On an operation in the Northwest where 22,000 Douglas fir, western larch and a few lodgepole pine ties were cut the following costs were noted. A 160-rod chute was used to get the ties down a steep place followed by a $4\frac{1}{2}$-mile wagon haul where two trips per day were taken and frequently loads of 50 to 60 ties handled per load. Skidding for a distance of $\frac{1}{8}$ to $\frac{1}{4}$ mile was done by hand.

	Cost per Tie, Firsts.	Cost per Tie, Seconds.
Stumpage	$.06	$.06
Cutting	.14	.09
Skidding	.03	.03
Piling brush	.02	.02
Piling at chute	.01	.01
Chute and chuting	.01	.01
Hauling	.05	.05
	$.32	$.27

The Northern Pacific (see specifications) paid 38 cents apiece for the fir and larch firsts and 28 cents apiece for the seconds.

Photograph by Joyce-Watkins Co.

FIG. 76.—Loading ties from barges to cars at Metropolis, Ill. Large quantities of ties produced along the tributaries of the Ohio and Mississippi Rivers are sent by barge or raft to a convenient point for loading, inspection and acceptance by the railroad companies.

Sawed Ties.

The subject of sawed ties has been briefly touched upon from time to time in the above discussion. They constitute but a small portion of the total number of ties produced (about 20 per cent) and are made chiefly on the Pacific Coast of hearts of logs, where the most knots are found. They bring from 32 to 40 cents per tie for Douglas fir or 60 to 70 cents for white oak or more, depending upon such factors as species, specifications, etc. Very commonly they are sold by the thousand board feet. Switch ties, which are much longer, are practically always sawed and sold by the thousand board feet. Knots do not detract from the value of a tie if they are sound and not so placed as to lessen its strength or life.

Some sawed ties are made in the East in portable mills and in double or twin-circular mills, by slabbing either 2 or 4 sides.

Generally speaking it costs more to deliver sawed ties on the market than hewed ties. In the central hardwood region it is commonly understood that it costs about 5 cents per tie more to deliver sawed white oak ties on the market than hewed ties, with the same given conditions of timber, accessibility, specifications, etc. In this region the cost of sawing ties on four sides is 10 cents apiece for ties 7 in. in thickness, 8 in. in width and 8½ ft. long and 8 cents apiece for ties 6 in. in thickness, 8 in. in width and 8 ft. long. Felling and logging of timber to the sawmill is about 12 cents per tie for the first-named size and 10 cents for the latter size. The added cost of sawed ties over hewed ties is due usually to the increased logging expense of hauling the log and waste slabs to the mill. In hewing, the tie is made on the ground, skidded to the haul-road and then brought directly to the railroad.

A typical example of the cost of producing sawed ties 7 in.×8 in.×8 ft. long along the Ohio River was as follows:

	Cost per 1000 Feet, Board Measure.	Cost per Tie at 30 Ties per 1000 Bd. ft.
Stumpage	$6.00–$10.00	$.200–$.333
Felling	1.25– 1.25	.041– .041
Logging	1.50– 2.00	.050– .067
Sawing, yarding, etc	4.00– 5.00	.133– .167
Hauling (2–6 miles)	1.00– 2.50	.033– .083
Totals	$13.75–$20.75	$.457–$.691

As noted before, where sawlogs run about ten to the thousand board-feet, about 30 ties, 7 in.×8 in.×8 ft. can be sawed from each thousand board-feet.

The cost of sawing Douglas fir ties in the Northwest was found to be as follows, at one mill. Lumber was the main product and only the smaller logs and hearts of larger logs were sawed into ties:

	Cost per 1000 Feet, Board Measure.	Cost per Tie at 30 Ties per 1000 Bd. ft.
Stumpage	$2.00	$.067
Cutting logs (felling and bucking)	.60	.020
Skidding	1.25	.041
Hauling to mill	2.75	.091
Sawing	2.00	.067
Overhead: depreciation, interest, taxes, sales expense	1.25	.041
	$9.85	$.327

SEASONING

Cross ties are always seasoned before being placed in service on the track or before preservative treatment for the following reasons:

1. Seasoned ties as in the case of all timbers are more durable than in the green state because the water content is reduced and the likelihood of attack by fungi lessened.

Photograph by A. R. Joyce.

FIG. 77.—Conventional methods of piling cross ties. On the right, softwood ties are piled by the open method; on the left, the hardwood ties are piled by the alternate method in order to season more slowly and prevent excessive checking.

2. Seasoning increases the effectiveness of preservative treatment.
3. A decrease of from 30 to 40 per cent of the weight of ties by seasoning means a corresponding decrease in hauling charges and freight rates.
4. Proper seasoning prevents serious or unnecessary checking and splitting.

The rate of seasoning is determined largely by the structure of the wood, the season of the year, general climatic conditions, methods of piling and location of the ties.

Hardwoods such as oak, gum, maple, beech, etc., season slowly and with difficulty as compared to such softwoods as the pines, firs, cedars spruces and redwood.

Winter-cut ties are less likely to fungus and insect attack and when properly piled will season out sufficiently during the following spring and summer. In all cases, ties should be peeled as soon as cut in order to facilitate the most rapid seasoning. Some ties such as gum and beech season with difficulty and if piled too open and exposed to the sun's ray may split and check very seriously.

The following table shows the rate of seasoning for peeled hemlock ties, stacked in 7 by 2 forms and surrounded by other piles. They were cut in the winter, but showed no apparent loss in weight up to the time of initial weighing:[1]

Date of Weighing.	Time Seasoned from First Weighing. Days.	Moisture Content of Dry Weighing. Per Cent.	Average Weight per Cubic Foot. Pounds.
April 13	0	129	55.0
May 13	30	95	46.8
June 13	60	82	43.7
July 13	90	72	41.3
August 13	120	65	39.6
September 13	150	60	38.4
October 13	180	56	37.4
November 13	210	53	36.8

The warmer and drier the air and the greater the circulation of air currents, the more rapid will be the loss of water from the ties and consequently its rate of seasoning. Ties, therefore, season more quickly in the South than in the North and more rapidly in summer than in winter. Ties should never be piled to season on low, swampy ground, or where there is not a good circulation of air currents. Piling in or near a rank growth of grass or weeds should always be avoided and piles should be elevated above the ground on two cull ties or by some other means to permit freedom of air currents underneath.

There are many forms of piles in common use. Some are shown in the accompanying illustration. The following are the principal forms used by our railroad systems:

(*a*) Solid piling, arranging 7 to 9 ties each way, with no spacing and, therefore, little chance for circulation of air. This is rapidly going out of practice, as it results in too slow a rate of seasoning.

(*b*) Half-open piling, in which about 4 in. of spacing is allowed between the ties, which are placed seven in a tier, each way. Not advocated, as it is still too close for proper seasoning.

(*c*) Triangular piling. Advocated where most rapid seasoning is desirable and where plenty of piling space is available. Costs more than other forms and is little used.

[1] See "The Seasoning and Preservative Treatment of Hemlock and Tamarack Cross Ties," by W. F. Sherfesee, U. S. Forest Service Circular 132, p. 11.

(*d*) Open-crib piling, where ties are placed in alternate layers 7 one way and 2 the other. This is known as 7 by 2 piling. Variations of it, such as the 9 by 2 and 7 by 1, 8 by 1, and 8 by 2 are also used. This is the most common form and is now specified by most of the progressive railroad systems of the country. Ten tiers or layers of ties resting on stones or cull ties, with 45 ties to the pile is a common form. It permits of free circulation of air and experiments have shown it to give the best results. The 7 by 1 method is commonly used with hardwoods whereas the 7 by 2 method is used with softwoods.

When green ties or those that have been in the water are exposed to too rapid drying by warm temperatures, direct rays of the sun and strong wind currents, the ends of the ties, due to more rapid evaporation of moisture, are likely to shrink and check. Many ties are culled on inspection when checked too severely. Close piling will tend to decrease the checking, together with piling in the shade and other similar precautionary measures. However, in all cases, a few ties, especially those of certain species which season with difficulty, will split and check. Many railroads are now following an old European practice, which consists of driving "S" irons in the ends of the ties, across the incipient check to prevent further opening. Their use is shown in the accompanying diagram.

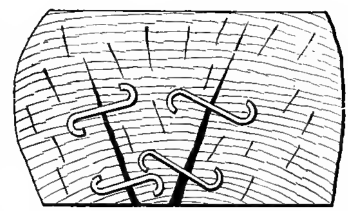


Fig. 78.—Method of using "S" irons to prevent the further opening of checks in cross ties.

Oak ties should be given a minimum period of seasoning of eight months after cutting in the late winter, but they should preferably be exposed under favorable conditions of seasoning for fully twelve months. Other dense and heavy hardwood ties, such as beech, birch, maple, sycamore, and locust should receive the same length of seasoning period.

Yellow pine, Douglas fir, western larch, and tamarack ties should be seasoned from five to eight months; hemlock, jack pine, cedar, cypress, redwood and chestnut ties from four to six months. If accurate moisture determinations cannot be conveniently made, seasoning should be continued until their weight is constant.

LIFE OF UNTREATED TIES

Until comparatively recent years, nearly all cross ties were placed in service in railway tracks in the untreated condition. White oak, chestnut and longleaf pine were practically the only species used and they gave satisfaction until higher prices were demanded with the decreasing available supply.

The life of untreated cross ties depends upon a number of factors, principal of which is the durability of the species involved. However, the length of service is determined by the following factors aside from natural durability:

1. Size of tie, including both thickness and face. Small ties rot away or shatter under heavy rolling stock much faster than larger ones.

2. Amount of sapwood. Even the sap of white oak rots away much faster than the heartwood.

3. Degree of seasoning. It has already been explained that thoroughly seasoned ties are much more durable than those in a green or partially seasoned state.

4. Climatic conditions. It has been demonstrated that white oak ties in a warm, humid climate will not last more than from five to six years, whereas in a colder and dry climate they may last from eight to twelve years. Ties resist decay in the climate of the West much better than in the East.

5. Condition of the road bed, such as character of the ballast, drainage facilities, etc.

6. Weight of rolling stock, frequency of trains, and whether on main or branch lines, sidings, etc.

7. Protection against mechanical wear. The use of tie plates, screw spikes, dowels, etc., is of material assistance in adding to the length of service of all forms of cross ties.

It is obvious from the above, therefore, that it is impossible to forecast the life of untreated ties in the track. The variation within the individual species is very great, depending upon these factors. The following is offered as a rough guide in estimating the life of the principal species used for ties in the untreated condition.[1]

Species	Length of Life in Years.
Beech	2– 4
Birch, yellow or red	2– 4
Cedar, eastern red	12–15
Cedar, northern white	10–15
Chestnut	5– 8

[1] For further data see "Durability Records of Cross Ties," by C. P. Winslow and C. H. Teesdale in Proceedings, American Wood Preservers' Association, 1916.

Species	Length of Life in Years.
Cypress	9–14
Elm, white	3– 5
Fir, Douglas	6– 9
Gum, red	3– 4
Gum, black	2– 4
Hemlock, eastern	2– 3
Hemlock, western	4– 7
Hickory	2– 5
Larch, western	6– 8
Locust, black	12–20
Maple, hard	2– 4
Oaks, white	7–11
Oaks, red	3– 6
Pine, loblolly	2– 4
Pine, lodgepole	2– 5
Pine, longleaf	6– 9
Pine, shortleaf	3– 5
Pine, western yellow	4– 7
Pine, white	3– 6
Redwood	8–14
Tamarack	6 –9

THE PRESERVATIVE TREATMENT OF TIES[1]

It is estimated that in 1915 over 37,000,000 ties or nearly 30 per cent of all those used that year were treated by some artificial means to prolong their life. About 80 per cent of all wooden materials subjected to preservative treatment are cross ties.

The principal preservatives are coal tar creosote and zinc chloride, the former being used in humid or non-arid climates and the latter in the semi-arid regions of the West. (Zinc chloride leaches out of the wood in regions of medium to heavy rainfall.) Sometimes a combination of both is used (Card process).

Cross ties are almost wholly preserved by the so-called pressure treatment, that is, the ties are loaded on trucks and run directly into long cylinders or retorts where steaming or vacuum may be applied and then the creosote oil is forced into the wood fibers under pressure until an

[1] For further information regarding timber preservation, see "The Preservation of Structural Timber," by H. F. Weiss, Annual Proceedings of the American Wood Preservers' Association, and various publications of U. S. Forest Service on the subject.

absorption of from 6 to 10 lb. of oil is retained per cubic foot of wood. When zinc chloride is used, the same general process is followed except

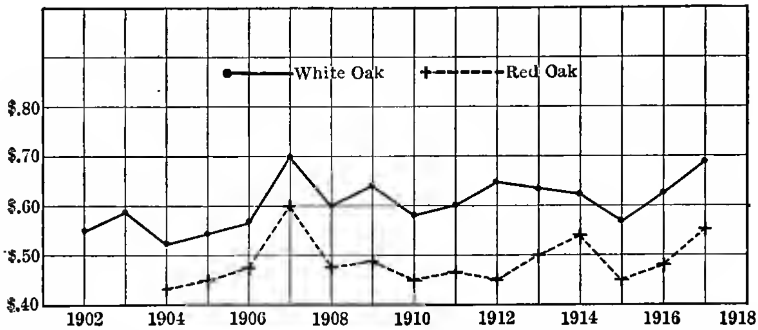


FIG. 79.—Graphic representation of the price levels of No. 1 white and red oak cross ties delivered f.o.b. cars at East St. Louis for the years 1902 to 1917, inclusive. All ties were 6″×8″×8′.

that a different preservative is used. Many variations of both the creosote and zinc chloride forms of treatment are used.

NUMBER OF CROSS TIES TREATED BY PRESERVING PLANTS DURING 1915, BY KINDS OF PRESERVATIVES AND KINDS OF WOOD[1]

Kind of Wood.	Total.	Zinc Chloride.	Creosote.	Zinc Chloride and Creosote.	Miscellaneous.
Oak	16,885,517	7,954,492	7,365,673	1,565,352	
Southern pine	8,541,203	3,257,565	5,243,516	40,122	
Douglas fir	3,553,854	2,760,952	787,247	....	5655
Beech	2,933,737	100,000	2,469,202	364,535	
Western pine [2]	2,007,609	1,702,167	301,581	3,861	
Tamarack [3]	932,038	449,660	390,017	91,496	865
Gum	277,886	204,653	1,650	71,583	
Birch	173,971	55	173,916		
Elm	50,846	50,846			
Maple	36,942	316	36,626		
All other	1,601,982	1,338,578	307,641	45,763	
All kinds	37,085,585	17,819,284	17,077,069	2,182,712	6520

[1] From Proceedings, American Wood Preservers' Association.
[2] Includes lodgepole pine and western yellow pine. [3] Includes western larch.

THE PROTECTION OF TIES AGAINST MECHANICAL WEAR

Railway engineers estimate that between 10 per cent and 75 per cent of all untreated ties that are unprotected by means of tie plates fail and must be renewed because of severe mechanical abrasion. This is especially true of the softer woods, which are readily cut by the rail when heavy axle loads and frequent trains are the rule. Those species which ordinarily decay rather quickly, such as loblolly pine, hemlock and beech, should not be protected with tie plates if laid untreated as they will decay before they wear out. Other soft but durable woods such as redwood, northern white cedar, western cedar, southern juniper, etc., unless protected by means of tie plates and screw spikes will wear out before they fail from decay.

As mentioned in the first part of this chapter, among the prime requisites that determine the desirability of any wood for tie purposes are hardness or ability to resist impact, ability to resist spike pulling and lateral displacement and sufficient strength to resist strains due to center binding. A composite expression of these properties to show the relative mechanical value of the principal woods used for cross ties has been devised by the U. S. Forest Products Laboratory. Proportionate weight has been given to the various properties involved and the following table constructed:[1]

TIMBERS ARRANGED IN ORDER OF THEIR MECHANICAL VALUE AS TIES

No.	Species.	Average Composite Value.
1	Black locust	1666
2	Sugar maple	1140
3	White oak	1050
4	Red oak	972
5	Beech	955
6	Longleaf pine	914
7	Red gum	825
8	Shortleaf pine	800
9	Western larch	790
10	Tamarack	740
11	Eastern hemlock	700
12	White fir	610
13	Lodgepole pine.	590
14	Western yellow pine	560
15	Northern white cedar	420

The protection of cross ties against mechanical wear is afforded by means of improved forms of spikes and by the use of tie plates. Various forms of screw spikes and tie plates have been tried out with very satisfactory results by the European state railways and to-day practically all their trackage is protected by both screw spikes and tie plates. Many

* See "Woods Suitable for Cross Ties," by R. Van Metre in Annual Proceedings of American Wood Preservers' Association, 1916.

of our more progressive railway systems and especially those with frequent and heavy traffic are installing the latest accepted forms on all newly laid track and tie renewals.

The passing of trains over the track results largely in an undulating or pumping action in its effect on the ties. In addition to this motion, which is responsible for the cutting of the ties by the rails, there is strong lateral pressure tending to spread the rails, especially on curves. The latter action causes a displacement of the spikes. Eventually the spikes are bent backward and pulled out. The grinding action of the rail on the tie causes it to cut and finally check until together with the necessary respiking the tie is literally worn out.

FIG. 80.—The effect of the nail spike and the screw spike on wood fibers of ties. The former works loose more readily and is less firm than the screw spike. The latter is almost universally used in Europe and is being gradually adopted in this country. The D., L. & W. Railroad has used it with great success.

This discussion, therefore, may be summarized under the following heads of (1) spikes and (2) tie plates:

1. *Spikes.* The function of spike is to hold the rail in place and prevent spreading. In driving the ordinary nail spike the fibers are crushed to a considerable extent so that it is more or less easily pulled out by the pumping and lateral pressure jars. Tests[1] carried out by Prof. W. K.

[1] From "Holding Force of Railroad Spikes in Wooden Ties,," by W. K. Hatt. Forest Service Circ. 46, 1906.

Hatt at Purdue University to compare the force required to pull nail and screw spikes show some very interesting results. The common nail spikes were $5\frac{1}{2}$ in. long and $\frac{9}{16}$ in. square in cross section and weighed 165 to the 100 lb. The screw spikes were also $5\frac{1}{2}$ in. long, with a diameter of $\frac{5}{8}$ in. at the root of the thread and weighed 85 to the 100 lb. The result of these tests showed that the resistance of the screw spike was 3.15 times that of the nail spike in chestnut, 2.1 times in loblolly pine and 1.8 times in white oak. Other tests showed that the screw spike is far superior to the nail spike in resisting lateral displacement. The loosening of the ordinary spike permits of the accumulation of moisture around it and furthers the rotting of the tie. When respiking is practiced the holes are sometimes filled with treated hardwood tie plugs.

The dilatory introduction of the screw spike is due chiefly to the abundant and relatively cheap tie timber available for our railroads. With the increased cost of cross ties and use of treated material, length of service is of great importance and this can be greatly enhanced by the use of devices to prevent abrasion and mechanical failure as well as by preservative treatment. Aside from this consideration, the objections raised to the use of screw spikes are

1. Increased initial cost over nail spikes.
2. It requires a longer time to insert screw spikes and this is likely to delay traffic at times.
3. Screw spikes require special machinery to drive them and boring both of which require larger labor and equipment costs.
4. Difficulty of re-gauging the track from time to time as track becomes worn.

In justice to these spikes, however, it should be mentioned that these objections are largely of minor consequence.

2. *Tie Plates.* These are placed immediately between the tie and the rail and are designed to distribute the impact and weight of the passing trains over a greater area than that afforded by the base of the rail and thus reduce the likelihood of rail cutting. With the use of increased rail weights, such as 100 and 110 lb. and even heavier rails with their wider flanges, the tendency to rail cutting has somewhat diminished. But the increasing weight and frequency of trains has more than counterbalanced this advantage on most of our larger railway systems.

Many forms of tie plates have been introduced and used. Wooden tie plates have been tried, but without much success, because they soon split and buckle under the great impact. In order to be effective tie plates should be of sufficient size to offer a much larger bearing surface than the base of the rail on the tie. The bottom of many of the plates is ribbed or provided with prongs or sharp points which embed themselves into the tie. The general sentiment, however, is in favor of a flat plate. In either case, the upper face should be provided with a shoulder on which the outer part of the screw spike head may be supported. Otherwise the lateral thrust may bend the spike out of position.

Two screw spikes are provided on each side of the rail and holes are made in the plate designed to accommodate rails and spikes of given dimensions. Tie plates should, in all cases, be as wide as the tie and from 6 to 9 in. long. When hewed ties are used in the treated condition they should be bored and adzed prior to treatment to provide an even bearing surface for the tie plate. Many of our treated ties are now being laid with screw spikes and plates to prevent mechanical wear and thereby increase their length of service.

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CHAPTER XIII

POLES AND PILING

GENERAL

WITH the advent of the telegraph and later the telephone as means of communication there was created a great demand for poles on which the wires are supported. Still later the street railway and interurban trolley systems and the electric light and power transmission lines added very materially to this demand until, at the present time, between 4,000,000 and 5,500,000 poles valued at from $8,000,000 to $10,000,000 are now annually needed for new construction and renewals due to failure from breakage or decay.

No government statistics have been published to show the amount of piling annually used in this country, but it is estimated that nearly as much timber is utilized for piling as for poles. When one takes into consideration the great quantities of piles used for bridge construction, trestle, wharf and harbor work along rivers, lakes and seaports, it is evident that the annual consumption of this form of material must be very large.

At first, practically all species were used for poles and piles. Accessibility and initial cost determined very largely the timbers used for our first telegraph and telephone lines, but it was soon discovered that most poles decay at the ground line in from two to five years.

At the present time even our most durable species are being treated with some wood preservative to prolong their service in the pole lines.

QUALIFICATIONS DESIRED IN POLE AND PILE TIMBERS

In making a selection of the various woods available for poles, the following properties are the determining factors:

1. The wood must be durable in contact with the soil. Poles decay most rapidly at the ground line because of the alternate dry and moist conditions at that point. Since poles are used in the round almost exclusively, it is important that the sapwood be durable.

2. The timber must be accessible and available in such quantities that it can be placed on the market at a reasonably low price.

3. It should be light in weight in order to transport and erect the poles with comparative facility, but still more importantly to secure low freight rates.

4. The wood should be sufficiently strong to resist the stresses and strains incident to carrying a load up to 80 wires, some of which may be No. 8 B. W. G. copper wire under the pressure of high winds, sleet, ice storms, etc.

5. The pole should be cylindrical, straight, with gradual taper, and free from excessive checks or other defects which will detract from its strength or shorten its life. At the present time the market is preferring poles (at least of certain species) which have large butts.

6. The surface of the pole should be susceptible to use with climbing irons. This is rather a minor consideration and yet some workmen have difficulty in climbing poles of certain species and object to their use.

7. When the poles are to be treated, the wood should be capable of penetration by creosote or other preservatives. The percentage of poles being treated is rapidly increasing so this has an important bearing.

In general, the same qualifications as outlined will hold for piling, but in addition to these properties, the timbers must be capable of being driven without breaking or splitting; they must withstand very heavy top loads; they must be sufficiently straight so that the axis is kept within the pile, and they must be clear and sound throughout.

SPECIES AND AMOUNT USED

The various species of cedars combine the above qualifications to a remarkable degree. The two principal species used for poles, northern white cedar or arbor vitæ (*Thuja occidentalis*) and western red cedar (*Thuja plicata*) make up about 65 per cent of all the woods used for pole purposes in this country. The chief sources of these poles are in the cedar districts of the Lake States, northern Idaho and western Washington. Most of our cedar poles now come from the Lake States, where large quantities of northern white cedar are cut, but the best poles for size, shape, durability and strength come from the western red cedar of the " panhandle " of Idaho. Excellent poles are also cut of the same species in western Washington, but the tree naturally grows to better pole sizes in northern Idaho. Some southern white cedar or juniper (*Chamaecyparis thyoides*) is cut for poles in New Jersey, Virginia and North Carolina, but the amount is small compared to the other cedars cut for pole purposes. The cedars are used throughout the country, but especially in the Northeast, North and Northwest. It is likely that, in the future, the Northwest will be called upon to supply more and more of our pole timbers. Most of our cedar poles are cut on large logging operations.

Chestnut is the next most prominent pole wood. It has long been a favorite pole timber in the Northeast and especially along the Atlantic Seaboard from New Hampshire to Georgia. Chestnut contributes from 12 to 20 per cent of our annual supply of poles. It makes an excellent pole timber on account of its durability and light weight, but it is inferior to the cedars both in the properties of shape and durability. It is a rapidly growing wood and reproduces so thriftily that it would be an important pole timber to encourage in forestry practice for the future were it not for the chestnut bark disease (*Endothea parasitica*) which has rapidly depleted much of the native chestnut in the past nine years. Chestnut is found in many of the woodlots in the Northeast and in the southern Appalachian section, where it is cut and marketed largely by small owners.

Oak poles have been coming into more common use in recent years for rural telephones, the extension of which has been remarkable. They are chiefly used in short lengths. Many species of oak are used and they are widely distributed, the particular kind being largely determined by the locality in which they grow. White oak is, of course, preferred on account of its durability. Oak poles are very heavy, however, and, therefore, are not shipped to great distances on account of prohibitive freight rates. In 1911 oak furnished 199,590 poles or about 6 per cent of the total pole supply. In 1907 only 76,450 oak poles were cut and used.

Pine, including chiefly longleaf pine with a limited amount of other southern pines such as loblolly and shortleaf and a small quantity of western yellow and lodgepole pines, is next in order of quantity. Although most of the pine poles are used in the round form, many southern pines are sawed into square, hexagonal and octagonal forms. Pine poles are not as durable as cedar poles and are much heavier, so they are used to a very large extent, locally. They cannot compete as pole woods without preservative treatment. The longleaf pine is far superior to the other pines for pole purposes when used in the untreated condition.

Cypress poles are used next in order of quantity, but they have decreased in amount from over 100,000 in 1907 to about 73,000 in 1911. This condition is largely due to the fact that the wood brings a higher price in the form of lumber. The total available supply of cypress, moreover, is rapidly decreasing and it is becoming more difficult to cut it in suitable sizes for poles. Cypress poles are only cut in the Southern States, chiefly in the cypress districts of Arkansas, Missouri, Louisiana and Mississippi.

The use of Douglas fir poles is rapidly increasing in the Northwest, where they are largely cut. In 1906 only 9601 Douglas fir poles were cut; in 1910 over 56,000 were cut. Western red cedar poles, which are produced in the same region, are much superior for pole purposes, espe-

Photograph by U. S. Forest Service.

FIG. 81.—Peeling western red cedar poles in the Priest River Valley, Kaniksu National Forest, Idaho.

cially in the properties of durability and light weight, so it is not likely that fir poles will be extensively called into greater demand in the future except for local purposes.

Tamarack poles are largely cut in the swamps of the Lake States. They grow to good pole sizes, are straight and well shaped and are durable, but they are much heavier for shipment than northern white cedar, which grows in the same districts.

Almost all the redwood poles, which are cut exclusively in California, are sawed because this tree is seldom found in sizes suitable for pole purposes. Redwood makes an excellent pole because of its superior durability, light weight, sufficient strength, etc., but its sawed form, requiring an additional cost for production, prevents its wider use over the country in competition with cedar and other poles placed on the market in the round form.

Other species entering to a limited extent in the pole market in order of quantity are osage orange, used locally in Oklahoma, Texas and Kansas, spruce in the Northeast, hemlock, locust, sassafras, catalpa, mulberry, butternut, ash, elm, cottonwood and a few others used locally.

When it is considered that five kinds of wood—cedar, chestnut, oak, pine and cypress—supply over 90 per cent of all poles used it is readily observed that the total amount supplied by other species is of comparatively little consequence in the pole trade.

The following table prepared by the Census Bureau in co-operation with the U. S. Forest Service shows the number of poles purchased by species for the years 1907 to 1911, inclusive, and for the year 1915:

NUMBER OF POLES PURCHASED

Kind of Wood.	1915	1911	1910	1909	1908	1907
Cedar	2,521,769	2,100,144	2,431,567	2,439,825	2,200,139	2,109,477
Chestnut	651,643	693,489	677,517	608,066	516,049	630,282
Oak	199,442	199,590	265,290	236,842	160,702	76,450
Pine	546,233	161,690	184,677	179,586	116,749	155,960
Cypress	67,644	72,995	75,459	77,677	90,579	100,368
Douglas fir	[1]	24,833	56,732	24,877	19,542	15,919
Tamarack	[1]	24,543	30,964	29,889	24,123	13,884
Redwood	[1]	26,887	30,421	23,145	13,061	31,469
Osage orange	[1]	21,101	23,221	21,491	18,109	5,962
Spruce	[1]	10,166	22,929	11,423	8,088	10,646
Juniper	[1]	27,847	20,042	43,581	42,367	38,925
Hemlock	[1]	[1]	12,773	6,222	1,998	3,301
Locust	[1]	8,477	9,030	10,463	10,224	4,672
All other	91,233	47,258	30,073	25,653	27,424	85,953
Total	4,077,964	3,418,020	3,870,694	3,738,740	3,249,154	3,283,268

[1] Included with all other.

SPECIFICATIONS AND PRICES

For commerical purposes, poles are classified by 5-ft. lengths, top diameters, and sometimes by the diameter at a specified point, usually 6 ft. from the butt as in chestnut. The minimum length is generally regarded as 20 ft. and from the poles run in 5-ft. lengths up to 75 ft. or more for special purposes. Practically two-thirds of our poles are from 20 to 30 ft. in length as these are the sizes most in demand. Only about one-fifth are from 30 to 40 ft. in length, one-twentieth from 40 to 50 ft. and only 1 to 2 per cent exceed 50 ft. in length.

The telegraph and telephone companies purchase about 75 per cent of all the poles used. A good share of the remainder are purchased by the electric railroad and the electric light and power companies. The steam railroads purchase only about 6 per cent of all the poles.

Specifications are prepared by the pole associations or by the telephone, telegraph and other companies to classify the poles according to dimensions, shape, freedom from defects and appearance.

The following are the latest specifications of the Western Red Cedar Association with headquarters at Spokane, Wash., for standard telephone, telegraph and electric light poles, 20 ft. long and with 4-in. top diameter and up.

All poles must be cut from live, growing cedar timber, peeled, knots trimmed close, butts and topssawed square; tops must be sound and must measure as follows in circumference;

4-in. top 12 -in. circumference
5-in. top 15 -in. circumference
6-in. top 18½-in. circumference
7-in. top 22 -in. circumference
8-in. top 25 -in. circumference
9-in. top 28 -in. circumference
10-in. top 31 -in. circumference

Crook.

No pole shall have more than one crook, and this shall be one way only, the sweep not to exceed 1 in. to every 6 ft. in length. Same to be determined in the following manner: Measurement for sweep shall be taken as follows: That part of the pole when in the ground (6 ft.) not being taken into account in arriving at sweep, tightly stretch a tape line on the side of the pole where the sweep is greatest, from a point 6 ft. from butt to the upper surface at top, and having so done, measure widest point from tape to surface of pole, and if, for illustration, upon a 30-ft. pole said widest point does not exceed 5 in., said pole comes within the meaning of these specifications.

Butt Rot.

Butt rot in center, including small ring rot, shall not exceed 10 per cent of the area of the butt. Butt rot of a character which impairs the strength of the pole above the ground is a defect.

Knots.

Large knots, if sound and trimmed smooth, are not a defect.

Dead or Dry Streaks.

A perfectly sound, dead or dry streak shall not be considered a defect when it does not materially impair the strength of the pole.

The following are the standard specifications of the Northwestern Cedarmen's Association of the Lake States covering the output of northern white cedar:

Standard Telegraph, Telephone and Electric Poles. Sizes 4-in., 25 ft. and upwards. Above poles must be cut from live growing timber, peeled and reasonably well proportioned for their length. Tops must be reasonably sound, must measure in circumference as follows: Seasoned 4-in. poles, 12 in.; 5-in. poles, 15 in.; 6-in. poles, 18½ in.; 7-in. poles, 22 in. If poles are green, fresh cut or water soaked, then 4-in. poles must measure 12½ in.; 5-in. poles, 16 in.; 6-in. poles, 19½ in.; 7-in. poles, 22¾ in. in circumference at top end. Length may be ½ in. scant for each 5 ft. in length and 6 in. long for any length from 20 ft. up.

One-way sweep allowable not exceeding 1 in. for every 5 ft., for example, in a 25-ft. pole, sweep not to exceed 5 in., and in a 40-ft. pole 8 in. Measurement for sweep shall be taken as follows: That part of the pole when in the ground (6 ft.) not being taken into account in arriving at sweep, tightly stretch a tape line on the side of the pole where the sweep is greatest, from a point 6 ft. from the butt to the upper surface at top, and having so done measure widest point from tape to surface of pole and if, for illustration, upon a 25-ft. pole said widest point does not exceed 5 in. said pole comes within the meaning of these specifications. Butt rot in the center including small ring rot outside of the center: Total rot must not exceed 10 per cent of the area of the butt. Butt rot of a character which plainly seriously impairs the strength of the pole above the ground is a defect. Wind twist is not a defect unless very unsightly and exaggerated. Rough, large knots if sound and trimmed smooth are not a defect.

