Forest Products

By Nelson Courtlandt Brown

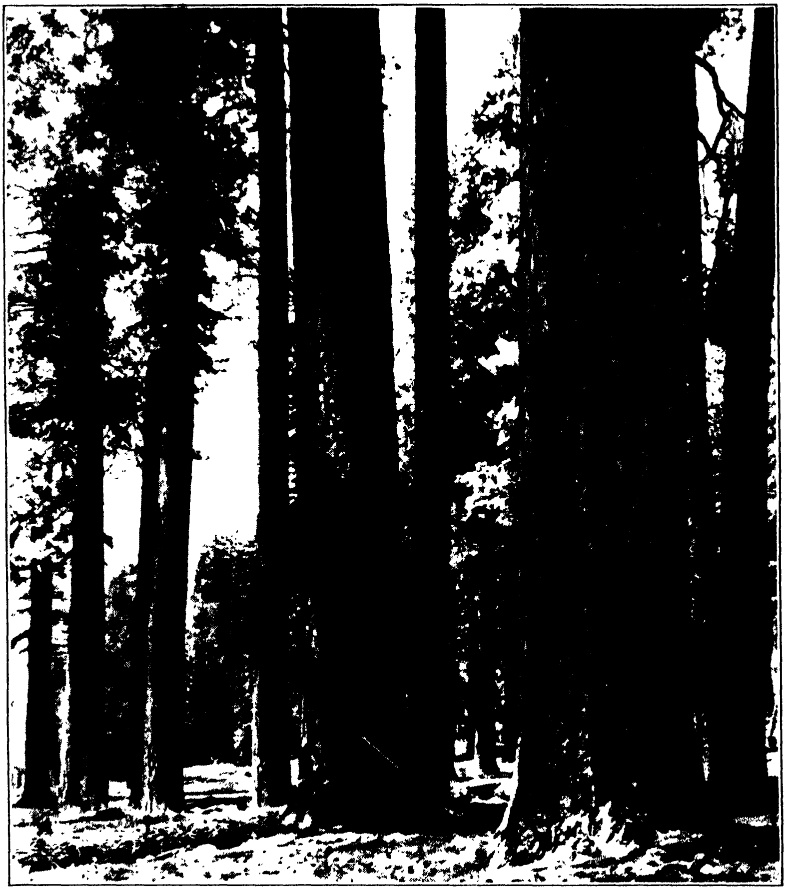
FOREST PRODUCTS

LOGGING

LUMBER

By the late Franklin Moon
and Nelson Courtlandt Brown

ELEMENTS OF FORESTRY
Third Edition



Timber—the most important and universally useful raw material of the future. If properly protected and managed, the American forests can supply all of the forest products needed by this Nation. During and since the last World War, wood has literally been rediscovered. This is a scene in the ponderosa pine forests of the West where this species is found in 12 states. This tree is not only the source of high-grade lumber and veneer but also an important source of supply for boxes in the vegetable and fruit trade of the western states. It is also coming into use for poles. *Courtesy Western Pine Association.*

Forest Products

THE HARVESTING, PROCESSING, AND MARKETING OF MATERIALS OTHER THAN LUMBER, INCLUDING THE PRINCIPAL DERIVATIVES, EXTRACTIVES, AND INCIDENTAL PRODUCTS IN THE UNITED STATES AND CANADA

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Preface

Since a previous book was published in 1935 on Timber Products and Industries following a revision of the first book on Forest Products; Their Manufacture and Use, published in 1919, the subject of forest utilization has received greatly increased emphasis and recognition as the "bottleneck" of successful forestry practice in the United States and Canada.

The many forest products other than lumber and their increasing importance have focused attention on integrated and multiple utilization of our forest resources with the result that managed forests are becoming successful business enterprises. Furthermore, increasing amounts of capital funds are being attracted to them. Timber—long regarded as a highly speculative and perhaps precarious investment—is now rated with higher favor by bankers, investors, and those having to do with the investment of capital funds to support various business ventures using wood.

The gradual disappearance of virgin forests and the necessity of profitably utilizing regrowth forests to sustain wood-using industries have given the subject a new and broader significance. Forestry is gradually emerging as a business as well as an art and science. Forestry must pay its way, and forest products will cost what it costs to produce them. This new concept has gradually replaced the crusading spirit of warning the Nation against a probable timber famine.

Wood is being recognized as a universally useful raw material. Wood seems destined to become the most important raw material of the future not only in the United States but also in many parts of Europe. Great progress has been made during and since World War II in the efficient utilization of our timber resources; in the recovery of much material formerly wasted and in the use of species formerly neglected or seldom marketed.

Nature has provided the North American continent with abundant and widely useful forests. In spite of wasteful logging and conversion processes in the past and with the aid of fire protection and prevention programs, it seems likely that these resources will be maintained and increased by private enterprise with the help of Federal and state forestry agencies.

New phases of utilization, especially prelogging, relogging, salvage and sanitation cuttings, mechanized logging, quality control, and improved processing and conversion methods, have given a new significance to the part played by forest products in our national forestry program as well as in our national economy. New techniques in manufacture and processing have greatly advanced the use of plywood, pulp and paper products, densified wood, fiberboards, rayon, plastics, and many others. Some materials like fuelwood and hardwood-distillation products have naturally decreased in importance. Many others have advanced in production, and many new products are being developed as a result of research and mill experience.

Emphasis in this text has been given to fundamental principles in order to assist the student in an elementary understanding of some of the processes. Because of the limitations of a book of this kind, the treatment of each subject has of necessity been very brief. A complete volume could be written on many of the topics. Many good books have already been published on one of them, namely, the pulp and paper industry, which is one of the great industries of the United States and Canada.

Foresters and those interested in these products should have a working knowledge of the relative importance of the various items that come from our forests. The efficiency in the harvesting of these products and their values determine the profitability of forest-management plans.

Our prosperity and national welfare are intimately related to the wise use of our natural resources. Summarized, our strength, wealth, and happiness are largely dependent upon how we manage these resources—soils to cultivate, fish to catch, waters to control, minerals to dig, and trees to chop. Forestry has emerged from an idealistic dream of Gifford Pinchot fifty years ago to a very realistic and important part of our national existence. More than one million men are employed; more than 70,000 logging operations, more than 100,000 sawmills and woodworking industries, and about 15% of our capital are concerned with the production of forest products in the United States and Canada.

The wise use of our forests and the continuance of an ample supply of wood for the future are accepted national policies. The proper and profitable utilization of our timber resources will determine the intensity of silviculture and forest-management programs. Forestry has four component parts: (1) forest protection, (2) silviculture, (3) forest management, and (4) forest utilization. These are inseparable and interdependent.

It is hoped that this text will assist the forestry student in acquiring a better understanding of the complex and ever-widening subject of Forest Products and the part it may play in the development and maintenance of a wise and adequate forestry program for the United States and Canada.

NELSON COURTLANDT BROWN

August 1950.

Acknowledgments

The forest products industries have been universally co-operative and helpful in making full information available to the author on numerous trips to the various forest regions. Some of the well-known authorities on various products have been especially helpful in reviewing and checking the chapters, supplying original data, or advising the author. Among them are Thomas D. Perry, author of *Modern Plywood* and *Modern Wood Adhesives,* a trained and experienced engineer in the woodworking industry, for the chapter on veneers and plywood; Charles C. Larsen, formerly with the Vermont Forest Extension Service who has enjoyed wide experience in the maple sugar and sirup industry; W. W. Woodbridge of the Red Cedar Shingle Bureau of Seattle for the chapter on shingles; J. W. Bicknell and Valentine O. Goodell of the Plantation Division of the U. S. Rubber Company of New York for the chapter on rubber; Professor C. E. Libby and Dr. E. C. Jahn of the department of pulp and paper manufacture, New York State College of Forestry, for the chapter on wood pulp and its products; B. N. Johnson, procurement manager, Koppers Company, Richmond, Ind., for the chapter on cross ties; Gordon E. Falkenau, container consultant in the engineering department of the DuPont Company, Wilmington, Del., for the chapter on boxes and crating materials; Eugene F. Grenaker, American Turpentine Farmers Association, Valdosta, Ga., for the chapter on naval stores; C. D. Dosker of Gamble Brothers, Louisville, and P. A. Hayward, managing director of the Hardwood Dimension Manufacturers Association, Louisville, for the chapter on hardwood dimension; Dean Williams, editor of the *Journal of the American Leather Chemists' Association,* for the chapter on tannins and dyes; J. J. Forbes of the U. S. Bureau of Mines for the chapter on mine timbers; and H. C. Jack, president of Wood Flour, Inc., for the chapter on wood flour.

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Many forest industries are now on a sustained-yield basis of timber production, especially the larger pulp and paper and lumber manufacturers. They and the cross-tie, timber-preservation, cooperage, pole, naval-stores, and wood-distillation concerns have been most helpful and willing to supply information. The U. S. Census Bureau statistics have been freely drawn upon. The regional lumber manufacturers' associations and various organizations such as the American Forest Products Industries, Forest Products Research Society, the American Pulpwood Association, Cork Institute of America, The American Paper and Pulp Association, the Northeastern Forest Utilization Council, Connwood, the National Lumber Manufacturers Association, the various loggers' associations and specialists have been of assistance. Individual lumber and pulp and paper companies, the Weyerhaeuser group, The Long-Bell interests of Kansas City and Longview, and many others, have been of great assistance.

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Abbreviations

For brevity in the case of reiterated and frequently occurring expressions, the following are generally used:

Thousand board feet	M b.f.
Board feet	b.f.
(One board foot equals a piece 1″ × 12″ × 12″)	
Thousand	M
Inches	″
Feet	′
Horsepower	hp.
Diameter breast high	d.b.h.
(4½′ above ground)	
Free on board	f.o.b.
Per cent	%
Revolutions per minute	r.p.m.
Pounds	lb.
Fahrenheit	F.
Centigrade	C.
Degree of temperature	°
British thermal units	B.t.u.

PART I

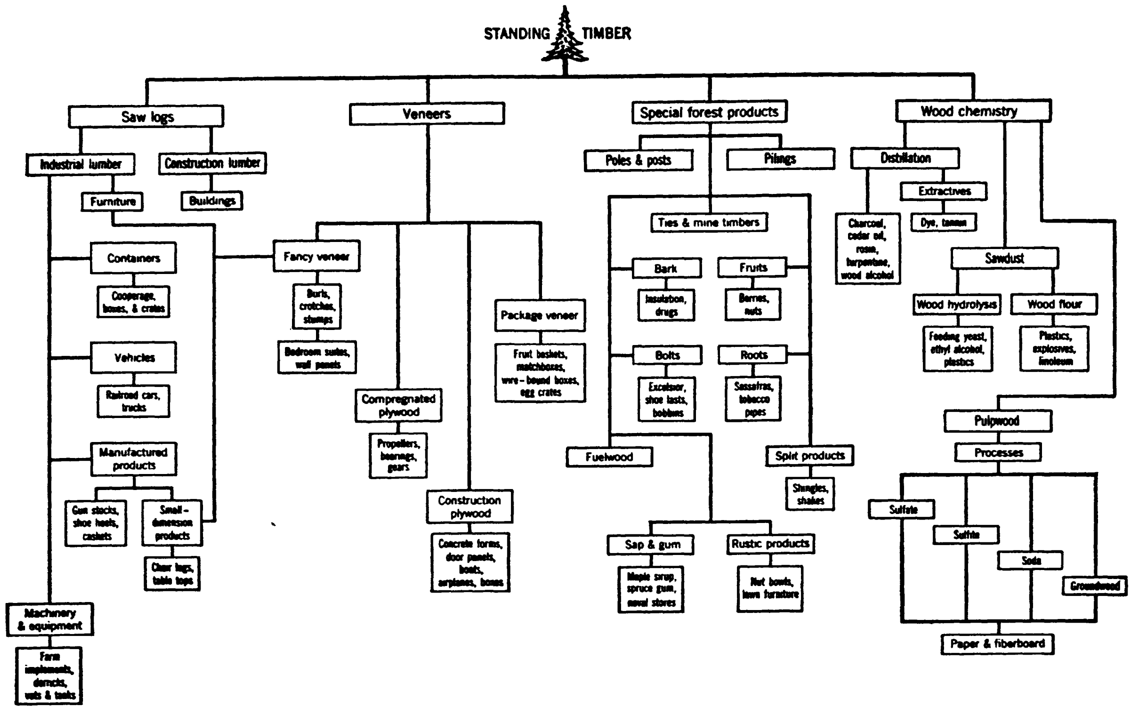
Introduction, Economics, and General Considerations

1 · INTRODUCTION AND SCOPE

Economical and efficient harvesting of timber crops and their conversion into a wide variety of useful materials constitute a very important part of the program of American forestry. Through scientific research and trial of improved commercial practices in the woods and at the processing plants, better and more useful products are made available to our people. Profitable and efficient utilization is the determining factor of successful forest management. New methods of harvesting, converting, processing, and merchandising the myriad of forest products have distinguished the development of American forestry during the past 50 years and notably since World War II. The province of the subject is large and expanding. New uses, new outlets for timber products, and a better knowledge have characterized the fields of both chemical and mechanical utilization. Although some progress has been made, we are still in the infancy of knowledge of wood and its potentialities for wise and profitable use.

To lessen the great wastage of good raw material is an important problem in the development of American forestry. Only a relatively small portion (less than one half) of the trees felled are ultimately utilized. This is a fundamental reason why forest utilization assumes such large proportionate importance in the general program of American forestry.

Improved conversion methods, new and efficient uses, and the broadening of the demand for timber products mean greater employment and therefore increased happiness and welfare of our



Products of North American forests. This is a summary outline of how our standing timber is converted into some of the major products. In some cases as in pulpwood many of the end products are not shown because of limitations of space.

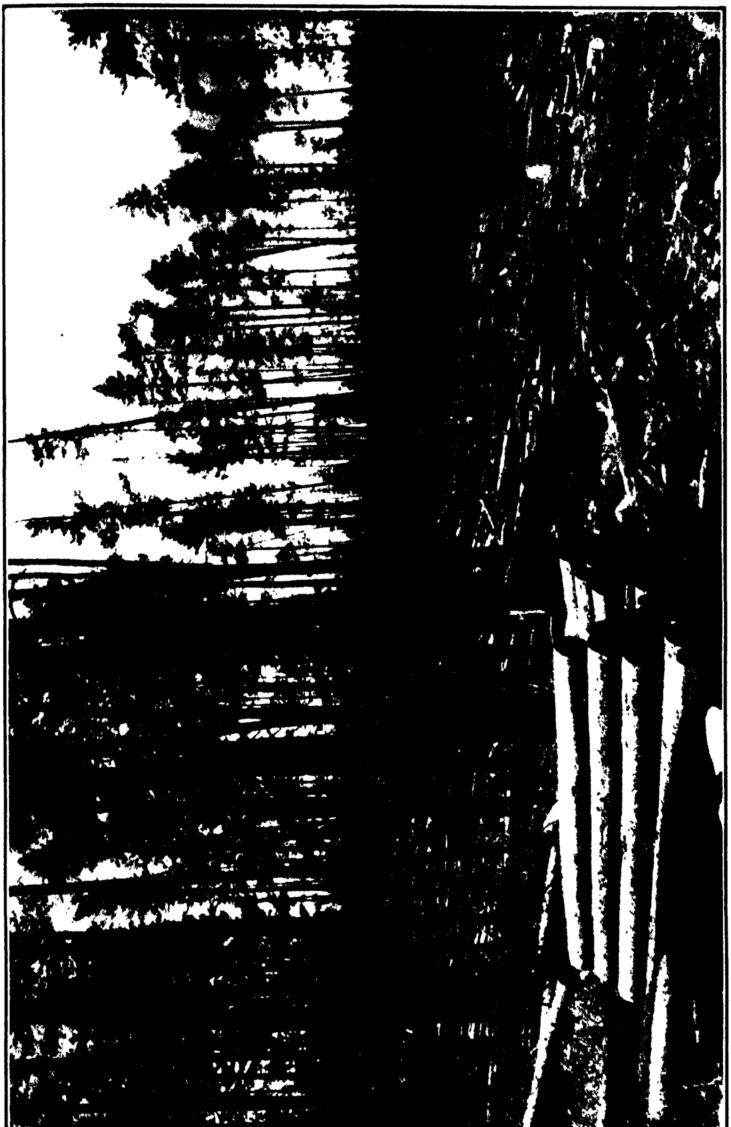


FIGURE 1. Integrated and diversified utilization in the Rocky Mountains where several classes of forest products are obtained from lodgepole pine. In the left foreground are mine props decked for loading. From the same area saw logs, lagging, cross ties, poles, posts, and fuelwood are produced. *Courtesy U. S. Forest Service.*

people. Permanent and stabilized communities dependent upon forest industries are replacing the former nomadic and transitory features of the lumber and forest product businesses.

The availability of large quantities of second-growth timber of smaller sizes and larger sapwood content than found in virgin timber has directly affected the economics of these industries, especially the raw-material supply and the market outlets for them. Many small and scattered stands remaining from large logging operations, the increasing importance of farm woodlands, rapid increment of second-growth timber, integrated utilization, prelogging and relogging, sustained-yield management, and selective logging have changed many aspects of forest utilization. Wasteful, antiquated, and uneconomical practices have characterized the naval-stores, tight-cooperage, hewed-cross-tie, maple sugar, veneer, and plywood industries in previous years. The development and expansion of the wood-pulp, plywood, fiber- and insulation-boards, rayon, densified-wood, plastics, Cellophane, and other forest-products industries through laboratory, woods, factory, and merchandising research have revolutionized some phases of these industries.

Changes in geographic distribution have also marked these industries. The South and Pacific Northwest have made notable forward strides in the successful development and improvement of some of these industries, notably in pulp and paper. There is no forest region that is not of considerable importance in the manufacture of one or several of the products described in the text.

2 · RELATIVE IMPORTANCE OF PRINCIPAL FOREST PRODUCTS

For many years, lumber was the principal product of the forest, and fuelwood in enormous quantities was consumed until recent decades; however, there has been considerable diversification in the utilization of standing timber. There are more than 4000 separate items of use. Chemical as well as mechanical utilization has been greatly expanded and in some products vastly increased. Table 1 indicates the relative importance in wood volume of the principal forms of products expressed in percentages in the United States. These products are sold in units

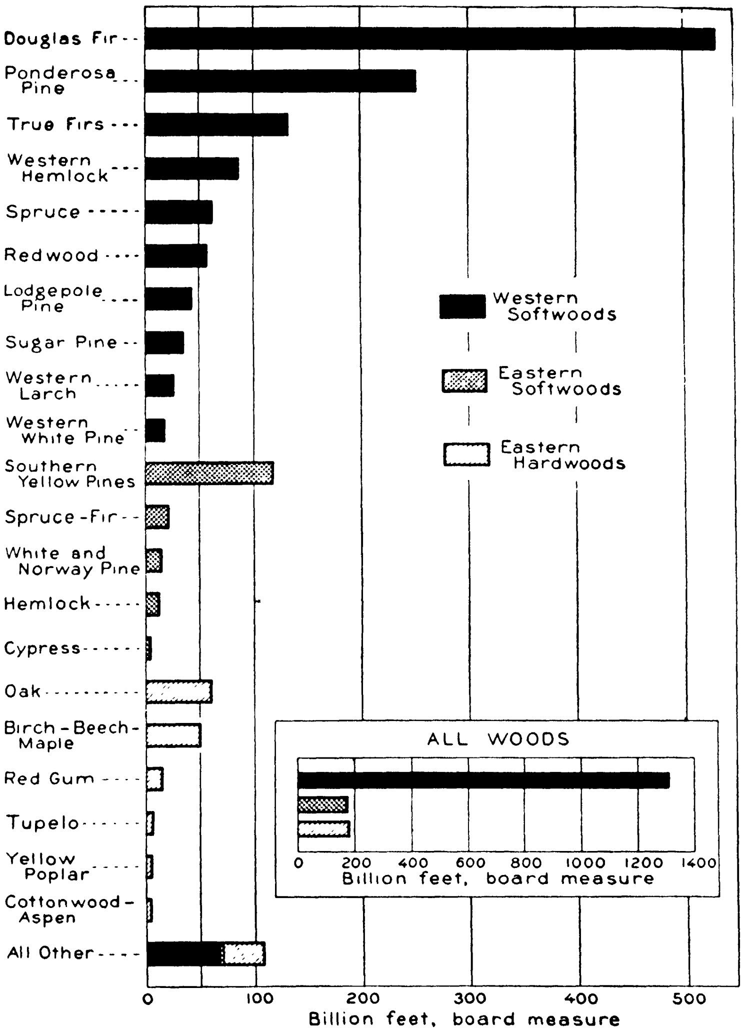


FIGURE 2. Saw-timber stand of the United States by important woods.

of cords, board feet, pieces, bolts, square feet, cubic feet, weight, etc., but their relationship is best expressed on the basis of a common measurement factor as follows:

TABLE 1

PRINCIPAL FOREST PRODUCTS

Item	*Percentage*
Lumber	59.4
Fuelwood	12.6
Pulpwood	11.4
Veneer logs and bolts	3.9
Fence posts	3.3
Hewed ties (not including 1.5% sawed ties classified as lumber)	1.6
Logs and bolts, other, used in manufactures	1.6
Mine timbers (round—not sawed)	1.5
Cooperage (slack and tight)	1.3
Poles	0.6
Distillation wood (hardwood)	0.2
Piling	0.2
Other cordwood and miscellaneous	2.4
	100.0

FOREST PRODUCTS AND TRANSPORTATION

During a normal year, 3,230,000 carloads of forest products are originated on class I railroads throughout the Nation. Gross revenues received from them totaled more than $620 million or 10.54% of the total revenue for all carload traffic. In the South, forest products accounted for 18.69% of the total carload traffic. During the year, the railroads expended more than $171 million for cross ties, piling, switch ties, and many other forms of forest products. Table 2 shows the great variety as well as the large volume of forest products transported on our railroads. Most of them are primary products of the forest, but they include some manufactured forms.

3 · CLASSIFICATION OF FOREST PRODUCTS

For a proper understanding of the province of this broad subject of forest products, it is advisable to divide them into several classifications. There may be a simple and elementary classification such as (1) primary products of the woods as saw logs, bolts, poles, posts, and cross ties; and (2) secondary products, that is, those requiring further manufacture, reduction, or treat-

TABLE 2

Products of Forests	*Number Cars Originated*	*Per Cent of Total Cars*	*Gross Freight Revenue Received*	*Per Cent of Total Freight Revenue, All Carload Traffic*
Logs, butts, and bolts	488,470	1.32	$ 16,639,631	0.28
Posts, poles, and piling	160,948	0.44	28,465,148	0.48
Fuelwood	18,699	0.05	998,861	0.01
Railroad ties	91,196	0.25	12,525,419	0.21
Pulpwood	560,785	1.52	36,553,799	0.62
Lumber, shingles and lath	946,156	2.56	306,636,653	5.21
Box, crate and cooperage material	108,459	0.29	20,366,852	0.35
Veneer, plywood and built-up wood	37,382	0.10	16,034,242	0.27
Rosin and turpentine	21,544	0.06	6,028,255	0.12
Other products of forests not specifically listed above	121,181	0.33	12,076,154	0.21
Wood pulp *	82,044	0.22	29,871,696	0.51
Wrapping paper *	64,619	0.17	21,001,878	0.36
Paper bags *	38,296	0.10	12,793,741	0.22
Paperboard, fiberboard and pulpboard *	178,166	0.48	45,451,506	0.78
Furniture *	136,387	0.37	31,481,323	0.53
Wooden containers *	42,682	0.12	5,028,726	0.09
Knocked-down fiber-board and paperboard containers *	133,043	0.36	18,391,079	0.31
Total	3,230,057	8.73	$620,344,963	10.54

* Manufactured products.

ment. Some products require little or simple preparation to make them available for commerce and industry; other products need further remanufacture and refinement. Another simple and broad classification would be (1) products from living trees including gum naval stores, maple sap and sugar; and (2) those from felled trees, which obviously make up a vast majority of products. Another classification may be based upon (1) chemical reduction, such as pulp (except groundwood), tannins, dyes, naval stores, wood distillates, maple sugar; and (2) those mechanically reduced such as cooperage, veneers, and various forms of containers and packages.

A still more detailed classification may be based upon (1) construction materials such as cross ties, poles, piling, and some forms of plywood; (2) containers such as cooperage, boxes, crates, and some of the veneers and plywood; and (3) chemical products such as the chemical pulps, tannins, dyes, and naval stores. No classification except a very simple and broad one can be entirely logical and consistent. Veneers and plywood are used for construction materials and for containers and packaging in addition to being utilized for many aesthetic effects in furniture and interior finish. Wood pulp is reduced by both mechanical and chemical processes. Many construction materials, such as poles, piling, cross ties, and posts, are chemically treated to prolong their length of life in service. A simple classification which it is hoped will be readily grasped and understood by the student has been adopted for the present book. This, it seems, lends itself best to pedagogical procedure. Each product is assigned to its major classification, although some, such as pulp and veneers, may be found in two or more divisions.

4 · TECHNICAL PROPERTIES IN RELATION TO USES

Wood varies widely in its composition, structure, and technical properties. Each species of possible commercial importance must be carefully studied and analyzed as to its physical, chemical, and mechanical properties in their relation to current or prospective uses. We are only beginning to acquire complete knowledge regarding wood and its properties. Through Federal, state, industry, association, and educational research, new light is constantly being thrown upon the technical properties, and this knowledge is being applied to improved wood uses.

In addition to these properties, information about seasoning and conditioning processes, prevention of sap stain and other deteriorating influences, durability, weight, treatability, and grades in relation to their uses is of vital importance. Both fundamental understanding of technical properties and familiarity with their application in the industries are important and necessary. Availability, abundance, value, and problems of harvesting and conversion are important factors.

Some species such as southern pine and Douglas fir, are strong, stiff, hard, durable, abundantly available, and relatively inex-

FIGURE 3. Several items made of wood treated with methylolurea to increase the dimensional stability and the durability of these products. From left top to right bottom, they are bowling pin, section of corrugated filter frame, a tool handle, two leaves from a zigzag carpenters rule, sections of tubular wood core for paper rolls, an industrial pulley, and a dowel. *Courtesy William Rittase.*

pensive. They therefore make excellent multipurpose construction timbers, lumber, cross ties, and other products where these qualities are important. The cedars, cypress, and redwood, which are exceedingly durable, light in weight, and readily converted, make excellent siding, poles, shingles, posts, and even cross ties for railroads on which traffic is not frequent or rolling stock heavy. Spruce has long, strong fibers, is relatively free from resinous and gummy substances, and therefore is adaptable for the production of pulp and paper by certain processes. White oak, being impervious to liquids and without disagreeable odors or flavor, is in great demand for barrels and other forms of tight cooperage. Basswood, which is light in weight, soft, white colored, and possesses excellent working qualities, is used for fine-quality boxes and for Venetian blinds, moldings, novelties, picture frames, and excelsior. Elm is tough and useful for barrel hoops. Black walnut, black cherry, and mahogany season well, possess attractive figure, color, and grain, and are regarded as premier woods for furniture, interior finish, cabinetwork, and the like. Douglas fir occurs in large sizes, is relatively inexpensive, and makes an ideal wood for general construction as well as for the manufacture of veneers and plywood, which have come into such wide demand.

These are only a few simple illustrations of the relationship of properties to utilization. Each species, moreover, varies widely in its growth rate, weight, and usefulness even within each tree. Cherry in some regions has excessive gum pockets, which tend to degrade the lumber and lower its value. Butt logs of most species generally contain the best wood and are freest from defects. Therefore they yield the clearest and most valuable boards. Top logs may be valueless because of excessive number and size of knots and other defects. Some species check and split readily on exposure to the air after manufacture or crosscutting. Sapwood differs from heartwood in its chemical composition, moisture content, and appearance. Sapwood in some species, such as redwood, western red cedar, catalpa, and yew, is relatively very narrow, whereas it is comparatively wide in maple, ash, hickory, beech, and some of the pines.

Second-growth timber generally contains larger proportions of sapwood than virgin timber. In some species as willow, spruce, true firs, hemlock, and cottonwood there is little difference in structure and appearance and, therefore, in value between sapwood and heartwood. The darker color of heartwood is generally due to the deposition of certain tannins, gums, resins, etc. Heartwood is more durable and heavier and generally contains a lower moisture percentage; consequently it is generally more valuable. For spools, handles, and spokes, sapwood is often preferred.

Handles for hammers, axes, shovels, rakes, etc., are preferred from second-growth ash and hickory.

Tests have indicated that the heartwood of these species is fully as satisfactory from a scientific or technical viewpoint as sapwood, indicating that there are unwarranted trade and popular prejudices in the uses of many woods. White maple from sapwood is often preferred to heartwood for certain purposes. There

FIGURE 4. The problems of using small regrowth timber and thinnings from regrowth and plantations have intensified the difficulties of efficiently utilizing our forest products. This illustrates the use of thinnings from regrowth Douglas fir forests to provide raw material for preshaped log siding stacked outside specialty mill in Pacific Northwest. *Courtesy American Forest Products Industries.*

is a sharp distinction between sap and red gum in the lumber market. Sap may degrade lumber produced from red gum trees. Thus, in some species, sap may be a defect and in others much preferred. Sapwood takes preservative treatment more readily than heartwood—a factor of importance in cross ties, poles, posts, piling, and other materials used in a treated condition.