The following are the specifications of one of the largest purchasers of poles in this country as applied to chestnut. To determine the character of poles to be used, pole lines are divided into the following classes:

Class A. A 50-, 60-, 70- or 80-wire line, the heaviest used.

Class B. Heavy trunk line with a capacity for 40 wires on four 10-pin cross arms. Ten of the wires may be No. 8 B. W. G. copper.

Class C. Light trunk line with a capacity for 20 wires on two 10-pin cross arms.
Class D. Light line with a capacity of 12 wires on two 6-pin cross arms.
Class E. Branch line with a capacity for 2 wires on brackets.

	Class A.				Class B.		
Length of Pole, Ft.	Circumference Top, In.	Circumference 6 Ins. from Butt, In.	Price f.o.b. Car	Length of Pole, Ft.	Circumference T.p, In.	Circumference 6 Ins. from Butt, In.	Price f.o.b. Car
25	24	36	$3.00	20	22	31	$1.75
30	24	40	4.00	25	22	33	2.00
35	24	43	5.00	30	22	36	3.00
40	24	45	6.00	35	22	40	4.00
45	24	48	6.50	40	22	43	5.00
50	24	51	9.00	45	22	47	6.00
55	22	54	10.00	50	22	50	8.00
60	22	57	13.00	55	22	53	9.50
65	22	60	15.00	60	22	56	12.00
70	22	63	19.00	65	22	59	14.00
75	22	66	24.00	70	22	62	17.50
				75	22	65	22.50

	Class C.				Class D.		
Length of Pole, Ft.	Circumference Top, In.	Circumference 6 Ins. from Butt, In.	Price f.o.b. Car	Length of Pole, Ft.	Circumference Top, In.	Circumference 6 Ins. from Butt, In.	Price f.o b. Car
20	20	27	$1.50	20	20	24	$1.25
25	20	30	1.75	25	20	27	1.50
30	20	33	2.25	30	20	31	2.00
35	20	36	3.50	35	20	35	3.25
40	20	40	4.50	40	20	39	4.25
45	20	43	5.50	45	20	43	5.25
50	20	46	7.00	50	20	46	7.00
55	20	49	8.00				

	Class E.		
Length of Pole, Ft.	Circumference Top, In.	Circumference 6 Ins. from Butt, In.	Price f.o.b. Car
20	15½	23	$ .85
25	15½	26	1.00
30	15½	29	1.75
35	20	34	2.10
40	20	38	3.10
45	20	42	4.00
50	20	46	5.00

All poles shall be of sound, live white chestnut, squared at both ends, reasonably straight, well proportioned from butt to top, peeled and knots trimmed to the surface of the pole.

The dimensions of the poles shall be according to the following table: The "top" measurement being the circumference at the top of the pole, the "butt" circumference being 6 ft. from the butt. The company reserves the right to make its own inspection and reserves the right to reject any poles which are defective in any respect. The prices set opposite the various dimensions in each class are the approximate average prices paid in 1917 for chestnut, loaded on cars, ready for shipment in New York State. (Shown on p. 306.)

The sweep permissible in the above poles measured at the 6-ft. mark and at the top of the pole is as follows for the different sizes:

Length of Pole, Ft.	Maximum Permissible Sweep, Ins.
35	10
40	11
45	10
50	11
55	12
60	13
65	14
70	15

In inspection work, the inspector usually carried the following equipment:

2 75-ft. waterproof tape lines.
1 50-ft. steel tape line (used in checking the accuracy of the waterproof tapes).
1 6-ft. brass safety chain, small size, with key ring or one end for measuring poles at 6-ft. mark.
2 iron prods for examining poles for bad tops, rotten knots, etc.
1 set of marking hammers.
1 timber scribe for marking poles 6 ft. from butt.

The following are the specifications adopted by the Western Red Cedar Association for piling.

STANDARD CEDAR PILING

All piling must be cut from live, growing cedar timber, peeled, knots trimmed close, butts and tops sawed square. Top must be sound. Butts may contain rot, the average diameter of which is not over 10 per cent of the diameter of the butt. (This rot not to exceed 1 per cent of the area of the butt.)

Length.

All piling shall be furnished in the following lengths: 16 ft., 20 ft., and multiples of

5 ft., over 20 ft. Owing to the inaccuracies of cutting cedar in the woods by hand, a variation of 6 in. in length is allowable.

Tops.

Piling 30 ft. and shorter must measure at small end not less than 30 in. in circumference.

Piling 35, 40, and 45 ft. must measure at small end not less than 28 in. in circumference.

Piling 50 ft. to 70 ft., inclusive, must measure not less than 25 in. in circumference at small end.

Butts

Butts must measure not less than 14 in. of more than 20 in. in diameter the widest way.

Crook.

Piling may contain crook one way providing a line drawn from the center of the top to the center of the butt does not fall outside the body of the piling at any point

Cat Faces and Dry Streaks.

A sound cat face not to exceed 10 per cent of the length of a piling is permissible. A sound, dead or dry streak shall not be considered a defect when it does not materially impair the strength of the piling.

In addition to red cedar, the following timbers are commonly used for piling purposes in the West: Douglas fir, western hemlock, western yellow pine, redwood and, to some extent, eucalyptus.

In the East, most companies classify piling as permanent or temporary. The former must be of white oak, chestnut or longleaf pine and must be peeled. The latter may be of almost any species that can be driven with a pile driver, but the following are generally used: Red and black oak, beech, maple, ash, hickory, elm, black gum or sycamore. They are used in the unpeeled condition. The following are customary dimensions: The diameter at the middle of the pile shall be not less than 12 in. and the diameter of the butt shall not exceed 20 in. The minimum diameter at the top for piles up to 30 ft. in length shall be 9 in.; for those from 30 to 50 ft., 8 in., and for those exceeding 50 ft., 7 in. A line from the center of the butt to the center of the top shall lie within the pile. Permanent piles usually command a price of from 14 to 20 cents or more per lineal foot, delivered at the railroad tracks, while temporary piling brings only from 8 to 15 cents per linear foot. The larger prices are paid for the longer pieces.

The following table shows the lengths and top diameters in which western red cedar is sold, the average weight for each size and the prices which obtained on board cars at a prominent pole shipping center in northern Idaho for the years 1912–1916, inclusive:

Length in Feet.	Top Diameter in Inches.	Average Weight in Pounds.	Prices f.o.b. Cars, Northern Idaho.				
			1912.	1913.	1914.	1915.	1916.
20	4	100	$ .55	$.60	$.55	$.55	$.60
20	5	135	.70	.75	.70	.65	.75
20	6	190	.90	1.10	1.05	1.00	1.10
25	4	150	.75	.85	.75	.75	.85
25	5	200	1.00	1.20	1.10	1.00	1.20
25	6	250	1.50	1.25	1.50	1.40	1.85
25	7	325	2.00	2.25	1.85	1.75	2.25
25	8	400	2.50	3.00	2.50	2.50	3.00
30	6	350	2.00	2.25	1.95	2.00	2.25
30	7	400	2.75	3.75	2.50	3.00	3.75
30	8	500	3.25	4.50	3.25	3.50	4.50
35	6	400	3.00	4.00	3.00	3.50	4.00
35	7	500	3.50	4.75	3.75	4.00	4.75
35	8	625	4.00	5.50	4.25	4.75	5.50
35	9	800	4.50	6.00	4.85	5.25	6.00
40	7	650	4.00	5.50	4.25	5.00	5.50
40	8	800	4.50	6.00	4.85	5.50	6.00
40	9	1000	5.00	7.00	5.40	6.50	7.00
45	7	850	4.75	6.50	4.85	6.00	6.50
45	8	1000	5.50	7.00	5.40	6.25	7.00
45	9	1200	6.00	8.00	6.00	6.75	8.00
50	7	1050	5.50	7.50	5.40	6.25	7.50
50	8	1200	6.00	8.00	6.00	7.00	8.00
50	9	1400	7.00	9.00	6.65	8.00	9.00
55	8	1400	7.00	9.00	6.65	8.00	9.00
55	9	1600	8.00	10.00	7.25	9.00	10.00
60	8	1600	8.00	10.00	7.25	9.00	10.00
60	9	1850	9.00	12.00	8.25	11.00	12.00
65	8	1850	9.00	12.00	8.25	11.00	12.00
65	9	2200	11.00	16.00	10.00	14.00	16.00
70	8	2200	11.00	16.00	10.00	14.00	16.00
70	9	2600	14.00	21.00	12.50	18.00	21.00
75	8	2600	14.00	21.00	12.50	18.00	21.00
75	9	3000	21.00	28.00	18.00	25.00	28.00
80	8	3000	21.00	28.00	18.00	25.00	28.00
80	9	3500	30.00	35.00	25.00	33.00	35.00

The prices that have obtained for northern white cedar during 1916 have been about as follows, on board cars in the pole yards in the Lake states:

Length in Feet.	Top Diameter in Inches.	Prices f.o.b. Cars.
20	4	$.47
20	5	.57
20	6	.65
20	7	1.25
25	4	.60
25	5	.75
25	6	1.60
25	7	2.50
30	6	3.00
30	7	4.75
35	6	5.50
35	7	8.50
40	6	8.50
40	7	10.50
45	6	10.50
45	7	13.00
50	6	13.00
50	7	16.00
55	6	16.00
55	7	18.00
60	7	25.00
65	7	30.00
70	7	40.00

LOGGING AND PRODUCTION OF POLES AND PILING

General Considerations.

The logging of cedar poles and piles in both the Lake States and in the Northwest is usually carried on as a systematic and separate operation, either before or after the logging of the saw timber. This is done in order to prevent unnecessary breakage of the lighter and weaker cedar by the heavy woods worked up into saw logs.

A very large percentage of chestnut and oak poles are logged and delivered to the pole yards or to the railroad by farmers and small woodlot owners, the work being done in the winter when other work is rather slack. Some of the northern white cedar and western red cedar is still cut by ranchers and those engaged in clearing land, but the production of poles is carried on as a separate industry more in northern Idaho and in northern Michigan and Minnesota than in any other centers.

The sawing of long logs into tapered poles from redwood, pine and occasionally from a few other woods is rapidly going out of practice.

Generally speaking, the logging consists of felling the tree close to the ground (as large butts are preferred), sawing off the top at even 5-ft.

lengths, trimming off the branches, peeling, skidding, and hauling to the railroad, driving or floating to the pole yard.[1]

Pole logging is the cheapest form of logging per unit of volume, since practically the whole tree trunk is taken out in one operation.

The following table is interesting as showing the size of trees of various diameters, taken at breast height ($4\frac{1}{2}$ ft.) required to yield poles of specified lengths and top diameters. It was devised as a result of the measurement of 478 western red cedar trees in northern Idaho by officials of the Forest Service:

Length in Feet.	Diameters at Breast Height in Inches.				Number of Trees Used as Basis.
	5-in. Top.	6-in. Top.	7-in. Top.	8-in. Top.	
20	8	9.5	....	....	48
25	....	10.5	11.8	....	49
30	....	11.6	13.0	14.8	65
35	....	....	14.7	14.9	51
40	....	....	16.5	16.7	51
45	....	....	16.7	17.9	52
50	....	....	16.9	18.4	51
55	....	....	....	18.7	25
60	....	....	....	19.8	25
65	....	....	....	21.8	25
70	....	....	....	23.2	20
75	....	....	....	24.3	9
80	....	....	....	25.7	7

The following table shows just the reverse of the above table in that it gives the sizes of poles that may be obtained from trees of different

Diameter, Breast High in Inches.	Height of Tree in Feet.					Number of Trees used as Basis.
	50	60	70	80	90	
	Length of Poles in Feet.					
13	25	25	25	25	25	11
14	30	30	30	30	30	17
15	35	35	35	35	35	6
16	....	....	40	40	40	14
17	....	....	40	45	45	6
18	....	....	45	50	50	11
19	....	....	....	....	55	6
20	....	....	....	....	60	4

[1] For details regarding general logging methods see "Logging," by R. C. Bryant, John Wiley & Sons, New York City.

diameters. It was made by E. H. Frothingham for chestnut in Connecticut.[1] All poles are assumed to have a 7-in. top.

Stumpage Values.

As in the case of all timber values, the value of pole stumpage depends upon the species involved, accessibility, quality of poles, difficulty of logging and marketing, supply and demand, etc. Cedar pole stumpage is practically the only pole stumpage traded in, since the other kinds of poles are largely cut and marketed by the owners or cut along with large logging operations, as is largely the case with such poles as cypress, pine, redwood, Douglas fir, etc. In the latter case they are purchased along with the saw timber and at specified values per thousand feet.

Stumpage values in both northern white and western red cedar are based on the lineal foot and on the piece. It is customary in some localities to charge 2 cents per running foot for all poles up to and including 40 ft. in length, and 3 cents for all poles over 40 ft. in length. In other centers of operation, a separate stumpage value is placed on each pole of given length and top diameter.

The following table shows the stumpage values for western red cedar

STUMPAGE VALUE OF WESTERN RED CEDAR POLES IN NORTHERN IDAHO

Length, Lineal Feet.	Top Diameter, Inches.	Board Measure per Pole.	No. Poles per M.Ft. B.M.	Stumpage Value.		
				Per Pole.	Per Linear Foot.	Per M.Ft. BM.
20	5	20	50.00	$.09	$.005	$4.50
20	6	25	40.00	.12	.006	4.80
25	6	35	28.57	.19	.01	5.43
25	7	40	25.00	.29	.01	7.25
30	6	50	20.00	.30	.01	6.00
30	7	75	13.33	.44	.015	5.87
30	8	90	11.11	.59	.02	6.55
35	6	75	13.33	.54	.015	7.20
35	7	90	11.11	.68	.02	7.55
35	8	115	8.70	.90	.025	7.83
40	7	125	8.00	.93	.02	7.44
40	8	135	7.40	1.12	.03	8.29
45	7	145	6.90	1.03	.02	7.11
45	8	175	5.72	1.34	.03	7.66
50	7	180	5.55	1.50	.03	8.32
50	8	215	4.65	1.50	.03	6.98
55	8	295	3.38	1.93	.035	6.52
60	8	310	3.23	2.10	.035	6.78
65	8	360	2.78	2.60	.04	7.23
70	8	390	2.50	2.80	.04	7.17

[1] See "Second Growth Hardwoods in Connecticut," Forest Service Bulletin No. 96, by E. H. Frothingham.

in northern Idaho expressed on the basis of each sized pole as well as by linear feet and by the thousand feet, board measure. It also shows the amount of board-feet in each sized pole and the average number of poles required to make a thousand board-feet. All figures are based on the Scribner Decimal C Scale and on measurements taken by 10- and 5-ft. sections.

Both western and northern white cedar when found in good pole sizes bring much better stumpage values when sold in the pole form than as saw logs or for any other purpose.

Felling and Peeling.

Winter-cut poles are much more in demand than those cut at other seasons of the year. Peeling, of course, is more difficult and expensive at this season, but many specifications of purchasing companies call for winter-cut poles as they dry out much more readily in the following spring and summer. Many dealers claim that they are more durable and stronger, but there is nothing to support this contention other than the likelihood that winter-cut poles are less susceptible to checking and insect and fungous attack than those cut in the spring or summer.

In making poles, one man usually works alone and is paid by the lineal foot. He uses an axe for undercutting and limbing and a one-man, 5-ft. saw for felling and sawing off the top. With the axe or broadaxe he peels off the bark by standing on the tree trunk and working backward, taking off a continuous strip 3 to 5 in. in width and turning the pole with a cant-hook until all the bark is removed.

Peeling is done easiest from about May 1st to August 1st, but the same prices for felling and peeling usually prevail throughout the year on continuous jobs.

The rates paid for felling, limbing, topping and peeling vary with the region, demand for labor and many other factors. On one large pole operation in northern Idaho, .8 cent was paid per foot for all poles up to 40 ft. in length, 1 cent for poles 40 to 60 ft. long, and $1\frac{1}{2}$ cents for all poles 60 ft. and up in length. Sometimes a straight rate of 1 cent for felling and 1 cent for peeling is paid on the more difficult jobs. Since most of the poles are from 20 to 35 ft. in length the cost averages about 1 cent per ft. for both operations.

Piling is seldom peeled for the reason that it seasons better with the bark on and checks less. When intended for preservative treatment, however, all piling is peeled.

Skidding.

This operation usually consists of dragging the pole, by using a team and tongs or choker, to the landing, chute or stream. It costs from ½ to 1½ cents per lineal foot depending upon the usual factors of distance charges for teams and labor, topography, ground cover, size of poles, etc. On some operations 15 cents per pole is paid for all poles up to 35 ft. long. For those above this, 1 cent per lineal foot is paid.

Hauling and Other Forms of Transportation.

This is also a very variable charge. Hauling is done on sleighs in winter and on wagons in summer. On some of the larger logging operations, skidding takes the poles directly to a railroad or to a drivable stream.

On fair country dirt roads from 4 to 7 40-ft. poles will be a good load for one team and wagon. On sleighs from 10 to 15 green poles, 30 to 40-ft. in length, may be handled in one load.

Hauling costs on a large cedar operation, using wagon haul, were as follows for 30-ft. poles:

1 mile	$ .15 per pole
1–2 miles	.25 per pole
2–4 miles	.75 per pole
4–6 miles	1.00 per pole

For poles below and above this standard a proportionate reduction or increase was made.

The cost of driving cedar poles and piles an average distance of 25 miles in Michigan was 5 cents each (average of all lengths). Rafting 30 miles varied in cost from 3 cents each for 20-ft. poles up to 5½ cents for 30-ft., 25 cents for 40-ft., and 40 cents for 60-ft. poles. The cost of driving and rafting rises very rapidly with the length. On narrow, winding streams poles are driven with great difficulty, as jams are frequent.

Yarding, Seasoning and Shipping.

Proper yarding and seasoning facilities are of great importance in the pole business. Up to the present time little attention has been paid to methods of seasoning and the poles have been piled on top of each other indiscriminately.

If piled too closely and too high they are likely to be attacked by fungi before they season properly while, if exposed too much to the sun

Photograph by U. S. Forest Service.

FIG. 82.—Loading chestnut poles to be hauled to market at Allen s Cove, Perry Co., Pennsylvania.

Photograph by E. T. Chapin Co.

FIG. 83.—The beginning of a new pole yard in northern Idaho. These are western red cedar poles, which are produced in great quantities from this section. The poles are skidded by team from the woods to this landing, where they are loaded on cars and sent to the distributing yard.

and the drying action of the wind, they may check seriously. If poles are to be treated, they should be thoroughly seasoned. In any case, seasoning is of importance in saving freight charges. The decrease in weight in the seasoning process may be anywhere from 20 to 50 per cent according to Weiss, or 180 to 850 lb. per pole.

When the top diameter of green poles is measured, 1 in. is customarily allowed for shrinkage in circumference, although shrinkage in such species of low specific gravity as the cedars and chestnut would be much less than in oak, or the heavier pines. When end checking becomes evident, the poles should be protected from further deterioration by means of "S" irons.

The best method of seasoning is to provide skids or stickers between the poles so that free currents of air may carry off the moisture. When once seasoned the poles should be shipped at once or a roof placed over them.

All poles should be seasoned for four full seasoning months. In determining what should constitute an equivalent of this period, the calendar months have been rated as follows:

January	equals	$\frac{1}{8}$	seasoning month;
February	equals	$\frac{1}{8}$	seasoning month;
March	equals	$\frac{1}{4}$	seasoning month;
April	equals	$\frac{1}{2}$	seasoning month;
May	equals	$\frac{3}{4}$	seasoning month;
June	equals	1	seasoning month;
July	equals	1	seasoning month;
August	equals	1	seasoning month;
September	equals	1	seasoning month;
October	equals	$\frac{3}{4}$	seasoning month;
November	equals	$\frac{3}{8}$	seasoning month;
December	equals	$\frac{1}{8}$	seasoning month.

Yarding, seasoning and loading costs from 1 to $2\frac{1}{2}$ cents per lineal foot, depending upon yarding facilities, amount handled, labor costs, efficiency, labor-saving devices, etc. Heavy cranes, log loaders and gin poles are used for unloading, piling and loading. Loading alone costs about 1 cent per lineal foot.

Poles over 40 ft. in length must be loaded on two flat cars. The following table shows the approximate number of western red cedar poles of each size used for single and double car-load lots:

Photograph by E. T. Chapin Co.

FIG. 84.—Method used in piling poles to facilitate drying. Nearly 5,000 000 poles are annually required for our telephone and telegraph lines, electric light and power lines, etc.

NUMBER OF POLES REQUIRED TO MAKE CAR-LOAD LOTS

WESTERN RED CEDAR

(Single Load—on One Car.)

6-in. top, 25 ft.	175 to 225 poles
7-in. top, 25 ft	150 to 175 poles
8-in. top, 25 ft.	120 to 140 poles
6-in. top, 30 ft.	130 to 175 poles
7-in. top, 30 ft.	120 to 150 poles
8-in. top, 30 ft.	90 to 120 poles
6-in. top, 35 ft.	120 to 150 poles
7-in. top, 35 ft.	100 to 120 poles
8-in. top, 35 ft.	90 to 110 poles
7-in. top, 40 ft.	90 to 120 poles
8-in. top, 40 ft.	85 to 110 poles

(Double Load—on Two Cars.)

7-in. top, 45 ft.	80 to 95 poles
8-in. top, 45 ft.	70 to 85 poles
7-in. top, 50 ft.	70 to 85 poles
8-in. top, 50 ft.	60 to 75 poles
8-in. top, 55 ft.	55 to 70 poles
8-in. top, 60 ft.	50 to 65 poles
8-in. top, 65 ft.	45 to 60 poles
8-in. top, 70 ft.	40 to 50 poles

Summary of Costs.

It is very difficult to give average costs which will obtain for any number of operations. Each logging chance presents its own difficulties and no two operations are identical in scarcely the smallest respect.

The following are offered as being fairly representative of the average logging costs found in the western red cedar region of northern Idaho:

Items.	Cost per Running Foot.		
	Low.	Average.	High.
Stumpage	$.01	$.02	$.03
Cutting and peeling	.008	.01	.015
Skidding	.005	.008	.01
Transportation	.005	.01	.02
Storage and loading	.01	.015	.02
Sales and general expense	.01	.015	.015
	$.048	$.078	$.11

Photograph by U. S. Forest Service.

Fig. 85.—Loading southern white cedar telephone and telegraph poles at Wilmington, North Carolina. The swampy regions of eastern Virginia and the Carolinas contain some excellent stands of this cedar.

The highest figures will hold for operations where long poles are being logged as a rule and where transportation is more expensive. The minimum estimates, on the other hand, are generally for shorter length poles and where conditions are more favorable for economical logging.

In logging chestnut in eastern woodlots, the following are the approximate itemized costs per lineal foot:

Items.	20-30 Foot Poles.	35-50 Foot Poles.
Stumpage	$.02	$.03
Cutting and peeling	.007	.015
Skidding	.004	.008
Transportation	.008	.018
Storage and loading	.01	.015
General expense	.015	.017
	$.064	$.103

It does not generally pay to log and market chestnut poles in the 25- and 30-ft. lengths according to many operators, as there are insufficient profits. The shorter lengths are commonly sold as piling, which bring better prices as a rule.

LENGTH OF SERVICE UNTREATED

The length of service which untreated poles will give depends upon a number of factors. These are as follows:

1. Kind of wood. It is obvious that the cedars, chestnut, redwood, white oak, cypress, etc., are preferred for pole purposes on account of their exceeding durability along with their other favorable qualifications.
2. Size of pole. Large poles will give much longer service than those of small diameter. Poles decay at the ground line first and therefore those with large butts which are of greatest diameter at the ground line are much preferred, other conditions being equal.
3. Climate, precipitation, etc. Poles placed in warm, humid climates will not last as long as those placed in arid or colder regions.
4. Local conditions of soil, drainage, moisture, etc.
5. Breakage due to sleet or ice storms, heavy winds, etc.

Altogether, under average conditions, the principal woods used for poles will probably last as follows, in the untreated state:

Species.	Years.
Northern white cedar	12–16
Western red cedar	12–16
Southern white cedar	11–15
Chestnut	8–12
White oak	7–11
Cypress	11–15
Longleaf pine	6–10
Loblolly pine	4– 6
Redwood	12–15
Western yellow pine	2– 4
Lodgepole pine	2– 4
Douglas fir	6–10

Photograph by E. T. Chapin Co

FIG. 86.—Method employed in piling and loading poles on cars.

The life of untreated piling depends upon a number of factors, chief of which are: (1) the kind of wood; (2) size; (3) amount of abrasion and wear and tear to which it is subjected; (4) damage by marine borers (teredo, limnoria, xylotrya, etc.); (5) exposure to elements which encourage decay. Piles retained entirely underneath the surface of water or in the ground will last almost indefinitely.

Much of our piling is only temporary in its requirements, such, for example, as for temporary trestle and bridge construction, false work, etc. For such purposes almost any species may be used. For wharf, dock, trestle or other construction in the warmer salt waters (south of Delaware Bay on the Atlantic Coast and the entire Pacific Coast up to British Columbia) the danger from marine borers is so great that untreated or unprotected piling may be riddled and rendered useless in from one to four years.

White oak, Douglas fir and longleaf pine are the principal timbers used for piling purposes where great strength and durability are required. When exposed, untreated, to the usual conditions of decay, such, for example as wharf or dock piling, trestlework, etc., but without the presence of marine borers, these woods should remain in service for from seven to eleven years. Other less durable species must be replaced in from four to seven years depending, of course, upon the local conditions of decay, abrasion, etc.

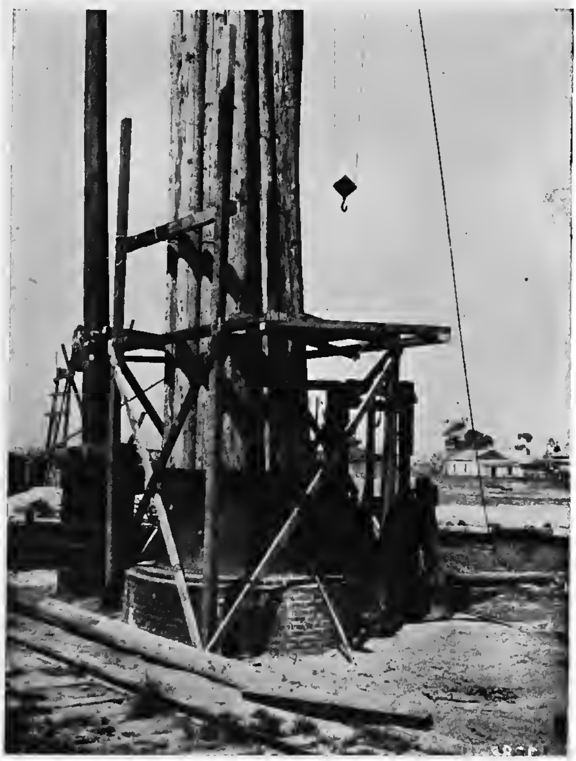
THE PRESERVATIVE TREATMENT OF POLES AND PILING

Consumers of poles and piles are actively taking up the work of preservative treatment to prolong their life in service. It has not only been demonstrated that the increased cost due to treatment is more than justified in the longer service rendered, but when the cost of taking out old poles, replacing them with renewals together with the cost of restringing the wires are taken into consideration, there is a great annual saving. Even the most durable poles are now being treated before placement. Within the past decade the amount of poles and piling that has been subjected to preservative treatment has more than doubled.

Inasmuch as poles deteriorate from decay most rapidly at the ground line it is only necessary to treat that portion of the pole which extends from the butt up to a point about 6 in. above the surface of the ground. Many methods of artificially treating the pole or providing for its setting in the ground have been experimented with. Among these are: (*a*) charring by means of painting with crude oil and setting fire to it; (*b*) brush treatment or coating with creosote or other toxic preservative; (*c*) setting in a collar of concrete or crushed stones. The first two (*a*) and (*b*) will probably prolong the life of a pole from two to six years but the last named (*c*) does not justify the additional expense incurred.

In all cases, poles should be thoroughly air seasoned before being subjected to any form of artificial preservative treatment.

Probably 95 per cent or more of the poles that are treated in this country are given the open-tank treatment, whereby a penetration of from one-third to 3 in. or more of the preservative from the surface is secured on the butt of the pole. Many pole companies have recently installed open-tank plants in connection with their pole yards or distributing depots, where the poles are raised by means of a derrick and stood on end in a hot bath of creosote at a temperature of about 215° F.



Photograph by U. S. Forest Service.

FIG. 87.—Method of treating poles in an open tank to increase their length of service. The butts are treated up to a point above the ground level. Wilmington, Los Angeles Co., California.

for about two hours. The creosote oil is then permitted to cool or cold oil is pumped in. The heating process causes the water and air in the wood to expand. The cool bath causes a contraction in the cells and intercellular spaces and the oil penetrates the partial vacuum caused by change in temperature. Experiments have shown that a penetration of .3 in. for chestnut up to 3.1 in. for western yellow pine has been secured by this method. Absorption of from 20 to 50 lb. of creosote oil per pole is usually secured.[1]

Kempfer has shown the possibilities, cost and annual saving in the treatment of poles by both the brush and open-tank methods in comparison with the untreated condition of many of the kinds of timber used for pole purposes.

ESTIMATED FINANCIAL SAVING DUE TO CREOSOTE TREATMENT OF POLES

Species.	Size of Pole. Diameter, Ins.	Size of Pole. L'gth, Feet.	Character of Treatment.	Amt. of Preservative Applied per Pole, Lb.	Estimated Cost of Treatment.	Estimated Cost of Pole in Place.	Estimated Length of Life, Yrs.	Annual Cost.	Annual Saving Due to Treatment.
Chestnut	7	30	Untreated	0	.....	$6.00	10	$0.77	
			Brush	7	$.020	6.20	13	.66	$0.11
			Open-tank	25	.75	6.75	16	.62	.15
Southern white cedar	7	30	Untreated	0	.....	5.00	10	.65	
			Brush	5	.20	5.20	13	.55	.10
			Open-tank	40	.95	5.95	18	.51	.14
Northern white cedar	7	30	Untreated	0	.....	7.00	14	.71	
			Brush	5	.20	7.20	17	.64	.07
			Open-tank	50	1.05	8.05	22	.61	.10
Western red cedar	8	40	Untreated	0	.....	9.50	10	1.23	
			Brush	8	.30	9.80	13	1.04	.19
			Open-tank	40	1.35	10.85	20	.87	.36
Western yellow pine	8	40	Untreated	0	.....	8.00	3	2.94	
			Brush	6	.30	8.30	5	1.92	1.02
			Open-tank	60	1.90	9.90	20	.79	2.15
Lodgepole pine	7	35	Untreated	0	.....	7.00	5	1.62	
			Open-tank	40	1.25	8.25	20	.66	.96
Loblolly pine	6	35	Untreated	0	.....	2.50	3	.92	
			Entire pole open-tank or pressure	200	2.45	4.95	20	.40	.52

In 1915, 2,512,780 cu. ft. of poles were treated. This is equivalent to 4,282,175 lineal feet. Assuming 7 ft. to be the average length of butt treatment, this means that 611,739 poles were treated during that year.

The table on p. 324 shows the ground line and height of treatment for different-sized poles used by one of the large companies operating in western red cedar.

More cubic feet of piling are now treated than of poles. It is practically essential to treat all piling placed in waters containing marine borers as outlined above. Instead of treating only a portion of the stick, as in the case of poles, the whole pile is preserved.

[1] For further information regarding this subject see "Preservative Treatment of Poles," by W. H. Kempfer, Bulletin 84, U. S. Forest Service 1911, also Proceedings, American Wood Preservers' Association, Baltimore, Md.

GROUND LINE AND HEIGHT OF TREATMENT FOR WESTERN RED CEDAR POLES

Length of Poles in Feet.	Ground Line in Feet from Butt.	Height of Treatment in Feet.
16	$3\frac{1}{2}$	5
18	$3\frac{1}{2}$	5
20	$3\frac{1}{2}$	5
25	$4\frac{1}{2}$	6
30	$5\frac{1}{2}$	7
35	6	$7\frac{1}{2}$
40	6	$7\frac{1}{2}$
45	$6\frac{1}{2}$	8
50	$6\frac{1}{2}$	8
55	$6\frac{1}{2}$	8
60	7	$8\frac{1}{2}$
65	$7\frac{1}{2}$	9
70	$7\frac{1}{2}$	9
75	$7\frac{1}{2}$	9
80	$7\frac{1}{2}$	9

Photograph by U. S. Forest Service.