The forester must be fully acquainted with the technical properties of wood and their commercial application in order to be able to determine the most profitable utilization of each species. He should possess an accurate knowledge of the strength, stiffness, cleavability, hardness, toughness, flexibility, durability, chemical composition, growth rates, weight, and other properties, as well as available supply, problems of harvesting and conversion (logging and manufacturing), conditioning, grading, market outlets, and values when finally used.

Present interest in expanded chemical utilization * has emphasized the importance of chemical properties. When wood is thoroughly dried (about 6% moisture content) it is often found to contain about 99% organic and 1% inorganic matter. The inorganic matter comprises the ash when the wood is burned. Wood consists chiefly of carbon and oxygen with smaller amounts of hydrogen and still smaller quantities of nitrogen, potassium,

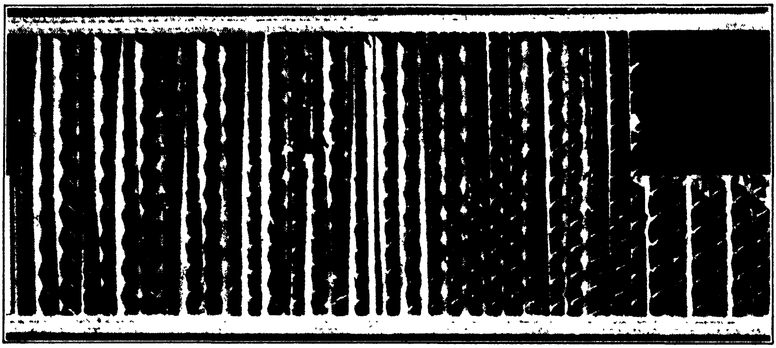


FIGURE 5. Cross section of sandwich-type wall panel fabricated from resin-treated paper corrugations faced with plywood. This is one example of many new products made from wood. This form was devised to assist in the important housing problem. *Courtesy U. S. Forest Products Laboratory.*

sodium, calcium, and magnesium. Wood fibers are composed of a skeleton of cellulose which includes varying quantities of lignin and, in some species, tannin, resins, various kinds of oils, and gums.

It is important that the forester be as fully informed as possible regarding the physical and chemical properties of wood so that each species may be employed properly and efficiently and thus contribute to more complete and satisfactory utilization.

5 · DECREASING USE OF SPECIAL PRODUCTS

The most important decrease in utilization of important products has been in the use of fuelwood. This was due to the increasing consumption of coal, natural gas, artificial gas, and electricity

* See *Wood Chemistry* by L. E. Wise, *et al.*, Reinhold Publishing Corp., New York, 1944.

as sources of heating and power. This, in turn, has been due largely to changing customs and improved living conditions both in rural and urban communities. Wood as fuel represented about 60 to 70% of all wood utilized in the United States during the early years of its history. It is still second to lumber in importance in volume consumption.

Cross-tie production has decreased particularly in the hewn forms owing to (1) decrease in new railroad construction and (2) increased life in service as a result of preservative treatment. Early in this century (1907) about 153 million cross ties were produced annually. This decreased to about 40 million in 1939 and rose again to about 45 million cross ties. On August 14, 1948, the passing of the tiehack was suitably commemorated in a memorial statue erected by the Wyoming Tie and Timber Company near Dubois, Wyo.

Due to the introduction and use of other materials, there has also been a decrease in the use of cooperage, hardwood-distillation products, lath, and shingles. With the growing scarcity and rising costs of good white oak for tight cooperage, there has been a shift to the use of metals, especially for beer, oils, and many other liquids, and to other forms of containers for both dry and liquid products, although wood fiber or veneer instead of solid wood may still be the raw material. Formerly, white oak was pre-eminently favored for many forms of cooperage, especially tight cooperage. Other hardwoods, particularly red, black, and tupelo gums and southern pine and other softwoods, have largely replaced oak for many kinds of cooperage.

With the passing of chestnut due to the blight disease, power and public-utility companies turned to the use of creosoted southern pine and to western red cedar and Douglas fir poles, and recently also to lodgepole pine, western larch, northern white cedar, and other species. More poles are being treated; recently more than 8 million poles were treated in one year (1948).

The hardwood-distillation industry is a natural concomitant of war. During the First and Second World Wars, this industry rose to great heights. However, owing to the increasing substitution of synthetic materials for methanol and acetic acid and other chemical products and the decreasing demands for charcoal, the use of wood in this industry has greatly lessened.

With changing building customs, the demand for both wood lath and wood shingles has decreased, although wood in fiber rather than solid form is still largely involved. Metal lath and fiberboards have replaced wood lath to a considerable extent.

FIGURE 6. Veneer logs cut from farm wood lots in New Hampshire being scaled for their board-foot content before delivery to veneer mill. These logs are largely hard maple and yellow birch, with some beech, white ash, and an occasional black cherry. *Courtesy American Forest Products Industries.*

The interior plastering of rooms is not so popular as formerly. Composition shingles have largely replaced wood shingles. This has been due to the following conditions:

1. Changes of residential forms of construction from rural to urban areas.

2. The element of fire hazard which was zealously exploited by competitors and often taken into account by urban building codes and insurance underwriters.

3. Decreased production of shingles and decreased selling effort against active competition from substitute forms of shingles.

The wood shingle, when properly air-dried, cut on the quarter grain, and properly applied with rust-resistant nails, has given excellent service for 20 to 30 years or more.

6 · INCREASING USE OF IMPORTANT PRODUCTS

During the past 20 years, the most important relative advances in quantitative production, as well as in the techniques of pro-

FIGURE 7. Marked, measured, and stacked spruce and balsam fir pulpwood ready for loading on sleds for winter hauling. Bolts marked "X" indicated spruce and those marked "S" indicated fir. Photograph taken on Hollingsworth & Whitney lands in Maine. *Courtesy U. S. Forest Service.*

duction, among the important forest products have been with (1) veneers and its principal end product—plywood, (2) pulpwood and pulp products, (3) wood plastics, (4) densified or modified wood, (5) laminated structural members, (6) improved methods of deriving naval stores, and (7) hardwood dimension. Concurrently with these changes has been the increasing interest in the utilization of vast quantities of materials formerly wasted in the manufacture and processing of lumber, lumber products, cross ties, and other major products of the forest.

With the increase in population, the demand for pulp and pulp products has been very large, resulting in the increase in the annual production of pulpwood from about 6 million cords per year in 1925 to more than 22 million cords in 1950. The relative production of plywood has increased more than any other important forest product, owing largely to the demand for Douglas fir plywood as a building and structural material. Douglas fir has proved to be an ideal wood for the manufacture of rotary-cut veneers because of its large size, relatively clear wood, and comparatively low cost per unit (square foot).

7 · INCREASED AND MORE EFFICIENT UTILIZATION FROM PRELOGGING, INTEGRATED LOGGING, AND RELOGGING

Within recent years many changes have come about in harvesting and processing methods. Prelogging consists of taking out certain species and generally smaller sizes that should be harvested first or would be injured or broken (shattered) later in the normal logging operations. For example, cedar poles are taken out of the forests of northern Idaho and pine poles from southern forests in advance of the main logging job. Peeler logs for veneer are often taken from Douglas fir stands before felling of the principal stand: also understory hemlock and cedar in the old-growth Douglas fir forests are taken out in prelogging operations, hemlock for pulpwood and cedar for shingles and saw logs. Approximately 8 M b.f. per acre are being taken from the old-growth Douglas fir and hemlock stands in prelogging operations. Operators take out suppressed West Coast hemlock and western red cedar, the former for pulpwood and the latter for cedar logs intended for saw logs and shingle bolts.

Integrated logging is the separation of the primary product into those forms that command the highest values as end products, its objective being diversified rather than single-purpose conversion. For example, from one logging operation, the standing timber may be converted into two or more products depending upon species, size, and value, such as (1) saw logs, (2) pulpwood, (3) poles, (4) posts, (5) veneer logs, (6) fuelwood, whereas formerly the entire operation may have been conducted for saw logs. There may be 2 to 10 or more separate products removed from

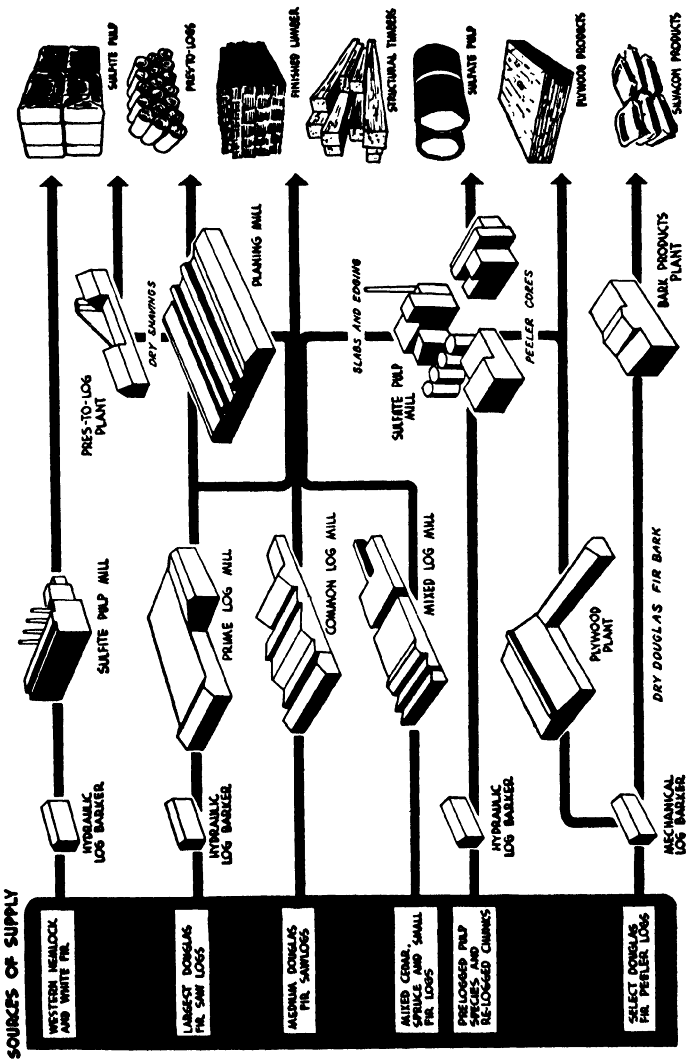


FIGURE 8. Integrated and diversified manufacturing operations for more efficient utilization of forest resources in the Pacific Northwest. This shows the processes and end products of various sources of supply. *Courtesy Weyerhaeuser Sales Co., St. Paul.*

the same felling areas. Sometimes certain species are allocated to the highest-value product such as black cherry for furniture, ash for handle bolts, black walnut for veneer logs. Integrated logging has been widely developed in the South and Northwest, and also in northern Idaho and western Montana.

An excellent example of integrated utilization is found in the

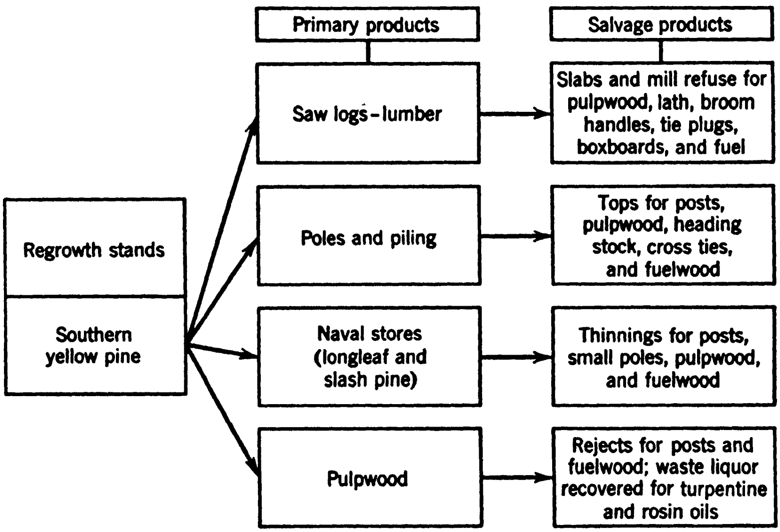


FIGURE 9. Integrated utilization—master plan of primary and secondary (salvage) products in converting standing southern pine timber into some of its principal end uses.

Appalachian hardwood region. The highest-grade logs in species, sizes, and quality, such as oak and yellow poplar, are used for peeler logs for veneers. Some of the best white oak logs are separated for tight cooperage stock. The better logs in size and quality of all species go into lumber. The smaller logs and the poor species such as black gum and beech go into the coal mining operations for props and caps which also take small sizes from cull timber and tops. "Wolf" trees and tops of all species, especially beech, are used for cross ties. Many hardwoods are also used for pulpwood and fuelwood. "High grading" or "creaming" the forest for the best sizes in past years has deteriorated forest conditions in many sections.

An interesting example * of integrated and complete utilization of forest resources and how they are adapted to local markets is shown in the Pocono region of eastern Pennsylvania on a private tract of 2000 acres of which about 1000 acres are forested with merchantable timber, the remainder being planted with ornamental and Christmas trees and operated for farm purposes.

FIGURE 10. Example of selective cutting in ponderosa pine stands as commonly found in all the Rocky Mountain and Pacific Coast states. Integrated and diversified utilization has kept pace with improved logging procedures and resulted in more efficient utilization of our forest resources. *Courtesy Western Pine Association.*

There are a small sawmill, a planing mill, and a small woodworking plant for processing saw logs into locally salable products —also a Christmas-tree plantation of about 100,000 trees and a natural stand of timber of about 500 acres growing Christmas trees. The native forest is composed of white pine, red spruce, hemlock, and several hardwoods, principally beech, yellow and black birch, maple, cherry, white ash, and red oak. There is an excellent market for Christmas greens and boughs of hemlock and spruce, locust posts, spruce poles, mine props and timbers,

* From data supplied by S. R. Wagner, Wagner Forest Products, Pocono Lake, Pa.

fuelwood, sawdust and shavings for cattle bedding, mill slabs and edgings for fuelwood, and several varieties of evergreen ornamental trees and wildlings including rhododendron and mountain laurel.

The sawmill, planing mill, and woodworking plant have machinery to make about everything from lumber for a complete house, summer cabin, garage, etc., such as framing, flooring, paneling (knotty pine), siding, and sheathing. Folding tables, rustic furniture, and the like are made from small sizes of lumber and materials otherwise wasted. This business is located in the center of a large and active resort and recreational region and near the Scranton and Wilkes-Barre coal districts. Products that will find local outlets or markets are emphasized and encouraged. Even hunting and fishing privileges are sold through private hunting clubs. A roadstand is in operation along a main highway, and cottages are built of lumber from the mill for the recreational trade.