FIG. 88.—Pole yard and treating plant at Gaulsheim, Germany. Note the straight, uniform character of the poles. These are largely composed of spruce and fir.

In 1915, 6,295,284 cu. ft. of piling were treated largely by creosote and the pressure process. This is equivalent to 9,352,778 cu. ft. of piling or 467,639 piles each of 20-ft. length.

It is very necessary that all bark be carefully peeled before treatment and that large amounts of creosote oil be forced into the wood. If the piles are subject to attack in salt waters, from 18 to 24 lb. of creosote per cubic foot are advisable; if free from attack, from 10 to 14 lb. of oil per cubic foot is regarded as sufficient to retard decay. The full cell or Bethell process of pressure treatment in large cylinders is the method most commonly used in preserving piles. On account of their susceptibility to treatment, reasonable cost, and other qualifications such as strength, shape and availability, the southern yellow pines, western yellow pine, and Douglas fir are preferred for treated piling.

Properly preserved piles have been known to last from twenty-five to thirty-five years in waters containing marine borers. The cost of creosote treatment is usually from 3 to 7 cents per cubic foot.

SUBSTITUTES FOR POLES AND PILING

With the gradually increasing cost of wooden poles the large companies which use the greatest number have naturally investigated the possibility of other materials. In many cities the telephone and telegraph lines are placed in underground conduits.

The chief substitutes for overhead lines are concrete, reinforced concrete, iron and latticed steel poles and steel towers, the last named being used to some extent for heavy transmission lines.

Up to the present time these materials have not replaced the wooden pole to any great extent and it is not likely that they will for some time to come, for the following reasons:

1. High initial cost that is scarcely justified in service rendered.
2. Excessive weight and consequent difficulty and expense in handling and transportation.

Concrete and reinforced concrete poles are still in the experimental stage of development, and all forms of substitutes lack sufficient length of service to draw definite conclusions.

Reinforced concrete, wrought and cast iron and steel piling have been introduced to a much smaller extent than in the case of poles, so that little is known of their possibilities. It is likely, however, that difficulties of corrosion in case of iron and steel and cracking due to alternate freezing and thawing with concrete piles, together with the objections given above for pole substitutes, will render their introduction rather slow and doubtful.

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CHAPTER XIV

POSTS

THERE are no government statistics available showing the annual production of fence posts in this country, but it is estimated that there are 500, 000, 000 posts consumed annually. They are used chiefly on farms and by the railroads along rights of way, which are always inclosed by fencing.

The posts used on farms are largely cut in local woodlots, generally on the farm woodlots, whereas those used by the railroads are generally produced in regions of an abundant supply of durable timber. In California and the Southwestern States, redwood (*Sequoia sempervirens*) is the particular species sued for posts. In the Northwestern States and on the western plains the principal wood used is western red cedar (*Thuja plicata*). In the Central West and in the Lake States, the particular species used for fence posts is northern white cedar (*Thuja occidentalis*) from Wisconsin, Minnesota, and Michigan and locally produced locust, white oak, catalpa, mulberry, hackberry, etc. In the Northeast common woods used for fence posts are northern white cedar and chestnut; in the East, chestnut, sassafras, catalpa, and white oak are the principal fence post woods and, in the South and Southeastern States cypress, southern white cedar (*Chamaecyparis thyoides*), juniper, or eastern cedar (*Juniperus virginiana*), and longleaf pine are used.

Posts are generally cut in 7-ft. lengths, although they may be cut for special purposes up to 20 ft. in length. Sometimes they are cut in multiples of 7 ft. or thereabouts and then cut into the desired lengths at destination. This is generally for convenience and economy in handling. Fence posts are generally used in the round, in which case they are usually from 4 to 6 m. in diameter at the top end. Most of the western red cedar, redwood posts, and frequently those of chestnut, northern white cedar, cypress and longleaf pine are split posts. Rail fences are rapidly disappearing from use, especially in regions where the native timber supplies and good split timber are being depleted. Consequently fence posts to be used with rails are seldom used any more. The old zigzag rail fence which did not require the use of ordinary posts is also fast disappearing on account of the labor involved in splitting out the rails, the disappearance of native forests, the economy in using the wire type of fence and the saving in ground space with the latter form. In many regions fence posts are pointed at the lower end and driven into the ground with a maul after preparing the hole with a crowbar or other similar tool.

The requirements for desirable fence post woods are practically the same as those described in connection with poles.[1] Briefly the principal

Photograph by U. S. Forest Service.

Fig. 89.—Over 500,000,000 posts are used annually on the farms and along the railways of this country.

qualifications are durability, lightness in weight, straightness and ability to hold the nail well. The paramount qualification, however, is durability.

The business of getting out posts assumes the character of an industry only in regions where pole production is carried on as a regular business. At many pole operations, all poles 20 ft. and less in length are sometimes classified as posts and sold as such. The principal regions where posts are produced on a large scale are in the swampy sections of the

[1] See Chapter on Poles and Piling.

Lake States where the northern white cedar is cut, the redwood forests of northwestern California, the western red cedar forests of northern Idaho and western Washington, the southern white cedar swamps of eastern Virginia and North Carolina and the cypress belts of the Gulf Coast. In all of these sections posts constitute a by-product of the pole industry. All tops, small trees and defective poles are made into posts which are principally marketed for the railway trade. Few of these posts are in the round. Most of them are halved or quartered or split posts made from defective butts or crooked poles or tree trunks which will not make satisfactory poles.

Photograph by U. S. Forest Service.

FIG. 90.—Preservative treatment of fence posts by the open-tank method. The fire heats the creosote in the two barrels through the connecting pipe.

The development of the great agricultural sections of the central and Far West and the division of the larger farms and ranches into smaller units has greatly stimulated the production of posts on a large commercial basis. The subdivision of farms and ranches is still taking place in an important way throughout the West and requires immense quantities of fence posts, which often constitute an important part of the local retail lumber yard stock in each community.

With the growing scarcity of posts and their rise in price the concrete and iron post has been introduced to some extent and will no doubt continue to be used on even a larger scale in the future, particularly in regions where there is a scarcity of good durable post material and on farms and about enclosures where the additional expense incurred in the use of these forms is a matter of little consequence to the purchaser.

The gradual scarcity of good fence post material has caused the planting of many wood lots primarily to supply fence posts. It has also caused the introduction and use of wood preservatives to treat woods which had formerly never been used for posts because of their perishability. Posts have been charred and the tops pointed to increase their life in service, but the most satisfactory method is to treat the portion of the post to be imbedded in the soil with creosote. This is usually done by the open-tank method of treatment.[1] Such non-durable woods as red oak, Carolina poplar, box elder, white pine, spruce, loblolly pine, shortleaf pine, hemlock, yellow poplar, elm, basswood and other species which grow naturally or are planted can be made into excellent fence posts by a preservative treatment costing from 6 to 12 cents per post.

[1] See the various publications of the Forect Service dealing with the preservative treatment of fence posts as well as miscellaneous articles in the annual proceedings of the American Wood Preservers' Association from 1910 to 1919, inclusive.

CHAPTER XV

MINE TIMBERS

GENERAL

In the early history of this country comparatively little mining beneath the ground was carried on. However, with the development of coal mining, principally in Pennsylvania, a heavy demand was gradually created for mine timbers in both the sawed and round forms. At first the only means of support were "mineral pillars," which consisted of pillars of ore left in the chambers as a means of support. As the value of the minerals increased and the operations became enlarged and more systematized, wooden supports called props, caps and collars were substituted for the old mineral pillars.

Wood has given great satisfaction and although it is possible that concrete and steel may, to a limited extent, replace the wooden supports in the various types of mines, their comparatively high cost and the difficulty of installation will doubtless restrict their use to a considerable degree.

It is estimated by the U. S. Geological Survey that there are approximately 50,000 mines in this country. However, probably only 5000 of these use timber for props, caps, collars, lagging, mine ties, shaft shoring, etc. There are many mining operations classified as mines according to the government statistics, but a large number consist of quarries, placer mines, oil and gas wells, salt works, clay pits and coal strippings, which use little wood.

The only available complete figures showing the use of timber in mines were compiled by R. S. Kellogg in 1905 for the U. S. Forest Service. This compilation estimated that we use in round numbers about 200,000,000 cu. ft. or about 2,500,000,000 bd.-ft. of round and sawed timbers. At the present time (1919) this material would be valued at about $13,000,000. Of the total amount only about 17 per cent is composed of sawed timbers and lumber.

Most of the mines gather the round timber material from the region about the mines.

Pennsylvania, with its important coal mines, both anthracite and bituminous, is the most important state in the consumption of lumber and timbers. This state probably purchases more than 50 per cent of the total value of mine timbers used in the entire country.

KINDS AND AMOUNT OF WOODS USED

The character of wood used in American mines is not highly specialized. Generally speaking, almost any kind of wood which is sufficiently strong will meet the requirements. Altogether, durability is the most important single requirement and where woods of great durability are not available, woods of a more or less perishable nature can be treated to increase their life in service in the mines. Furthermore, in many of the mines of this country, the use of wood as a means of support and for mine ties, mine rails, etc., is only temporary, and after a period of service of from two to four years, they are either left to decay or removed and placed in service in some other location. Where woods are to be in service only two to four years, almost any species will serve the purpose, because even our most perishable woods will last, generally, from three to four years.

The conditions found in most of our underground mines, however, are exceedingly favorable to decay because of the damp condition of the atmosphere and the relatively high temperatures involved.

It has been determined that hardwoods constitute by far the most important source of supply for mine timbers. Of the total cubic footage of round timber, namely, 165,535,000 cu. ft., over 86,000,000 cu. ft. were of hardwoods, 38,000,000 of softwoods, and the remainder amounting to somewhat over 41,000,000 cu. ft. were not specified as to their character. The preponderating use of hardwoods can be probably attributed to the fact that the most important wood-using mines of the country are located in hardwood regions.

For the purpose of classifying the utilization of wood, all mines have been divided into the following category, namely, bituminous, anthracite, precious metal, iron, and miscellaneous mines. Most of the wood-using mines of this country are found in the bituminous class and they are also the most prominent in the use of timbers. All of the anthracite mines are found in Pennsylvania and are also very important consumers of both round and sawed timbers. The precious metal mines are located principally in the West, in such states as Montana, California, Colorado, and Arizona, where generally speaking, there is a fairly good supply of timber, except in the last-named state. These mines use wood principally in the sawed timber form.

The following table from Kellogg shows the quantity and cost of timber used in mines in 1905:

Mineral Product.	Number of Mines.	Round Timber, Cubic Feet.	Sawed Timber, Board-feet.	Total Cost.
Bituminous coal	2940	91,309,700	140,790,000	$6,379,931
Anthracite coal	216	43,676,000	101,210,000	4,433,125
Precious metals	1718	15,282,500	164,956,000	4,405,690
Iron	143	13,484,000	13,929,000	914,449
Miscellaneous	146	1,783,700	15,059,000	322,692
Total	5163	165,535,900	435,944,000	$16,455,887.

The following table shows the kind and quantity of timber used in the 5163 mines of this country, according to the figures compiled by Kellogg. Oak constitutes by far the most important species among the hardwoods and the pines constitute about one-half of all of the softwoods.

Softwoods.	Round Timber, Cubic Feet.	Sawed Timber, Board-feet.
Pine	19,100,000	96,602,000
Fir	4,360,000	78,772,000
Hemlock	4,155,800	60,802,000
Spruce	1,104,200	5,403,000
Mixed softwoods	9,685,600	32,166,000
Total	38,504,600	273,745,000
Hardwoods		
Oak	28,174,400	58,693,000
Chestnut	1,543,800	908,000
Beech	522,900	1,597,000
Aspen	142,100	
Maple	136,600	5,973,000
Elm	117,200	932,000
Hickory	94,400	
Poplar	....	475,000
Mixed hardwoods	54,915,500	60,333,000
Total	86,646,500	128,911,000
Not specified	41,483,800	33,288,000
Grand total	165,535,900	435,944,000

SPECIFICATIONS AND PRICES

Sawed timbers and lumber which are used in the mines of this country are always purchased on the basis of the thousand board-feet and are bought in various sizes from the sawmills and local lumber yards. The specifications are not at all standardized and the prices obviously fluctuate with the lumber market.

The round timbers are purchased largely from the local region. In Pennsylvania the sections about the anthracite and bituminous coal mines have been heavily cut off for mine ties, props, mine rails, and collar timber. The Butte mining district is dependent to a large extent on the lodgepole pine timber from the Deerlodge National Forest and to a less extent on the western yellow and lodgepole pine cut in western Montana. The Birmingham mining district of northern Alabama has been heavily cut off for the important iron and coal mines. Northern Michigan supplies a great many hardwoods for the copper districts of northern Michigan. The forests of the Arizona copper mining districts and the precious metal mines of California have also been depleted to some extent for mine timbers. However, California has such an abundant timber supply that the demand for material for her mines represents but a small percentage of the total demands on the forests in that state. The mines of this country are not generally located immediately in or near abundant sources of forest wealth, except in California.

The specifications and prices vary a great deal with the local conditions. Specifications for mines in Illinois and Indiana would not suffice for those in Pennsylvania, and the same would be true of the various metal mines of the West.

The following are the standard mine timber specifications and prices for one of the most important mining companies in Pennsylvania which annually consumes large quantities of timbers. These prices were quoted in 1917.

All mine material to be cut from sound, living timber, felled between August 1st and March 1st. Timber must be reasonably straight, have all knots trimmed even with the surface, and free from defects that impair the strength and durability for their intended use. All measurements to be made at the top end under the bark. Material to be inspected at point of loading unless otherwise advised. No shipments accepted unless covered by regular order. Prices quoted are f.o.b. cars D., L. & W. R.R.

Prop Timber.

Prop timber to be 10 ft. to 30 ft. (averaging 15 ft.) long, of any kind of hardwood, and including hemlock, pitch pine, spruce and chestnut.

Price { 6 in. diameter top 2 cents per lineal foot.
8 in. diameter top $3\frac{1}{2}$ cents per lineal foot.

Collar Timber.

Collar timber to be of hemlock, pitch pine, spruce or chestnut, 10 per cent oak permitted.

Price:
- 10 in. diameter top to be 10 ft. to 30 ft. (averaging 15 ft.) long.
- 12 in. and 14 in. diameter top to be 18 ft. to 30 ft. long.
- 10 in. diameter top, 6 cents per lineal foot.
- 12 in. diameter top, 11 cents per lineal foot.
- 14 in. diameter top, 14 cents per lineal foot.

Mine Rails.

Mine rails are to be 3 in. by 5 in. by 12 ft., and of hardwood, such as beech, birch, maple and oak. A small percentage of 10-ft., 14-ft. and 16-ft. lengths will be accepted. To be edged to size and ends cut square. Rails containing any defects that would injure them for the purpose intended will not be accepted.

Price, $13.00 per thousand board-feet.

Flat Mine Ties.

Flat mine ties are to be 5 ft. long, hewn or sawn on two sides, on an average 5 in. thick and 5 in. face. Nothing less than 4 in by 4 in by 5 ft. will be accepted. To be of oak or chestnut. A small percentage of pitch pine (*Pinus rigida*) will be accepted.

Price 9 cents each.

The manufacture of round mine timbers is almost entirely a woods operation.[1] The trees are felled, bucked and swamped and then peeled.

The following represents the costs involved on a winter operation on the Deerlodge National Forest where lodgepole pine stulls were produced for the Butte mining district:[2]

Operation.	Cost per Thousand Feet.
Shoveling snow	1.68
Felling trees	.48
Trimming trees	.19
Brush disposal (piling and burning)	.73
Cutting into stull lengths	.93
Peeling	1.55
	$4.56

The use and life of mine timbers depend upon the local conditions. Where the various mine tunnels require more material for support and there is likelihood of a shifting in the strata of rock or soil, considerably larger quantities of material must be used. Furthermore, on account of

[1] For further information regarding logging methods, see "Logging," by R. C. Bryant. John Wiley & Sons, New York City.

[2] From "Utilization and Management of Lodgepole Pine in the Rocky Mountains," by D. T. Mason. U. S. Forest Service, Department of Agriculture, Bulletin No. 234.

the warm moist air in most of the mines, the timber is readily subject to attack by decay and insects. In coal mines it very frequently happens in extreme cases that the timbers up to from 12 to 15 in. in diameter will become completely decayed in about three years if used in the untreated condition. The expense involved in resetting these timbers is very great, and furthermore, such replacements generally interfere with the working operations of the mines.

Besides decay, other prominent reasons for the destruction of mine tmbers are wear and tear, breakage, fire and wastage. Taken all together, these represent about 50 per cent of the causes for the destruction of mine timbers, the remaining 50 per cent being the result of decay and insect attack. Wooden rollers and drums must be frequently replaced on account of wear, and large amounts of timbers themselves destroyed by " crush " and " squeeze," or by " swelling ground " and a great deal of temporary timber is lost in mine workings which become filled with waste rock and dirt called " slush " after the coal and other ore has been mined.

The relative importance of the various destructive agencies in the American mines is shown in the following table:[1]

Causes of Destruction.	Percentage.
Decay and insect attack	50
Waste from all causes	25
Breakage and fire	20
Wear	5

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[1] From "The Preservation of Mine Timbers," by E. W. Peters, U. S. Forest Service Bull. 107, 1912, p. 6.

CHAPTER XVI

FUEL WOOD

GENERAL

Wood furnishes fuel for a great variety of purposes. It is chiefly in demand on farms and in small rural communities for general heating purposes and for the preparation of food. It is also used as fuel in the generation of electric and steam power, electric lighting, in the manufacture of brick, etc. Since wood is largely used on farms, it is principally cut from woodlots and small holdings. Cordwood cut for fuel also comes from material otherwise wasted, such as slabs from sawmills, tree tops, branches and defective material left on the ground after logging operations, scrubby growth and inferior trees which are not in demand for any other form of product. The fuel cutter does not take what the sawmill or other wood using industries can use. If the demand for fuel wood were doubled in this country it could be easily taken care of without the use of good timber. Transportation is the chief problem in the further utilization of fuel wood in this country. The larger markets, aside from the farmers and the rural communities, are not in close proximity to the principal fuel wood supply so that at the present time enormous quantities of material are wasted and left to rot in the woods due to prohibitive transportation charges.

There is approximately as much wood used at the present time for fuel as for lumber. It probably brings the lowest delivered market price of wood in any form. Its use is decreasing in this country due to the increasing introduction of the use of natural and artificial gas, coal, electricity and fuel oil. There is much less wood used at the present time for heat and power than formerly. In thirty years, the coal output has multiplied 6 times and many new natural gas and oil wells have been developed.

The war greatly stimulated the use of wood fuel, particularly in 1918 and 1919, when there was a shortage of coal.

AMOUNT USED

It is estimated that, at the present time, about 100,000,000 standard cords of wood valued at $350,000,000 or about $3.50 per cord are used every year in this country. This amount would be equivalent, assuming that 500 bd.-ft. are equal to one cord, to 50,000,000,000 bd.-ft. of material or 9,000,000,000 cu. ft., assuming that there are 90 cu. ft. of solid wood per cord.

Photograph by Nelson C. Brown.

Fig. 91.—Beech, birch and maple cordwood cut and stacked for seasoning in the woods, In the winter, this is hauled out on sleds. Photograph taken near Cadosia, Delaware Co., New York.

Sargent estimated that in 1880 there were used in this country 146,000,000 cords valued at $322,000,000 or $2.21 per cord. At that time the population was only about 50,000,000, whereas it is now in excess of 100,000,000 people. In spite of the increase in population of over 100 per cent, therefore, the total amount of wood used for fuel has decreased very considerably, owing to the introduction of other forms of fuel such as gas, oil and coal as outlined above.

From statistics [1] gathered by the U. S. Forest Service, the leading states in the consumption of wood fuel on our farms are Alabama, Georgia, Kentucky, Tennessee, Mississippi, North Carolina, Arkansas and Texas in order. These eight states consume about 50 per cent of the total amount used on our farms in this country.

The quantity of fuel wood used in any one locality depends very largely upon the following factors:

1. Climate. It is natural that more fuel wood will be used in colder climates than in the southerly ones unless near coal or oil fields.
2. Cost of other fuel. The use of wood is determined very largely in any given region by the cost of the available coal, oil and gas.
3. Transportation facilities. Very often wood is available in abundant quantities but transportation facilities are lacking.

Several years ago considerable fuel wood was reduced in form to charcoal in isolated regions of long hauls to save transportation charges. The general use of charcoal for fuel purposes, however, has been reduced to a considerable extent and the old method of making charcoal has nearly gone out of existence, due to the introduction of modern methods of both hardwood and softwood distillation.

There are great possibilities for closer utilization of our raw wood supplies in the development of wood for fuel. The value of fuel wood in many of our smaller towns and cities has risen so rapidly that it is now competing successfully with coal or other materials for fuel purposes, and although it will be a long time before fuel wood can be utilized in an intensive way as in the European nations, we shall undoubtedly save, in the future, enormous quantities of material now wasted in the woods in logging operations and poor and defective timber now left to decay.

The following table [1] shows the amount and value of wood fuel used on the farms of this country during 1917:

[1] From "The Use of Wood for Fuel," U. S. Dept. of Agr., Bull. 753, 1919.

WOOD FUEL USED ON FARMS

	Number of Farms 1917 (Estimated).	Cords per Farm.	Number of Cords per State.	Value per Cord.		Value of Wood used on Basis of December, 1917, Values.	
				December, 1917.	December, 1916.	Value per Farm.	Total Value.
Maine	60,000	13	780,000	$6.40	$4.50	$83.20	$4,992,000
New Hampshire	27,000	12	324,000	6.40	4.60	76.80	2,074,000
Vermont	33,000	15	495,000	6.00	4.35	90.00	2,970,000
Massachusetts	37,000	10	370,000	6.35	4.70	63.50	2,350,000
Rhode Island	5,000	10	50,000	5.80	4.00	58.00	290,000
Connecticut	27,000	13	351,000	6.00	4.50	78.00	2,106,000
New York	215,000	14	3,010,000	4.60	4.00	64.40	13,846,000
New Jersey	33,000	8	264,000	5.10	4.00	40.80	1,346,000
Pennsylvania	218,000	9	1,962,000	3.50	2.60	31.50	6.867,000
Delaware	11,000	13	143,000	4.20	3.10	54.60	601,000
Maryland	50,000	13	650,000	4.15	3.20	53.95	2,698,000
Virginia	190,000	18	3,420,000	3.20	2.40	57.60	10,944,000
West Virginia	99,000	16	1,584,000	2.90	2.30	46.40	4,594,000
North Carolina	259,000	17	4,403,000	2.75	2.10	46.75	12,108,000
South Carolina	185,000	14	2,590,000	3.00	2.10	42.00	7,770,000
Georgia	300,000	16	4,800,000	2.50	2.00	40.00	12,000,000
Florida	55,000	11	605,000	3.10	2.60	34.10	1,876,000
Ohio	271,000	13	3,523,000	3.60	3.00	46.80	12,683,000
Indiana	215,000	12	2,580,000	3.70	3.30	44.40	9,546,000
Illinois	250,000	9	2,250,000	4.60	3.40	41.40	10,350,000
Michigan	209,000	13	2,717,000	5.25	4.00	68.25	14,264,000
Wisconsin	180,000	13	2,340,000	5.50	4.20	71.50	12,870,000
Minnesota	157,000	11	1,727,000	5.40	4.30	59.40	9,326,000
Iowa	215,000	5	1,075,000	4.70	4.20	23.50	5,052,000
Missouri	275,000	13	3,575,000	3.20	2.60	41.60	11,440,000
North Dakota	90,000	3	270,000	7.50	6.40	22.50	2,025,000
South Dakota	90,000	3	270,000	6.20	6.00	18.60	1,674,000
Nebraska	135,000	3	405,000	4.25	3.90	12.75	1,721,000
Kansas	180,000	6	1,080,000	4.25	3.30	25.50	4,590,000
Kentucky	265,000	18	4,770,000	2.20	1.70	39.60	10,494,000
Tennessee	250,000	19	4,750,000	2.20	1.75	41.80	10,450,000
Alabama	270,000	18	4,860,000	2.00	1.80	36.00	9,720,000
Mississippi	285,000	16	4,560,000	2.30	1.90	36.80	10,488,000
Louisiana	122,000	15	1,830,000	2.50	2.25	37.50	4,575,000
Texas	430,000	9	3,870,000	3.40	2.80	30.60	13,158,000
Oklahoma	210,000	10	2,100,000	3.10	2.75	31.00	6,510,000
Arkansas	225,000	19	4,275,000	2.35	2.00	44.65	10,046,000
Montana	35,000	10	350,000	4.80	4.50	48.00	1,680,000
Wyoming	15,000	10	150,000	4.50	3.80	45.00	675,000
Colorado	55,000	6	330,000	4.50	3.70	27.00	1,485,000
New Mexico	45,000	9	405,000	4.20	4.00	37.80	1,701,000
Arizona	12,000	9	108,000	5.75	5.40	51.75	621,000
Utah	23,000	8	184,000	5.00	4.00	40.00	920,000
Nevada	3,000	11	33,000	7.00	6.00	77.00	231,000
Idaho	36,000	9	324,000	5.00	4.60	45.00	1,620,000
Washington	65,000	11	715,000	5.20	4.50	57.20	3,718,000
Oregon	50,000	12	600,000	4.70	3.90	56.40	2,820,000
California	95,000	10	950,000	7.40	5.80	74.00	7,030,000
United States	6,562,000	12.6	82,777,000	3.42	2.75	43.13	282,915,000

SOURCES OF SUPPLY

As noted above, the farmers' woodlot and small scattered holdings are the principal sources of fuel wood at the present time. Slab wood and other refuse from sawmills are used, to a considerable extent, in and near towns in which sawmills are located. Many areas that have been recently logged over are now being culled for fuel wood; choppers and in some cases, gasoline-driven cut-off saws being introduced to lower the cost of production. In the East, refuse from logging operations and sawmills are being sent to market in box cars up to distances of 300 miles.

Wood is probably relied upon for fuel purposes more in the South and in the Far West than in any other sections, due both to the cheap and abundant supply of wood and the comparative remoteness of an available supply of coal. In the central prairie region very little wood is used, due to the lack of native timber in that section. Coal is used to a very large extent.

In an investigation carried on by the office of Farm Management in the U. S. Department of Agriculture covering 950 families living on farms in all parts of this country and with an average of 4.8 persons per family, the average annual consumption of wood per person was 2 cords or 9.6 cords per family. It was also shown that on the average farm the value of wood fuel is more than twice as much as the value of coal fuel used.

In the Northeast, the oaks, maples, hickories, birches, beech, chestnut and other heavy hardwoods are largely relied upon for fuel purposes.

In the South, the southern pines, chiefly longleaf pine, is used almost entirely for fuel purposes. In some sections, hardwood such as oaks, hickories, ash and a few others are used, but the resinous hard pine is much preferred.

In the Rocky Mountain region, Douglas fir and western yellow pine are relied upon very largely for fuel. Lodgepole pine and Engelmann spruce are used to a limited extent, but they are very inferior for fuel purposes. Sage brush, greasewood and mesquite are also used in the treeless and desert regions of the southern Rocky Mountain region.

In California, the live oaks, western yellow pine and Douglas fir are the principal woods used for fuel. In southern California and to a limited extent in other sections, eucalyptus is relied upon very largely for fuel. In the Northwest, Douglas fir, western larch and hemlock, furnish most of the wood fuel.

It is estimated that about 4,000,000,000 cu. ft. of mill waste furnishes power for the 30,000 sawmills in operation in this country. This is made up of slabs, edgings, trimmings, sawdust and defective material.

FUEL VALUES

The value of equal weights of dry wood for fuel purposes is practically the same with all species. According to this rule, therefore, specific gravity may be used as a direct means of comparing the heat values of the different species. This, however, does not hold with resinous woods.

Photograph by U. S. Forest Service.

FIG. 92.—Woodyard with a capacity of 5000 cords of fuel wood along the Potomac River at Washington, D. C. Rivers afford cheap transportation for low-priced forest products such as fuel wood. This is mixed pine and hardwoods brought by small sailboats from forests along the lower Potomac.

Aside from weight, however, other considerations often determine the value of different kinds or classes of wood for fuel purposes. The principal other considerations that may be mentioned are as follows:

1. The design, construction and regulation of furnaces, stoves and fire places all have an important bearing upon the question of getting the maximum fuel value out of any wood. Oak and hickory burn with practically a smokeless flame, whereas others often burn with more or less smoke due to improperly regulated flues, drafts, etc.
2. The degree of dryness. Much heat is lost in driving the re-

maining moisture from green wood. The following table shows the per cent of available heat given out by wood burned at different moisture contents:

Condition of Wood.	Per Cent of Water.	Per Cent Heat Given Out.
Kiln dry	2	100
Air dry (split)	10	90
Air dry (chunks)	20	80
Half dry	35	60
Green	50	40

3. The character of seasoning. Some woods decay if left in the open before they are thoroughly seasoned. This may hold true of beech, birch and other woods under certain conditions.
4. The rapidity of burning. When certain woods are burned too rapidly full heat values are not derived.

The average heating value of dry wood has been determined to be 4600 calories per kilogram or 8028 British thermal units per pound.

The following table[1] shows the relative fuel value of non-resinous woods based upon their specific gravity.

	Specific Gravity (Dry).	Relative Fuel Value per Unit Volume (Dry Wood).
Hickories, average	.64	100
Oaks, average	.58	91
Beech	.56	89
Birch	.55	87
Maple	.55	87
Ash	.52	81
Elm	.52	81
Tamarack	.49	76
Chestnut	.42	65
Douglas fir	.42	65
Hemlock	.39	61
Lodgepole pine	.37	58
White pine	.36	56
Redwood	.35	55
White fir	.35	55
Spruces, average	.33	52
Alpine fir	.31	48

In respect to resinous woods the fuel values can only be approximated according to the resin content. It is said that the califoric value

[1] From "Fuel Value of Wood," by H. S. Betts and E. Bateman, 1913. U. S. Forest Service.

of resin is about twice that of wood. Betts and Bateman have compiled the following table, giving approximation of the fuel value of longleaf pine of varying resin content compared to that of hickory. The fuel value of resin is taken as 9400 calories per kilogram.

APPROXIMATE RELATIVE FUEL VALUE OF LONGLEAF PINE CONTAINING DIFFERENT AMOUNTS OF RESIN AND HICKORY

Resin Contents, Per Cent.	Specific Gravity (Dry).	Relative Fuel Value Unit Volumes of Dry Wood, Hickory 100.
0	.44	69
10	.49	84
20	.55	103
30	.63	128
40	.73	160
50	.88	206

Other woods to which this table could be applied are the other pines such as shortleaf, loblolly, western yellow, piñon, pitch, lodgepole and jack pines and a few others such as the cedars, juniper, cypress, etc.

It has been determined that 1 lb. of good coal is equivalent to about 2 lb. of seasoned wood in heating values. Assuming that there are 80 to 90 cu. ft. of solid wood to the average cord, the weight of a cord of medium, heavy and light woods would be approximately 4000, 3000, and 2000 lb. respectively for seasoned sticks containing 15 to 20 per cent moisture. The following table shows the number of cords of different kinds of seasoned wood necessary to give approximately the same heating value of 1 ton of coal:

1 cord	Hickory Oak Beech Birch Hard maple	Ash Elm Locust Longleaf pine Cherry	Equivalent to 1 ton coal
$1\frac{1}{2}$ cords	Shortleaf pine Western hemlock Red gum	Douglas fir Sycamore Soft maple	Equivalent to 1 ton coal
2 cords	Cedar Redwood Poplar Catalpa Norway pine	Cypress Basswood Spruce White pine	Equivalent to 1 ton coal

PRINCIPAL MARKETS

It is estimated that at least 80 per cent of the total amount of fuel wood cut for that purpose is used on our farms. Ten per cent is utilized in the small towns of 1000 population or less and the rural communities scattered among these towns.

Other principal markets are in mining and smelting mills, in the manufacture of brick and tile, and in the manufacture of salt and wool. Formerly great quantities of fuel wood were used for railroad locomotives, steamboats and general power purposes. At the present time, however, coal and oil have very largely supplanted wood for these purposes.

In the smelting of copper, green wood is used in the refining process to remove the impurities. This is done by introducing compressed air beneath the surface of the copper and applying until the fracture of the sample of copper shows that sufficient copper has been oxidized to insure the removal of all impurities. Then converter poles are introduced beneath the surface of the molten copper, their action being to reduce the oxide of copper back to metallic copper. This is carried on until the sample shows that this result has been accomplished and the sample has acquired what is technically known as a "set." The best woods for smelting purposes are green hardwoods.

AMOUNT OF SOLID WOOD PER CORD

The standard cord is generally accepted as a pile of wood 4 ft. wide, 4 ft. high and 8 ft. long. This is a stack of 128 cu. ft. The amount of solid wood found in a standard cord of this size varies between 89 and 64 cu. ft. and depends upon such factors as the size, straightness and form of the sticks, split or round, etc., and the method of piling. The following table shows the volume of solid wood per cord for sticks of different length and diameter:

VOLUME OF SOLID WOOD PER CORD[1]

Length of Sticks, Feet.	Diameter at Small End.		
	Over 5.5 In. Cubic Feet.	5.5 to 2.5 In. Cubic Feet.	2.5 to 1 In. Cubic Feet.
2	91	84	65
4	89	82	64
8	84	77	59
12	78	71	54

[1] From "Factors Influencing the Volume of Solid Wood in the Cord," by R. Zon. Forestry Quarterly, Vol. I, No. 4, 1903.

The converting factor of 90 cu. ft. per standard cord is generally adopted in those regions where fuel wood is commonly cut.

The converting factor of 500 bd.-ft. per standard cord is also generally accepted, although this factor depends upon a number of conditions.

Ten per cent of the volume is generally allowed for shrinkage from the green to the dry condition of the sticks. According to Zon, green hardwood in seasoning shrinks from 9 to 14 per cent, depending upon the species while softwoods shrink only 9 to 10 per cent.[1]

CUTTING, HAULING AND DELIVERING TO MARKET

The following description and costs are given for the full standard cord of 128 cu. ft. capacity. Many other forms of stacked cordwood or units are commonly used in different parts of the country. For example, in portions of the Lake States and Far West, a long cord of 160 cu. ft. capacity is sometimes used. In other places the short cord is used or a face cord made up of a stack of wood 8 ft. long, 4 ft. high but instead of 4 ft. in length the sticks are 12, 16, 18, 24, 30, 37, 50, 56 in., etc., in length. These various face cords are used for special kinds of fuel wood and for marketing in small lots.

The work of cutting, hauling, etc., is usually done by common labor, the men using the single-bitted splitting axe, cross-cut saw, wedges and on large operations, a double-bitted axe as well. Where considerable fuel wood is cut the men usually work by contract, doing the cutting and hauling for a given amount per cord.

Stumpage values vary considerably with the different regions. The price runs from about 25 cents to $1.00 or more per cord. This value depends upon the species, local demand, cost of cutting and hauling and placing on the market, etc. In the Northeast stumpage values of 50 cents to $1.00 per cord are common. In the South 25 cents per cord is an average price. In the Far West from 25 to 50 cents per cord is the usual prevailing stumpage value.

The operations of cutting and stacking fuel wood in cord lots are generally done together and they usually cost from 90 cents to $1.45 per standard cord. Many contracts in favorably sized and located timber regions have been made for cutting and stacking for $1.00 to $1.10 per cord. Foreign laborers, skilled in this work, have been known to make from $3.00 to $5.00 per day at these prices. The cost usually depends upon the kind and condition of wood, its size, local charges for labor, location of timber and general working conditions.

[1] See "Untersuchungen über den Festgehalt," by Franz Baur.

Stacking is sometimes done in open crib fashion to facilitate seasoning, which requires from one to two months, depending upon the weather, size of individual sticks, method of piling, etc.

When the individual sticks are more than 6 to 8 in. in diameter they are commonly split in two. When over 10 to 12 in. in diameter they are quartered.

Gasoline engines equipped with a portable cut-off saw are commonly employed to buck up limbs, tops and defective trees into cordwood. About $2\frac{1}{2}$ cords per hour can be cut up by 2 men working with a 2 h.p.

Photograph by U. S. Forest Service.

FIG. 93.—Two cut-up saws operated by electric motor, cutting 23 to 35 cords per day each. The wood in lengths from 4 to 12 ft. is reduced to stove and fire-place sizes. Durham, North Carolina.

engine. This same equipment and crew will cut up 4-ft. cordwood into 12-in. stove lengths at the rate of 1 to 2 cords per hour.

Hauling includes loading of the cordwood on the wagon, hauling and unloading at the yard or into a freight car. In the North it is usually done on sleighs in the winter time. Otherwise the ordinary wagon haul is employed for this purpose.

The usual wagon load will take from 1 to $1\frac{1}{2}$ cords. Up to $2\frac{1}{2}$ cords or more may be taken on a sleigh. The cost depends upon the distance, the load, condition and grade of the road, cost of labor and team, working hours, and general efficiency. It is customarily considered that it does not pay to market cordwood when the haul is longer than 6 miles unless there is a favorable down-hill haul and the market demand offers sufficiently high prices. Six trips per day are commonly made on a 1-mile haul on the average country road, 4 trips on a 2-mile, 3 trips on a 3-mile and 2 trips on a 4-mile haul. The inconsistency apparent in these figures is explained by the fact that in the larger number of trips per day,

Photograph by U. S. Forest Service.

FIG. 94.—Hauling cordwood near Custer City, Pennsylvania. This load contains about $1\frac{1}{4}$ cord of beech and hard maple. About 100,000,000 cords of fuel wood are annually consumed in this country.

relatively more time is taken up in loading and unloading. The following table shows the approximate total cost per cord of cutting and

Daily Hauling Capacity for One Team.	Teaming Wage Rate per Day	Total Cost with Interest, per Cord.	Daily Hauling Capacity for One Team.	Teaming Wage Rate per Day.	Total Cost with Interest, per Cord.
1 cord........	$5.50	$6.80	4 cords......	$5.50	$2.52
	5.00	6.36		5.00	2.39
	4.50	5.83		4.50	2.26
	4.00	5.30		4.00	2.12
2 cords......	5.50	3.98	5 cords......	5.50	2.23
	5.00	3.71		5.00	2.12
	4.50	3.45		4.50	2.01
	4.00	3.18		4.00	1.91
3 cords......	5.50	3.00			
	5.00	2.83			
	4.50	2.65			
	4.00	2.47			

delivering for various wage rates and hauling capacities including interest charges at 6 per cent for one year.[1]

Considerable fuel wood is hauled on our railroads, especially to all the larger cities. Cordwood takes the same freight rate, usually, as lumber, pulp wood and other forest products. From 12 to 18 cords are the usual capacities per car, depending upon the size of the box car, size of sticks, method of piling, etc.

In many of the western cities and villages, 4-ft. cordwood is used for fuel in furnaces and much of this material is hauled in carload lots from nearby logging operations or cut-over timber.

PRICES

The cost of fuel wood varies considerably in the different regions. It depends upon the supply, demand, cost of other forms of fuel, cost of cutting, marketing, etc. In the Northeast the following prices usually prevailed before the war for the full cord delivered in town wholesale:

Hickory	$7.00 to $10.00
Beech, birch, ash, hard maple and oak	5.00 to 8.00
Soft maple, poplar, chestnut, etc.	4.00 to 6.00
Mixed lots	4.00 to 8.00

Wood delivered to the consumer costs considerably more than these prices; usually from $2.00 to $3.00, depending upon the demand, desired length, character of wood, etc. It is commonly figured that it costs 50 cents per cord to buck up wood from the 4-ft. length to the 12- or 16-in. length for stove or fire-place use.

In the South and West prices are generally much below these. Standard sized cords are delivered in town, wholesale, in the Southern pine belt, the Northwest and Lake State regions for from $3.00 to $5.00, depending upon local conditions.

In portions of the Rocky Mountain regions where timber is very scarce sage brush is sometimes used for fuel. In Nevada the large, main stems are trimmed by Indians at $3.00 per cord and delivered to the user at about $6.50. Sage brush burns rapidly and does not hold heat very long.

Around sawmills, excess slab wood, edgings, etc., are sold for prices less than round or split cordwood. In connection with one large sawmill in the West 16-in. slab wood is sold for $3.50 a cord delivered at the

[1] From "Second Growth Hardwoods in Connecticut," by E. H. Frothingham, U. S. Forest Service Bulletin 96, p. 24.

house. It is estimated that it cost $1.75 to handle and deliver this, but the profit, $1.75 per cord, is looked upon as so much salvage by the lumber company. When logs run about 5.2 per thousand feet for 16-ft. lengths, 1000 ft. log scale will yield about one-third of a cord aside from the lumber when slabs are cut thin. One large sawmill concern cutting ties figures that it cuts 30 ties and one cord of fuel wood per thousand feet of logs. This large comparative amount is explained by the fact that the logs are small and heavy slabbing is done in order to face the

Photograph by U. S. Forest Service.

FIG 95.—About 500 cords of wood piled in the municipal woodyard of Columbia, South Carolina. The use of wood fuel was greatly stimulated during the war.

ties properly. Other sawmills sell excess fuel wood for from 25 cents to $1.00 per load at the refuse pile, the consumer doing the loading and hauling. No measurements are taken; the buyer simply taking as much as his wagon will hold.

After the entrance of this country into the war, the prices for wood fuel advanced, generally, throughout the country. Where coal was particularly difficult to secure, the price of wood fuel advanced to hitherto unquoted prices.

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CHAPTER XVII

SHINGLES AND SHAKES

HISTORY

SHINGLES have been used from the earliest historical times to protect buildings from the weather both as roofing and as siding. Up to comparatively recent times they had been made by the slow process of hand work. The logs were cut into bolts, hand rived with a frow or broadaxe and the shingles were shaved with a drawing knife. Sometimes a "shaving horse" was used in early colonial times. A man who could rive 500 shingles in a day was considered an expert worker.

Until a few decades ago, white pine, chestnut and southern white cedar were relied upon for the major portion of shingles used in this country. The rustic shingle maker was often able to tell from the general appearance of the tree whether it would rive properly or not. Frequently, however, a large block was cut out of the side of the large virgin white pine trees to test their splitting qualities. If the wood did not split well the tree was left a prey to the next forest fire, which quickly ignited the resin which had exuded from the exposed portion. This pioneer custom was very wasteful, since only the butt log was used for shingles and very frequently a tree that would now produce 3000 shingles was made to produce only about 500 shingles.

Hand-made shingles were generally of two kinds, known as "joint" and "lap." The latter were longer with one edge thicker than the other and nailed on the roof so that the edge of one lapped over the edge of the other like weather boards. The "joints" were nailed edge to edge like sawed shingles. Hand-made shingles called "shakes" are still made from sugar pine and redwood in California and will be discussed later in this chapter.

The introduction of shingle machinery proved to be a great economy in saving the available raw material. With the shingle saws, shingles which included knots, cross grain, etc., could be made not only from butt logs of the best trees, but from the tops and partially decayed butts.

Gradually the center of the shingle industry moved to the Pacific Northwest, where the western red cedar, which grows so abundantly in that region, was found to be an ideal shingle wood. In the East, shingle mills are usually located in connection with sawmills, the shingles often being made of defective or misshapen portions of the butt logs of white pine, yellow pine, spruce, cypress, etc.

Shingle machines were introduced on a commercial basis about 1880. Several years before that time western red cedar shingles were shipped around South America to the Atlantic seaboard. The shaved shingle industry had already assumed large proportions in the Puget Sound and Columbia River sections. With the opening of the Northern Pacific Railroad in 1883 came a great impetus in the manufacture of sawed shingles and their distribution not only in the Northwest, but throughout the prairie states. About the year 1892 and the year following came a rapid increase in production and several hundred million shingles were shipped to the Far Eastern markets. About 200 shingle mills were then in operation in western Washington. At the present time, western red cedar shingles are sent to every state in the Union and compete successfully with shingles made from all other species. There are approximately 350 shingle mills in Washington at the present time, most of which are operated as separate industries. There are probably fewer shingle mills to-day in the Pacific Northwest than a few years ago, but there is a much larger annual output, however, due to the larger capacity of the individual mill. Some of the larger shingle mills now have a daily capacity of from 100,000 to 250,000 shingles or more per day of ten hours. Some of the British Columbia mills exceed any of the Washington mills in daily capacity.

QUALIFICATIONS OF SHINGLE WOODS

The qualifications that are demanded in a wood used for shingles are as follows:

1. Durability. Shingles must withstand varying conditions of moisture, the effects of weathering and the rapid changes of temperature. Non-durable woods are practically unused for shingle purposes.

2. Light weight. This factor is very important in transportation. In order to compete successfully, the wood must be light in weight in order to bear the heavy transportation charges incident to the shipping of shingles to great distances. Shingles are always thoroughly seasoned before shipment by rail.

3. Nail-holding power. Shingles must retain nails without loosening. Zinc nails are commonly used in connection with many of our shingles, as they do not rust.

4. The shingle must not check, warp or twist out of shape when once placed flat on the roof. Prevention of leakage is of great importance. Shingles should preferably be straight and even grained.

To meet the above qualifications, the western red cedar is an ideal shingle wood in addition to the fact that it is abundantly available. Other trees, such as the northern white cedar and the southern white cedar, make practically the same quality of shingles as the western variety of cedar, but they are more inclined to be knotty and narrower in width inasmuch as they are made from much smaller trees. Other species yielding shingles of very high quality are cypress and redwood.

ANNUAL PRODUCTION

About 8,000,000,000 to 12,000,000,000 shingles are produced annually in this country. The latter amount has been produced for some time, but for the last few years the production has decreased, due to numerous cities inaugurating fire laws which prohibit the use of shingles in new buildings within city limits. Of the total production, between 70 and 80 per cent is made up of western red cedar. These shingles are largely manufactured in the State of Washington, which alone produced 73 per cent of all the shingles made in this country in 1917. Oregon and northern Idaho also turned out large quantities of shingles and a few western red cedar shingles are also made in western Montana.

Northern white cedar shingles are made largely in northern Michigan, Maine and in Minnesota. Southern white cedar shingles are produced chiefly in eastern Virginia and North Carolina.

Next to cedar, cypress is the leading shingle wood, but only slightly over 600,000,000 cypress shingles are annually manufactured in this country. Next, in order, are yellow pine, redwood, spruce and chestnut. A few shingles are also made from hemlock, western yellow pine, white pine and a few others, but their total amount is of little comparative consequence in the shingle markets of this country.

Western red cedar is practically the only kind that has a national market. The northern white cedar is consumed largely in the Central West and Northeast and southern white cedar in the Southeast and East. Cypress shingles are used throughout the East and southern pine shingles find their principal market in the South. All other shingles are used very largely in restricted local regions except redwood, which has developed a wide market outside California as well as within that state.

Next to Washington, which is pre-eminently the leading shingle manufacturing state, according to the government statistics for 1917 the following were the leading states in order of production: Oregon, cutting western red cedar; Louisiana, with its cypress and yellow pine shingles; California, cutting redwood; Maine, turning out large quantities of northern white cedar, and Michigan, with its great cedar output.

RAW MATERIAL

The material used for the manufacture of shingles comes to the mills in the form of bolts or logs. This material is usually logged in large lumber operations and sold directly to the shingle mills, which constitute a separate industry in the Northwest. Very often the poorer quality of logs are separated and sold to the shingle mills since very excellent shingles can be made from hollow butted logs. Ranchers and those clearing land commonly cut cedar trees into 52-in. bolt lengths and sell them directly to the mills. Logging of shingle logs is done largely by donkey engines and railroads, or by chutes, railroads, and by the use of drivable streams. The production of the raw material for the manufacture of shingles is usually carried on by separate companies.

Shingle logs cost between $8.00 and $15.00 or more per thousand board-feet delivered at the mill. Bolts in 52-in. lengths bring from $3.00 to $8.00 or more per cord at the mill. The cost depends upon the quality of the timber and the local demand at the time of delivery. The market on shingles fluctuates rather rapidly, so that the value of the raw material fluctuates accordingly.

In logging southern white cedar for shingle production, the trees are cut into 5 ft. 2 in. and 6 ft. 2 in. lengths, which will make 3 bolts for 20-in. shingles out of 5 ft. 2 in. logs and 4 bolts for 18-in. shingles from 6 ft. 2 in. logs. A shingle cord in eastern Virginia and North Carolina in 1907 was considered to be a stack of bolts 4 ft. high by 5 ft. wide by 7 ft. long and contains 140 cu. ft. or 600 log feet.

At the present time a shingle cord in this region is considered to be a stack of bolts 8 ft. long, 4 ft. high and 4 ft. wide and contains 128 cu. ft. This is considered equivalent to 500 ft., board measure, by the Doyle rule.

In the manufacture of cypress, southern pine, and white pine shingles, defective or misshapen logs are commonly butted by means of a cut-off saw at the the top of the jack ladder in the saw mill and the short lengths sent down a chute to the shingle mill on the lower floor.

The following shows the cost of logging shingle bolts on a typical operation before the war in western red cedar in Washington:

COST OF LOGGING SHINGLE BOLTS,[1] WESTERN RED CEDAR

Operation.	Cost per Cord of Shingle Bolts.
Cutting	$1.50
Skidding	.50
Loading	.25
Hauling	1.00
Yard expenses	.25
Loading	.25
Total	$3.75

[1] This cost was for the period of the winter of 1916-1917.

The prices received for bolts on this operation varied from $4.75 to $5.50 per cord. Eight thousand Star A shingles were derived from each 1000 ft. of logs. Each cord of shingle bolts contained, on an average, about 850 bd.-ft. Each cord was made up of 25 to 40 bolts, each 52 in. in length.

Generally, the shingle manufacturers prefer their shingle bolts in such sizes that from 20 to 30 make up a cord and it is commonly accepted that a cord of these bolts is equivalent to about 70c bd.-ft.

No trees less than 15 in. at the butt are accepted for making shingle bolts. The western red cedar usually grows with a large flared butt, especially in the oldest and biggest specimens. In these cases, the swollen butt is cut up into shingle bolts and the upper part of the bole, which is less tapered, is utilized for saw-logs or for poles and piling unless too large. The best timber for shingle purposes and from which the best shingles are made are the trees with a straight, slightly tapering, and limbless bole, straight grain and as free as possible from such defects as rot, shake, checks, etc.

The operation of taking out bolts for the shingle mills may either precede or immediately follow the logging operation for saw-logs. The latter practice is more frequently followed and very close utilization is customary, even defective or hollow logs and high stumps being used where low transportation charges justify the expenditure. A few years ago, when all stumps were cut from 5 to 20 ft. high or more with the aid of spring-boards, shingle mills, moved from place to place, obtained their raw material at a relatively low figure and it generally was of such high quality that profits were excellent.

The logging expense during 1916–1917 on a large operation in southern white cedar was as follows:

COST OF LOGGING SHINGLE BOLTS, SOUTHERN WHITE CEDAR [1]

Operation.	Cost per Thousand Bd.-ft.[2]
Sawing	$4.67
Skidding	1.02
Teaming	.69
Railroad operation	1.88
Freight paid other railroads, various distances	.27
	$8.53

[1] Data supplied by Reber F. Clark.
[2] As noted above each cord contains about 500 bd.-ft. by the Doyle rule.

SHINGLE MACHINES

There are various forms of shingle machines now placed upon the market. Formerly they were entirely of the horizontal variety with a provision to make the standard shingle with a thick butt and a thin tip. Machines used in the early days of the industry were devised to cut from 1 to 10 blocks at the same time. In recent years, the horizontal machines have been largely supplanted by the upright shingle machines.

The equipment in a modern shingle mill usually consists of the following machinery:

(1) A drag or swinging circular cut-off saw, usually run by steam or electricity to cut logs or bolts to the desired length. Drag saws are generally preferred with large timber as they are adaptable to all sized logs. However, they are objectionable because they do not make a smooth cut and, therefore, result in rough butted shingles. Bolts are usually cut into shingle block lengths by means of small stationary circular saws.

(2) A bolter or "knee bolter," a circular saw revolving in a horizontal plane and fed by a small carriage controlled by the knee of the operator. This saw is used to remove the bark and any exterior defects and cut the bolt into proper sizes for the shingle machine.

(3) The shingle machines were formerly of the horizontal type, as stated above, but have been largely replaced by the upright machines which were introduced within recent years from the Lake States. All

types are regulated to make the standard sized shingle having the thick butt and thin tip, and with provision for taking from 1 to 10 blocks at a time.

The vertical type consists of a set of stationary circular saws revolving in a vertical plane. A vertical sash frame holds the block and operates with a longitudinal reciprocating motion. Attached to the frame are spur rolls, one above and the other below, which automatically alternate the butt cut from the top to the bottom of the block, with each backward stroke of the frame. This, of course, means a minimum of waste, which runs as low as 10 per cent of the raw material in the most modern mills using the upright machine.

(4) The jointer or clipper consists of a single or double rip saw, or a wheel jointer. The latter is a rapidly revolving steel wheel carrying from 4 to 8 knives set in radial fashion. The jointer edges or "joints" the shingle, making the two sides parallel and trimming off wane or uneven edges.

(5) The shingle packer. This consists of a bench frame and two slotted, overhanging steel rods. After the packer or operator places the shingles into the frame the rods are pressed down, packing the shingles tightly together, the thin tips overlapping, while the metal strips are nailed. Foot levers are used to draw the wooden cleats together and hold the shingles tight until the strips are fastened.

The following table represents the average daily output of the various forms of shingle machines now in use in the Puget Sound region, based on a ten-hour working day:

OUTPUT OF VARIOUS TYPES OF SHINGLE MACHINES

Type of Machine.	Average Daily Output of Shingles.
Ten block	180,000–210,000
Double block	110,000–130,000
Single block	75,000– 90,000
Hand machine	45,000– 55,000
Upright	25,000– 30,000

The minimum figures of output given in this tabulation would obtain for so-called combination mills where the better class of logs are sawed into lumber, whereas the maximum figures obtain in those mills where both the good and poor timber is run into shingles and where efficient men and methods are used.

MANUFACTURE OF SHINGLES

The following tables [1] will convey the best idea of the output, number and duties of men employed at a large shingle mill using logs for raw material in western Washington, where both day labor and piecework prevail as is the case with most of the large shingle mills. The daily output was rated at 200,000 shingles and the annual capacity at 50,000,000. This is figured on the basis of 250 working days in the year. The output was evenly divided between the two popular grades of "stars" and "clears" and the average cost of the raw material in log form, delivered at the mill, was $10.00 per thousand board-feet.

The following day labor was employed at the rates given:

Employee.	Daily Wage.
1 engineer	$3.50
1 filer	6.50
1 drag sawyer	3.50
1 power bolter	3.00
1 deck man	2.75
1 boom man	2.00
1 trimmer man	3.00
1 tally man	3.00
1 head loader	3.50
1 second loader	2.50
1 wood man	2.00
1 band nailer	1.75
Total	$37.00

The following piecework charges were involved, the cost being expressed per thousand shingles:

Operation.	Cost per M. Shingles
Packing	$.090
Knot sawing	.130
Sawing	.055
Knee bolting	.045
Total	$.32

[1] From "Western Red Cedar in the Pacific Northwest," by J. B. Knapp and A. G. Jackson.

By dividing the daily labor charge ($37.00) by the daily output (200,000 shingles) the charge per thousand shingles is found to be $0.185. The fixed charges, including maintenance, interest, watchman, insurance, taxes, depreciation, office expenses and night watchman come to $0.16 per thousand and the raw material in the form of logs at $1.125 per thousand. The total charges, therefore, may be summarized as follows:

Item.	Cost per M. Shingles.
Daily labor	$0.185
Piece work	0.32
Fixed charges or overhead	0.16
Raw material (logs) delivered	1.125
Total cost of production	$1.79

The average selling price over a given period based upon 50 per cent "clears" and 50 per cent "stars" was 1.86\frac{1}{8}$ per thousand. This left, therefore, a net profit to the operator of 0.07\frac{1}{8}$ per thousand. The annual net earning on the 50,000,000 output would amount to $3750.

The following is a summary of costs together with the number of men employed at a single mill in Washington where the raw material was received in the bolt form.

The following itemized daily costs were observed at this mill:

Item.	Daily Charges.
8 cords of bolts at $6.00 per cord	$48.00
2 knots sawyers at $4.50 per day	9.00
1 shingle packer at $4.50	4.50
1 sawyer and filer	10.00
3 laborers at $2.50	7.50
1 engineer	2.50
Depreciation and miscellaneous expenses	3.00
Total daily charge	$84.50

This mill received an average of about $2.00 per thousand for their shingles and the mill turned out 50,000 shingles per day, making the gross daily income $100. Deducting the above daily expense of $84.50, there was a net daily income of $15.50. The average cost of the manufacture of shingles at this mill was, therefore, $1.69 per thousand shingles.

The removal of the tariff on shingles by the Federal Government has seriously affected the manufacturers in Washington and Oregon. British Columbia manufacturers have the advantage of cheap, Oriental labor, better grades of raw material since the timber runs better in that section, and greater concentration of capital and industrial conditions. There were 115 shingle establishments in British Columbia in 1915, but the average mill has a much larger capacity than the average mill in Washington, the largest mills turning out 700,000 shingles in a ten-hour day. In 1915 British Columbia exported over 1,259,000,000 shingles to the United States, leaving only 348,000,000 for domestic consumption.

SPECIFICATIONS AND GRADING RULES

The manufacturers of shingles have made many efforts to standardize mill grading by the organization of grading bureaus. The western red cedar shingle manufacturers are now well organized as a branch of the West Coast Lumbermens' Association. Some companies still determine their own methods of grading.

The basis of all shingle grades is (1) size (including length, width, and thickness), and (2) freedom from defects. Practically all shingles are made in 16-, 18- and 20-in. lengths and 4-, 5-, and 6-in. widths. Some are 24 in. in length in both the narrow and the larger widths. The larger shingles are from $\frac{1}{2}$ to $\frac{9}{16}$ of an inch in thickness at the butt and the shorter ones $\frac{3}{8}$ of an inch. The thin end or tip varies from $\frac{1}{16}$ to $\frac{1}{8}$ in. in thickness. Some grades permit "feather tips."

The thickness of a shingle is a direct criterion of its length of service, other conditions being equal, since erosion and wearing due to rains and the weather will often determine its usefulness. Shingles must be thick enough to resist the stress induced by alternate moistening by rain and drying by the sun. Very wide shingles are not desirable, because they are very apt to warp and split as the result of alternate expansion and contraction with the weather. Western red cedar is commonly made into extra wide shingles, but those 10 in. wide and under are preferred.

Some shingles are cut on the vertical or quarter grain and are much more desirable because they wear better, and are less likely to check and warp.

At the present time, the standard sawed shingle of western red cedar is regarded as being 16 in. long, 4 in. wide, $\frac{1}{16}$ in. thick at the point and $\frac{1}{2}$ in. thick at the butt end.

The following are the official specifications of the shingle manufacturers of the West Coast Lumbermens' Association in the Northwest as applied to western red cedar:

Perfection-18 in.

Variation of 1 in., under or over, in length, allowed in 10 per cent. Random widths, but not narrower than 3 in. When dry 20 courses to measure not less than $8\frac{3}{4}$ in. To be well manufactured. Ninety-seven per cent to be clear, remaining 3 per cent admits slight defects 16 in. or over from butt.

Puget A-18 in.

Random widths, but not narrower than 2 in. When dry, 20 courses to measure not less than $8\frac{1}{4}$ in. Admits feather tips and 16-in. shingles resulting from shims, and other defects 8 in. or over from butt.

Eureka-18 in.

Variation of 1 in., under or over in length allowed in 10 per cent. Random widths, but not narrower than 3 in. When dry, 25 courses to measure not less than $9\frac{3}{4}$ in. To be well manufactured. Ninety per cent to be clear, remaining 10 per cent admits slight defects 14 in. or over from butt.

Skagit A-18 in.

Random widths, but not narrower than 2 in. When dry, 25 courses to measure not less than $9\frac{1}{4}$ in. Will admit feather tips, and 16-in. shingles resulting from shims, and other defects 8 in. or over from butt.

Extra Clear-16 in.

Variation of 1 in., under or over, in length, allowed in 10 per cent. Random widths, but not narrower than $2\frac{1}{2}$ in. When dry, 25 courses to measure not less than $9\frac{1}{2}$ in. To be well manufactured, 90 per cent to be clear, remaining 10 per cent admits slight defects 12 in. or over from butt.

Choice A-16 in.

Random widths, but not narrower than 2 in. When dry, 25 courses to measure not less than 9 in. Admits wane and 12-in. shingles resulting from shims, and other defects 6 in. or over from butt.

Extra *A*-16 in.

Variations of 1 in., under or over, in length, allowed in 10 per cent. Random widths, but not narrower than 2 in. When dry, 25 courses to measure not less than $7\frac{3}{4}$ in. To be well manufactured. Eighty per cent to be clear, remaining 20 per cent admits defects 10 in. or over from butt. If not to exceed 2 per cent (in the 20 per cent allowing defects 10 in. from butt) shows defects closer than 10 in., the shingles shall be considered up to grade.

Standard A-16.

Random widths, but not narrower than 2 in. When dry, 25 courses to measure not less than $7\frac{1}{2}$ in. Admits wane and 12-in. shingles resulting from shims, and other defects 6 in. or over from butt.

Probably about 90 per cent of the shingles turned out in the Northwest are made up of the "Extra Clear" and "Extra Star A Star" grades, about equally divided.

The following are the official specifications of the Northwestern

Cedarmen's Association as applied to the northern white cedar in the Lake States:

Shingle Specifications.

Extra Star A Star Shingles shall be manufactured as follows: Ten in. clear and better from butt, with all clears in: nothing narrower than 3 in. in width allowed. Five butts to measure 2 in. when sawed. All Extra Star A Star Shingles to be 16 in. in length. Standard Star A Star Shingles shall be 5 to 10 in. clear from butt, nothing narrower than 2 in. allowed: 5 butts to measure 2 in. when sawed. Ten per cent sap is allowed in this grade.

The following are the specifications used for southern white cedar in eastern Virginia and North Carolina:

Smooth Sawn Shingles.

To be sawn on circular saws as smooth as possible.

To be 4 in., 5 in. and 6 in. wide, and 16 in., 18 in. and 24 in. long.

The 16-in. shingle to be $\frac{3}{8}$ in. thick at butt, and $\frac{1}{16}$ in. thick at point.

The 18 in. shingle to be $\frac{1}{2}$ in. thick at butt, $\frac{3}{32}$ in. thick at point.

The 24 in. shingle to be $\frac{9}{16}$ in. thick at butt, and $\frac{1}{8}$ in. thick at point.

No. 1 Grade: To be all heart or to show one heart face, a little sap on reverse side will be admitted, in fact, if sap is barely visible on edge of face side it will be admitted, admits knots, but they must be sound and tight.

"A" Grade: This grade compares with No. 1 grade in all respects, except that any amount of sap is admitted, they may be all sap, or part sap, or part heart. Will admit knots but they must be sound and tight.

"Star" Grade: This shingle to take practically all shingles below Grade No. "A," will admit any amount wane edges, provided there is a full face for a length of 6 in. from butt. Bark to be removed from edges. Will admit any amount of knots, which do not have to be sound or tight. The 4-in. shingle will not admit any knot holes, especially if they are near the center of the shingle. The 5-in. and 6-in. shingles are not graded as closely in this respect and will admit small knot holes. No badly split or rotten shingles put in this grade.

The following are the official grading rules of the Southern Cypress Manufacturers' Association as well as of the Hardwood Manufacturers' Association of the United States as applied to cypress shingles:

Bests.

A dimension shingle, 4, 5 and 6 in. in width, 16 in. long, each width packed separately, 5 butts to measure 2 in., to be all heart and free of shake, knots and other defects.

Primes.

A dimension shingle, 4, 5 and 6 in. in width, 16 in. long, each width packed separately, 5 butts to measure 5 in., admitting tight knots and sap, but free of shake and other defects, but with no knots within 8 in. of the butts.

This grade may contain shingles clipped two-thirds of the width and one-eighth of the length on the point.

Star A Star.

A random width shingle 3 in. and wider, 14 in. to 16 in. long otherwise the same as primes.

Economy.

Dimensions, 4, 5 and 6 in. each width separately bunched, admitting sap and sound knots, may have slight peck 5 in. from butts, imperfections on points no objection and admitting 14 in. shingles.

Clippers.

All shingles below the above grades which are sound for 5 in. from the butts, worm holes and slight peck excepted, random widths 2½ in. and wider.

The count of the manufacture of these shingles, of all grades, is based on 4000 lineal inches in width, making 1000 standard shingles, consequently there would be only 667 6-in. shingles packed and counted as 1000 standard shingles; 5 in. dimensions being counted in like proportion.

In making reinspection of shingles, one bundle out of twenty bundles, taken at random, shall be cut open, the results of this investigation to form the basis of arriving at the grade of the entire shipment.

The following table [1] shows the average selling prices of the two principal grades of western red cedar shingles. These two grades make up approximately 95 per cent of all western red cedar shingles made.