INTEGRATED LOGGING AND PRELOGGING IN SOUTHERN OPERATIONS

Wherever possible and depending upon size and length, the following sequence is observed in southern prelogging operations. The first cuttings are usually conducted for poles and piling. The next step is to take out the saw logs and finally the pulpwood

Age of Stand (Years)	10-20	20-35	25-40	40-65
Products from Southern Pine ----- Second Growth and Plantations →	Posts Pulpwood Fuelwood →	Cross Ties Pulpwood Naval Stores Cooperage Stock →	Poles, Piling Naval Stores Pulpwood Cross Ties Saw Logs →	Saw Logs Poles Piling Pulpwood Naval Stores

FIGURE 11. Integrated uses of southern pine stands at various expected age classifications under favorable growing conditions.

including the tops left from saw logs and pole and piling operations. Normally the highest stumpage is paid for piling, namely, about $40 per M b.f. by Doyle scale up to 60′ to 80′ in length. Next in value, poles of 40′ to 70′ long command a stumpage of $30 to $35 per M b.f. Then saw logs commanding a stumpage value of $15 to $40 per M b.f. are taken and finally pulpwood which has commanded stumpage values of $2 to $4 per cord. Thus, the most valuable product is removed first because of possible injury or breakage in later logging, followed in order by those products of lower values. This is combined integrated utilization and prelogging, which means highly efficient and profitable use of the tree crop. The pulpwood industry is to be largely credited with this important development in the South.

Relogging consists of returning to a cutting area that has been previously logged for the larger and better-quality timber and taking out trees that were not considered profitable at the time the original felling operation took place. Many broken pieces, short and small logs that could not be efficiently logged with heavy machinery in the main operation, are taken. It is a form of salvage logging in many cases. For example, salvage logging may assume the form of cutting burned timber before insects and decay have destroyed it. Again, it may be used in the recovering of insect-infested timber without fire damage. Salvage logging is also a name used in connection with some forms of relogging operations. There is much relogging to recover pulpwood from old logging jobs as well as to secure peeler blocks (veneer bolts) from snags and windfalls in the Northwest or to recover good saw timber left in previous logging operations.

According to the Tennessee Valley Authority, more than 150 different wood products valued at more than $200 million were manufactured or processed by forest-products industries in the 125 counties of the valley in 1946. The six pulp and paper mills in the valley accounted for 21% of the total value.

It is estimated that the forests of the Northwest are producing approximately 25% more per acre than before the last World War because:

1. Each tree is producing a larger volume as a result of smaller size limits used, lower stumps, and utilization of top logs resulting in less wastage.

2. Species are cut that would not be taken before, notably the true firs and small-sized hemlock. A substantial part of this additional production per acre is secured through relogging of many of the areas formerly cut.

All these methods except integrated logging, have been most intensely developed in the Northwest. However, they have been applied and are used in the South and in other sections of the United States.

With the establishment of the Great Southern Lumber Company at Bogalusa, La., in 1909, integrated utilization began to make slow but positive progress in the South. Now it is an accepted principle on many logging operations that the products should be diversified rather than single purpose and that the raw material should be separated into its most profitable and useful products. In the South, emphasis has been on the integration of pulpwood and saw-log production and, to a less extent, of poles and cross ties, from the same stands. Pulpwood may be a product of thinning—producing forms of fiber products from the management of timber stands primarily for saw logs. On some operations, certain species and sizes may be best devoted to cross ties; veneer logs are selected from hardwood stands that principally produce saw logs. Black cherry and walnut logs are separated from the other primary products of the hardwood forests for the manufacture of furniture and similarly ash logs for handle stock. On the West Coast, the largest and best Douglas fir logs are known as peeler logs for the manufacture of veneer. West Coast hemlock is largely separated for use as pulpwood; about 70% of this species going into pulp. Thus, each species, size, and quality of product is assigned to its highest utilitarian use. A good example of integrated utilization exists in the South where the stumpage values of trees of certain diameters are found to be three times as much in the form of saw logs as in the form of pulpwood, and still greater when the trees are used for pole and piling purposes. Much trading of logs in the Northwest assumes the form of integrated logging. For example, a plywood company doing its own logging will trade hemlock and white fir logs to pulp mills, Douglas fir saw logs to sawmills, and cedar to shingle mills in return for peeler logs produced by those companies. Much progress has been made in the development of integrated utilization of primary products during the past 40 years.

SANITATION AND SALVAGE CUTTINGS

Since 1940, sanitation and salvage cuttings have been used on forestlands of the International Paper Company * and other

* From data supplied by J. E. McCaffrey and C. A. Brown.

southern operations which have added much to the complete and efficient utilization of their timber resources.

These cuttings consist of taking out the tops for pulpwood (salvage cuttings) that have been left from saw-log operations. They also include the cutting and use for pulpwood of deformed, crooked, diseased, and otherwise defective trees (sanitation cuttings) left from saw-log operations. The usual practice is to secure about one-half cord of pulpwood from the tops of each thousand board feet of saw logs cut. The saw timber on the holdings of this company in the South generally averages about 2 saw logs per tree. This leaves one to three sticks of 5′3″ pulpwood in the tops. Formerly these tops were left to rot and be wasted. However, they added considerably to the fire hazard. Also the sanitation cuttings meant the elimination of deformed and crooked trees from the stands. This relieved undue competition among the trees left for later cuttings. These salvage and sanitation cuttings resulted in better silviculture and more complete utilization. A good example of these cuttings was shown by one dealer who shipped 14 carloads on an average per week of pulpwood (15 cords per car). Of this quantity, 85% was composed of salvage and sanitation cuttings as above.

These new developments have definitely contributed to better and more efficient utilization of standing timber throughout the United States.

8 · SOURCES OF WASTE IN HARVESTING STANDING TIMBER *

Much wastage has attended the conversion of American and Canadian timber to useful forms. A large portion of the trees felled on logging operations is still wasted before reaching final utilization. This is due principally to unfavorable economic conditions, that is, failure to determine a profitable outlet for waste in logging and manufacture. The degree of utilization is closely related to market prices and transportation costs. High stumpage and end-product values mean more complete and efficient utilization of raw materials produced from our timberlands. Fundamentally, the percentage of utility of a tree depends upon two

* For further reading see Wood Waste in the United States, *U. S. Dept. Agr. Forest Service Rept.* 4 of Reappraisal, Washington, D. C., 1947.

factors: (1) economic conditions and (2) technical knowledge for creating processes and equipment to produce materials we want and are willing to pay for.

Great improvement in utilization has been noted during the last several years, in spite of the fact that less than one half of the trees cut in the woods is used, as contrasted with about 80

FIGURE 12. Power-driven chain saws have reduced stump heights and materially saved much good wood formerly wasted. This shows a very low stump cut of longleaf pine that has been turpentined. *Courtesy Southern Pine Association.*

to 90% in various parts of Europe. The greatest wastage occurs in large-scale conversion of the relatively lower-priced species such as southern pine and Douglas fir. It is estimated that more than 6 million cords of softwood, or 42 cords per acre, are annually left in the woods after logging in the Douglas fir region. This quantity is sufficient to supply about one-fourth the entire Nation's demand for pulpwood The principal sources of waste in the woods and at sawmills and processing plants in converting standing timber to lumber and other forest products * are shown in Table 3.

* For further treatment of this subject see *Lumber* and *Logging,* both published by John Wiley & Sons, New York.

TABLE 3

		Percentage of Total Wood Volume Wasted
Items of woods losses		
Stumps	2	
Tops, limbs, and branches	10	
Defective stems and those shattered in felling	4	
Miscellaneous, as improper log lengths, transportation losses, storage decay losses	1	17
	—	
Items of manufacturing losses		
Bark	7	
Saw kerf	9	
Edgings and trimmings	6	
Slabs	8	
Seasoning	2	
Remanufacture	3	
Miscellaneous	1	36
	—	—
Total woods and manufacturing losses		53

More and more of these losses are being reduced by improvements in conversion processes and in the increased utilization of some of these materials, notably in prelogging, relogging, salvage, and sanitation cuttings described previously. Mechanically operated chain and circular saws have definitely reduced losses in felling, especially in the Northwest where springboards were commonly used with high stumps.

9 · DEVELOPMENTS IN REDUCING WASTE

Many of the products described in this book serve in a substantial manner to reduce the waste incident to the harvesting of American timber. Some improved practices apply to one or several products. Some apply only to lumber or closely related products. Integrated utilization, that is, a combination of several uses from a given tract of timber, or varied uses of the primary product logs, has marked the developments of the last several years. Furthermore, some products may include a combination use of both woods and mill waste, as in pulpwood.

Some of these commodities furnish opportunities for improvements in more efficient utilization of raw materials from the forest.

It seems likely that, with further experimentation and research, still further progress may be made in increasing the use of materials now wasted in the process of converting standing timber into useful commodities. Among the more important developments, as applied to the major product (lumber) and minor products, are:

1. Installation of pulp and fiberboard mills partially to utilize woods and sawmill waste, particularly in the Pacific Northwest and South. Large quantities of sawmill waste are hogged and shipped to mills in the Douglas fir region. A large fiberboard plant in Laurel, Miss., uses large quantities of mill waste. Heretofore, the mill refuse has been burned at considerable expense; it is now sent to a large pulp mill. Pulp mills in the South use mill and woods waste and silvicultural thinnings and cuttings made purposely for pulp as well as for improvement of the remaining forest.

2. The use of band saws in small and portable mills as well as in large mills; also Swedish gang sawmills on the West Coast which manufacture principally softwood boards of 2″ dimension and 1″ boards. Many of these mills are the sources of cross ties, boxboards, crating stock, hardwood dimension stock, hardwood flooring, tool, implement, and vehicle stock. Approximately 10% of the total volume of saw logs goes into sawdust. Circular saws convert almost twice as much wood into sawdust as band or gang saws.

3. Lower stumps and increasing utilization of top logs. National Forest timber sales set excellent standards in these and other respects for the efficient utilization of standing timber. Stumps are being cut much lower unless butt rot is present. Private operators appreciate that the best wood in the tree generally occurs in the butt log and that stumps therefore should be cut as low as possible. Many longleaf and slash pine stumps are being utilized for pine distillation in the South. The use of power saws has materially assisted in cutting lower stumps.

4. Increasing conversion of top logs into cross ties, boxboards, piling, posts, small poles, pulpwood, and fuelwood. In Arkansas, top logs of white oak, once wasted, now serve for heading in the important local cooperage industry.

5. Increased manufacture of broom and other handles; and automobile, furniture, tool, and implement parts; toys, novelties,

and other products from slabs, edgings, and other forms of sawmill waste. Lath is still made from slabs but not in such large quantities as formerly, owing to the substitution of metal lath,

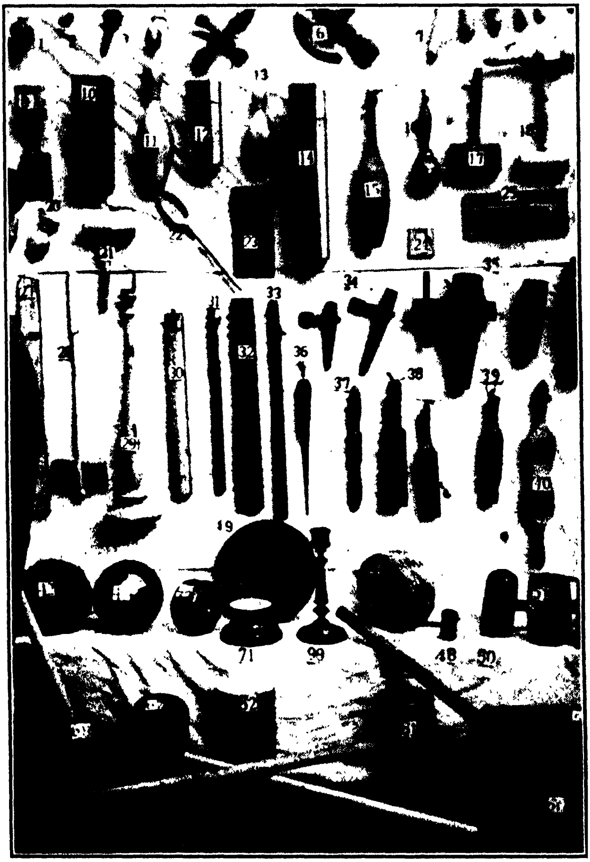


FIGURE 13. Sixty varieties of novelties, handles, toys, and other products manufactured from materials that would otherwise be wasted.

wallboard, and other forms of replacement. Less sawmill waste is going to the refuse burner, and more is devoted to the manufacture of small wooden parts and other small articles, aside from pulpwood, described above in 1.

6. Installation of boxboard and crating (shook) factories in connection with sawmills and other wood-using industries. The increasing demands for suitable containers, made by the Cali-

fornia, Florida, and Texas citrus trade, as well as by the fruit and vegetable growers in many sections, have directly affected the veneer, cooperage, and boxboard industries. Fruit and vegetables are being shipped in wire-bound boxes made of rotary veneers and in various forms of containers fashioned from veneer, plywood, and crating stock. About 13 to 16% of all lumber normally goes into boxboards and crating material. Additional large quantities are made from veneers and slabs from sawmills.

7. Increased use of hardwood dimension, that is, small squares and pieces of short lengths and narrow boards for chair and ladder rungs, furniture parts, automobile and trailer bodies, handles, and tool, implement, and machinery parts. This has resulted in much more efficient utilization of hardwoods, especially oak, maple, gum, yellow poplar, hickory, ash, birch, beech, elm, cherry and basswood.

8. Fuelwood from woods and sawmill waste. Gasoline motors have replaced steam boilers as sources of power for thousands of small sawmills, for reasons of greater efficiency and economy, and because slabs, edgings, and so on may be profitably sold for fuel in local markets. Probably the outstanding development in this connection has been the large consumption of sawmill waste for fuelwood in the Northwest, especially the use of hogged fuel for furnaces in connection with forced draft for heating hotels, industrial and office buildings, as well as homes. Hogged fuel has provided an annual outlet for many million cubic feet of material. Coal and oil are not locally produced in many sections of the Rocky Mountains and Pacific Coast, and hogged fuel as well as other forms of woods and sawmill waste are widely favored in these sections as sources of fuel supply. Enormous quantities of fuelwood are still wasted, however, owing to the prohibitive costs of cutting, assembly, and transportation, compared with delivered prices.

9. Uses for sawdust. Sawdust, amounts of which equivalent to about 3.6 billion b.f. are produced annually in normal times, is being increasingly employed for fiberboards, linoleum, and other floor coverings, for wood flour, plastics, and insulation for refrigerators. Other common uses are for packing in barrels and other containers, mulching for flowers and vegetables and for trees planted in the autumn, fuel under boilers, horse bedding, flour mopping and cleaning, and ice packing. However, in spite

of progress made, a very large percentage of sawdust is still wasted or disposed of at some expense.