Year.	Grade.	Average Price per Thousand.	Year.	Grade.	Average Price per Thousand.
1893	Star A Star	$1.39	1907	Star A Star	$2.39
	Extra Clears	1.61		Extra Clears	2.67
1894	Star A Star	1.10	1908	Star A Star	1.77
	Extra Clears	1.25		Extra Clears	2.20
1895	Star A Star	.90	1909	Star A Star	1.75
	Extra Clears	1.05		Extra Clears	2.10
1896	Star A Star	.92	1910	Star A Star	1.69
	Extra Clears	1.07		Extra Clears	2.14
1897	Star A Star	1.02	1911	Star A Star	1.55
	Extra Clears	1.16		Extra Clears	1.98
1898	Star A Star	1.15	1912	Star A Star	1.60
	Extra Clears	1.29		Extra Clears	2.00
1899	Star A Star	1.22	1913	Star A Star	1.65
	Extra Clears	1.36		Extra Clears	2.14
1900	Star A Star	1.25	1914	Extra Stars	1.65
	Extra Clears	1.46		Extra Clears	2.14
1901	Star A Star	1.37	1915	Extra Stars	1.43
	Extra Clears	1.61		Extra Clears	1.71
1902	Star A Star	1.75	1916	Extra Stars	1.27
	Extra Clears	1.99		Extra Clears	1.56
1903	Star A Star	1.50	1917	Extra Stars	1.55
	Extra Clears	1.83		Extra Clears	1.92
1904	Star A Star	1.36	1918	Extra Stars	2.19
	Extra Clears	1.59		Extra Clears	2.82
1905	Star A Star	1.36	1919	Extra Stars	2.23
	Extra Clears	1.62		Extra Clears	2.80
1906	Star A Star	1.78			
	Extra Clears	2.12			

[1] Taken from the "West Coast Lumberman," Seattle, as published in several issues.

The following table shows the average selling price per thousand pieces of southern white cedar shingles for the past five years. The two grades quoted represent approximately 93 per cent of all southern white cedar shingles manufactured.

Year.	Grade.	Average Price per Thousand Pieces.	Year.	Grade.	Average Price per Thousand Pieces.
1916	"A"	$4.50	1918	"A"	$8.25
	Star	3.50		Star	6.75
1917	"A"	8.00	1919	"A"	8.50
	Star	6.50		Star	7.00

THE LAYING OF SHINGLES

Shingles are used for both roofing and siding and in certain architectural designs lend a very attractive appearance to the structure. Stained shingles are especially coming into favor for siding either all or part of the building.

The placing of shingles does not always receive the attention commensurate with the cost of the work and the length of service expected. Improper nailing or carelessly laid joints often result in leakage. Shingles which are 6 in. wide (or wider) should have 3 or more nails. Those from 3 to 6 in. in width should be fastened with 2 to 3 nails.

The kind or form of shingle nails has a direct bearing on the length of life of any shingle. Those made of zinc, copper, or galvanized wire are much preferred to cut iron or wire shingle nails.

The pitch of a roof also has a direct bearing on the life of the shingle. Those on nearly flat roofs deteriorate much more quickly than those on steep roofs or those used for siding.

The following table shows the covering capacities of shingles and shakes when laid at varying exposures to the weather. It is based on 4 in. as the average width of shingles and 5 in. as the average width of shakes.

COVERING CAPACITIES OF SHINGLES AND SHAKES

Kind.	Inches to Weather.	Number Required to Cover 100 Sq. Ft.	Number Square Feet Covered by 1000.
Shingles	4	1080	93
Shingles	$4\frac{1}{2}$	1000	105
Shingles	5	790	133
Shakes	7	400	280
Shakes	10	290	345

Shakes are commonly 24 and 32 in. long. The former are laid 7 in. to the weather and the latter 10 in.

Shingles 20 and 24 in. in length, made of southern white cedar are often laid 5, 6 and 7 in. to the weather.

Southern white cedar shingles, 4 in. in width by 20 in. in length are usually laid 6 in. to the weather. Laid in this manner their length will admit of three laps, which are essential to a tight roof and make possible a four-ply shingle roof with a 2-in. under extension. Southern white cedar shingles have a covering capacity as follows:

Width.	Length.	Number of Pieces to 100 Sq. ft. Laid 6 In. to Weather.	Number of 100 ft. Square to M Shingles.
4	20	600	1.67
5	20	480	2.08
6	20	576	2.50

PACKING AND SHIPPING

Shingles are packed in regulation frames of standard length, thickness and width. All packing is done by hand and each grade is kept separate, the packer usually being paid by the piece.

In Washington all shingles are cut in random widths from $2\frac{1}{2}$ in. and up, the average being about 4 in. A standard bundle of 16-in. western red cedar shingles containing 250 pieces is 20 in. wide and has 24 tiers. The shingles overlap with the thin ends at the center. Foot levers are used to draw the center together while wood strips across the face and metal strips at each side bind the bundle in a compact manner.

Shingle packers or "weavers," as they are called, will pack from 30,000 to 80,000 shingles in a ten-hour day, while the average is around 45,000 a day. This capacity is determined largely by the ability and deftness of the weaver, and the average width and quality of the shingles.

The cost of packing ranges from about 7 to 12 cents per thousand shingles.

Figuring 4 bundles to the thousand shingles, there are about 880 bundles or about 220,000 shingles per car, of the larger sizes.

The following are the accepted rules for packing in the Northwest:

All shingles are to be packed in regulation frames, 20 in. in width. Openings shall not average more than $1\frac{1}{2}$ in. to the course. Perfection and Puget A shall be packed 20–20 courses to the bunch and 5 bunches to the thousand. All others shall be packed 25–25 courses to the bunch, 4 bunches to the thousand. Every bundle is branded with the full name of the grade. Color of wood and sound sap are not considered as defects.

Some of the southern white cedar shingles are packed 50 to the bundle, this requiring 20 bundles to make a thousand. In this case each separate width is bundled separately. A carload of these shingles will consist of between 60,000 and 125,000, depending on the sizes. The popular sizes are the 18- and 20-in. shingles, whereas the 16-in. shingle is the popular size with western red cedar.

In the Northwest shingles are usually kiln dried at temperatures of from 150 to 200° F., for from five to twelve days to reduce freight charges

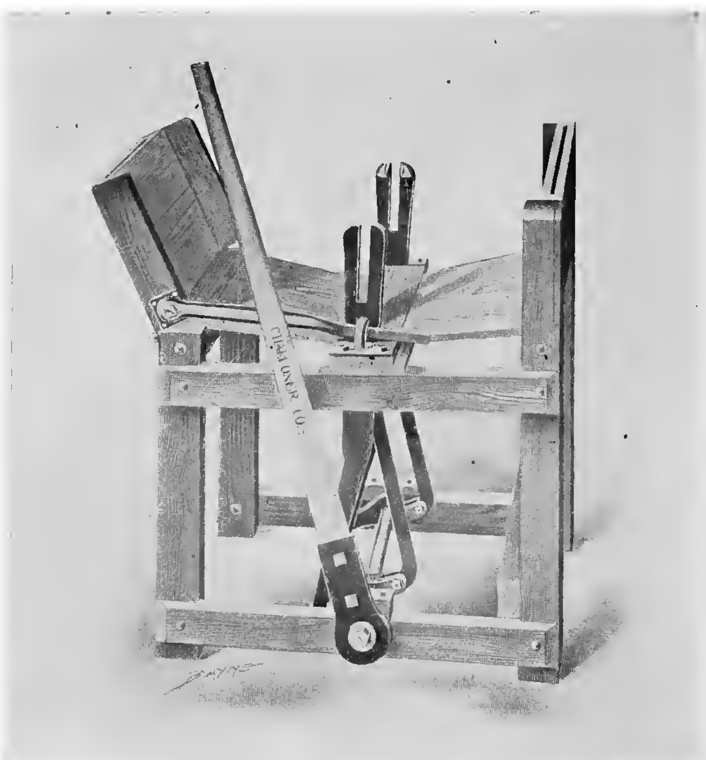

FIG. 96.—Shingle packer or buncher.

as much as possible. Many manufacturers have been somewhat overzealous in reducing the weight of their product by extreme artificial drying and have injured the durability of the shingles. This has been rapidly overcome, however, since the serious depression in the price of shingles during the year 1915.

Air seasoning has given much better results from the standpoint of durability, but it is so expensive as to be almost prohibitive in the case of western red cedar.

Water shipment charges are based upon the number of shingles rather than on weight, so that shingles shipped on vessels are often in the green condition and partially air-seasoned before reaching their destination.

The following standard shipping weights are recognized in the Northwest and delivered prices are customarily figured on this basis (see grading rules for further description of grades):

Grades.	Weight in Pounds per M Shingles.
Extra Star A Star, 16 in.	160
Standard A-16 in.	160
Extra clear-16 in.	180
Choice A-16 in.	180
Eureka-18 in.	200
Skagit A-18 in.	200
Perfections and Puget A-18 in.	200

The weights of southern white cedar shingles are as follows:

Length, Inches.	Width, Inches.	Weight in Pounds per M Shingles.
20	4	400
18	4	375
16	4	300

No artificial method of seasoning is generally applied to these shingles, which accounts for their relatively high weights. They are commonly shipped with little or no air seasoning as the wood contains a low per cent of moisture.

SHINGLE SUBSTITUTES

The competition of substitute materials for roofing purposes has become a serious problem with shingle manufacturers. Those promoting the use of substitutes for wood shingles have used the fire hazard as their great argument. The modern movement in favor of better fire protection in our cities has been used to favor the passage of ordinances in many cities prohibiting the use of wooden shingles in congested centers and restricting their use generally.

The forms of substitutes for wooden shingles include a great variety principal among which are asphalt, asbestos and combination shingles, tar roofing, slate, tile, various metal forms and several patent materials. The widespread demand for fireproof construction as applied to all kinds of structures and buildings, as a result of the great annual loss of life and property and the decreased insurance rates offered in conformance with fire underwriters' specifications have greatly stimulated the introduction and use of these substitute materials. The best indication of this condition is found in the statistics showing annual consumption of wooden shingles. It has remained about stationary in the past four years, whereas the demands for roofing materials of all kinds have been increasing from year to year.

Very little has been done until recently in the way of concerted effort to meet this competition. Efficient and widespread advertising, more careful methods of manufacture and the adoption of and adherence to stricter standards should be of material assistance in maintaining the demands for the wooden shingle.

Most of the substitutes are much more expensive and in addition require heavier construction in the building because of their additional weight. Moreover, wooden shingles, particularly cedar, cypress and redwood, are more durable as a rule than the other materials.

Probably the most effective means of combating this question is the fireproofing of the wooden shingle. Many experiments have been carried out with this purpose in view, but no method has been generally adopted as yet in the commercial field. The U. S. Forest Products Laboratory has developed experimentally a method which may prove to be commercially practicable. Air-dried shingles are subjected to a treatment with a solution of borax in water. The shingles are kiln dried to a moisture content of 10 per cent and then treated with a solution of zinc chloride and dried. It has been determined that shingles subjected to this treatment still retain their fire-resistant qualities after soaking them in running water for two weeks.

Wooden shingles have the following distinct advantages: They are durable, relatively cheap, light in weight and therefore require only light support; they do not rust or corrode; wood is an excellent non-conductor of heat; they are not affected by the wind if laid and nailed properly; they present a pleasing appearance and are easily laid.

DURABILITY AND PREVENTION OF DECAY

The value of any shingle wood depends very largely upon its durability. The durability in turn of shingles is dependent upon a number of factors, the chief of which are the species of wood, climate in which they are in service, pitch of the roof, size of the face of the shingles exposed to the weather, the thickness of the shingle, the method of laying, and last, but very important, the fire hazard involved.

The length of service varies considerably with the different species of woods used for shingles. The following shows the approximate service that the principal shingle woods should give under average conditions:

Species.	Length of Life.
Cedar (western red and northern and southern white)	15 to 30 years
Cypress	15 to 30 "
Southern yellow pine	6 to 12 "
Redwood	12 to 25 "
White pine	12 to 20 "
Chestnut	15 to 25 "
Western pine	8 to 12 "
Hemlock	7 to 12 "
Spruce	7 to 11 "

Shakes, which, as a rule, are much thicker than shingles, will last much longer than the periods given above. Split or cut shingles always last longer than sawn shingles. Instances are on record of cedar, cypress, and redwood shingles lasting for from thirty to fifty years or more, but this is an unusual exception. Decay is caused chiefly by water, the accumulation of moss and debris on the roof, splitting, warping, etc. The use of preservatives has been widely introduced to prevent decay.

The following methods, briefly enumerated, are the principal processes of preventing decay. Along with the prevention of decay various stains and preservatives are used to lend attractiveness to the appearance of the structure when used with various coloring agents.

1. Dipping. This is the most common method, the shingles being merely dipped in the preservative, and nailed to the roof. The shingles should be thoroughly air dried before dipping, and the preservative should be applied warm or hot. The exposed part of the shingle only, is dipped. They are usually given a final coating of preservative after being laid. Preservatives used are creosote, carbolineum and various patent forms.

2. Brush treatment. This is a cheap and less efficient method in which the shingles are merely painted with a preservative, after being laid. Paint aids chiefly in keeping shingles flat and preventing leaks.

3. Impregnation. This is the most efficient method, in which the

shingles are treated by the open tank process, about 10 lb. of preservative being applied to each bundle of shingles. The absorption should not be so great as to cause the running of preservative oil from the shingle on unusually warm days.

4. Staining. Stains are usually some compound of creosote applied to the shingle. They are not very efficient and also have a strong objectionable odor.

The following costs are customarily involved in the preservative treatment of shingles:

Impregnation with creosote (open tank or pressure treatment), per thousand	$1.25 to 1.75
Dipping in creosote, per thousand	.60 to 1.50
Shingle stains, per gallon	.40 to 1.00
Brush treatment, once after laying, per 100 sq. ft.	.60 to 1.00
Brush treated, twice after laying, per 100 sq. ft.	.40 to .90

SHAKE MAKING

Shakes are split shingles and were in very common use up to the advent of the sawed shingle. In remote forest regions shakes are still made and used for roofing and siding mountain cabins and other buildings. Wherever transportation facilities are provided, sawed shingles compete successfully with shakes as they can be produced much cheaper.

Shakes are now made in isolated mountain regions in California, the Northwest, and in the southern Appalachian Mountains. In California many shakes are now made for tray bottoms, used in the drying of fruits such as raisins, prunes, and apricots. The practice is rapidly going out of existence, however.

Shake making is generally condemned because it is extremely wasteful of timber. Only the very best and most straight-grained trees which are free from knots and other defects will rive. The shake maker, therefore, often lowers the value of a forest stand in a serious way by taking out only the largest and clearest timber of which only a small portion is utilized. The experienced shake maker looks over the best trees and takes a test chip or block out of one side of a tree. He continues this until he finds a tree of the proper riving qualities.

Sugar pine, redwood, and western red cedar make excellent shake timber and all are commonly used in inaccessible districts of the West where these trees are found. In the Southern Appalachians, chestnut, white oak and red oak are sometimes used, but the industry is rapidly diminishing both because of the development of the country and the lack of suitable and cheap timber.

When a tree is found that will rive, it is felled, swamped and bucked up into blocks the length of the shakes. The blocks are next set on end for bolting. Circles the width of the shake are marked out on the face of the block, the center which has a diameter of from 3 to 6 in., being culled as it is too knotty. Next, the shakes are marked out in outline form so that they can be split out along the radius. Shakes split out along the quarter grain in this fashion are much stronger and more durable. The sapwood is usually trimmed off and only the heartwood taken.

Photograph by U. S. Forest Service.

FIG. 97.—About 100,000 shakes made from five sugar pine trees in the Sierra National Forest, California. These sold at $4.00 per thousand. Shake making is exceedingly wasteful and is rapidly going out of practice.

After the shakes are diagrammed on the face of the block they are split out. The shake maker uses the following tools: A cross-cut saw, axe, maul or mallet, 1 or 2 wedges, and a frow. The frow consists of a steel blade 6 to 10 in. long with a wooden handle at right angles to the blade. It is usually made locally in a blacksmith shop and has a rather thick wedge edge. They cost from $.75 to $1.00 or more. With a frow and a wooden maul the bolts are first quartered, and then split up into suitable sized bolts for riving into shakes. Immediately after splitting the shakes are piled in fours, crib fashion and thoroughly seasoned before being used or hauled to the market.

As a rule, roof shakes are 32 in. in length, 5 in. wide and $\frac{3}{16}$ of an inch thick. Tray shakes are generally 2 ft. long, 6 or more inches in width, and $\frac{1}{4}$ in. thick. In California, it is estimated that each roof shake contains about $\frac{5}{24}$ ft., board measure, and each tray shake about $\frac{1}{4}$ ft., board measure. Only about 4000 roof shakes are made from each thousand board-feet of the tree actually used. About 25 per cent of the available saw timber of the trees taken for shake making is wasted. This portion is not used because of knots, cross-grain, sapwood, and defects of various kinds.

The following costs of production have been observed in California. The usual selling price for roof shakes sold at the point of making runs between $6.00 and $8.00 per thousand shakes.

Operation.	Cost per M Shakes.
Felling and trimming	$0.10 to $0.12
Bucking	1.25 to 1.60
Riving	1.80 to 2.10
Piling	.10 to .10
Baling (including wire)	.15 to .15
Piling debris	.15 to .22
Stumpage	1.25 to 1.60
Total per thousand	$4.80 to $5.89

Tray shakes for use in the California valleys are commonly split out, but they are also sawed out at so-called tray mills. The operation is practically the same as in making roof shakes, but the operator is not so particular about the type of timber taken. Tray shakes are, as a rule, much longer, wider and thicker than roof shakes, and are sometimes graded into first and second classes. Tray mills which saw their product sometimes turn out from 12,000 to 16,000 tray boards per day. They bring from $13.00 to $15.00 or more per thousand delivered at the railroad.

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CHAPTER XVIII

MAPLE SYRUP AND SUGAR

HISTORY AND DEVELOPMENT

THE making of syrup and sugar from the sap of the maple trees was discovered and developed in a very crude way by the Indians long before the first white settlers came to this country. Interesting passages from the journals of early explorers refer to the tapping of the maple trees in the early spring throughout the St. Lawrence Valley and the northeastern part of this country. The earliest extant written record seems to be in 1673. Many legends have been handed down to the white settlers concerning the first discovery of the use of the maple sap by the Indians.

They tapped the tree by making a sharp incision in the bark or in one of the larger roots and collected the sap by conveying it by means of a reed or a curved piece of bark into a receptacle made of clay or bark. The journal of a white settler captured by the Indians in 1755 tells of a large trough of 100 gal. capacity made of èlm bark which was used for the collection and the storage of maple sap.

The early settlers quickly took up the process and made many improvements in the way of receptacles and utensils. The Indians had boiled down the sap by repeatedly dropping hot stones into it. They had also learned to convert the sap into sugar by allowing it to freeze in shallow vessels, the ice being skimmed off and thrown away and this process continued until the sap was sufficiently refined to crystallize. Although the same general method was followed, little marked improvements were made by the early colonists. The axe was used to cut a diagonal notch in the tree and later a circular hole was cut, followed by the use of the spile or spout to convey the sap into a bucket. Iron or copper vessels were substituted for the crude bark or wooden troughs or hollowed logs.

Still later the trees were tapped by the use of an auger, holes being bored an inch or more in diameter in which were inserted hollow or half round spiles of sumach or alder. The sap was collected in wooden buckets, and more recently galvanized iron and tin buckets came into common use.

The "boiling down" or evaporation process in the early days was also very crude. It was done in the open woods with no shelter from sun, wind, rain or snow. The resultant impurities from this lack of protection meant a very inferior grade of product. Frequently a pole was stretched between two forked posts and from this an old-fashioned potash kettle was suspended over an open fire. Sometimes a long, heavy pole supported by a post or the crotch of a tree and balanced at the other end with weights was used. The latter method permitted the kettle to be swung over or away from the fire. As the sap was boiled down the impurities were skimmed off. When it was boiled down to the

Photograph by U. S. Forest Service.

FIG. 98.—The old primitive and wasteful method of tapping sugar maples used by the Indians and sometimes by the early settlers. The rough-hewn receptacle and wooden trough have been replaced by the covered bucket and the iron spout.

proper consistency, or to a thin syrup, it was stored in a vessel and the process repeated with fresh sap. Very often the syrup resembled a tarry mass; dark, heavy, and exceedingly inferior in quality in comparison to the modern product.

The work of making the syrup into sugar is known as "sugaring off." This was accomplished by continued boiling until the syrup attained a waxy consistency when dropped in the snow. It was then poured immediately into small moulds where it crystallized into sugar.

Succeeding the suspended iron kettle came the open furnace, built of flat stones or brick with grates placed over them and space provided for from four to six kettles. The next step was the use of the boiling pans which varied in width from 30 in. to 3 ft., in length from 6 to 10 ft., and only about 6 in. deep. These pans came into use about the middle of the last century. In 1865 pans with partitions to produce an alternating flow of sap were introduced and rapidly adopted. The latter made possible the gradual flow of sap from one side to the other through succeeding compartments until it finally emerged in the form of syrup. This principle is incorporated in the modern evaporators, which have been in common use for the past forty years and which are used in connection with all of the larger commercial sugar orchards. They have a capacity of converting from 25 to 400 gal. of sap into syrup in an hour.

The modern evaporators are usually from 2 to 6 ft. in width, 4 to 8 in. deep, and from 6 to 24 ft. long with corrugated bottoms to increase the heating surface. The rate of flow through the compartments is obviously of the greatest importance. Most of the present models use automatic regulators by which the flow of sap from the tank or reservoir increases or diminishes with the heat underneath the pan. The evaporator is always operated now in a sugar house conveniently located to the maple orchard. Its use will be more fully explained later in this chapter.

As the evolution of the modern evaporator came about in gradual improvements, so the methods of collecting the sap and maintaining the sugar grove progressed from time to time. At first the sap was gathered in wooden buckets and carried by hand to the kettle or sugar house. Then a barrel on a sled drawn by horses or oxen was used as larger groves were tapped. The most modern improvements are exemplified in a system of pipes which convey the sap directly by gravity to the storage tanks along the roadside or to the sugar house. One large Adirondack sugar bush used a narrow gauge railway for bringing the sap from the woods to the sugar house.

Another great advance in the industry has been in the cleanliness of the methods of tapping, gathering and manufacturing of both syrup and sugar and, therefore, in the purity of the product. At the present time, covers or lids are used on the pails hung on the trees on most of the up-to-date operations. Formerly rain, snow, leaves, twigs, pieces of bark, etc., fell in. Boiling was practiced in the open and here the same opportunity was afforded for impurities to fall in. The lightest colored sugar and syrup are only derived from the purest sap and by the use of the most sanitary utensils and methods. The purest product secures the best prices on the market so it is considered of the highest importance to use the most sanitary methods in every respect.

It must not be assumed from the foregoing that all our maple sugar and syrup are made with the use of the evaporator and other up-to-date methods. Only the larger commercial operations tapping from 50 or 100 up to several thousand trees every year can afford these improvements. Both products are made on most of the farms in the Northeast where sugar maples are available, but on many places only a comparatively few trees are tapped and the syrup and sugar made in the home kitchen and only for home use.

Photograph by U. S. Forest Service.

Fig. 99.—The old-fashioned method of reducing the sap to syrup by "boiling down" in copper kettles in the woods. The modern evaporator has replaced this method in large sugar bushes because it is more efficient and sanitary.

In the early colonial days, maple sugar was made as an article of food. With the advent of cane sugar, it ceased to be an important necessary commodity on the markets and is now classed as a luxury. The demand for both sugar and syrup as luxuries has kept the industry alive and it is on the steady increase. However, in spite of the strong demand, the production has remained about stationary for the past two decades or more because of the large amount of adulteration. It is estimated that approximately seven-eighths of the total product is adulterated before it reaches the ultimate consumer. The increase in demand, therefore, results in the use of more adulterants so that the producers do not profit from this strong demand. Organizations to combat this evil and to place their product directly in the hands of the consumer, as well as to standardize and advertise their product, have done much good work, notably among them being the Vermont Maple Sugar Makers' Association, organized in 1893. The growers, consequently, do not like to sell their product to these "mixers," as they are called, and prefer to sell the sugar and syrup direct. This results both in protecting the trade against a spurious product and in bringing in more returns for their work.

SPECIES OF MAPLES USED

There are about 70 species of maples distributed over the world, of which Sargent recognizes 13 species or varieties as growing in the United States. The most important in the making of sugar and syrup is the sugar maple (*Acer saccharum*) which also goes by the names of hard or rock maple. Probably between 80 and 90 per cent of all the maple sugar and syrup is made from this tree. All of the other native maples yield a sweetish sap, but only a few of them are capable of producing sugar on a commercial scale.

Sugar Maple.

The sugar maple is found throughout the eastern part of the United States, but for the production of sugar and syrup it does best in western New England, New York, Pennsylvania, the northern Appalachians, northern Ohio and the Lake States. The southern varieties of sugar maple, namely, *A. floridanum* and *A. leucoderme*, do not yield sugar or syrup.

Throughout its northern habitat, the sugar maple is one of the most prominent trees in the forest, growing in mixture particularly with yellow birch and beech and on the higher elevations with spruce. It has a very wide range of soil requirements and is found both on moist, well-drained soils as well as on gravelly, dry hillsides.

It is classed as a tolerant tree so that its crown is rather deep and broad even when growing in close association with other trees or under the shade of other dominant specimens.

Sugar maple sometimes reaches a height of from 100 to 120 ft. although it commonly grows to a height of from 60 to 80 ft. Its diameter averages between 14 and 24 in. and it is said to occasionally reach 4 ft. in diameter. It is a very slow growing tree and frequently reaches an age of between three hundred and four hundred years.

This tree is readily planted in the form of new groves and it is easily reproduced naturally so that, in spite of its slow rate of growth, there will always be little difficulty in maintaining sugar groves for the future of this industry.

Black Maple.

The black maple (*Acer nigrum*) which is sometimes recognized as a variety of sugar maple, also occurs throughout the North and East, but commercial production of maple sugar and syrup is limited to the Northeast as in the case of the true sugar maple. In Vermont the black maple is commonly considered superior to the sugar maple as a producer of high quality as well as large quantity of sap. In general appearance and characteristics, it is very similar to the sugar maple and is usually found on lower elevations and along the banks of streams and in the lower valleys.

Red Maple.

This maple (*Acer rubrum*) has a wider natural range than any of the other maples found in this country. It grows best along the borders of streams and in swampy soils. It is a much more rapidly growing tree but does not reach the size, either in height or diameter, of the sugar maple. It is used for sugar production in the Middle and Western States to a limited extent, but its sap is very low in yield of both syrup and sugar.

Silver Maple.

The silver maple (*Acer saccharinum*) is found from New Brunswick to Florida and west to the central prairies. It commonly grows along with the sugar maple, but altogether prefers the low lands bordering swamps and streams. It yields a plentiful flow of sap, but it is very likely to discoloration and its season is very short and uncertain. It is seldom used when sugar or black maples are available. It grows to a good size, but does not occur as frequently as the three maples mentioned above. It is not likely that it will ever be an important source of syrup and sugar production.

Other Maples.

The other maples, such as the Oregon maple (*Acer circinatum*), mountain maple (*Acer spicatum*), striped maple (*Acer pennsylvanicum*), box elder (*Acer negundo*), etc., are of no importance in this industry.

It is of the greatest importance that the best forest conditions are maintained in the sugar grove. The sap and sugar production is directly proportionate to the leaf area of the trees and it is said that this leaf area is of greater importance than the amount of light the leaves receive. Each tree, therefore, should have full room for development consistent with the largest available number of trees per acre. At the sample time the crown canopy of the trees should be sufficiently dense to prevent the growth of grass underneath and to maintain a good covering of humus and leaves on the ground.

The gradual northern spring with cold nights, warmer days and slow yield of frost from the ground are conducive to a long and continuous flow of sap. Sudden thaws and rapid changes of temperature are injurious to this flow. The ground should be kept as moist as possible under the humus covering. A good blanket of snow gradually melting off helps very materially to keep the soil moist and, therefore, to induce the maximum flow of sap.

The careful nurturing of the young maples, the thinning and improvement of the grove, etc., are silvicultural problems which are deserving and receiving more and more attention from the sugar makers. Some growers even advise the sowing of 500 lb. of nitrate of soda per acre to induce vigorous leaf growth and, therefore, sweeter and more sap during the following spring.

ANNUAL PRODUCTION

It is estimated that an equivalent of about 45,000,000 lb. of maple sugar are annually made in this country. This is based upon the assumption that all sap is made into sugar.

The annual production of maple sugar and syrup reached the height of its importance in 1860. At this time the cane sugar came into competition with it as a food commodity. In 1870, as a result of this competition, the production fell heavily but rose again in 1880 and remained about the same in 1890. About this time both syrup and sugar came into strong demand as table luxuries and this demand stimulated its production very materially.

In 1900 there were produced about 12,000,000 lb. of sugar valued at $1,074,260 and 2,056,611 gal. of syrup valued at $1,562,451. In 1909 the value of the sugar and syrup crop was $2,541,098. There has been a distinct tendency in the production to fall off in those parts of the country where sugar was produced for home consumption only, whereas in regions where the industry is of larger commercial importance, it has increased in considerable amounts. For example, in Vermont, New York and northern Ohio, the industry has made rapid strides within the past five years through a strong demand for the products, organization of the growers and more stringent laws to prevent adulteration without proper labeling.

In 1909 there were produced 14,060,206 lb. of sugar and 4,106,418 gal. of syrup. The great majority of these products are made in Vermont, New York, Ohio, Pennsylvania, Michigan and New Hampshire, listed in order of importance. These states supply about 95 per cent of the sugar and over 80 per cent of the syrup. Vermont is said to specialize more in sugar while Ohio turns most of its production into syrup. New York engages in the production of both syrup and sugar without discrimination. Other states passively engaged in the work are Indiana, Wisconsin, Massachusetts, Maine, West Virginia and Maryland. The census for 1909 shows a number of other states such as Iowa, Connecticut, Rhode Island, Illinois, Nebraska, North Carolina, Virginia and others, but the total number of trees tapped and products made in them are of very little importance.

In 1909 there were over 18,899,533 trees tapped valued at $5,177,809.

A census of the more important sugar orchards in Vermont showed the average orchard to contain a little over 1000 trees. It is generally understood that by a sugar bush one means a grove where at least 100 buckets are installed. In New York some of the sugar groves contain between 8000 and 17,000 buckets, although the usual sugar orchard runs between 300 and 1500 buckets.

Practically every county in Vermont engages in the industry on a commercial scale. The leading counties in order of production in this state in 1914 were Orleans, Franklin, Caledonia, Lamoille, Windham, Washington and Orange. The leading centers in New York are in St. Lawrence and Franklin and Lewis Counties, the Saratoga-Warren County section, the Delaware-Schoharie County unit and Cattaraugus-Chautauqua County unit. Geauga County is the center of production in Ohio.

CONDITIONS NECESSARY FOR COMMERCIAL OPERATIONS

In the establishment of an operation for making syrup and sugar within the natural range of sugar and black maple, where sap flows in commercial quantities, there are several considerations which should be kept in mind. It is assumed that in engaging in the work on a commercial scale the purchase of modern equipment such as evaporator, sugaring-off arch, tin buckets and covers, etc., is included.

These considerations may be summarized as follows:

1. There should be trees enough for at least 100 buckets. The larger the number of buckets above this minimum the greater is the profit per bucket.

2. There should be at least from 60 to 80 trees or more per acre large enough to be tapped. The individual tree should be preferably well formed, with deep crowns and of good size.

3. The trees should lie on gentle or sloping topography from which the sap can be collected on a sled with little difficulty. Although trees on southerly slopes run earliest in the season, there is no indication that they yield more sap than trees on other exposures.

4. Very little capital is necessary to engage in the work, as the manufacturers of equipment usually allow the growers to pay for this investment out of the annual profits of the business.

Other important considerations bearing upon the financial aspects of the making of syrup and sugar are: (*a*) No skilled labor of any kind is required; the work being done by the farmer and his family and hired help unless the groves are of the largest sizes. Three men can look after the work of tapping the trees and gathering the sap on an orchard of 2000 trees or less, while it requires only one man to look after the evaporator. (*b*) The sugar season comes at a time of the year when the regular work of the farm is least active, thus giving the men an opportunity to give most of their time to it. Under average conditions the gathering of the sap is finished by the middle of the afternoon and one man is left to complete the work of making syrup or sugar until the last of the day's sap is run through the evaporator.

SAP FLOW AND SEASON

The flow of sap from the maple tree has not been thoroughly understood until comparatively recent years. Many investigations have been carried on by the Vermont Agricultural Experiment Station which thoroughly cleared up a number of doubtful points.

Maple sap ordinarily contains from 2 to 6 per cent of sugar with an average, under all conditions, of about 3 per cent. The sap is composed largely of water, and the other component part sbesides sugar are various mineral ingredients such as lime, potash, iron, magnesia and certain vegetable acids.