10. Uses for bark. Bark of some species, notably that of California redwood, is shredded, baled, and used for insulation and packing. Many uses have been developed for Douglas fir bark at Longview, Wash. Hemlock and white oak bark, and also tanbark oak, have extensive applications for tanning purposes. The harvesting of cascara bark furnishes a local industry and some employment in the Pacific Northwest. Silvacon, a product of Douglas fir bark, is described later in the text.

11. Uses for shavings. Shavings from planing machines are being successfully converted into briquettes and sold for fuel in several mills in Idaho, Washington, Oregon, California, and elsewhere. This product is described later in the text.

12. Much less wastage in making tight cooperage. Less wastage in making tight cooperage, especially split staves, has distinguished this industry during the past 10 years. It has been demonstrated that sawed staves are as impervious to liquids as split staves, but strong prejudices, especially in the export trade, continue in favor of split staves.

13. Cross ties sawed more than formerly. The exceedingly wasteful hewing method of making cross ties is not so prevalent. Slabs made from tie sidings at sawmills produce clear grades of lumber and are being profitably sold and utilized.

14. Greatly improved practices in the gum-naval-stores industry. Former wasteful methods of streaking, cupping, and collecting gum have been changed, with resultant increase in value of the product. Life of trees for tapping has been extended, and more economical practices are in effect generally, as is noted in the chapter on naval stores.

15. Developments of new products from waste. Relatively little progress was made until about 1925 in the utilization of enormous quantities of waste incident to the manufacture of lumber other than as fuel. Within the past 20 years, largely because of changed economic conditions, large quantities of sawdust, slabs, edgings, and other sawmill refuse and woods waste have been converted into fiberboards, insulation boards, pulp, wood flour, fuel for heating both commercial structures and dwellings, fuel briquettes and Pres-to-logs. Bark once widely wasted is now being converted into nine different commercial products

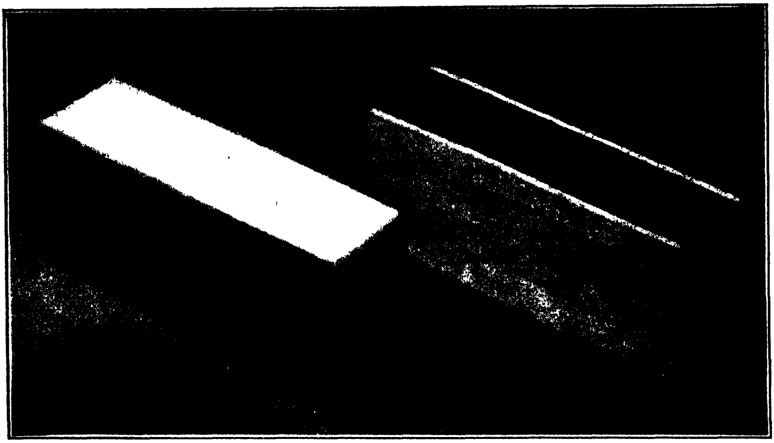


FIGURE 14. Wood sandwiches. Examples of so-called "sandwich" materials fabricated at the U. S. Forest Products Laboratory. At the left is pure cellulose acetate faced with papreg which is a compressed laminated paper product impregnated with resin. At the right, highly carbonized rubber faced with plywood. *Courtesy American Forest Products Industries.*

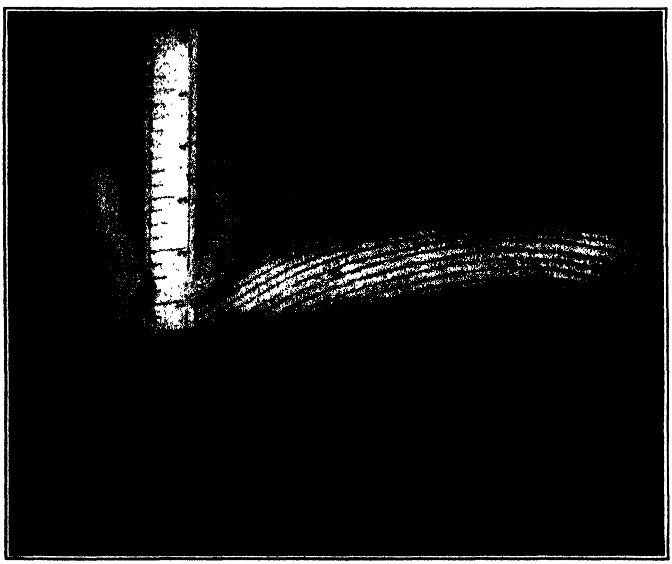


FIGURE 15. Example of one form of densified wood known as Staypak shown in foreground as compressed to less than ½″ in thickness from the original piece of white fir almost 2″ thick. *Courtesy U. S. Forest Products Laboratory.*

at one West Coast sawmill. Among these bark products are glue extenders, molding compounds, soil enrichers, and even cork. Both bark and wood flour serve as filler for plastics. Hogged sawmill waste and sawdust are under trial for conversion at a new plant near Springfield, Oreg., into wood sugars and then into alcohol, with many other possible by-products such as lignin, methyl alcohol, naval stores, fodder yeast, molasses, and furfural. Sawmill waste has also been converted into high-grade charcoal suitable for use in chemical industries.

10 · FACTORS DETERMINING THE MOST PROFITABLE FORM OF PRODUCT

The success of American forestry in the business of growing and using timber is largely dependent upon satisfactory financial profits secured from these operations. Successful and efficient utilization is the keynote of handling our timberlands on a satisfactory basis. This success, in turn, is dependent to a large degree upon the knowledge of the most profitable form of utilization. A given forest may be converted into a great variety of products. The forester should be able to determine which products will yield the greatest profits in the harvesting of the raw timber and converting it into useful forms. This is dependent on the knowledge, experience, and skill of the forester or operator in charge. For example, a white oak forest in Indiana may be converted into saw logs, veneer, tight cooperage stock, handle or implement stock, hardwood dimension, or specialized forms of furniture, automobile construction, or other uses.

The forester should be able to determine which of these outlets provides the greatest profit. The stumpage value of this oak may vary with each product—that is, if converted into lumber, the value of the standing timber may be less than if converted into rotary or sliced veneers. Black walnut when converted into certain forms of veneers may be far more valuable than when converted into certain forms of lumber. Southern pine timberland may, under certain conditions, find its most profitable outlet as naval stores, piling, poles, material for softwood distillation, pulpwood, or a combination of these products.

It is the duty of the forester to determine which is the most profitable outlet for the available raw material, which is the standing timber. In the Northeast, hard maple may find its most valuable stumpage price as a source of material for heel stock, mangle rolls, or furniture stock, rather than as lumber for the general market. Perhaps a maple grove may be most valuable as a continuing source of annual tapping for sugar and sirup. Spruce of a certain size in Canada and New England may be

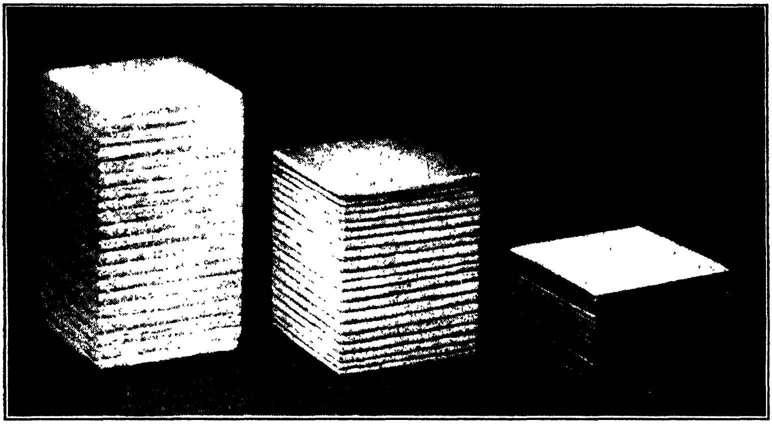


FIGURE 16. Illustration of compressed wood known as Compreg. This is one of several forms of compressed, densified, or modified wood. All three piles have the same amount of wood in them, but they have been subjected to different pressures. At the left are ⅛" untreated strips with assembly pressure of 150 lb. per in. In the center, wood has been treated with resin under pressure of 250 lb. On the right, the block has been compressed by 1000 lb. of pressure. Compreg can be compressed to one-third its normal thickness and is adaptable to appreciable molding before the resin sets. *Courtesy American Forest Products Industries.*

more valuable for lumber than for pulpwood. Port Orford cedar may be most valuable for export in the log form or for conversion into specialized forms of boat-building lumber.

The forester must be fully acquainted with every possible outlet for each kind of wood, so that he may advise or direct its conversion to hardwood distillation, cooperage, veneers, cross ties, or other products in order that the most satisfactory price may be obtained for the standing timber. Some of these may be the major product or a by-product or the means of converting woods and sawmill offal, otherwise wasted, into profit.

In some sections of the United States, integrated use has to a considerable extent replaced lumber as a single-purpose product; forests are being managed to supply several products instead of a single one. Our lavish and profuse resources in timberlands have naturally created economic conditions that have not been conducive to high utility. As these conditions change from superabundance to a balanced situation, it can be anticipated that the utilization of raw materials from the forests will increase accordingly.

The principal factors to be considered in determining the most profitable product are (1) species; (2) sizes available; (3) local, regional, or national market possibilities and prices; (4) quantities available; (5) quality of the standing timber (freedom from knots or other defects, straightness, and form of bole, etc.); (6) accessibility; and (7) method of transportation (truck, rail, stream, or barge delivery, etc.).

QUALITY CONTROL * AND THE UTILIZATION OF LOW GRADES AND REGROWTH TIMBER

The problem of complete and efficient utilization of low grades of lumber and low-grade trees has always been a perennial problem in forest utilization. To do this at a profit has been difficult and in some sections and with some products impossible. As shown in the records of grade outturn of the various-sized logs and species, a very large share of our timber products is composed of low-grade or defective material: that is, lumber and forest products with a large number of knots and defects such as wane, pitch streaks, stain, pitch pockets, checks, and shake. With greater dependence on regrowth instead of on virgin forests, this problem is becoming intensified.

The profitable utilization of the lower grades of lumber and defective and misshapen regrowth timber has been an important and chronic problem in forestry.

Generally, defective trees, small logs, and top logs have been converted into cross ties, posts, mine timbers, box and crating materials, small poles, pulpwood, and fuelwood whenever possible. In some sections of the United States, however, there is not a profitable market or outlet for some of these materials. The

* For further reading on quality control see *Management of Inspection and Quality Control*, by J. M. Juran, Harper & Brothers, New York, 19‥

hogging or conversion of some of them into chips for manufacture into fiberboards, floor coverings, and a mulch for trees and vegetable crops is dealt with later in the text. This is also related to integrated logging which is also discussed. Because of the increasing problems of profitably using regrowth timber, this subject is intimately related to quality control.

As the name suggests, quality control is the operation of making certain that the products from a factory, mill, or assembly line conform to standards set by the manufacturer's or buyer's specifications. Quality control men do not wait for the final inspection of the finished product to discover defects and discard material not up to specifications. They detect defects in the manufacturing process as they occur. Sometimes this is done by constantly sampling parts as they pass through the operation. Quality control has developed notably in the hardwood dimension and the plywood industries. Serious losses have occurred during the manufacturing processes. In one instance a wooden product was not properly located in the machine; in another a slight alteration in the tooling was necessary. In the third example tool-sharpening habits had to be changed. Many thousands of dollars have been saved in some instances through the reduction of rejected goods which generally takes place on final inspection. In this way, production costs are reduced by detecting, as they occur, improperly manufactured products that fail to conform to specifications. Thus, quality control employs the law of probability in detecting trouble in a production line or manufacturing process before the defective goods accumulate. This system of quality control was worked out in principle about 1925 by Dr. W. A. Shewhart * of the Bell Telephone Laboratories. Quality control is spreading rapidly throughout the wood-products industries as well as in many other manufacturing processes. This has great potentialities in helping to solve the utilization problems of the country.

* For further information, see *Economic Control of Quality of Manufactured Products*, by W. A. Shewhart, D. Van Nostrand Co., New York, 1931.

11 · DEVELOPMENT OF STABLE COMMUNITY LIFE THROUGH PERMANENT AND DIVERSIFIED INDUSTRIES MAINTAINED BY SUSTAINED-YIELD MANAGEMENT

Considerable progress has been noted in the development of permanent and stable communities through sustained-yield production as well as sustained utilization of forest products by diversification of industries dependent upon tributary timber for their sources of supply. Integrated use of forest produce has marked the progressive development of the past two decades. There have been more year-round than seasonal activities and employment, which have given greater stability and a sense of security to employees in these industries. The following are notable examples of outstanding communities with one or more forest industries, which have been the very "fiber and lifeblood" of their existence and stability. The payrolls from these industries have meant permanence of commerce and trade, banking, and transportation, as well as export business at seaboard communities. Some of these communities may be partly or wholly dependent upon forest industrial enterprises.

1. Laurel, Miss., where there are large sawmills of both pine and hardwood, a large fiberboard mill (Masonite), furniture and veneer mills.

2. Brewton, Ala., where there is a large longleaf pine sawmill, timber-preservation plant, turpentine still, veneer mill, boxboard factory, and other units supplied by forests managed on a sustained-yield basis.

3. Tupper Lake, N. Y., an important sawmill and wood-using industry center for more than 100 years. There are now three sawmills producing northern hardwoods, hemlock, and white pine lumber and turning out specialty materials. Two of these mills produce rough turned blanks for bobbins, lumber for boxes and crating materials, flooring, and a number of specialties. The annual production is about 35 to 40 million b.f. The largest sawmill in the East has two band saws and one gang. It also has a large veneer mill which specializes in wood and paper dishes, wooden tableware, and commercial veneer. Much of the

hardwood lumber goes into the important furniture industries of New York and New England.

4. Cloquet, Minn., where there are white pine sawmills, pulp and paper plants, insulating- and fiberboard plants, and similar industries in and about this city.

5. Longview, Wash., with two of the largest sawmills in the world, large pulp and paper mills utilizing sawmill waste, veneer, box shook, and related activities—also a timber-treating plant. The Weyerhaeuser Timber Company maintains a large forest-products laboratory which has developed outlets for bark utilization and many others.

6. Tacoma, Wash., one of the most varied and important lumber and wood-producing centers in the United States. There are 26 mills in the area employing about 2600 men; three of them employ more than 500 each. A large pole company with treating facilities produces about 25,000 poles per year. There is a large kraft paper mill with 300 tons daily capacity and a newsprint mill producing groundwood for newsprint with production of 50 tons of newsprint per day. Tacoma is outstanding in veneer and plywood production and in the manufacture of doors and furniture. Normally more than 223 million sq. ft. of plywood are produced from several plants. In one year, more than 4,100,000 doors were manufactured. There are 14 furniture factories employing about 1600 men. There are two large box factories which make wooden and plywood boxes and furniture panels. There is a large fiberboard plant and numerous woodworking, millwork, and cabinet factories. There are also three shingle mills, two wood-flour mills, and a variety of other establishments which utilize a vast amount of logs from the storehouse of near-by Douglas fir, West Coast hemlock, spruce, cedar, and white fir forests.