It is the alternate freezing and thawing, peculiar to the climatic conditions in the early spring throughout the Northeast, that is most conducive to commercial sap flow. Moderately warm days and cold nights below the freezing point are considered best in Vermont, and it is current opinion that a temperature of 25° F. during the night and a maximum of 55° F. during the day, with damp, northerly or westerly winds are the conditions under which the best flow is obtained. These changes of temperature cause a certain expansion and contraction of the gases within the cells and intercellular spaces in the wood which results in an alternate pressure and suction. During the sugar season this force varies from a suction of 2 lb. per square inch at night to a pressure of about 20 lb. per square inch during the day.

The commercial flow of sap ordinarily runs from about the middle of March until about the middle of April in the region from Vermont to northern New York, inclusive. In Ohio and western New York the season is usually from late in February to early in April. The beginning of the sap season, of course, is determined wholly by the weather and the latitudes. Records show that the flow has commenced as early as the first of February and as late as the early part of April in the Northeast. The following records were obtained in Ohio from 1880 to 1912 by a sugar grower who kept an actual record of the opening and closing date of each season:[1]

Year.	Opening Date.	Closing Date.	Number of Days.	Year.	Opening Date.	Closing Date.	Number of Days.
1880	Feb. 24	Apr. 1	37	1897	Mar. 9	Mar. 9	23
1881	Mar. 9	Apr. 16	38	1898	Mar. 3	Apr. 11	39
1882	Mar. 2	Apr. 1	30	1899	Feb. 20	Apr. 11	50
1883	Mar. 1	Apr. 10	41	1900	Mar. 8	Apr. 14	37
1884	Mar. 12	Apr. 14	33	1901[1]			
1885	Mar. 27	Apr. 18	22	1902	Mar. 7	Apr. 6	30
1886	Mar. 15	Apr. 11	27	1903	Feb. 26	Mar. 15	17
1887	Mar. 2	Apr. 9	38	1904	Mar. 2	Apr. 6	34
1888	Feb. 21	Apr. 10	50	1905	Mar. 16	Mar. 29	13
1889	Mar. 11	Apr. 9	29	1906	Feb. 13	Apr. 2	48
1890	Feb. 17	Apr. 7	49	1907	Mar. 14	Mar. 23	9
1891	Feb. 13	Apr. 11	57	1908	Mar. 5	Mar. 26	21
1892	Feb. 22	Mar. 30	37	1909[1]			
1893	Mar. 7	Apr. 3	27	1910[1]			
1894	Feb. 27	Apr. 7	39	1911	Feb. 16	Apr. 4	47
1895	Mar. 23	Apr. 12	20	1912	Mar. 17	Apr. 9	24
1896	Feb. 27	Apr. 10	43				

[1] No records were taken in this year.

The longest run on this record is fifty-seven days and the shortest only nine days. The average is thirty-four days. The season ends

[1] See "The Production of Maple Sirup and Sugar," by A. H. Bryan and W. F. Hubbard, Farmers' Bulletin 516, U. S. Dept. of Agriculture, 1912, p. 20.

when the leaf buds begin to swell. The season, of course, begins earlier in the South than in the North. Professor J. L. Hills, Director of the Vermont Agricultural Experiment Station, has determined in his investigations of sap flow many interesting findings, the chief of which may be summarized as follows:

1. The amount of sap flow from a tree under given conditions is directly in proportion to the leaf area and the amount of sunshine it receives. The starch is stored in certain sapwood cells during the preceding summer and through the action of enzymes is transformed from starch into sugar. The alternate freezing and thawing causes expansion and contraction which, with the large amount of moisture drawn up from the roots, excites pressure at the tap hole. Trees in the open with wide, deep crowns, therefore, give much more and richer sap than forest grown specimens with long, straight boles and small shallow crowns. A tree 15 in. in diameter and 50 ft. in height was determined to have 162,000 leaves. This leaf space is equivalent to 14,930 sq. ft. in area representing about one-third of an acre. The weight of the water in the leaves in this tree is estimated to be 242.2 lb. and the total water content of the tree is set at 1220.57 lb.

2. No more sugar or syrup is obtained by tapping on the branchy or south side of the tree. The compass direction makes no apparent difference in the yield of sap, sugar or syrup. A healthy and fresh portion of the bark indicates the best place in which to tap a tree.

3. Most of the sap flow comes from the first 3 in. of sap wood. Deep tap holes, therefore, are not considered best. Tapping is seldom done now to a depth of more than $2\frac{1}{2}$ in. It was determined that in a tap hole 6 in. deep, four-fifths of the sugar came from the first 3 in. Deep tapping does not compensate for the extra labor of boring and increased injury to the tree.

4. The best point at which to tap a tree is about 4 ft. from the ground. This point yields both more sap and better quality sap than lower or higher elevations. An experiment showed that 51 per cent of the total yield of sugar came from a tap 4 ft. from the ground, whereas only 27 per cent came from a root tap and only 22 per cent from a higher tap hole.

5. The best size of tap hole is from $\frac{3}{8}$ to $\frac{5}{8}$ of an inch. Seven-eighths of an inch is the size most commonly in use to-day. Generally speaking, the larger the tap hole the more sap and sugar for the time being will be yielded. However, the smaller size holes yield practically as much sap and the hole will rapidly heal over so that the tree is not materially injured. In all cases the tap hole should be cut by a short bit, should

be cleaned of all shavings and borings before the spout is inserted and the bark should be left intact.

6. Sap pressure exists on all sides of the tap hole. That is, the pressure from above and below is the same and the flow of sap from the side also shows the same amount of pressure.

7. Most of the sap flow occurs between the hours of 9 A.M. and noon. Over an extended period 63 per cent of the total sugar was contained in the sap which ran before noon. After 3 P.M. there is very little flow if any at all.

8. The removal of the sap from the tree does not seem to have any material effect on its growing ability or general health conditions. Assuming that 3 lb. of sugar are made to the tree, only from 4 to 9 per cent, according to the size of the tree, of the total sugar contained is removed.

9. Buddy sap, which is the common term applied to the green sap collected toward the end of the season and from which a resultant reddish syrup is made, is commonly attributed to the swell of the buds. Investigation shows that this is caused by the development of a certain group of bacteria. These micro-organisms infect the sap as it flows out of the tap hole and while in the spouts and buckets. This infection increases with the sugar season and is the cause of the souring of sap and the buddy flavors which are common in syrups made at the termination of the season. This tendency may be eliminated and the quality of the product much improved by observing the following:

(*a*) By keeping the spouts and buckets thoroughly clean by washing often and regularly.

(*b*) By using metal spouts and buckets instead of wooden ones.

(*c*) By collecting the sap frequently and boiling it as soon as possible after collection.

WOODS OPERATIONS

Tapping Trees and Distribution of Buckets.

Tapping should take place just before the season opens. A sharp bit should be used since a dull, rusty one leaves the hole rough. Smooth-surfaced cuts always give best results. The tap hole should not be over 3 in. deep and a depth of from 2 to $2\frac{1}{2}$ in. is considered best since this depth will completely grow over in a year and heal itself. The best diameter is now considered to be $\frac{7}{16}$ in., although holes of from $\frac{1}{4}$ to $\frac{3}{4}$ of an inch or more are used.

Immediately after tapping, the spout is inserted. Care should be used to remove all chips, bark, etc., from the hole, before inserting the spout. It should be done immediately, followed by the hanging of the pail.

In long or intermittent flowing seasons, when the tap holes are likely to be contaminated, the holes should be reamed out once, using a reamer

Photograph by U. S. Forest Service.

FIG. 100.—Tapping a sugar maple in the Adirondacks at Horseshoe, New York.

$\frac{1}{16}$ in. larger than the original tap hole. This cleans the exposed surface of all slimy substance and induces stronger flow.

There has been considerable discussion regarding the number of taps per tree. There is no question but that overtapping not only impairs the life of the tree, but seriously interferes with tapping during succeeding years. The writer knows of one very large tree on which 30 buckets were hung in one year. The ensuing year the tree sickened and died. The following table shows the number of taps that should be used, depending upon the size of the tree:

Diameter of Tree in Inches.	Number of Taps.
8 to 12	1
12 to 16	2
16 to 24	3
24 and up	4 or more

Some prominent owners of large sugar groves advocate the tapping of only one hole in each tree during a season.

Tapping should be done in the thrifty part of the tree where the bark looks best. It is commonly done on the southern side of the tree because that side warms up the earliest in the season and the first sap flow is considered best, but experiments show that under average weather conditions, the flow of sap is equal on all sides. It is always advisable to avoid tapping near an old tap scar.

Two men working together will tap and hang about 400 to 500 buckets per day working from eight to nine hours per day. The cost, therefore, of the distribution of buckets and of tapping is about 1 cent per bucket.

There are at least twelve different kinds of metal sap spouts or spiles on the market. They cost from $2.00 to $3.00 per hundred and for each particular brand there are special advantages claimed. They have displaced the old sumach or alder or half round wooden spiles except on the smallest and most inaccessible orchards.

The general principles involved in the selection of a satisfactory spout may be summarized as follows:

1. It must provide for an easy and maximum flow of sap.

2. It must hold firmly in the tree and not only support the bucket and cover but it must be attached and removed easily and the bucket must be held in such a position that it may be emptied without unhooking it from spout. Buckets should never be hung from a nail.

3. It should be placed in the hole in a level position and must not be driven in deep enough to split either bark or wood, and yet it must prevent leakage.

4. It should exclude the air and prevent drying out at the end of the first run of sap.

5. It must be inserted in and withdrawn from the tap hole with the least difficulty.

On many of the most modern operations, after the spout is taken out at the end of the season, the tap holes are plugged with cork stoppers. During the following growing season the hole readily heals over with a fresh layer of wood and bark.

The flaring rust-proof tin buckets of 13- and 16-qt. capacity are rapidly superseding the old wooden bucket. They are hung, together with the covers, directly on the spout. The flare shape is used to prevent ice from breaking them. Galvanized iron is never used because of the poisonous nature of the metals used in galvanizing.

The advantages of the tin over the wooden buckets are:

1. They do not dry up and leak.
2. They can be easily rinsed and cleaned after each run.

Fig. 101.—Modern tin pails with covers to keep the sap free of rain, bark, twigs, and other impurities. Photograph taken at Hardwick, Vermont.

3. They do not soak up sap and sour the contents as the wooden buckets do, unless frequently scalded.
4. The tin bucket is durable, light in weight and when nested they are compactly stored.

The 13-quart rust-proof tin buckets cost from $25 to $30 per hundred depending upon the number purchased. The covers cost about $8.00 to $9.00 per hundred.

Collection of Sap.

Preliminary to the work of tapping the trees, setting the buckets and the gathering of the sap, haul roads are customarily broken through the snow so that as soon as tapping is commenced, preparations can be made to bring in the sap immediately.

Gathering was formerly done entirely by hand, the men going from tree to tree with buckets into which the new sap was poured from the pails hanging on the trees. This was a slow and laborious method and with the development of larger commercial operations, especially in sugar groves where the number of trees tapped range from 1000 or more, a gathering tank of from 25 to 160 gal. capacity is placed on a sled which

Photograph by U. S. Forest Service.

FIG. 102.—A recent development in the maple sugar and syrup industry—a pipe line to conduct the sap directly from the forest to the sugar house. Note also the modern covered buckets.

is drawn about by a team. The gathering tank should be of metal, preferably of tin or galvanized iron and provided with some form of strainer at the top to keep out such impurities as leaves, twigs, etc., and also to prevent the contents from spilling out. Haul roads are laid out on a systematic basis with reference to reaching the largest number of trees from the coves and draws and with reference to the location of the sugar house. Pipe lines are now used to some extent in the larger sugar orchards under such favorable conditions as large numbers of trees, rather steep topography and a central location for the sugar house. Narrow gauge railroads have been used, but this is an extreme refinement which will never be adopted to any extent.

Under ordinary conditions two men and one team work together. This crew will gather the sap from 500 buckets per day, making two collections during the day. The men pour the sap directly into gathering buckets which are emptied into the tank on the sled. Gathering should be done as frequently as possible and the sap should always be taken up after from 2 to 4 qt. of sap flow. The leaving of sap in buckets too long results in discolored sap, which means a low grade of syrup.

It costs about $50 per season for gathering sap on a bush of 500 buckets.

MANUFACTURE OF SYRUP AND SUGAR

The Sugar House.

In laying out a new operation, the first consideration is the location, size and equipment of the sugar camp or sugar house and its cost. These

FIG. 103.—A typical sugar house in the "sugar bush." A large pile of dry wood is available for heating the evaporator under the shed at the right.

are determined, in turn, by the number of trees to be tapped. In an orchard containing 500 buckets or more, it must be located with reference to the minimum length of sap haul on one of the principal woods roads. The house should be placed on a well-drained slope to permit the emptying of the gathering tank by gravity into the storage tank.

It should never be built in a cold, damp hollow where a poor draft will be afforded the chimney.

For a camp of 500 buckets, the house should be about 14 by 20 ft. in ground plan, with 8-ft. posts, rough siding, ventilator at the ridge and paper roofing. This may be constructed for from $75 to $150, depending upon cost of materials and labor and method of construction. This will provide nicely for a 3 by 12 ft. evaporator.

For larger operations and where further refinements are justified, a house with two compartments and a separate woodshed, with brick or concrete paving on the floor, a well-equipped work bench and provision for maintaining an even temperature and avoiding drafts are considered advisable. Where sugaring-off is practiced a two-compartment house is usually required. The primary requisites in the construction and operation of the sugar house are comparative inexpensiveness, convenience and cleanliness.

Fuel.

Well-seasoned wood, split rather fine and prepared well in advance, should be kept stacked in the woodshed adjoining the evaporator room. Some makers use the old fence rails and odd pieces of wood picked up in the grove. It should preferably be cut in the spring so it will have a whole summer season in which to thoroughly dry out.

It usually requires about 8 face cords of 2-ft. wood or 4 full cords (of 128 cu. ft. each) to evaporate the sap from about 500 buckets, or expressed in other words, about 6400 gal. On many of the Vermont operations it is commonly considered that it requires 1 cord of wood to provide sufficient heat to make 300 lb. of sugar. For the larger evaporators, some of the operators estimate that they use a full cord every day.

The cost of cutting, hauling and ricking the fuel wood in the woodshed is usually figured at from $2.00 to $2.75 per full cord.

Equipment and its Cost.

Many of the smallest groves operated for home consumption still use the old-fashioned methods such as wooden buckets and spouts and boil down the sap in a kettle on the kitchen stove.

The minimum number of buckets with which modern equipment is used is about 40. It is doubtful, however, if such a small operation would ordinarily justify the rather large initial expenditure involved. For this work the following equipment is recommended:

A sugaring-off arch and pan which serves the purpose of an evaporator as well	$27.00
40 sap spouts with hooks at $2.75 per hundred	1.10
40 16-qt. buckets at $29 per hundred	11.60
40 bucket covers at $8.75 per hundred	3.50
1 thermometer	1.25
1 strainer	1.50
One $\frac{7}{16}$-in. tapping bit	.25
One $\frac{1}{2}$-in. reamer	.50
Total	$46.70

Gathering and storage tanks are not usually used in such small outfits as this.

It is generally considered in the industry that it scarcely pays to engage in the work with modern equipment unless one has a bush of at least 100 buckets. The necessary outfit required for a 500-bucket sugar bush equipped only for making syrup is as follows:

COST OF EQUIPMENT

Evaporator—capacity 90 gal. sap per hour	$145.00
500 buckets—rust proof at $27.00 per hundred	135.00
500 bucket covers at $8.00 per hundred	40.00
500 spouts at $2.75 per hundred	13.75
Gathering tank at 160-gal. capacity	20.00
1 10-bbl. capacity storage tank	15.00
Thermometer, dipper, skimmer, strainer	3.25
One pair of gathering pails	2.50
200 1-gal. syrup cans	24.00
Total	$401.00

With good care this equipment should last twenty years or more.

It is at once evident that the cost of operation and equipment per bucket decreases as the number of buckets increases. For example, in the above estimate, by dividing the total cost of initial equipment by the number of buckets, the cost per bucket is $.802 ($401 ÷ 500 = $.802 per bucket), whereas in an orchard of 2000 trees where the total cost of initial equipment is about $1170, the cost per bucket is only $.585 ($1170 ÷ 2000 = $.585).

The cost of labor per bucket is also less because while two men with one team can take care of 500 buckets, with the above equipment, three men with two teams could easily handle 2000 buckets.

Manufacturers of evaporators, sugaring-off arches and other sugar makers' utensils usually provide for the payment of the initial equipment out of the profits of the business from year to year. It is estimated that the average annual gross income from each bucket in the bush varies from 25 to 40 cents. The average cost of operations, including interest on equipment, depreciation of utensils and tools, labor taxes, etc., will total about 15 cents per bucket in a sugar bush of 500 buckets.

Photograph by U. S. Forest Service.

FIG. 104.—Gathering the sap in a northern New York sugar bush. Sufficient snow is still on the ground when the sugar season is on to require the use of snowshoes.

The expense per bucket decreases directly as the number of trees increases. From the profits of from 10 to 15 cents per bucket, therefore, together with the depreciation charges, this initial cost of equipment can be readily paid off.

There are several types of evaporators or "arches," as they are called, on the market. Each make has certain advantages claimed for it but in general the same principle is followed in all. As mentioned before they vary in width from 2 to 6 ft., and from 6 to 24 ft. long. They cost from about $40 for a small capacity type for a 50-bucket bush up to around $500 for the largest size, which has a capacity of from 350 to 500 gal. of sap per hour. The latter are only used in the largest sugar orchards. All the evaporators are divided into compartments through which the sap passes in the evaporation process. Underneath, a fire, with flues leading the length of the pan, furnishes the necessary heat.

In the selection and use of an evaporator the following general principles should be followed:

1. The capacity should be sufficient to handle the sap from the number of trees tapped without night work. In no case should sap be left over for the next day's run.

2. The sap should be converted into syrup as soon as possible after leaving the tree. In the conversion process, a large heating surface covered by shallow sap is used to reduce the sap to syrup in the shortest time.

3. As the sap enters the evaporator, it should be kept constantly moving through the various compartments until it finally comes out as syrup. The light and heavy sap should never be allowed to mix as in the old kettles or pans. When the sap reaches a temperature of 219° F., it should weigh 11 lb. to the gallon in conformance with the law.

When it is desired to make sugar from the syrup, a sugaring-off arch and pan are set up, usually in another room of the sugar camp. For the smallest orchards, this can be used instead of an evaporator for making syrup, but where 50 trees or more are tapped a small evaporator is advisable. The accompanying illustration shows the firebox underneath and the general manner of construction. They cost about $30 for a 50-gal. capacity size. In dimension, this is 23 in. long by 45 in. wide and 11 in. deep. This will sugar-off syrup in about one-half hour.

Another important feature of every sugar camp is the storage tank into which the sap is emptied when brought from the trees. This should be located outside the main house in order to be kept as cool as possible and elevated so that the bottom of the tank will be at least 12 in. above the level of the evaporator so that the sap will flow by gravity to the regulator which governs the rate of flow. It is very essential to have a large capacity storage tank to take care of from 8 to 15 bbl. of sap or more.

Other important items of equipment for the sugar camp are a good weighing scales, a thermometer, a saccharometer for testing the density of syrup, a skimmer, a felt strainer, sugar molds, funnel and sugar cans.

Process.

Many of the details of syrup and sugar making have already been covered or at least touched upon in a brief way. By the time the sap first comes in from the bush, all the utensils should be thoroughly cleaned and scalded, the sugar house carefully swept and dusted out and the firebox prepared for the fire. The automatic feeder or regulator is then opened and the sap allowed to flow from the storage tank into the evaporator until it covers all the corrugations. As the sap heats up, the first part to reach the syrup end is dipped back until the proper density is reached. Many of the modern evaporators have a heater in connection with them which warms up the sap from the waste heat so that it evaporates much more quickly.

FIG. 105.—Interior of a sugar house showing the steaming evaporator at the left and the "sugaring-off" arch at the right.

The sap is maintained just as shallow as possible without danger of burning as this method permits the most rapid evaporation. When the fire gets hotter, a greater flow of sap is induced through the regulator, or, if scorching is likely, the fire is checked by means of dampers or other patent devices. As impurities or scum come to the surface, they are skimmed off. The sap gradually turns an amber color as it reaches the syrupy stage and deposits of malate of lime (called niter in Vermont and silica in Ohio) are noted on the bottom of the evaporator as the current reaches the end of the pan. Many devices, such as siphons, interchangeable pans, reversing the current, etc., are used to obviate this precipitation. It is estimated that on the average evaporator used, the sap covers about 50 ft. of surface through the various compartments before it finally emerges as syrup.

It has been determined that sap boils at 213° F. At 219° F. (at 500 ft. in elevation above sea level) the syrup will have attained a specific gravity of about 1.325 and weigh 11 lb. to the gallon, a point at which it will not granulate. At the beginning of the season sap ordinarily contains about 6 per cent of malate of lime; later in the season it may contain from 25 to 30 per cent of the total dry matter of the sap. If the malate of lime is not removed before the syrup is taken off, temperatures should run about 221° F. An increase or decrease in the altitude of 500 ft. affects the thermometer 1° F. for the purpose of boiling.

Every few minutes the syrup is run off and strained through felt to remove any malate of lime not already eliminated or any impurities of any kind. It is then put up when still hot into tin cans or glass jars, the former usually of 1 or ½ gal. size and the latter of 1 or 2 qt. capacity. Care must be taken to observe that the containers are absolutely clean and when filled are made airtight and kept in a cool place.

When sugar is to be made, the syrup is placed over the sugaring-off arch and heated until it is so thick that it pours slowly or becomes waxy in the snow or in cold water. This occurs at a temperature of about 230° F. It is then turned into molds. Experienced sugar makers can readily tell when the syrup has sugared-off, but some operators use a saccharometer or thermometer to determine this. When hard, the sugar is wrapped in wax paper. The first run of sap always makes the best sugar. In fact, that from the last of the season will sometimes fail to "cake."

YIELDS OF SAP, SYRUP AND SUGAR

The yield of products in this industry varies considerably with the season, size of the tree, character of tapping and many other conditions which have been covered under the subjects of sap flow, tapping, etc. Yields are often expressed on the basis of the individual tree. However, this is not a satisfactory basis, because much depends upon the size of the tree, the number of buckets hung, its past and present condition, etc. A general figure for all trees, an average of 3 lb. of sugar per season per tree is sometimes used. This varies, however, from 1 to 7 lb. per tree.

The most satisfactory basis of determining the yields is expressed in terms of the individual bucket. Both costs and yields are now coming to be expressed in terms of buckets rather than the individual tree. By a sugar bush is usually meant a unit of 100 buckets or more regardless of the number of trees.

The following average figures have been derived as a result of investigation covering conditions in New York, Vermont and Ohio:

From a standard bush of 500 buckets, there is an average yield under all conditions, of about 6400 gal. of sap. This will be equivalent to about 200 gal. of syrup or 1500 lb. of sugar. These equivalents are based upon a determination that 32 gal. of sap under average conditions are required to make 1 gal of syrup and that $4\frac{1}{4}$ gal. of sap are required for 1 lb. of sugar.

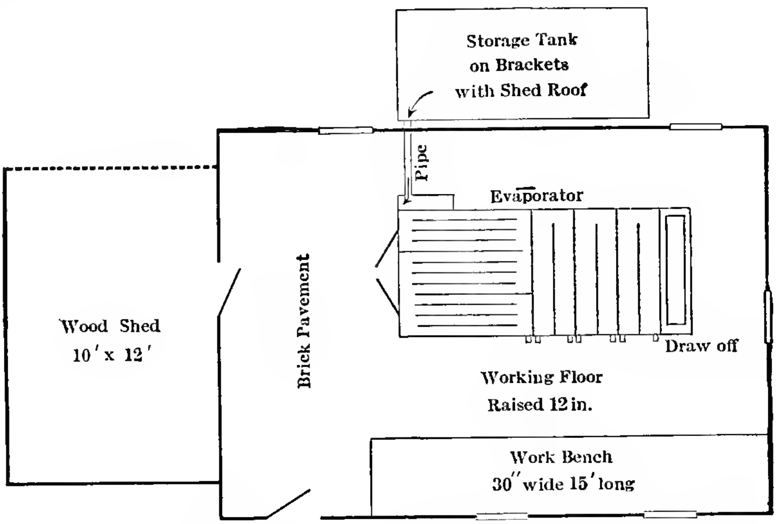

FIG. 106.—Ground plan of a 14- by 20-ft. sugar house equipped with a modern evaporator.

An average of 12.8 gal. of sap are secured from each bucket in the average bush. Each bucket, therefore, yields about $\frac{2}{5}$ gal. of syrup or about 3 lb. of sugar. The number of buckets on each tree, of course, is determined by its size, as explained under the subject of tapping. There are extreme instances on record of groves which averaged 19 gal. of sap per tree per season and of one tree which actually produced enough sap to make $30\frac{3}{4}$ lb. of sugar in one season. One maple tree in Vermont yielded 175 gal. of sap in a single season.[1] Usually from 5 to 40 gal. of sap are obtained from each tree.

A gallon of good syrup will make about $7\frac{1}{2}$ lb. of sugar testing 80 per cent.

[1] See Proceedings of the Vermont Sugar Makers' Association for 1906.

There is a variation of between 28 and 40 gal. or more of sap to an average gallon of syrup. A standard gallon of syrup will weigh about 11 lb. net.

USES AND VALUE OF PRODUCT

Formerly, the country merchant usually set the price for both syrup and sugar because he took them in trade from the farmer and sold them at the best prices he could obtain. The Sugar Makers' Association in Vermont has done a great deal to develop and broaden the market and, as a result, the makers are coming more and more to sell their product directly to the consumer. It is now shipped and sold directly to individuals and stores all over the country. The far-reaching possibilities of successful marketing have, however, scarcely been touched. In marketing, lies the success of the whole operation to a marked degree, as it does in fact with most commodities.

A few years ago, maple sugar could be purchased in gallon cans for from 75 cents to $1.00 per can. The same product is now worth from $1.25 to $2.75 per gallon can, delivered to the consumer.

Fairly good profits can be made at $1.25 per gallon, retail, but much of the product is still sold wholesale, especially the inferior grades at prices varying from 70 cents to $1.10 per gallon, depending upon the quality of the product and the season. There are no uniform grades adopted. Each maker decides upon his own system of grading and sometimes there are four grades based on flavor and color.

In fancy, nicely labeled cans or jars, some of the best syrup brings as high as $3.00 or more per gallon, retail.

It is said that the best average prices are received in Michigan for the reason that the makers have a common understanding that syrup is always worth at least $1.25 a gallon and that this should be the lowest possible figure in order to make a reasonable profit.

A few years ago, sugar brought from 8 to 12 cents per pound depending upon its quality, size of cake and kind of package. Now it brings from 12 to 20 cents per pound and the very best sugar, put up in small cakes and nicely packed and labeled, brings from 20 to 30 cents per pound. "Stirred sugar," a special product, brings from 20 to 25 cents per pound.

As to whether there is greater profit in syrup or sugar has long been an open question. As noted before, Vermont has heretofore specialized more in sugar than any other section and Ohio turns out syrup for the market almost entirely. Probably not one-tenth of the sugar made twenty years ago in Vermont is now produced in that state. It is likely that about 75 per cent of all the sap that is harvested is turned into sugar.

Comparing prices, it is very evident that sugar must be worth more than 16 cents a pound, with $7\frac{1}{2}$ lb. of sugar equivalent to a gallon of syrup, to compete with syrup at $1.25 a gallon. Then, too, the added cost of manufacturing sugar must be offset by still higher prices.

FIG. 107.—A maple tree on the Spalding farm, Amsden, Vermont with 32 buckets hung at one time. Excessive tapping is injurious to the tree.

As noted before, probably seven-eighths of all syrup and sugar sold on the market is adulterated and sold under another name resembling or implying the pure product. Most of it is used as a table luxury and for use in flavoring preparations, confections, etc. The inferior sugar and poorest syrup, sometimes called "black-strap," is utilized for sweetening chewing tobacco.

Since the war, the value of maple sugar and syrup has advanced markedly and many orchards heretofore tapped little or not at all have been brought into production.

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CHAPTER XIX

RUBBER

GENERAL

Rubber—also commonly called india rubber and caoutchouc in the trade—is the product of the milky juice or latex found in a variety of trees, vines and shrubs of the tropics. The true function of latex in the life and development of the tree has not been fully determined as yet. It is found secreted in the vessels and small sacs in the cortical tissue between the outer bark and the wood. It also occurs in the leaves, roots and other parts of certain tropical plants.

The latex is derived from the bark by making an incision at regular intervals through the outer layers of bark. This milky fluid contains from 20 to 50 per cent of crude rubber.

Rubber is one of the most important forest products used by mankind. The value of rubber imported to this country is more than twice the total value of all other forest products brought to this country from foreign sources, including lumber, tanning materials, dyewoods and materials, pulpwood, wood pulp, etc. In 1917 the value of rubber imported to this country was $233,220,904.

The rubber industry has made greater advances, measured both in the quantity and value of its product, than any other forest industry in the world. The demands of the automobile industry for rubber tires have been enormous, and the production of crude rubber has been equal to the demand. Little rubber of any kind was used fifty years ago and the process of making crude rubber available for modern arts and industries was only discovered less than one hundred years ago.

In the year 1900 the total world's production of rubber was only 120,713,600 lb.; in 1910 the total output was 157,920,000 lb., but in 1915 the production rose rapidly with the increased demands for rubber tires for automobiles, and in that year the output was 355,492,480 lb. Moreover, the demand was not satisfied even with that enormous yield and in 1918 the world's production had risen to the enormous total of about 600,000,000 lb.

Had the native resources of the various rubber trees been depended upon, it would have been quite impossible to meet the heavy demands. Prior to 1900 the wild rubber trees supplied practically all the world's supply of rubber. Since that date, however, the production of rubber from planted trees in the Far East has made remarkable strides and in 1918 furnished over 83 per cent of the world's supply.

The successful attempts to transplant the principal original source of rubber, which is generally called Para rubber (*Hevea braziliensis*), from its native habitat in Brazil to the Far East has revolutionized the entire industry.

Photograph by U. S. Rubber Company.

FIG. 108.—Two-year-old rubber trees grown in plantation in Sumatra. One company has 70 square miles of planted rubber trees.

The total annual value of rubber products in this country is estimated (1919) at over $1,000,000,000. The United States consumes about 70 per cent of the total world's rubber production.

HISTORY

The history of the production and manufacture of india rubber has been full of interest. Although rubber, as a material, has been known for many centuries, its development and extensive use has taken place within the past century. The development of the automobile industry has been the impetus which has created an enormous demand for rubber and within the past five years the demand has increased over 250 per cent.

The history of india rubber dates from Columbus' second voyage to the Western Hemisphere. One of his recorders, Herrera, described the use of rubber balls made of the latex of certain trees by the natives of Haiti. They were used entirely for amusement purposes. A book published in Madrid in 1615 refers to certain trees in Mexico which produced a crude form of rubber. It is said, however, that india rubber was first studied scientifically by a French scientist named Le Condamine, who sent samples of the crude rubber product to the French Academy in Paris in 1736. The name india rubber was suggested by a chemist named Priestley about the year 1770. At that time the only use developed for rubber, which was in an exceedingly crude state, was for the purposes of erasure.

The first rubber is said to have been brought to this country about 1800. In that year Charles Goodyear, the man whose inventions and experiments made possible the extensive use of this product, was born.

The manufacture of some crude forms of rubber began in 1820 in this country, when a few establishments were created in New England to import and make rubber for erasing purposes. At that time it was an exceedingly coarse and hard material, full of foreign matter and very expensive. It remained for Charles Macintosh, a Scotch chemist, to develop a method for waterproofing cloth in the year 1823 and the name still obtains for certain forms of waterproof garments. In 1852 an American sea captain brought to Boston 500 pairs of rubber boots which he had secured in Brazil. These sold readily and brought from $3.00 to $5.00 or more per pair.

The rubber industry in this country, however, in its broader sense, really dates from the work of Charles Goodyear, who first succeeded in making rubber less susceptible to the influence of changing conditions of heat and cold. It had been determined that the admixture of sulphur rendered the rubber less sticky, but it is said that the art of vulcanizing was learned purely through accident, Goodyear having dropped some of the rubber admixture by accident on a hot stove without the usual melting result. He first patented his process in 1844, which really marks the beginning of the great industry in this country.

Generally speaking, vulcanizing consists in mixing sulphur with rubber and then submitting the admixture to heat up to about 250° to 320° F for from one to three hours depending on the thickness of the goods. This renders it elastic, impervious and unchangeable in various ordinary.

temperatures. Commercial rubber hardens at the freezing point (32° F.) and temporarily loses its elasticity but, on the other hand, it does not become brittle.

The center of the American rubber industry is at Akron, Ohio, to which many large automobile tire concerns have gravitated within the past decade.