7. Crossett, Ark., which has developed into a very important integrated utilization center with large and active producing forests contributing to it on a sustained-yield basis. There are two sawmills with an annual output of about 50 million b.f., a large pressure-timber-treating plant, a wood-distillation plant producing charcoal, acetic acid, wood alcohol, and a variety of oils. The sulfate kraft mill produces 300 tons of kraft paper and cylinder board per day. There is also a large paper-bag plant.

8. Brunswick, Ga., and vicinity, where there are timber-treating plants, sawmills, veneer plants, pole and piling yards, turpentine stills, pulp and paper mills, etc.

9. Bogalusa, La., where a large container mill, sawmill, timber-treating plant, and several wood-using industries are located.

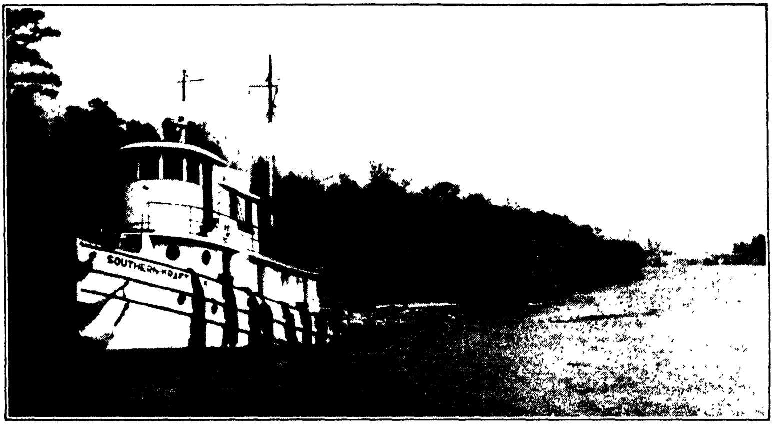


FIGURE 17. The annual production of about 22 million cords of pulpwood has become a very important business in the American forests. Pulpwood has become the third most important product of our forests, following lumber and fuelwood. This picture shows a tow of four barges, 32 ft. wide and 126 ft. long, each barge containing 250 cords—total in tow, 1000 cords equal to about 60 carloads by rail. This 5′ 3″ pulpwood is towed about 110 miles from Wilmington, N. C., as well as from other points to Georgetown, S. C., where the largest pulp and paper mill in the world uses about 2500 cords per day. This mill receives wood by rail, truck, and barge. *Courtesy Joseph E. McCaffrey.*

10. Portland, Oreg., and vicinity, where there are several large sawmills, box factories, pulp and paper mills, timber-treating plant, many woodworking industries and furniture factories; this is also a great lumber-export, intercoastal, and coastwise shipping center. It is the headquarters of several large lumber associations and of the regional office and experiment station of the U. S. Forest Service.

11. Aberdeen and Hoquiam, Wash., where there are several sawmills, veneer mills, pulp and paper plants, box-shook factories, shingle mills, and exporting and shipping centers for lumber, cross ties, timber, and piling.

12. Coeur d'Alene, Idaho, and vicinity, which is an important center in northern Idaho for lumber, pulpwood, cross ties, western red cedar poles, posts, match blocks, and other forest products. This is a leading center for concentration, manufacture, and shipment of these products as well as headquarters of important timber interests, forest industries, and supervisor headquarters of an important National Forest.

13. Rainelle, W. Va., which has the largest single hardwood mill in the world and is located in the heart of the Appalachian hardwood region. There are three 9′ band mills processing principally oak, maple, beech, birch, ash, yellow poplar, gum, hickory, basswood, and other hardwoods. It is an important center for the fabrication of semimachined materials principally oak, beech, birch, and maple flooring, parquetry flooring, interior trim of all kinds, bowling-alley stock, solid furniture hardwood dimension, completely machined and ready for assembly at destination plants. Also a considerable volume of wood residue is manufactured and sold in the hogged-up form for use in other industries.

14. Kingsport, Tenn., a center of large and important industries of many kinds, including a hardwood sawmill, a rayon and plastics plant, a large pulp and paper mill, and miscellaneous industries partly or wholly dependent upon the forest as a source of raw material.

15. Memphis, Tenn., for many years the great national production center of the hardwood industry. In a normal year, more than 53 million b.f. are produced from 28 active sawmills in and about Memphis. There is a cross-tie timber-treating plant, the largest hardwood-flooring plant in the world, many woodworking concerns making furniture, hardwood dimension, and specialty blanks for such items as golf heads, skis, handles, tools, implements, and a great variety of wood products. There are five important veneer and plywood plants. Hardwood logs come to this active center from Arkansas, Tennessee, Mississippi, and up and down the Mississippi Valley.

16. Eureka and Humboldt County, Calif., one of the more important lumber and forest products centers on the West Coast. There are 46 billion ft. of standing timber in the county and 60% of the world's supply of redwood. In 1944, there were 40 mills, and, in 1950, 160 mills. The annual cut has been about 600 million b.f., largely from six of the largest redwood mills.

There are many specialty products such as battery separators of which 175 million are annually produced; wire-bound boxes; fruit, vegetable, and fish boxes; barrels and box covers; a plant making insulation from ground redwood bark and redwood soil conditioner. A large plant makes redwood crossarms; another, cross ties; still another, shingles. There are three veneer and plywood plants and four mills making redwood novelties such as redwood burls and souvenirs.

17. Goodman, Wis., founded in 1907 with only a sawmill. This is a unique development in integrated and complete utilization of forest resources under sustained-yield management. By selective logging on 70,000 acres the forest growth has been accelerated to provide for increasing demands for wood products. In addition to the sawmill, there are several forest industries making finished hardwood dimension for furniture and other industries and face and center stock veneers for plywood. A large hardwood-distillation plant makes charcoal for steel industries using carbon; crude methanol and acetate of lime for distillers making commercial solvents and wood defibration chips for making prepared roofing and plastics. This leaves only the sawdust and bark which, in turn, are used for fuel in the power plant.

18. Neopit, Wis.,* an interesting utilization center and sawmill town of the Menominee Indian reservation of 234,000 acres established in 1854 by treaty between the Menominee tribe of Indians and the U. S. Government. In 1908, Congress authorized a cut of 20 million b.f. per year. The economy of the entire reservation is built around its lumber industry. Income from the sale of lumber and forest products provides capital for logging and sawmill operations for the support of two parochial schools and a modern hospital and for pensions and other relief for the tribe's old and indigent members. Few communities or groups of people in the nation are as nearly self-sufficient as the Menominees in Wisconsin. The forest is on a sustained-yield basis of management and will supply the sawmill with logs indefinitely. It contains about 1 billion b.f. of hemlock, white pine, and northern hardwoods. In addition to the sawmill, there are a chipper, lath mill, planing mill, dry kilns, and pallet plant. The sawmill averages about 8 M b.f. per hour of hemlock or 6 M b.f. per hour

* From data supplied by John W. Libby, Forest Supervisor.

of white pine or 4.5 M b.f. per hour of hardwoods. The planing mill processes about 10 M b.f. per hour, and the dry kiln has a capacity of 220 M b.f. The pallet plant was installed to utilize low-grade lumber and has an annual input of 2½ million b.f. It produces about 500 pallets per 8-hour day. Slabs and edgings go to the lath mill and chipper. Most of the lath is used for snow fences, whereas the chips are employed in the manufacture of roofing. Thus, there is complete utilization of raw material, steady employment, community stability, and no depletion or exhaustion of capital forest resources.

19. Eugene, Oreg., containing 53 sawmills with a daily capacity of 2140 M b.f. In one year Lane County, in which Eugene is located, produced about 1⅓ billion b.f. Other important industries are a shingle mill; a plywood plant with a yearly capacity of 80 million sq. ft.; a box plant with 1500 M b.f. annual capacity; 2 creosote timber-preservation plants; 5 pole and piling plants; 11 remanufacturing plants; a furniture factory; a molding, sash, and door plant; an excelsior plant; a fabricating plant; a handle factory; and a hardwood mill.

20. Roseburg, Oreg., containing 24 sawmills with a daily productive capacity of about 1 million b.f. Douglas County, in which Roseburg is located, recently had an annual production of about 800 million b.f. of sawed products. It also has a pencil slat plant; a plywood plant with 36 million sq. ft. annual capacity; a pole and piling producer; 7 remanufacturing plants; a molding, sash, and door plant; and a battery separator plant.

Many other communities of equal or less importance might be mentioned, such as Seattle, Springfield, Oreg.; Vancouver, B. C.; Lewiston, Idaho; Franklin, Va.; Gardner, Mass.; Brunswick, Ga., St. Joe and Pensacola, Fla.; Louisville, Ky. Some are entirely dependent upon forest industries, manufacturing one or several products such as, in the South, lumber, cooperage, veneer, wood pulp, distillates, and naval stores; in other parts of the country there are pulpwood and paper mills, cross-tie units (chiefly small sawmills producing lumber as well), wood-distillation, tannic acid plants, pole, piling, and post-concentration yards.

12 · FARM WOODLANDS AS SOURCES OF FOREST PRODUCTS

Many forest products are produced from small farm timber tracts. Collectively these woodlands contribute an enormous quantity. In some sections of the North and South, in addition to supplying saw logs, they are important sources of pulpwood,

FIGURE 18. Some unusually fine yellow poplar veneer logs cut from farm wood lots in New York as decked on elevated landing ready for truck shipment to veneer mill. *Courtesy American Forest Products Industries.*

cross ties, fuelwood, mine timbers, poles, posts, piling, bridge timbers, naval stores, distillation wood, grape stakes, hop and bean poles, and many other forms. The yearly value of the forest products from farm woodlands is normally about $240 million. Fuelwood is produced principally from farm woodlands. Each farm family uses 12 to 25 cords annually, the average being 17 cords.

About 185 million acres (about 75% of all privately owned forest) are found in farm woodlands and, of this area, 95% is in the eastern portion of the United States. The average small private forest—largely farm forest is only 62 acres in area, and there are 4,200,000 owners of these small holdings. The farm woodland is relatively most important in the Central States, largely in the Ohio Valley, where it includes one half of the commercial timber. In the South and Middle Atlantic States, farm woodlands comprise one third of the commercial forests. Furthermore, these woodlands are located favorably in relation to important wood-consuming centers and industries. The *most* important single element in successful management of farm woodlands is a profitable outlet for the products of them. In Maryland, Indiana, Ohio, Michigan, New York, Florida, Tennessee, Georgia, Virginia, Alabama, Texas, Arkansas, the Carolinas, and Mississippi, special efforts have been made to develop and encourage better marketing of forest products from these scattered and relatively small wood lots. Farm foresters of the U. S. Forest Service and Extension Foresters have been of great assistance in this activity. In many states, the cash income derived from the sale of cross ties, pulpwood, poles, posts, piling, and the like represents a very substantial share of the owner's annual income. Unfortunately, trees are too frequently felled at their most rapid-growing period; they should be left until they attain larger sizes. Wood accumulates in woodlands as money at interest in the bank and constitutes a growing financial asset which is coming to be more and more recognized.

The largest total acreage of forest found in farm woodlands is in the South. The second most important acreage is found in the Central States, the third in the Lake States, the fourth in the Middle Atlantic States, and the fifth in New England. Relatively little farm woodland area is found in the Pacific Coast States, but even this is coming to be of importance. In the Rocky Mountain region, farm woods are of relatively little importance.

In Vermont and New Hampshire farm woodlands rank first in cash income among all the farm crops. According to the U. S. Forest Service, woodland represents 41% of all farmlands in Vermont and produces 54.8% of all cash income, exceeding the next ranking incomes such as potatoes, hay, and truck crops, in order of importance. This relatively large income from woodland is attributed principally to maple sirup and sugar.

In Indiana, farm woodlands represent 15% of farmland areas; they yield an annual cash income of over $1 million, which represents 1.9% of all farm cash incomes, and they rank eighth among all crops in value. The average cash income from farm woodlands is frequently $100 per year per farm in many parts of the country.

13 · PRINCIPAL DEVELOPMENTS AND ADVANCES MADE IN RECENT YEARS

Starting with rather primitive conditions and relatively little interest in efficient utilization and featured by abundant timber supplies, low stumpage, and lumber values, and stimulated by energetic and active forestry programs, notable advances have been made in the techniques of forest utilization in the United States and Canada. These advances have been closely integrated with progress made in other major forestry fields, such as silviculture, forest protection, and management. These advances have largely been dependent upon and closely associated with changing economic conditions such as growth in population, westward expansion of the lumber industry, regrowth of forests in scattered locations, agricultural and industrial developments, and the effects of two world wars.

These developments and advances may be summarized as follows:

1. It is estimated that in 1900 the utilization of sound wood from trees cut in the forests was only about 30%. By improved methods, more intense utilization, and recovery of wood formerly wasted it is estimated that by 1950 the utilization of trees felled in the woods increased to about 47%.

This advance in more efficient utilization of standing timber is especially found in such higher-value species as the white (northern, Idaho, and sugar) and ponderosa pines, cypress, cedars, white oak, black cherry, ash, walnut, and yellow poplar, and to a considerable extent in southern pine, Douglas fir, the spruces, and redwood.

2. Widespread use of integrated utilization in connection with partial or selective logging insures current revenues, improves the growing conditions of the stand, and assures a program of sustained-yield management for the future. This has been widely applied except in some stands of mature and even-aged Douglas fir, lodgepole pine, western white pine, and aspen types of timber.

3. Concurrently with the gradual reduction of the number and importance of large sawmill and processing units especially in the Northwest and South, has come the development of large numbers of small sawmill operations and processing plants in

regrowth timber. There are now about 70,000 logging operations to supply 60,000 sawmills, wood-pulp, cross-tie, cooperage, and other wood-processing operations. These operations also provide raw material for veneers, poles, posts, fuelwood, and many others.

4. Notable developments for improving the methods used in manufacturing many products, especially in pulping and chemical processing, apply particularly to paper and pulp manufacture, plywood, naval stores, fiberboards, softwood distillation, and other phases of the forest industries.

5. Developments have been made in increasing the weight and hardness and improving the dimensional stability and other characteristics of wood through impregnation and pressure treatments known as wood densification. World War II brought forth many new forms of wood densification.

6. Great advances in the development of better adhesives have assisted in making plywood the most important product of relatively increased use among all forest products during the past 50 years Improvement in adhesives, particularly of moisture-resistant types, has made possible the use of plywood and glued-laminated wood assemblies in boats. It has also contributed to the use of laminated members for heavy truss construction and the gluing together of narrow boards to make wider ones and to the making of finger joints to join short lengths to make long pieces. These have materially assisted in closer and more efficient utilization of otherwise waste materials.

7. Over the 50-year period there has evolved a very significant unification of the viewpoints of the forester and the wood processer on problems of how best to convert and utilize both our virgin and regrowth forests. Widely at variance with each other at first, each has learned much from the other. The result has been an improved and usually workable plan for harvesting and utilizing our timber resources along lines that serve both current business returns and long-range forestry viewpoints.

Thus additional raw materials are being made available to the wood-using industries by improved forestry practices. Since 1930, and increasingly since 1940, thinnings and other stand improvement cuttings in regrowth forests and planted areas are developing new sources of wood, principally for pulp, poles, small logs, cooperage stock, posts, and fuelwood. In the Pacific Northwest, it is estimated that an average acre of second-growth

Douglas fir, after 20 years of age, loses one cord every year from decay and mortality. This loss can be largely salvaged by periodic thinnings. Such practices, somewhat experimental in the West but well established in the South and Northeast are

FIGURE 19. Several important and recent uses of wood. Chairs covered with rayon damask made from wood cellulose. The drapes are made of paper and may be replaced at less cost than cleaning of fabric draperies. *Courtesy American Forest Products Industries.*

substantially increasing the current supply of raw material and also contributing to longer future yields.

8. The gradual reduction of logging and wood-processing waste and the increased and more efficient utilization of the raw-material logs, has definitely resulted in the following:

(*a*) Man-hours of employment have increased.

(*b*) The life of our timber resources has been prolonged.

(*c*) There are greater industrial activity and increased life expectancy of forest industries dependent upon the multiple use of these resources.

Moreover, the increased stumpage values varying from 100 to 300% or more above prewar levels have resulted in more intensive utilization of our standing timber. Owing to the in-

FIGURE 20. Various wood plastic products. During recent years many cellulose and lignin products have been developed as a result of research. One acre of southern pine will produce about five times as much cellulose in a given period as will an acre of cotton. *Courtesy American Forest Products Industries.*

creased value of the end products, logs are utilized to smaller top diameters, lower stumps are cut, and many species heretofore considered of little or no value have come into active and profitable utilization. Many hardwoods have advanced in stumpage values of from $3 to $10 up to $10 to $40 or more and softwoods relatively more. In the case of prime peeler logs in Douglas fir, $40 to $60 per M b.f. stumpage have been paid. Prime white oak stave stumpage has brought $50 to $70 or more in Arkansas.

9. There is the gradual recognition that wood is destined to

continue as a very important, if not the most important, raw material of the future because:

(*a*) It has so many uses and is readily converted into many shapes, sizes, and forms.

(*b*) It is relatively inexpensive compared with other materials used for similar purposes.

(*c*) It is renewable.

FIGURE 21. Two good uses for wood lot thinnings. The fence posts and rails shown in the foreground came from thinnings—also the logs from which the barn was constructed. All are cut from lodgepole pine in the northern Rocky Mountain region where lodgepole pine is one of the important species. *Courtesy American Forest Products Industries.*

10. The increasing emphasis on wood utilization, the increasing prices for stumpage, and the expanded demand for many forest products have greatly increased the necessity for sustained-yield management throughout the country and notably among the larger timberland owners.

11. The program of forestry in the United States and Canada has been definitely advanced and intimately integrated with the increasing importance of utilization. This has been the key to a continued and successful program of forestry and is the "raison d'être" for its importance in the economic stability of the United States and Canada.

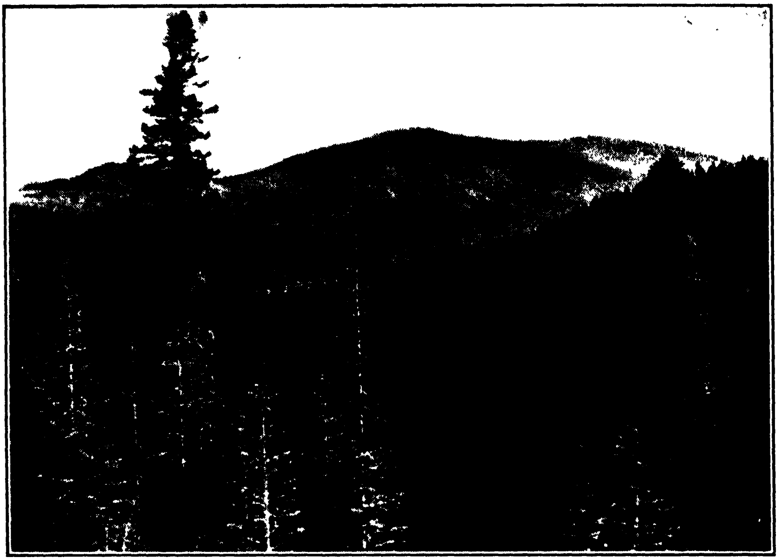


FIGURE 22. Timber sales on National Forests have established excellent standards of integrated and efficient utilization. Saw logs, mine timber, fence posts, cooperage bolts, veneer logs, naval stores, cross ties, poles, piling, pulpwood, fuelwood, distillation wood, Christmas trees, and many other products are cut and sold from some of them. This shows a dense stand of pine and fir on the Lassen National Forest, Calif., on which important timber sales are made.

FIGURE 23. Davis raft of Sitka spruce logs being towed from the Tongass National Forest in Alaska to destination in Puget Sound, Wash. These are unusually clear and straight logs used for producing airplane parts. A good share of the raft is submerged. Two cables hold the raft together. Other cables hold parts of the raft together. *Courtesy U. S. Forest Service.*

14 · CONVERTING FACTORS AND EQUIVALENTS

For statistical purposes as well as for the purchase and sale of various forms of forest products either exact or approximate equivalents have been established by the U. S. Forest Service. Table 4 gives the principal converting factors and equivalents used in expressing the volume of various forest products in terms of other forms of material. Although the cubic foot is probably the most accurate and easily applied unit in expressing the volume of forest products, it is not used, by itself, commercially except to a very limited extent.

TABLE 4

APPROXIMATE CONVERTING EQUIVALENTS

Material to Be Converted	*Board feet, Sawed*	*Cubic feet, Actual Solid Contents*
Board foot, lumber	1	12 b.f. equal 1 cu. ft.
Cubic foot, round	6	1
Cord	500	90
Hewed cross tie	33⅓	3½
Lath	5 laths equal 1 b.f.	60 laths equal 1 cu. ft.
Shingles	10 shingles equal 1 b.f.	M shingles equal 9 cu. ft.
Slack stave	3 slack staves equal 1 b.f.	40 staves equal 1 cu. ft.
Tight stave	1	12 staves equal 1 cu. ft.
Set slack heading	2	6 sets equal 1 cu. ft.
Set tight heading	4	3 sets equal 1 cu. ft.
Hoop	3 hoops equal 1 b.f.	40 hoops equal 1 cu. ft.
Pole, telephone	60	10
Pole, fence	10	2
Post	5	1½

(Table 4 continued on page 50.)

TABLE 4 (*Continued*)

REDUCING FACTORS

Material to Be Reduced	*Equivalent cubic feet*	*Cubic feet of Forest Material Required to Produce, Allowing for Usual Waste*
Lumber	M b.f. by 83	M b.f. by 219
Firewood	Number of cords by 90	Number of cords by 95
Hewed ties	Number of ties by 3.5	Number of ties by 12
Pulpwood	Number of cords by 90	Number of cords by 117
Shingles	M shingles by 9	M shingles by 22
Staves, slack	M staves by 25	M staves by 66
Staves, tight	M staves by 83	M staves by 333
Heading, slack	M sets by 167	M sets by 811
Heading, tight	M sets by 333	M sets by 1625
Hoops	M hoops by 25	M hoops by 59
Veneer logs	....	M ft. log scale by 184
Poles	Number of poles by 10	Number of poles by 13

APPROXIMATE QUANTITIES OF FOREST PRODUCTS REPRESENTED BY 1000 FT. OF TIMBER, BOARD MEASURE (1 M FT. B.M.) *

Product	*Quantity*
Shingles	10,000
Lath	5,000
Hoops	3,000
Slack staves	3,000
Tight staves	1,000
Slack heading, sets	500
Tight heading, sets	250
Fence posts	202
Round timber (ratio, 6:1), cu. ft.	166.667
Sawed material (ratio, 12:1), cu. ft.	83.333
Poles, telephone	16.667
Steres (m^3), used in Europe	7.25
Cords (4′ × 4′ × 8′)	0.5

* From Converting Factors and Tables of Equivalents Used in Forestry, *U. S. Dept. Agr. No.* **225**, 1947.

PART II

Construction Materials

15 · VENEER AND PLYWOOD *

VENEER

Veneers are thin slices or sheets of wood. They have been made and used since early Roman times. Until 1880, they were made principally from beautifully grained and handsomely figured woods which because of their value were seldom used in the form of solid boards. Thus face veneers were valued for their color, grain, and beauty. These qualities afforded the principal reasons for making veneers.

Within the past few decades, the veneer industry and its principal supplementary product, plywood, have advanced remarkably in quantity production. Many new uses, such as building, construction, concrete forms, containers, have created demands for increased production of plywood. There is a great wealth of comparatively low-value species which produce large-sized symmetrical logs relatively free from defects. These lend themselves very favorably to the production of plywood.

Furthermore, with the gradual depletion of the more valuable woods and the consequent rise in price of such species as walnut, mahogany, rosewood, and other imported species, it is natural that much high-grade furniture, interior finish, cabinetwork, and so on should be made with veneer faces, the centers or cores being composed of sturdy but less attractive species of moderate cost. This condition contributes to the more efficient utilization of our timber supplies, since the best quality of the more valuable species may be used for exterior faces and the interiors composed of strong but cheaper woods and lower grades.

At one time veneers were used almost exclusively for fine furniture and cabinetwork. Within the past two decades a great

* Revised and checked by Thomas D. Perry.

variety of new uses, as is explained later, have been developed and expanded.

Methods of making veneers. There are three methods of making veneers: lathe cutting (rotary), slicing, and sawing, as shown

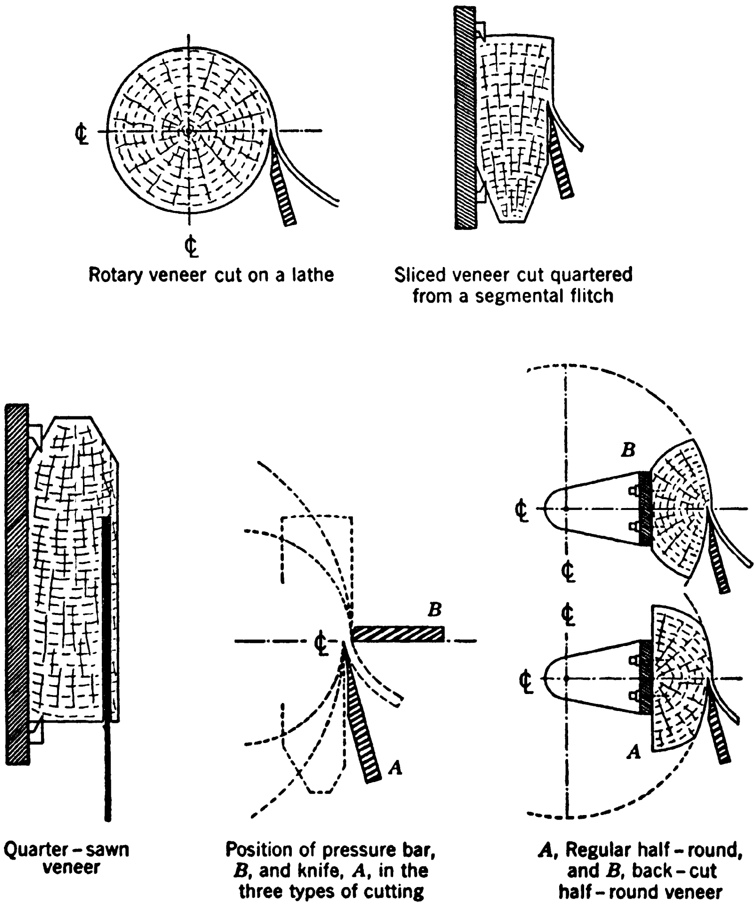


FIGURE 24. Methods of making veneers by the rotary, slicing, and sawing processes.

in Figure 24. For many years they were only sawed, and the introduction of other methods is a notable feature of twentieth century industrialism. The three methods may be described briefly as follows:

1. *Rotary-cut veneers.* The largest volume of veneers is made by turning a log upon a heavy lathe against a stationary knife. Probably about 90% of all veneers are made by this method. Continuous sheets of veneers are cut down to a 3¾″ to 10″ core, depending upon the species, character of veneers made, defects, etc. Thus, continuous sheets of veneer are cut off with the rings of annual growth. Rotary peeling always discloses the figure

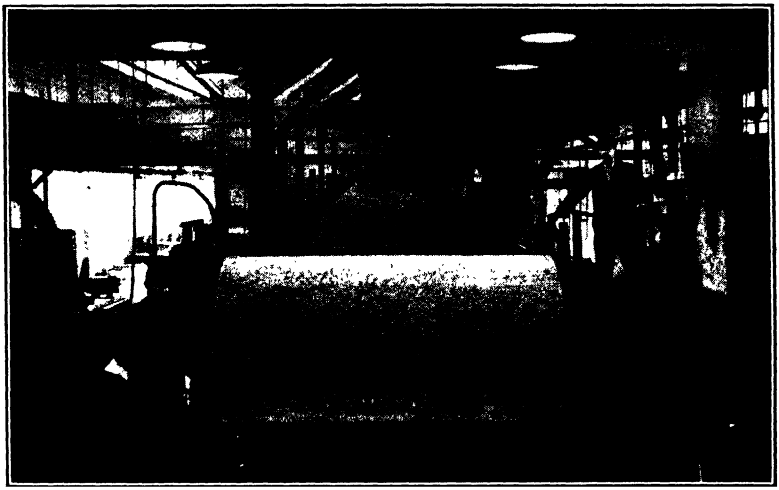


FIGURE 25. A large round Douglas fir log being peeled by the rotary veneer process, Seattle, Wash. *Photograph by Hart.*

of the wood as seen in a tangential or slash-grain surface. The finer figures of cabinet woods are exhibited by slicing on the quarter grain but, in some cases, rotary peeling discloses the choicest grain, as in bird's-eye maple.

Logs of the harder woods must be softened by boiling or steaming before they can be cut on the rotary lathe. The log is hoisted by power and swung into the lathe, which is equipped with heavy chucks for gripping the log at each end. The shafts holding the chucks may be lengthened or contracted according to the length of the veneer log to be cut. At each revolution, the knife is slowly moved into the log by an automatic gear mechanism, adjustable for any thickness of veneer. As the long, continuous sheet of veneer emerges from the lathe, it is conveyed to a table and clipped into desired widths for handling. The operation is relatively simple and inexpensive but requires skilled, experienced, and capable operators to secure the most efficient results.