Had it not been for the development of a successful method of artificially growing rubber trees, particularly in the Far East, rubber would be exceedingly expensive on account of the tremendous demands for it. Methods have been developed for the manufacture of rubber by synthetic processes, but no methods have been evolved to manufacture it on a basis to replace the natural rubber. Great strides have been made in the past decade, not only in the amount of imports of rubber to this country, but in the manufacture of the crude form, as well as in the handling of rubber plantations, the tapping of the trees and the reduction of the milky fluid or latex into the crude rubber state.

SOURCES OF SUPPLY AND METHODS OF PRODUCTION

Up to 1914 the principal source of india rubber was Brazil, where the province of Para was the center of production. The so-called Para rubber is the standard by which all rubbers have been judged. Since that year, the principal source of supply has been the plantations of the Malaya and the surrounding sections of the Far East and for the past five years the production of plantation rubber has had a most remarkable development.

Wild rubber is also produced in nearly all sections of the tropics. Aside from the regions mentioned above, considerable quantities of rubber are produced from a variety of plants in Central America, Africa, Mexico, the northern countries of South America and the West Indies.

The following species are the principal sources of rubber supply, in the approximate order of commercial importance:

1. Para rubber occupies the pre-eminent position in the world's rubber markets. It is derived from several species of *Hevea*, principally *Hevea braziliensis* (*Müll, Arg.*) which, in both the wild and planted forms, supplies about 80 per cent of the world's rubber production. There are extensive forests in the valley of the Amazon River, especially in the province of Para, but it also extends along the tributaries of this river to Peru, Bolivia, Venezuela and the Guianas. The rubber area in Brazil alone is said to cover 1,000,000 square miles. The Para rubber

trees frequently reach a height of 60 to 80 ft. and a diameter of 12 to 30 in. The tree flourishes best in damp, rich soil and where the temperature ranges from 89° F. to 94° F. at noon and never falls below 73° F. at night. The trees are seldom tapped until they are twelve to fifteen years of age, because they yield an inferior grade of rubber if tapped earlier. The rubber fluid or latex is collected during the dry season from June to February and, if properly carried on, the tapping is not injurious. Great efforts have recently been made to conserve the rubber forests, and practices which are destructive to the trees are being abandoned. It has been determined that the latex runs most freely in the early morning. The " seringuero," or rubber tapper, equipped with a small basket and a quantity of tin latex cups, goes out along the " estradas " or pathways cut through forest to each rubber tree. He makes a blow or incision with a hatchet and attaches the cup to the bark at the base of the incision to receive the latex, by either using clay as a plaster or by slipping the cup underneath the bark. The tapper uses his judgment as to how many cups each tree should carry. There may be up to 20 cups on each tree. The cups hold only a few ounces each. The tapper comes back to empty the cups into a pail the same day or next day, depending on how rapidly the trees are flowing. The latex secured from this tapping contains about 30 per cent of rubber and the average sized tree will yield about 10 lb. of rubber per year. The latex is collected, brought to camp and converted to the crude rubber state in the following manner. A fire is built of dry sticks and oily palm nuts (*Attalea excelsa*) and the natives make a piece of wood about 3 ft. long fashioned like a paddle, which is dipped in the latex and held over and revolved in the smoke of the fire. The smoke of the fire is usually controlled through a narrow bottle-like neck. As the milky fluid becomes dried and hardened on the paddle, the process is continued until a large ball or " biscuit " weighing 5 to 6 lb. or more is formed. The smoke has the peculiar property of firming and curing the latex. A skilled native is said to make from 4 to 6 lb. of rubber per hour by this method. Other forms of sticks are commonly used as well as the paddle-like form. This " wild " Para rubber, although containing many impurities and 15 per cent of moisture, is said to be the finest rubber product obtainable. The scrapings from the tree are mixed with the residue from the fire pots and collecting receptacles and made into large balls called " negro-heads." These contain from 20 to 35 per cent of impurities such as chips, bark, water, twigs, etc.

2. The " ule " or " caucho " rubber of Central America and Peru, generally called " centrals " in the trade is derived from *Castilloa elas-*

tica (Cerv.) which grows principally in Guatemala, Nicaragua, Southern Mexico and in northern South America west of the Andes. The same general method of collecting and treating the latex as described for the *Hevea* is followed, although there are many variations.

3. Guayule is the trade name applied to rubber from *Parthenium argentatum* from Mexico, which has entered the rubber markets in a prominent way during the past decade. It does not command the high price which Para rubber does.

4. The principal rubber plant of the African tropics is the *Funtumia elastica*, called " Africans " or " logos " in the trade. The rubber is of excellent quality, but it generally contains considerable impurities.

5. The climbing vines of Africa have entered prominently in the rubber trade, especially in Sudan, Congo and Mozambique. The vines are generally destroyed in the process of collecting the latex. They consist largely of several species of *Landolphia*, especially *L. owariensis*. The *Kickxia elastica* is also closely associated in this group and enters the trade under the name of " Africans."

6. The rubber tree commonly planted as an ornamental tree is the *Ficus elastica*, which produces the Assam or Rambong rubber of commerce, which is known in the American rubber trade as " East Indian." It attains a large size in Ceylon, India and Malaysia. Owing to the crude methods of collection it does not command a very high price. It furnishes much of the native wild rubber of India, Sumatra and Java.

7. Jelutong or Pontianak is the name of an East Indian rubber derived *Dyera costulata*.

8. The manihots or " manicobas," which is the common trade name, come largely from *Manihot glaziovii*, a native of Brazil, and a close relative of the tapioca plant. It grows at elevations up to 4000 ft. along the Andes Mountains.

9. Mangabeira is the trade name of the rubber derived from *Hancornia speciosa*, a native tree of Brazil. It is also called Pernambuco rubber.

10. Balata is the rubber from *Mimusops balata*, which grows in British and French Guiana.

11. Gutta percha is largely derived from a species called *Palaquium gutta*. Inferior guttas called gutta siak are secured from several species.

Many other plants yield a latex or rubber-bearing fluid and it is said that large forests of rubber plants are still undeveloped owing to their inaccessibility in the remoter districts of the tropics. However, the above represent practically all that are of present commercial importance.

RUBBER PLANTATIONS

Prior to the year 1900 practically all rubber was of the "wild" variety and largely produced in Brazil. Owing largely to the enhancing cost of rubber, due to its ever-increasing inaccessibility and remoteness, the cost of transportation to market, the lack of good labor in the upper Amazon districts and the restriction of production to the dry season of six months in each year, many attempts were made to grow several varieties of the rubber trees in artificial plantations.

In 1873 an Englishman, H. A. Wickham, was commissioned by the Government India Office, to attempt the introduction of rubber trees in India. In June, 1876, there were 70,000 young seedlings growing in the

FIG. 109.—Method of tapping rubber trees in plantation in Sumatra. The most successful tree for planting and the only one now being planted is the *Hevea braziliensis*, which has been the main source of wild rubber known as Para rubber.

Botanic Gardens of England. In the same year 2000 young plants were sent to Ceylon, but the trees did not flower until 1884.

The year 1888 was a turning point in the attempt to grow rubber in plantations, as the plants were introduced in Malaya, particularly in the region about Singapore, where the rubber plants were found to do much better than in Ceylon or India. Tapping experiments were also begun in 1888 and it was learned that the trees could be tapped every day except when they shed their leaves in February and March. Rubber plantations, however, were not made on any important scale until 1898 and it was not until 1905 that any extensive developments were made. In the latter year, it is estimated that there were 16,000 acres in plantations. The Dutch and later the French and Americans followed the example of the English. Since 1905 the development of rubber plantations has been remarkable. Many species were tried, including the *Ficus elastica*, the *Castilloas* and others, but it remained for the Para rubber tree (*Hevea braziliensis*) to be the most successful as well as the first to be tried by Wickham in his experimental plantations. It is the only one now used on new plantations. Over 35,000 acres of other species have been planted.

At the present time there are about 500,000 acres of rubber trees under cultivation in the Dutch East Indies alone and about 250,000 acres in Ceylon. The English have invested $36,000,000 in Dutch plantation properties, the French about $8,000,000, the Americans $9,000,000 and the Dutch about $7,000,000.

By the end of 1907 only about 1½ per cent of the world's rubber supply had been produced from plantation rubber. At that time, about $1.00 per pound was secured for this rubber at the plantations, which was considered a satisfactory price: By 1910 the price had risen to $2.50 per pound and a great boom was created in plantations. The present area (1919) of rubber plantations of all kinds is estimated at nearly 2,000,000 acres and new areas are being constantly planted. The soil and climate of the Far East seem to be peculiarly suited to the successful growing of the Para rubber in plantations. The following table shows the distribution of the planted areas in the Far East:

RUBBER PLANTATIONS IN THE FAR EAST

Region.	Area in Acres.
Malay Peninsula	1,033,069
Sumatra	250,388
Java	249,326
Ceylon	240,000
Burma, India	58,000
Southern India	44,000
Cochin China	42,500
British North Borneo	31,500
Other Dutch Indies	29,998
New Guinea	13,300
Total	1,992,582

There are said to be over $400,000,000 invested in rubber plantations and they supply (1919) about 83 per cent of the total world's requirements.

The trees in plantation are planted about 150 trees per acre (20×15 ft.) and do not become productive until four to seven years of age, when they are 5 to 7 in. in diameter at breast height. If tapped before this age the rubber yield is inferior. At seven years of age, the annual yield is only about ½ lb. per tree per annum. The average at twelve to fifteen years of age is about 1½ lb. per tree.

At first all the brush and weeds were removed from an area to be planted at great expense, but it was found that the hot tropical sun

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FIG. 110.—Close view of tapping methods and cups used in collecting the latex.

baked out the soil too readily and until the plants reached a size sufficient to shade the soil, it was necessary to grow some leguminous plants to both shade and enrich the soil.

The methods of tapping and reducing the latex have been greatly improved over the systems in vogue with wild rubber, although it cannot be said that they have reached a finality of development. A common method is to make a series of V-shaped incisions on four sides of the tree up to a height of 5 to 7 ft. from the ground. The latex is collected in a cup hung at the apex of each V. The "herring-bone" plan with a vertical incision and lateral channels on either side is used as well as the spiral system. Daily incisions are made at 45° until the trunk is nearly covered with scars. When the bark of the trunk is almost completely covered with cuts to induce the flow of latex, a period of years is generally allowed to elapse before beginning to retap the tree. Small sharp knives are employed in making the incisions instead of the axes or large cutters used in Brazil.

Instead of the primitive and wasteful method of reducing the latex to crude rubber, as followed in the forests of Brazil, the fluid is collected in large tanks or casks. It is coagulated by the admixture of an acid, usually acetic acid or lime juice. The coagulation gradually separates as a soft, white, or yellowish mass. This is washed by first passing through washing machines, and then through other machines, which compress it in thin sheets or long ribbons called crêpe. These are hung up and dried. Plantation rubber enters the market either in the form of crêpe in sheets or biscuits or in the form of large blocks made by compressing the sheets of crêpe together.

Plantation rubber formerly did not bring the same prices on the English and American markets as that commanded by the Para or "wild" rubber, but it now brings about the same or even slightly better price. It is much cleaner and freer from impurities than the wild rubber and contains only 1 per cent of water as against 15 per cent for the latter. It is generally regarded, however, that plantation rubber has not the tensile strength of the Para rubber. This may be due to the fact that the plantation rubber is generally procured from much younger trees.

The following table shows the relative importance of plantation rubber and the product of native forests of Brazil and other portions of the tropics:

PRODUCTION OF RUBBER FROM PLANTATION AND NATIVE SOURCES IN TONS FROM 1911 TO 1918, INCLUSIVE

Year.	Product from Plantations, Tons.	Product from Brazil, Tons.	Product from other Tropical Regions, Tons.	Total Production, Tons.
1911	14,419	37,730	23,000	75,149
1912	28,518	42,410	28,000	98,928
1913	17,618	39,370	21,452	78,440
1914	71,380	37,000	12,000	120,380
1915	107,867	37,220	13,615	158,702
1916	152,650	36,500	12,448	201,598
1917	204,348	39,370	13,258	256,976
1918	240,000	38,000	12,000	290,000

The above table shows the tremendous strides in production of plantation rubber, the almost stationary production of wild rubber from Brazil and the falling off in the product from all other sources, such as Central America, Mexico, Africa, the Guianas, etc.

METHODS OF MANUFACTURE[1]

Wild rubber contains many impurities such as dirt, stones, bark, leaves, chips, etc., as it comes to this country in its crude state in the form of biscuits or balls. The first process, therefore, in the manufacture of the various finished forms of rubber is thoroughly to cleanse it of all foreign matter. Wild rubber, which is generally called Para rubber from Brazil, contains a great many more impurities than the plantation rubber.

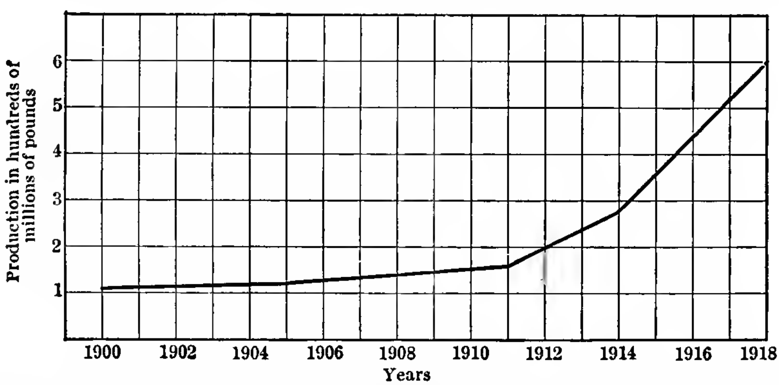

FIG. 111.—Curve representing the world's production of India rubber from 1900 to 1918, inclusive.

The latter comes to this country in sheets or packages and is much more free from impurities on account of the greatly improved methods of collecting and coagulating the latex.

The process of cleansing consists of washing the crude rubber in hot water for a period of about twenty-four hours. It is then passed through corrugated rollers in the presence of large quantities of water. This process removes the impurities and gives the rubber a more homogeneous structure. It is then placed in the drying rooms in sheets and after a thorough drying it is stored until desired for further use.

[1] The methods of rubber manufacture is a large and involved subject and can be covered only in a most brief and suggestive fashion in this work. For further reading on the manufacture and the chemistry of rubber it is suggested that several references in the bibliography at the close of this chapter be consulted.

Various methods of vulcanizing rubber are in common use at the present time. The method generally followed consists of kneading the crude rubber after it is washed and dyed with varying amounts of sulphur. It is later reduced to proper shape by cutting into small pieces and then running it through rollers. In general, there are two kinds of rubber, naturally hard and soft rubber. Hard rubber is often called "ebonite" in the trade. There are many classes of finished forms of rubber, each of which requires a different kind of treatment and a distinctive process of manufacture. The principal classes of rubber may be divided as follows:

1. Footwear.
2. Waterproof garments.
3. Mechanical goods, such as tires, belts, etc.
4. Electrical and scientific apparatus and articles.
5. Medical and surgical appliances.
6. Liquid or semi-liquid goods, such as varnishes, cements, etc.

PRINCIPAL USES

There are no statistics available to show the utilization of rubber in this country. An authority on rubber and its uses estimates the value of the different forms of rubber products as follows:

USES OF RUBBER

Uses.	Value.
Automobile tires	$250,000,000
Mechanical goods	200,000,000
Solid tires	175,000,000
Boots and shoes	100,000,000
Clothing, auto topping and similar goods	75,000,000
Automobile tubes	70,000,000
Rubber insulated wire and insulation	65,000,000
Druggists' sundries	30,000,000
Miscellaneous	30,000,000
Hard rubber	15,000,000
Motor cycle, bicycle tires, etc.	10,000,000
Rubber cements	5,000,000
Total annual value	$1,025,000,000

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CHAPTER XX

DYE WOODS AND MATERIALS

GENERAL DESCRIPTION

From the earliest times various forms of natural dyestuffs have been used for coloring purposes. The principal sources of these vegetable dyes have been the roots, bark, leaves, fruit and the wood of trees and other forest-grown material. Until the Civil War and shortly thereafter practically all of our dyestuffs came from some form of vegetable origin. Later the aniline dyes were introduced and came into prominent use.

Many of our important industries are dependent upon these dyestuffs and their consumption has increased very rapidly within the past decade. The industries consuming the largest quantities of dyestuffs are the textile for cotton, silk, wool, etc., paint, varnish, ink, leather, paper, wood, etc.

At the present time aniline dyes compose a large percentage of all the dyeing materials used. For certain purposes, however, a few dye woods are still held in high esteem in the textile and leather trades and other fields which consume large quantities of dyeing materials. For the fiscal year 1913 this country expended over $12,000,000 for foreign artificial dyestuffs imported to this country and only $961,534 for foreign importations of natural dyestuffs.

Germany has been the principal source of artificial dyes and before the war produced about 90 per cent of the dyestuffs consumed in the world's markets. These were manufactured from coal tar products made in Germany.

Since 1914 there has been a great impetus in the importation of natural dyes and in the introduction of new sources, notably osage orange which, before the coming of the white race to this country, was extensively used by the Indians to decorate their war bonnets, bows, arrows, etc. This and many other natural coloring agents were adopted from the Indians by the early colonists in the dyeing of their homespuns, etc. It is said that even during the Civil War, butternut dyes obtained from the husk of the nut were used to color the dull yellow suits worn by the Confederate soldiers.

MANUFACTURE OF DYESTUFFS

Most of the natural dyes are now produced from imported woods from Central and South America and the West Indies, the coloring matter being obtained from the parenchyma cells by extraction after reducing the wood to the powdered or chipped form. Dye woods generally contain only from 5 to 10 per cent of their weight in true dye color. The principle of wood dye extract operations consists first in removing the coloring material by lye washing made with the help of a suitable solvent, which differs with each wood to be treated, and then by concentrating the solution to the crystal, liquid or powdered form. The process employed in deriving these extracts varies with most of the large manufacturing concerns and the details are held with the greatest secrecy. However, the following is a very brief description of the process generally used in the reduction of our principal dye woods.

The wood is first run through a grinder or a very fine chipper or "hog." In the case the latter is used the chips are again shredded. The principle involved in reducing the wood to such fine proportions is to make the coloring material more readily available to the effects of the solvent which is used to separate and carry off the desired color from the wood cells. The chips or shredded wood are then submitted to a curing process, which consists of leaving them piled up in heaps 4 or 5 ft. in height in the open air. The piles are moistened with water from time to time and left in this condition for from four to six weeks. They are occasionally worked over with shovels to prevent heating and to allow full access to the air. The wood gradually turns to a deep color and sometimes certain chemicals are used to hasten the curing process. However, there is danger of over-oxidation. Extraction and concentration are next followed out. Extraction is accomplished in diffusion batteries consisting either of a set of open tanks or of closed copper extractors arranged in series. Ordinarily there are eight or ten of these batteries, the liquor from one cell being used as a solvent for the material in the next cell so that as concentrated a liquor as possible is obtained with a minimum amount of extracting water. The liquid extract is then evaporated in multiple-effect vacuum evaporators made expressly for this purpose. In this way an extract is obtained containing about 25 to 30 per cent of total solids at a temperature which is not injurious to the extract. All natural dyestuffs require a mordant, such as a solution of chrome for their proper fixation on fibers.

RAW MATERIALS USED

A very large share of our natural dyestuffs is made from West Indian and Central American woods. They are received in the log form from 3 to 8 ft. long and are sold entirely by weight. To be acceptable to the dye manufacturers, the logs must be thoroughly trimmed of all bark and sapwood and free from any dirt or other foreign material. Extracts from these dye woods are imported to a small extent, but they are considered inferior to those made in the extract manufacturing plants in this country.

Logwood or Campeachy wood constitutes about 75 per cent of all dye extract materials imported into this country. Fustic is next in importance; then there is a great variety of foreign woods occasionally used such as the Brazil-wood and other redwoods, sandalwood, etc. Other forest-grown materials used for dyeing purposes are catechu or cutch, sumach, gambier, etc. Other sources of natural dyes such as cochineal, indigo, turmeric and madder are not classified as forest products.

Osage orange is coming into use as the principal native dyeing material. Quercitron, the crushed bark of the black or yellow oak (*Quercus velutina*) is another important native source of dyes. Other native materials used to a vary limited extent are black walnuts and butternuts, sumach, yellow wood, mesquite, alder, red gum, bluewood and dogwood.

The following is a brief description of the principal forest-grown materials used for dye extracts in one form or another:

Logwood.

Logwood (*Hæmatoxylon campechianum, L.*) also called Campeachy wood, bois de sang, etc., is a thorny tree of the family *Leguminoseæ.* It is one of the oldest dye woods in common use and is now used more than all other woods together for coloring purposes. Its principal source is in Jamaica, Haiti and the Bay of Campeachy in Mexico, where it grows abundantly, but it is also exported from most of the Central American countries and many of the West Indies. It has been successfully introduced and grown in India. Varieties of logwood are sometimes recognized according to their source, but they are all generally accepted to be of one species.

The wood is very heavy, non-porous, coarse-grained and yellowish in color, which rapidly turns to a rich red on exposure to the air. It has a very pleasing odor, resembling the violet.

Logwood contains from 9 to 12 per cent of the coloring essence called hæmatoxylin, from which is derived hæmitin, the true dye color. Logwood is chiefly used for the black colors and it is considered superior to the aniline blacks. It is also used, to some extent, for blues and other dark colors and with other dye materials for composite colors. Its principal use is on silks and wool. When acids are likely to come into contact with it, logwood black is not considered so very good, but these cases are exceptional. It is also used on leather and to a limited degree on cotton.

Under normal conditions, logwood brings from $20.00 to $25.00 per ton delivered at our Atlantic ports, but since the war prices have risen enormously and have become very unstable due to over-speculation, the elimination of the German supply of aniline dyes and the exceptionally high ocean freight rates. Maximum prices of $110 per ton have been quoted and many sales have been made at from $55.00 to $80.00 per ton at New York and other ports. The importations of logwood increased from 30,062 tons for the year ending June 30, 1914, to 122,794 tons for the year ending June 30, 1917.

Brazil-woods.

Brazil-woods or the soluble redwoods include a variety of woods of the genus *Cæsalpinia* used for red dyes, which appear on the market under a great confusion of trade names. Although of the same genus they vary considerably in their value for dyeing purposes. The coloring matter braziline is found in varying quantities in all these woods, which are hard, heavy, durable and even grained in all species. Hypernic is the trade name applied to the extract obtained from the soluble redwoods.

Pernambuco-wood from *C. crista L.* is recognized as the most valuable of these woods and grows largely in Brazil and Jamaica. The wood is yellowish-red with a distinct brown or brownish red on the surface.

Brazil-wood from *C. braziliensis Sw.* comes from Brazil and generally throughout the West Indies and Bahamas.

Sappan-wood from *C. sappan L.* comes from Siam, China, Japan, Ceylon and the East Indies. Its wood is somewhat lighter in color than the other redwoods of this genus.

Lima-wood or Nicaragua wood from *C. bijuga Sw.* comes from the Central American countries and the northern countries of South America. Other trade names used for these and other species of *Cæsalpinia* are braziletto, peach wood, South American basswood, etc.

Brazil-wood normally brings from $23.00 to $26.00 per ton at the Atlantic seaboard ports. Since the outbreak of the European war it brought from $35.00 to $46.00 or more per ton. Extracts from the Brazil-woods are chiefly used in wool and cotton dyeing.

Fustic.

Fustic is the principal source of natural yellow dyes and has been in common use for a long time. Next to logwood it is the most important dye wood imported into this country. Owing to its comparative scarcity many substitutes have been used to displace it and osage orange is becoming a prominent competitor for yellow colors.

True fustic comes from the fustic tree of the West Indies and tropical America. The scientific name of the tree is *Chlorophora tinctoria, Gaud.* (also described as *Maclura tinctoria, D. Don* and *Morus tinctoria L.*). Fustic is sold under a variety of trade names such as old fustic, fustic mulberry, yellow wood, Cuba wood and mora. It contains two coloring principles, morin or moric acid and maclurin or moritannic acid, both of which are used for yellow dyes and are found in the commercial extract.

The fustic tree reaches a size of only about 2 ft. in diameter and about 50 ft. in height in its native habitat. The wood is fairly hard and heavy. The heartwood is a light-colored yellow which rapidly becomes a yellowish brown on exposure to air and light. The sap is white and very thin. It is always trimmed off before shipment to save freight as it does not contain sufficient coloring matter.

Fustic is usually imported in the form of logs from 2 to 4 ft. long and from 3 to 12 in. in diameter. It is sometimes brought to this country in the form of chips, powder, liquid extract and paste. The wood ordinarily brings from $18.00 to $22.00 per ton on the docks in this country. Since 1914 and during the heavy speculation in dyewoods it brought as high as $45.00 per ton, but seldom ran over $35.00 to $40.00 per ton.

Fustic dyes are largely used for yellows, browns and olives and in connection with logwood dyes for toning the darker colors, especially on woolens.

Red Sandalwood or Saunderswood.

Pterocarpus santalinus L. is used to some extent for red dyes through its coloring principle called santaline, of which it is said to contain 16 per cent. It grows in Java and the East Indies as well as in China and yields a very hard, heavy and slightly resinous wood which is described as being a deep orange-red with lighter zones running through it. On exposure it turns a very deep red. A number of other woods such as barwood (*Pterocarpus santalinoides, L'her*) and camwood (*Baphia nitida, Afzel*), which closely resemble it are sold as red sandalwood. All of these woods are commonly referred to in dyestuff circles as the insoluble redwoods.

Quercitron.

This is the crushed or ground bark of the black or yellow oak (*Quercus velutina, Lam.*) which is found throughout the East and particularly in the Middle Atlantic States and the southern Appalachian Mountains. The coloring matter is contained in a thin layer in the inner bark.

The bark is usually crushed into a fine brownish-yellow powder, the coloring principle of which is quercitrin. This may be decomposed, by using a dilute sulphuric acid, into quercitrin. Flavine is the trade name applied to a preparation of quercitron obtained by acting upon the bark first with alkalies and treating this extract with sulphuric acid. Both the liquid and solid extracts are used commercially for dyestuffs.

Flavine and quercitron find their principal use in dyeing cottons and woolens with tin mordants. Flavine is commonly used with cochineal or lac-dye for producing scarlet.

Venetian Sumach.

Venetian sumach, also called young fustic, wild-olive, smoke tree, wig tree, etc. (*Rhus cotinus L.* also called *Cotinus cotinus (L) Sarg.*) is imported to a limited extent from Hungary, Greece, Italy and other European countries. It produces a yellow dye called fustine, used chiefly in coloring glove leather and wool. It is sold very commonly as a substitute for the true fustic, although it is produced by a small tree or shrub which yields sticks up to 4 in. in diameter and 4 to 6 ft. in length. The heartwood is greenish-yellow and hard. This tree is not related botanically to the true fustic.

The coloring matter yields a fine orange color with alkalies and bright orange precipitates with lime and lead acetate.

Sumachs native to America, especially the staghorn sumach (*Rhus hirta*), which grows throughout a large part of the East, are used to a very limited extent in coloring cloth and fine leather. The leaves, leaf stalks and smaller twigs yield a yellow dye. A close relative of the sumachs, called chittam or American fustic (*Cotinus americanus, Nutt*), grows throughout the lower Mississippi Valley and yields a clear orange colored dye.

Osage Orange.

This tree is commonly found in the rich bottom lands of southern

Arkansas, Oklahoma and Texas. It is most abundant in the valley of the Red River. Its scientific name is *Toxylon pomiferum*, *Raf.*, and, besides osage orange it is commonly called bow-wood, mock orange, bodock, bois d'arc, yellow wood and hedge tree. It is frequently planted throughout the East both for its wood and as a decorative and hedge tree.

The tree is rather poorly shapen as a rule and seldom grows to be over 50 ft. in height and 2 ft. in diameter. The wood is exceptionally hard, heavy, strong, durable and coarse grained. It is a bright orange in color, which on exposure turns to a deep yellowish brown. The wood is in high demand for use as wagon and vehicle stock, especially for felloes and spokes and for cross ties, fence posts, handles and other specialized purposes. It was highly prized by the Indians as a material for bows and arrows, hence the name bois d'arc.

Osage orange, even in the time of the Indians, was used for dyeing purposes, and in the region of its natural growth has been used to a limited extent as a coloring matter. Since the outbreak of the European War, however, it has been extensively experimented with and is coming into commercial use as a substitute for fustic. The dyeing principles found in osage orange are morin or moric acid and moritannic acid or maclurin, as is the case with fustic. The extract from this wood is now manufactured and sold under the trade name of aurantine. The roots and bark also contain coloring principles which have been extracted by boiling. This practice, however, is limited to a very small local custom in the Southwest.

Results of experiments show that with iron and chrome mordants, osage orange dyes are satisfactorily fast to light, water and washing, especially when used on wools, and that they may be employed wherever dyes from fustic wood are used. Osage orange is also used on leather, wood, paper and, to small extent on cotton. It is especially effective for orange-yellows, old gold, deep tan, olive and chocolate shades. It is, moreover, used as a base for greens and grays in combination with other colors and with aniline dyes. In comparison with fustic, the advantages claimed for it are that it is cleaner, more uniform, yellower, faster and cheaper.

It is estimated by Kressman of the Forest Products Laboratory at Madison, Wis., that over 25,000 tons of waste material are now available annually from the manufacture of osage orange for various wood products and that altogether from 40,000 to 50,000 tons of osage orange could readily be shipped yearly from Texas and Oklahoma. In 1915 about 14,000 tons of fustic were imported to this country instead of the usual yearly importation of about 4500 tons prior to this date and it is likely that osage orange will gradually displace, to some degree, at least a good share of this material. The latter can be purchased in Texas and Oklahoma for about $5 to $8 per ton. It brought from $12.00 to $15.00 per ton delivered on the Atlantic seaboard in 1916 under the name of American fustic.

Cutch.

Cutch or catechu is used principally as a tanning agent and has been briefly described in the chapter devoted to tanning materials. It is the name applied to the dried extract derived from *Acacia catechu*, which is produced largely in India and Burmah. It is used somewhat extensively for brown dyes. With copper, tin and alumina mordants it yields a yellow dye principle called catechin. It also yields another dyeing principle known as catechutannic acid. The best varieties of cutch are said to come from Pegu. Bombay and Bengal cutch are also held in high esteem. They are used in cotton and silk dyeing for browns and composite shades. Catechu is frequently adulterated with starch, sand, clay and blood.

Gambier.

Gambier is also a dried extract used chiefly for tanning purposes in this country. It also goes under the names of gambier and pale catechu and is derived from the leaves of two species of the same genera, namely *Uncaria gambier* and *U. acida*.

IMPORTATION OF DYESTUFFS

The following table secured from records of the U. S. Department of Commerce shows the value of dy woods imported for each year by decades since 1860 and also the years 1917 and 1918:[1]

IMPORTATIONS OF DYEWOODS

Year.	Total Value.
1860	$ 838,186
1870	1,337,093
1880	1,808,730
1890	1,725,167
1900	862,462
1910	566,377
1917	4,326,576
1918	2,018,122

[1] The values given for the years 1917 and 1918 are those for the period ending June 30th in each of these years.

The following table shows the importations of dyewoods and dyewood extracts into the United States for the years 1906 to 1910, inclusive:

Material.	1906.		1907.		1908.	
	Amount.	Value.	Amount.	Value.	Amount.	Value.
Logwood, tons	36,624	498,602	37,901	478,656	21,809	248,578
Logwood extract and other extracts, lbs	3,443,676	295,188	4,542,257	368,704	3,576,676	230,475
Fustic, tons	5,783	89,513	3,483	54,765	4,452	53,884
Gambier, lbs	31,478,837	1,118,910	28,853,124	977,000	26,692,100	895,210

Material.	1909.		1910.	
	Amount.	Value.	Amount.	Value.
Logwood, tons	17,873	166,371	31,270	353,311
Logwood extract and other extracts, lbs	3,463,582	231,612	2,937,626	187,124
Fustic, tons	2,466	34,752	5,816	82,887
Gambier, lbs	31,000,855	1,313,990	25,808,720	1,264,023

IMPORTS OF DYEWOODS AND MATERIALS

(Years ending June 30th)

	1914.		1915.		1916.	
	Amount.	Value.	Amount.	Value.	Amount.	Value.
Logwood, tons	30,062	378,064	55,059	742,264	134,629	3,437,698
Other dyestuffs [1]	7,663	108,928	13,361	197,122	24,592	468,669
Gambier, lbs.[2]	14,936,129	571,067	14,169,490	542,200	12,819,859	928,924

	1917.		1918.	
	Amount.	Value.	Amount.	Value.
Logwood, tons	122,794	4,137,400	52,027	1,066,455
Other dyewoods, tons [1]	8,895	4,189,176	35,449	951,667
Gambier, lbs.[2]	10,133,625	859,873	8,964,832	955,352

[1] A large portion of the classification "Other Dyewoods" is composed of fustic wood.
[2] Gambier is used for tanning purposes as well as for dyeing.

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CHAPTER XXI

EXCELSIOR

GENERAL

EXCELSIOR consists of thin, curled strands or shreds of wood made by rapidly moving knives and spurs or fine steel teeth against a wood bolt. The spurs slit the wood and are followed by a knife which pares this slitted material off the bolt.

Excelsior first found its principal use as mattress stuffing, but has come into demand for a great variety of uses. The excelsior industry is about fifty years old in this country where it was first developed. The finished product first appeared on the market about 1860.

The term excelsior was first used as a trade name in advertising the product, by a single company, for upholstering purposes. For a long time it had been called wood fiber. Due to wide advertising by this individual concern, the name excelsior has been applied to all grades of the product. Although an American invention, the finished product has been greatly improved upon in European countries, where it has been largely used for filtering and other specialized purposes. At the present time the industry consumes over 100,000,000 bd.-ft. of forest material in this country every year.

Qualities Desired.

The qualities most desired in woods used for manufacturing excelsior are lightness in color and straight grain, together with tough but soft resilient fiber. It should also be light in weight, free from any disagreeable odor, and not brittle when the wood is manufactured in the air-dried form. It should preferably be free from resins or gums which are likely to discolor or taint any material with which it comes in contact.

The best all-around wood which meets these desirable qualities is basswood. Basswood excelsior always brings the very best prices on the market, but owing to its limited supply, and demand for other purposes, only a small portion of the total amount of excelsior produced annually in this country is made of basswood. In fact, basswood constitutes only about 14 per cent of the total supply, being exceeded by the various pines and cottonwood.

Uses and Value of Excelsior.

Excelsior is a staple article used by upholstery, carriage, automobile, mattress and furniture manufacturers and for packing miscellaneous articles which are susceptible to breakage. It is commonly used for packing glassware, china, druggist's and confectioner's goods, toys, hardware and other miscellaneous articles.

It is much preferred to other materials used for similar purposes such as shavings, sawdust, straw or hay, because it is free from dust and dirt, it is elastic, light in weight and odorless. Packing purposes consume the bulk of excelsior manufactured. In making excelsior mattresses the inner portion is usually filled with excelsior cut from $\frac{3}{16}$ to $\frac{1}{4}$ in. wide. Over this is spread a finer grade or wood wool to give a softer surface near the ticking.

The fine grade called wood wool, which is from $\frac{1}{100}$ to $\frac{1}{500}$ of an in. in thickness and about $\frac{1}{64}$ of an in. wide, is used for filtering purposes and for the manufacture of better grades of mattresses and other specialized products. Probably from 80 to 90 per cent, however, is made from the medium and coarse grades, which go chiefly for upholstering and for packing. These grades are from $\frac{1}{60}$ to $\frac{1}{100}$ of an inch in thickness and from $\frac{1}{32}$ to $\frac{1}{4}$ of an inch in width. One large department store in New York uses over $500 worth of excelsior per month, for which is paid around $16 per ton. A large toy company uses every day from 30 to 40 bales weighing 125 lb. per bale.

Dyed excelsior is used for packing fancy goods. Aniline dyes have been found to stain excelsior to excellent advantage. More recently the finer grades of excelsior have been woven into mats and floor coverings. In Europe it is very largely used for absorbent lint in hospitals and for filtration purposes. Its lightness and elasticity make it especially valuable for packing. Its resiliency makes it valuable for upholstering and mattresses, while its softness and ability to absorb liquid make it valuable as an absorbent lint. Long excelsior is used for twisting into rope for use in winding core barrels in making cast-iron pipes in large pipe foundries. This takes the place of marsh hay and is considered much superior.

Excelsior is sold by the weight. The market for the various grades is exceedingly unstable and prices fluctuate very widely and rapidly. The major portion of excelsior placed on the market, which is used for mattress stock and packing (common fine grade), sells for $8.00 to $22.00 per ton f.o.b. cars at the mill. The average price would probably be around $12.00 per ton before the war. The coarser grade of excelsior brings from $1.00 to $2.00 per ton below the common fine.

Wood wool, the finest grade of excelsior, brings from $24.00 to $35.00 per ton f.o.b. cars at the mlli. There is a general belief in the industry, however, that it does not pay to manufacture wood wool. It is only a question of difference in " feed " at the machines.

Woods Used and Annual Consumption.

Cottonwood, including the southern cottonwood and northern aspens or popple, make up over one-half of the total supply of wood used for excelsior in this country. Yellow pine comes next in order. The softer and less resinous varieties of yellow pine, particularly loblolly pine, Virginia scrub pine and shortleaf pine, are used to a large extent in Virginia and Georgia. Basswood constitutes about 14 per cent of the total supply and is manufactured throughout the Northeast and Lake States, but particularly in New York, Wisconsin, New Hampshire and Michigan. Other woods commonly used are willow, yellow poplar, white pine and buckeye. In Washington the black cottonwood is used. All of these woods are valuable for excelsior purposes on account of their soft wood, straight grain and resilient fiber. Red gum, soft maple, spruce, chestnut, hemlock, white cedar and cypress are used to some extent. On the Pacific coast, western yellow pine and Douglas fir are coming into use for the manufacture of excelsior.

The industry is scattered throughout the eastern part of the country. New York has the largest number of manufacturing plants, namely 29, but Wisconsin with 12 plants consumes the largest amount of wood annually. Other leading states are Virginia, New Hampshire, Georgia and Michigan.

Government statistics for 1911 show that during that year over 139,000 tons of excelsior were produced in 122 plants, which means that the average plant produced about 1150 tons annually.

Over 142,000 cords of wood were consumed in 1911 for excelsior and it is estimated that over 200,000 cords of wood are now used annually for this purpose.

MANUFACTURE

Excelsior plants are located with reference to a good supply of raw material and near the market with favorable shipping facilities. They do not require a very heavy investment. Many companies which use considerable quantities of excelsior for packing purposes operate one or more machines solely for their own requirements. The initial investment of a twenty-machine plant turning out daily from 60 to 100 bales of excelsior weighing about 200 lb. per bale and run independently of other operations is about $10,000, which sum will serve as a criterion for the cost of larger plants. Single upright machines alone cost from $150 to $200 installed. Single horizontal eight-block machines cost $1200 to $1600 installed. Excelsior plants are sometimes operated in connection with rotary veneer mills where the circular cores left after cutting veneer are utilized for the manufacture of excelsior.

Preparation and Cost of Raw Material.

Wood used for excelsior should be thoroughly air seasoned for at least a year. It is usually brought to the mill in bolts 37 or 56 in. long and

Photograph by U. S. Forest Service.

FIG. 112.—Raw material in the form of poplar bolts being placed in vertical excelsior machines. Photograph taken at Melvin Mills, New Hampshire.

piled in ricks either in the open or in sheds. Excelsior stock is always peeled and when over 6 in. in diameter it is customarily split into smaller billets. Many of the mills in the North bring in bolts in carload lots from a radius of from 50 to 100 miles.

Before going to the machine each bolt is cut up into lengths of from $15\frac{1}{2}$ to 24 in., with square ends. Each stick must be free from defects and reasonably straight. Bolts less than 4 in. in diameter are not desirable.

Prices for the raw material vary with the species, transportation and labor charges and local supply and demand. In Virginia, yellow pine cordwood is delivered at the mills for from $2.50 to $4 per full cord. Basswood brings from $4 to $7 per cord delivered at the mill in the North. Cottonwood, including popple or aspen, and other species bring from $3 to $5 per cord.

The factors affecting the amount of excelsior produced per cord are:

(*a*) Size and quality of the bolts, whether round or split, etc.

(*b*) Size or coarseness of the strands.

(*c*) Kind of wood. The heavier yellow pine will yield more than basswood or aspen.

(*d*) Amount of waste. The size of the "spalt" or the remainder of the bolt after cutting determine to a large extent the amount of excelsior produced.

Under average conditions it is considered that one cord of wood will produce about 2000 lb. of excelsior. This may vary, however, from 1650 lb. up to over 2300 lb. per cord, depending upon the above factors.

Excelsior Machines.

A complete plant consists of a battery of machines (up to 24 upright machines or from one to six horizontal 8-block machines), a wood splitter, a cut-off saw, a barker, knife and spur grinder, a baling press, a set of scales and necessary power together with shafting, hangers, pulleys, belting, tools, etc. About 5 h.p. is required to run each upright excelsior machine. One horizontal 8-block machine is equivalent in capacity to 10 to 12 upright machines.

This plant, using 24 upright machines would cost from $9000 to $12,000 depending on such factors as labor charges, freight, character of equipment, etc.

Excelsior machines are of two designs: (*a*) upright or vertical, and (*b*) horizontal. The following is a brief description of common forms of each type:

(*a*) Vertical or upright excelsior machine.

The vertical or upright machines are usually set up in multiples of 6 since one operator can look after six machines. Batteries of 18 or 24 machines are fairly common. The frame of each machine is 10 ft. high, and it occupies a floor space 4 ft. 2 in. by 12 in. Two vertical guides support a horizontal crankshaft bearing an 18-in. flywheel. To this wheel is attached a connecting rod which reciprocates vertically between the two guides and supports a steel frame. The spurs or teeth which cut the excelsior are attached to this steel frame. The spurs are flat pieces of steel $3\frac{1}{2}$ in. long, $\frac{1}{16}$ in. thick and $\frac{1}{2}$ in. wide at the base and taper to a point. The number of these points determines the grade of excelsior. They vary from 35 to 205 in number. Just above the steel frame is fastened a wide knife which follows the points and cuts off the scorings made by them. Two horizontal, corrugated feed rolls actuated in opposite directions serve to advance the bolt as fast as the cutting requires and can be easily regulated according to the fineness of the desired product. It ordinarily requires four to six minutes for a 2-ft. bolt to pass through one of these machines, each of which is capable of producing about 500 lb. of excelsior of medium grade in a ten-hour day.

(*b*) Horizontal excelsior machine.

A common form of the horizontal type is an 8-block machine consisting of 2 sliding steel frames, carrying 8 toolheads into which the knives and comb-like spurs are spanned. The sliding frames are moved with powerful cranks and pitmans on hard maple slides. Above these sliding frames are 2 stationary frames, each of which has 4 sets of rolls. The latter by their rotation press a wood block downward against the knives. This 8-block machine requires from 25 to 35 h.p. to operate it, depending on the grade of excelsior. Fine grades of wood wool require more power than the manufacture of coarser grades. One man can tend the machine and keep it supplied with blocks. It will turn out about 2 tons of wood wool or from 5 to 6 tons of packing or mattress stock in a day of ten hours.

Baling Press.

There are two common types of baling presses on the market. In general they follow the same principles as employed in hay or shaving presses. The following are two representative types:

The horizontal press has a steam cylinder mounted in a direct line with the plunger and the body of the press. The stroke of the plunger is central. The excelsior is placed in a hopper in front of the press and at each thrust the plunger forces the hopper-full into the press. This process is repeated until the bale is completed when it is wired and pushed out. The wire is first placed in grooves in the bottom and sides. Bales made by this type of press are 18 in., by 22 in. but they can be made 14 by 18 in. or 16 by 20 in. The bales of the first size weigh from 90 to 110 lb. each. This press requires 5 h.p. of steam when it is operated continuously. The diameter of the cylinder is 10 in., length of stroke 36 in., and extreme length of press $15\frac{1}{2}$ ft. The list price of this press is $380.

The other common type is an upright form in which the excelsior is collected directly in the press and the top is forced down and compresses the contents by a rack and pinion operated vertically. The common size of bales made by this form is 26 by 28 by 56 in. They weigh from 175 to 240 lb. each.

Description of Operation.

The wood is brought in from the storage shed or yard with a one-horse wagon or by a hand truck and unloaded near the cut-off or push saw. Here the operator cuts the 56-in. bolts in thirds, squares the ends, and his helper piles them in a place convenient for the men who feed the excel-

Photograph by U. S. Forest Service.

FIG. 113.—Vertical type of excelsior machines in operation at a factory in Union, New Hampshire. At each downward stroke, a sharp steel spur removes a thin strand of wood from the block.

sior machines. All the bolts must be squared so they will go through the machines evenly. Bolts over 6 in. in diameter are usually halved or quartered either by hand or by a bolt splitter in the larger mills.

The bolts are fed into the excelsior machines as fast as desired, the "spalt" or waste being thrown on a pile to one side and used on the bales or sold for fuel. Any grade of excelsior can be made, from the finest wood wool to the coarsest mattress stock, by an adjustment of the feed and different thickness of spurs. The capacity of each machine depends upon the feed, speed, kind of wood and attention of the operator. The excelsior drops to the floor and is collected on the other side of the machines. It is either moved by hand to the baling press or carried on a belt conveyer directly to the press.

Two men are usually employed to operate the press and weigh the bales. They are then rolled on trucks directly into the freight car or to a shed for storage. The minimum car load is usually 10 tons. From 100 to 125 bales weighing from 175 to 240 lb. apiece make up the average carload.

Labor employed at an excelsior mill is entirely unskilled and, therefore, only comparatively low wages are paid. In the South the men receive from $1.25 to $1.50 per day. In the North the prevailing wages are from $1.50 to $2.50 per day. A ten-hour day is usually observed and night shifts are used when the demand for the product justifies them.

Depreciation and insurance charges are usually heavy. The former is written off at the rate of about 10 per cent per annum. Owing to the highly inflammable nature of the product and the generally cluttered condition of the mills, the fire risk is rather high. Some companies pay $1.75 insurance per $100 valuation even when equipped with automatic sprinklers.

The following is an approximate estimate of daily labor and other expenses incurred at a plant equipped with four 8-block horizontal machines as manufactured by the Kline Co. of Alpena, Mich. This plant will use between 20 and 24 cords of wood per day and turn out about 20 tons of common fine grade or mattress stock in ten hours.

4 machine operators at $1.50 each	$ 6.00
2 balers at $1.50	3.00
2 helpers (boys) at $1.00	2.00
2 tyers and weighers	3.00
1 sawyer to square blocks	1.50
1 assistant sawyer	1.25
1 assistant to pile bolts	1.25
1 grinder to sharpen knives and spurs	2.00
1 assistant to grinder	1.50
1 foreman to look after machinery	3.00
1 cart driver to bring in bolts	1.50
1 man to load cars or pile goods in warehouse	1.50
1 fireman and engineer	2.50
fuel	7.00
1 general helper	1.50
oil and repairs	2.50
	$41.00

To the above figures must be added those for taxes, insurance, interest, depreciation, superintendency, selling charges, etc., which are very variable factors and which altogether should not total more than $3.50 per day. The cost of wood is roughly figured at one-third to one-half the total cost and varies considerably with the species, location, etc. This represents one of the largest of the excelsior operations, which can be run on a much more economical basis per ton of product than can the smaller operations.

In another mill using from 6 to 10 cords of basswood, poplar and willow per day and where the output is from 6 to 10 tons of excelsior of the medium grade, the following labor charges were incurred. This mill was equipped with 20 upright excelsior machines.

1 mill foreman	$ 2.50
1 teamster to bring in the wood from the yard	1.50
1 assistant to work with teamster	1.50
1 operator at the cut-off saw	2.00
1 wood piler to carry blocks from saw to a point convenient to the excelsior machines	1.50
3 operators to feed excelsior machines and look after them generally at $1.75	5.25
2 men picking up excelsior at $1.50	3.00
2 men to operate baling press, and tie and weigh bales at $1.50	3.00
1 assistant to truck bales to car or shed	1.50
1 grinder or filer	1.75
1 engineer and fireman	2.00
	$25.50

CHAPTER XXII

CORK

GENERAL

CORK is the outer layer of the bark of an evergreen oak (*Quercus suber*). Although the tree grows over a wide territory, the commercial production of cork is restricted to a comparatively small area bordering the western Mediterranean Sea, between the 34th and 45th degrees of latitude, North.

The Iberian peninsula is the great center of cork production and produces nearly two-thirds the world's supply of cork. It also grows widely in southern France, Italy, Corsica, Sardinia, Morocco, Algiers and Tunis, and, to a limited extent, in Greece, the Dalmatian Coast, Tripoli, and Asia Minor. Portugal probably produces more cork than any other country, but Spain is regarded as the center of the cork industry because it imports large quantities from Portugal and re-exports it together with the Spanish product in the various manufactured forms. The Tagus River Valley in Portugal and the provinces of Catalonia, Andalusia and Estremadura in Spain are the great sources of the world's cork supply.

There are 400,000 acres of cork forest in France, 818,000 acres in Portugal, about 850,000 acres in Spain, 1,000,000 acres in Algeria, and 200,000 to 250,000 acres in Tunis. The total area of cork oak forests is estimated to be betweeen 4,000,000 and 5,000,000 acres. The richest and most productive forests are in Portugal and Spain.

Cork has played an important part in civilization since the days of the ancient Greeks of the 4th century B.C. and the Roman Empire, for it is mentioned by Horace and Pliny as well as by Plutarch and an early Greek writer. Even in those early days cork was used both for bottle stoppers and for buoys for fishermen's nets. The introduction of glass bottles in the 15th century gave a great impetus to the industry and the importance of cork gradually increased until modern times.

In 1914 this country imported over $6,400,000 worth of cork in its various forms, and even in 1918 the value was over $5,000,000 in spite of the lack of ocean tonnage. In 1916 Spain exported cork and cork products to the value of about $6,900,000. The annual production of cork from all sources is estimated to be between 50,000 and 60,000 tons.

THE CORK OAK

The cork oak is generally a small, irregular tree from 25 to 50 ft. in height and from 8 to 18 in. in diameter, at breast height. The clear trunk is seldom over 12 to 15 ft. in height and the crown is usually somewhat dense and spreading. The cork oak forests resemble to some degree the live oak groves of the southeast and California, with the exception that individual cork oaks do not generally reach such a large size as the live oaks of this country.

FIG. 114.—A good stand of cork oaks in Andalusia, the province of southern Spain which is the center of production of that country. The trunk of the tree on the left including the lower branches is being stripped. Note the hatchet used to girdle and pry off the bark. The trees are usually stripped of bark every eight or nine years.

The forests are very open and there are ordinarily only from 30 to 60 trees per acre. All the trees are of native origin and grow wild and there are no extended attempts at artificial regeneration in its native habitat.

The trees are very slow growing and generally do not attain a size suitable for stripping until about twenty to thirty years of age or more. In Spain practically the only important government regulation governing the conduct of this industry, is the stipulation that no trees under 40 cm. in circumference (about 5 in.) at a point $1\frac{1}{3}$ meters above the ground can be stripped for their bark. Trees commonly attain an age of from 100 to 500 years or more. They generally grow on the lower slopes of mountains and on the poorer and more rocky soils which are unsuitable for agriculture. The best cork is said to be produced from the drier and more rocky soils.

In 1858 several cork oaks were introduced in this country and have grown well in the Southeastern States. The experiments were not sufficiently extensive, however, to determine any positive results regarding the possible introduction and growth of the tree in America.

There has not been any disposition evidenced either by the centralized or local governments in Spain to exercise any supervision over the cork forests except as noted above. They are such an important factor in producing wealth that the owners of cork oak forests realize their importance and give them excellent care. The general method of handling has been practically the same for the past several centuries and it is not likely that there will be any marked changes in the general methods either of cultivation of forests or in the methods of stripping.

HARVESTING THE BARK

All trees that are vigorous and healthy, from 5 to 6 in. and up in diameter, are stripped. Trees are stripped of their bark every six to eleven years, with an average of about eight to nine years. In the lowlands, where the soil is richer, the cork is thicker and more spongy and, therefore, of less value. The firm and heavier cork, which is much more desirable, is produced only on higher and drier soils in very open groves. This product is considered to be of superior quality even though much thinner. Young trees, generally speaking, produce the best quality of cork, although the first stripping, called "virgin" cork, is of very inferior grade and is used only for granulated cork. It is usually hard, thin, dense and tough, and very irregular. Trees as young as twenty years of age have, in special cases, been subjected to the stripping of their bark, but, ordinarily, the age of first stripping is much older than this, as the trees in Spain grow very slowly, and it is often from thirty to fifty years before trees will attain a diameter of 6 in. The first stripping does not injure the growth; on the other hand, it seems to stimulate further development of both the bark and wood growth.

There is no definite rule regarding the age at which trees no longer continue to yield commercial cork. Growers in Spain estimate that commercial cork is produced from trees up to three hundred to five hundred years of age. The most valuable cork is generally about an inch in thickness and this is produced from rather young, vigorous trees, about forty to fifty years of age, and from the lower branches of the older trees. The bark is stripped according to the vigor displayed. This is gauged by men long experienced in the business. All stripping is done by skilled workmen who decide for each tree how high the bark should be removed. A young, vigorous tree with thick bark can be stripped higher than one with thin bark, or one which presents a rather unprom-

FIG. 115.—Weighing pieces of cork in the cork oak forests of southern Spain, just after stripping and drying. Raw cork is usually purchased on the basis of weight before it is sent to the factory for manufacture.

ising or unhealthy appearance. On old trees the best cork is found on the lower portions of the larger branches.

In stripping the bark, a ring is customarily cut completely around the top and the bottom of the trunk; then a vertical cut is made up the trunk and as many other horizontal rings around the tree as seem necessary in order to facilitate the removal of the bark. The wedge-shaped handle of the hatchet is then inserted and the bark pried off. Each tree presents a different problem. On small trees one may often take off the whole bark in one section. On larger trees 2 to 4 vertical cuts up the tree may be necessary. There is no uniformity either in the length or width of the sections removed from the different trees. The stripping is done entirely with a hand-axe or hatchet especially designed for the purpose. The strippers are always careful not to injure the inner bark at any point, because if broken or disturbed this point becomes scarred and successive removals of bark are rendered much more difficult. On the old trees, stripping from the larger branches is done with the assistance of ladders.

One can always tell freshly stripped trees by the dull, red appearance of the inner bark. The cambium layer turns a rich dark red shortly after stripping and remains in this condition until the next year's growth. This is a characteristic sight throughout the cork oak districts.

The time of stripping varies in different parts of the cork region. The general rule followed is that it should be done when the sap is running freely. In Andalusia, in southern Spain, it is customarily done from June 1st to early in September, but the busiest season is in July. The operation may start early one year and the next year much later, as the season varies considerably. It is said that hot weather, following a good rainfall, is the most opportune time to strip the bark during the removal season.

As the strips and slabs are removed from the tree, they are piled up at a convenient point in the forest and later tied in bundles and conveyed on donkey-back to the nearest shipping station or bark scraping establishment.

In Algeria and Tunis the strippers customarily use a crescent-shaped saw for stripping, whereas in Spain and Portugal a hatchet with a long handle, wedge-shaped at the end is the only implement used in the stripping process.

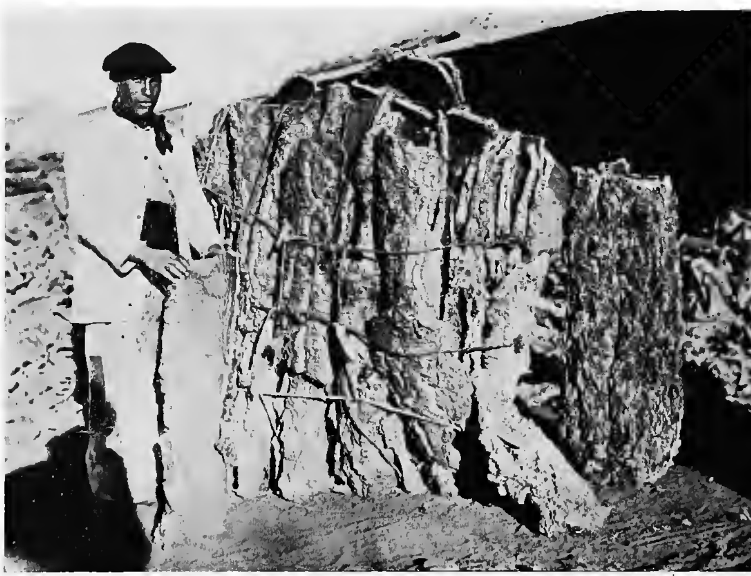
YIELD AND VALUE

The thickness of the bark varies from $\frac{1}{2}$ to $2\frac{1}{2}$ in., depending upon the size and age of the tree, the part of the tree, its condition, the character of the soil, etc. Each tree will yield from 45 to 500 lb. of cork, depending upon these same factors.

Ordinarily the bark is allowed to season from three to eight days in the forest, then it is weighed and sent to some central point to be scraped. The scraping process may be done either in the forest or at the shipping station. In the case of large operations, it is done at some large, central manufacturing point.

Purchases are ordinarily made on the basis of weight. Frequently buyers inspect the cork on the ground and count the strips by the dozen, the larger pieces being separated from the small ones. Generally speaking, it is estimated that on the average there are two pieces obtained from each tree. In Andalusia, in Spain, it is usually purchased by the quintal of 46 km. Whole forests or orchards are sometimes purchased at a fair price, the buyer occasionally doing the stripping himself. The price by weight may be figured either at the station or at the manufacturing or shipping point.

Prices prior to the war have been very variable. It is seldom graded aside from the general classification as noted above. Prices range from



Photograph by Nelson C. Brown.

FIG. 116.—Character of bark as it is brought to the factory from the forest. On the right is a piece about 4 ft. in length, stripped from the tree in one section. It is first boiled, then scraped and sorted by thickness and quality. Photograph taken at a large cork factory in Seville, Spain.

7 to 9 pesetas (roughly, from $1.40 to $1.80), per quintal, up to 20 or 25 pesetas (roughly, $4.00 to $5.00), according to the quality, classification, condition, size, thickness, and location.

MANUFACTURE

In the manufacturing process, the raw bark as it comes from the trees and after drying is first boiled in large copper vats for about three-quarters of an hour. The purpose of boiling in water is to soften the bark, and increase its volume and elasticity, to remove the tannic acid, and straighten out the curvature of the individual pieces for convenience in packing. The boiling is done by placing the pieces close together, one on top of another, and compressing by a heavy weight to keep them flattened out. Boiling softens the outer bark so that it may be scraped to remove the coarse and hard outer layer called "hardback." This layer may vary from $\frac{1}{16}$ to $\frac{1}{8}$ in., depending upon the nature and character of the bark. It is done by hand with hand rasps in most cases, and reduces the weight of the bark about 20 per cent. Efforts have been made to do the scraping by machinery, but it is generally agreed that the hand work

Photograph by Nelson C. Brown.

FIG. 117.—At a large cork factory in Seville, Spain. Under the open sheds on the right the crude cork is boiled and scraped. The best cork is made into wine stoppers.

is better, because the worker can better judge the character and requirements of the individual piece and rasp accordingly. Some pieces of bark are exceedingly rough and irregular and require much more scraping and individual attention than others. Some parts of one piece of bark may also be much more irregular than other parts.

After scraping the bark, it is trimmed with a knife either by hand or by machine, and sorted into grades. It is sorted first for thickness and then for quality. There are customarily from four to five grades of thickness and there are usually four sub-grades of quality to each thickness. There are no standard methods of grading requirements for either the thickness or quality among the various companies. All cork after manufacture is sold on the basis of samples. The slabs of cork to be shipped are then baled in hydraulic presses, and tied up with wire.

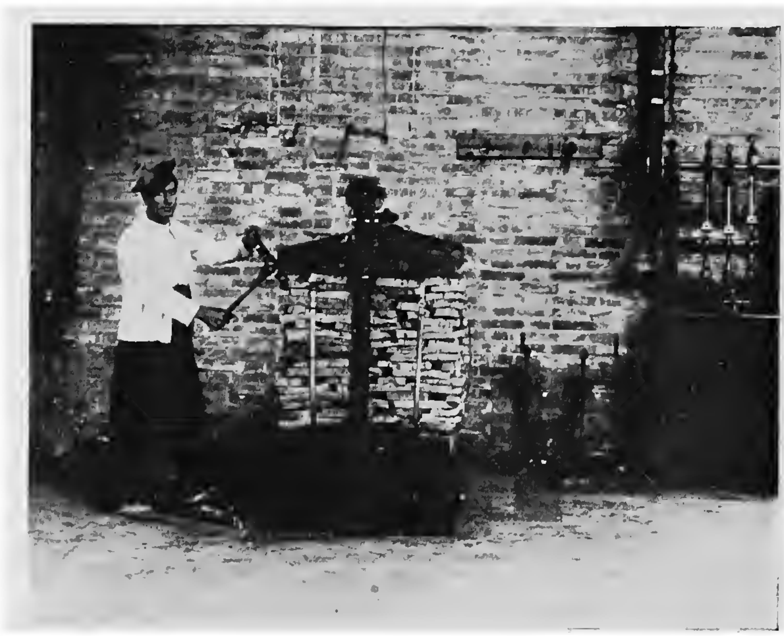


FIG. 118.—Baling cork after boiling, scraping, grading and trimming. Considerable cork is shipped to this country in this form. Photograph taken at a large cork factory in Seville, Spain.

UTILIZATION OF CORK

Cork possesses a number of properties which distinguish it and render it adaptable for use in a great diversity of ways. Its principal features are:

1. Lightness in weight.
2. Compressibility and elasticity.
3. Comparative imperviousness to liquids as well as to air.
4. Comparative strength and durability in relation to its other properties.
5. Low conductivity of heat.

The combination of these characteristics renders it invaluable for many specialized purposes. Its low specific gravity combined with its strength, toughness and durability, cause it to be in great demand for life-belts, buoys, floats, and for several special devices for the prevention of drowning.

Its impervious and compressible qualities bring it into wide use for bottle stoppers, which have been, for a long time, the principal use for the better classes of cork. Champagne and fine wine stoppers require the very highest grades of cork.

Its lightness in weight, softness and low conductivity of heat render it an excellent lining for hats and for soles of shoes.

The demands upon cork products have greatly increased during the last few decades. It is estimated that in the manufacture of solid articles

FIG. 119.—Sorting and trimming sheets of cork. The best grades are used for bottle stoppers.

from cork, there is a primary waste of from 55 to 70 per cent. This waste, however, is always collected, ground up and ultimately used for a great variety of purposes.

On account of its being a poor conductor of heat—exceeding most materials in this quality—its use for cork insulation in refrigeration has developed very broadly in the past twenty years. Probably about 50 per cent of the total cork product of the world, measured by weight, is used now for refrigeration. The American, Argentine, and Brazilian meat packers purchase vast quantities of cork boards composed of odd pieces of cork waste compressed together.

Large quantities are also used for heat insulation, either in the form of cork boards or for loose filling in the walls of ice boxes, cold-pipe lines, water coolers, cold storage rooms, and about the sides of freezing tanks in ice factories. Fur storage vaults, creameries, bakeries, candy factories, and breweries use it for insulation and it is extensively used on ships, clubs, hotels, etc., for the same purpose. When used in the board form, the sheets usually measure 12 by 36 in. and vary in thickness, depending upon the local requirements.

Cork flour is a prominent product. This is made entirely from cork waste and is one of the principal constituents of linoleum and cork floor tiling; cork shavings are used to stuff mattresses and boat cushions. Other common uses are table mats for hot dishes, pin cushions, entomo-

FIG. 120.—Baled cork scraps at a cork factory. Used principally for insulation at refrigerating plants.

logical cork for mounting insects, bath mats, washers, penholder tips, carburetor floats, churn lids, cork balls, gaskets, instrument and fishing-rod handles, etc. Recently it has come into greater use for cigarette tips and cork paper from $\frac{1}{100}$ to $\frac{1}{500}$ of an inch in thickness.

Spain, the most important country in the exportation of cork and cork products, has an export tariff of five pesetas (roughly, $1.00), per 100 km. or 220 lb. of cork in lumps and sheets. This duty has been the same for a number of years. There is no import duty in the United States for bark, but there is a large duty for manufactured cork, stoppers paying from 12 to 15 cents per pound, depending upon size, while other forms pay about 30 per cent of their value.

In 1916 the total exports of cork from Spain were as follows:

Form.	Number of Kilograms
Stoppers	26,471,820
Waste	4,231,885
Squares	1,726,123
Sheets and lumps	1,200,440
Other forms	344,870

Spain ordinarily imports over 4,500,000 kg. of cork from Portugal and after manufacture re-exports it. Most of the stoppers go to France, with a considerable quantity to the United States and Great Britain as well. The squares go chiefly to Argentina, France, and Italy, while, of the cork waste, nearly one-half goes to the United States and a good share of the remainder to Great Britain. Before the war, Germany was an important market for cork and cork products, so that there has been a general decrease in total exports since 1914.

The following table shows the value of the importation to this country of cork bark and manufactures of cork from all sources during the years 1914 to 1918, inclusive, each year ending June 30th:

IMPORTATION OF CORK TO THE UNITED STATES

Years.	Cork Bark. Value in Dollars.	Manufactures of Cork. Value in Dollars.
1914	$3,851,794	$2,647,838
1915	2,762,895	2,024,059
1916	3,134,884	941,243
1917	3,870,389	2,158,447
1918	3,061,829	2,017,146

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