Rotary-cut veneer has a firm (outside or tight) and a checked (inside or loose) side. The side adjacent to the knife is only slightly affected, but this condition must be considered in the drying process. Well-cut veneer under ⅛″ thickness shows little difference between the two sides.

This method is applicable to a great variety of woods and a wide latitude of thicknesses. The principal woods cut by this process are Douglas fir, ponderosa pine, southern yellow pine, red gum, cottonwood and tupelo, among the cheaper woods; and walnut, oak, maple, and yellow poplar among the more valuable woods. Practically all species that grow to sufficient size, that is, at least 12″ to 15″ in diameter, are used for rotary veneers.

2. Sliced veneers. The slicing process consists of rapidly moving a flitch of wood vertically downward with an angling, shear motion against a cutting knife. Many of the quartered oak veneers as well as most of the mahogany, Spanish cedar, rosewood, and other exotic species exhibiting a pleasing figure are made by this process. It is less wasteful of raw material than the sawing method but much more so than the rotary method.

First the flitch is properly steamed or cooked and then bolted to a heavy, steel frame known as the stay log, by screw dogs. On each downward stroke against the edge of a stationary knife, a slice of veneer is cut. On the upward motion the knife automatically recedes so there is no interference with the flitch. It then automatically advances the thickness of the veneer and continues the cutting process until the flitch is cut into slices down to the backboard. Generally, the veneer is cut into long, narrow strips which can be readily matched to exhibit the best-figured grain and design. Very thin veneers may be cut in this way. Sliced veneers have a usual thickness range from $\frac{1}{50}$″ to $\frac{1}{16}$″.

3. Sawed veneers. Flitches of the wood to be sawed are fastened to a "stay log" by screw dogs and mounted on a saw carriage. Thus the flitch, previously prepared to show a quartered face, is passed through the saw, similar to the method of sawing lumber.

The blade of the veneer saw consists of segments bolted to the circumference of the central disk or hub. The disk is thicker in the center and has a gradual taper toward the periphery, which gives it strength, rigidity, and uniform cutting. The kerf is usually $\frac{1}{20}''$ thick. This process is very wasteful of raw material and time and is, therefore, the most expensive method of making veneers. It is used principally for high-grade finish and furniture woods. Oak is the wood most often employed. Only about one-half the total volume of flitch is converted into veneers, the remainder being sawdust and "dog boards," the part clamped to the saw carriage.

Veneer thicknesses. Veneer is cut to a great variety of thicknesses, depending upon its ultimate use. Commercially, it is generally cut $\frac{1}{50}''$ to $\frac{1}{8}''$ thick. For highly specialized purposes it may be cut as thick as $\frac{3}{8}''$ or as thin as $\frac{1}{110}''$. Veneers cut by the slicing or rotary-cut methods may be cut to the latter thickness but it is generally impracticable to saw veneer thinner than $\frac{1}{32}''$. Veneers of much wider range of thickness are cut by the rotary method, the most common being $\frac{1}{7}''$, $\frac{1}{8}''$, $\frac{1}{10}''$, $\frac{1}{16}''$, and $\frac{1}{20}''$. The most common thicknesses in Douglas fir are $\frac{1}{7}''$, $\frac{1}{8}''$, and $\frac{1}{10}''$. Hardwood is commonly cut to $\frac{1}{20}''$. Sliced veneers are usually cut $\frac{1}{20}''$ to $\frac{1}{40}''$ in thickness. The great majority of sawed veneer is cut $\frac{1}{4}''$ to $\frac{1}{24}''$ in thickness, and $\frac{1}{20}''$ is most common.

Seasoning processes. For a large majority of uses, veneers must be carefully dried. For some purposes like basket weaving, moderately wet veneers may be desired. There are several methods followed in drying veneers.

Roller dryers: a series of rollers in pairs, several decks high, carrying the veneers through a hot air chamber. The rollers serve to keep the veneers flat. Drying time is 10 to 30 minutes, depending on thickness and species. Douglas fir veneer of $\frac{1}{10}''$ thickness is dried in 6 to 10 minutes.

Mesh dryers: similar to roller dryers, but the veneer is conveyed by articulated wire mesh belts. They are in general use for sliced veneers and satisfactory for most species of veneers but do not produce such flat stock as do roller dryers.

Plate dryers: steam-heated plates, drying several superimposed thicknesses between each pair of plates. This method is frequently used as a redryer just before gluing, as it produces flatter veneer than any other process.

Tunnel kilns: the veneer is held flat between racks or frames, and the trucks progress through the tunnel from the cold wet to the hot dry end. Heated air is forced endwise through the tunnel. This is particularly suitable for commercial (not face) veneers $\frac{1}{8}''$ thick and up.

Lumber kilns: heavy veneer is occasionally piled on kiln trucks and passed through regular lumber kilns.

Loft dryers: certain light-colored veneers, such as maple, are best dried by being suspended from wires or held on edge in racks, only slightly above-normal temperature being used in a loft or upper story. At certain seasons and in favorable climates this may be done outdoors.

It is important that veneers be dried immediately after cutting to avoid discoloration, stain, and mildew. In wet atmospheres this can be done only by using relatively high temperatures, before discoloration can start. The gums and southern pines are particularly susceptible.

Since all veneer shrinks substantially during drying, considerable waviness may occur in veneer sheets that can be largely prevented by roller dryers. Edge checking and wrinkling are most troublesome in high temperatures. Face checking in highly figured veneers is greatly reduced by slower drying at lower temperatures.

Qualities desired in veneer woods. The qualities desired in veneer woods depend largely upon the uses. For table tops, panels, fine furniture, and cabinetwork a pleasing figure and grain are the most desirable qualifications. Generally, however, low costs of raw material and desirable sizes are the most important factors. For the vast majority of purposes for which veneers are intended, the desirable qualities may be summarized as follows:

1. Veneer woods must be reasonably low in price because the ultimate products, such as plywood, berry and fruit baskets, crates, and cheese boxes, must be sold on the market at a relatively low price.

2. Logs must be available, readily accessible, and delivered at low cost at the veneer plant. There must be sufficient quantities of each species to provide a uniform product.

3. Comparatively large sizes are preferred. Because of its size, Douglas fir is admirably adapted for veneers as well as because of its low cost and abundance of supply. Furthermore, veneer logs must be reasonably straight and symmetrical in shape and

relatively free of knots, frost cracks, splits, checks, decay, worm holes, burned faces, etc.

Woods used and annual production. Formerly red gum, white oak, and yellow poplar were the outstanding species used for veneers. At the present time Douglas fir far exceeds all other

FIGURE 26. Yellow poplar veneer logs cut to 7′ lengths in the Appalachian Mountains. Note the indication of curly grain as shown by the bark of the log in center foreground. Short logs and bolts may be measured in board feet, cubic feet, cords, or individual pieces. Veneer logs generally command high stumpage values.

woods in the volume of production. Other important woods are ponderosa pine, southern yellow pine, red gum, oak, tupelo gum, ash, elm, and yellow poplar. Practically every species is made into veneers, at least to some extent. Although the relative volume is small, the highest grades of veneers are made from black walnut, white oak, and such exotic species as mahogany, Spanish cedar, and rosewood. Burls, knots, and stumpwood of black walnut are particularly valuable. The walnut stumps of the Southwest are sometimes dug out for many feet below the surface of the ground and used for fancy veneers both in the United States and abroad.

Veneers represent one of the most rapid advances in production of any forest product and are exceeded only by rayon and rubber in this respect. The production of plywood has made rapid progress, more so, relatively, than veneer production, for 1950 saw the largest production in the history of plywood. A large share of this plywood is of Douglas fir. When reduced to terms of

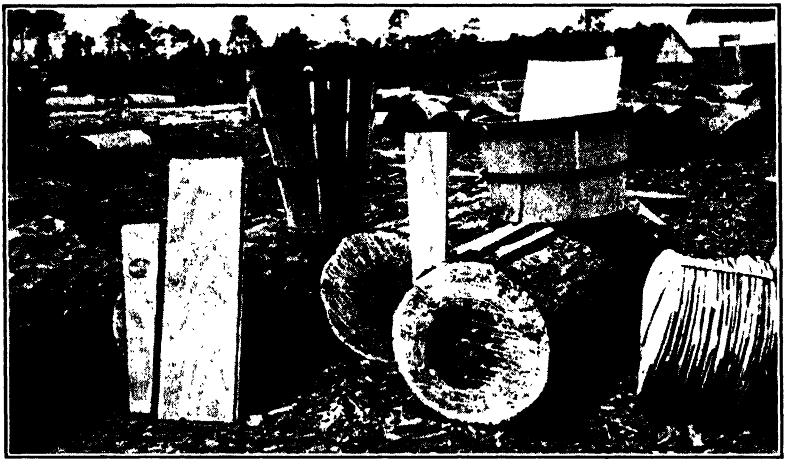


FIGURE 27. Selected southern yellow pine veneer bolts for the manufacture of hampers and baskets at Gainesville, Fla. Tops and bottoms and sides of hampers and baskets are made entirely of veneers.

3-ply stock, ⅜″ in the rough, the production is about 2000 million sq. ft. Douglas fir plywood in these specifications has shown remarkable increase in production from 55 mills in the Pacific Northwest, as evidenced by Table 5.

TABLE 5

DOUGLAS FIR PLYWOOD REDUCED TO SQUARE FEET OF ⅜″—3 PLY

1935	491 million
1940	1150 million
1945	1200 million
1948	1871 million
1949	1900 million
1950 (estimated)	2000 million

Utilization of veneers. The uses of veneers have been greatly expanded. From the viewpoint of broad classification, probably more veneers and the supplementary product (plywood) are used for containers than for any other purpose. The container industry, including the manufacture of boxes, baskets, crates, cases, trunks, drums, chests, barrels, hampers, and hoops, uses vast quantities of veneers. Many radio cabinets and other cabinets, dishwashers, furniture, and miscellaneous commodities are shipped in veneer or plywood containers.

The second most important outlet for veneers is for general construction, chiefly in the form of plywood for interior finish,

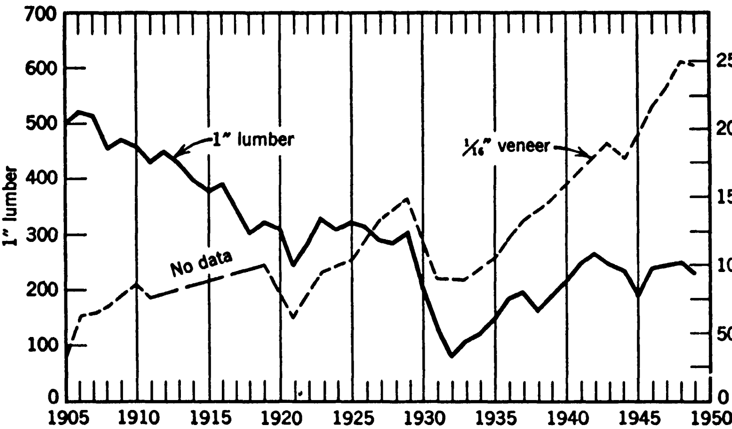


FIGURE 28. Per capita use of lumber and veneer. *U. S. Census.*

flooring, siding, subflooring, underroofing, sheathing, the finishing of attics for insulating purposes, and for concrete forms.

The third most important application is for furniture, which has always been an important consumer of veneers, especially for chairs and seats, drawer bottoms, table and dresser tops, and for high-grade interior finish.

The fourth classification may include a great variety of products, such as general millwork, musical instruments, refrigerators, automobile trailers, truck and bus bodies, sewing machines, aircraft, carriages, storage batteries, sleds, toys, woodenware, surgeons' splints, and dishes.

Utilization of waste. As rotary-cut veneer represents around 90% of the veneer cut, it presents the major problem of veneer waste. Primarily the rotary cutting of a log into veneer shows much better yield than the sawing of the same log into lumber.

There are two principal reasons: (1) the elimination of saw kerf and (2) the savings caused by not cutting to square edges, as in boards. The normal defects, knots, splits, stains, and doze, will affect both lumber and veneer alike, and the losses from shrinkage will be about the same. The lumber grades, however, are less rigid than for veneer, and the salable yield will increase somewhat. Veneer breakage is an appreciable factor. As a

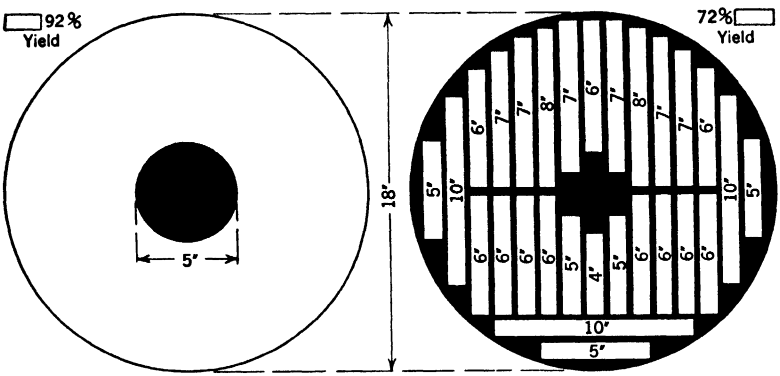


FIGURE 29. Cross sections of 18"-diameter logs showing the rotary veneer yield of 92% of total area on left compared with 72% on sawed lumber on right. Unless lumbering operations are carefully managed, this lumber yield seldom exceeds 60 to 65%. The standard Scribner-Doyle log scale allocates 58% yield to such a log.

whole, the yield of the log into veneer, of equivalent grade and condition, considerably exceeds the yield into lumber, an important factor in the conservation of our timber resources.

The loss in veneer cores depends on the soundness and length of the log, varying from about 3¾" to 10" in diameter. This core is often sawed into crating, sometimes used for mine props, and always available for fuel. Black walnut, Circassian walnut, and mahogany cores are sometimes sold for gun stocks to the manufacturers of shotguns, pistols, and rifles. Veneer cores are also made into heading and staves for slack cooperage, for cleats and crating stocks, and for a variety of miscellaneous purposes.

PLYWOOD

Plywood is a built-up board of laminated veneer, in which the grain of each piece is at right angles to the direction of the one adjacent to it. Kiln-dried veneer is united under heavy pressure with an adhesive (glue) making the joints as strong as or stronger than the wood itself. The alternating direction of the grain with each contiguous layer of veneer minimizes the shrinkage and warping coefficient of the product and prevents splitting or checking. Moreover, since wood is much stronger and stiffer along the grain than across the grain, plywood, by having longitudinal grain in both directions, distributes its strength and stiffness in all directions.

Plywood as a further development in the manufacture of veneers has assumed large proportions in both the domestic and export trade and received wide attention in building construction and architectural developments because of its many possibilities in utilization. It is usually manufactured in large-sized units, such as sheets up to 4′ wide and 16′ long and may be scarf-jointed to as large sizes as can be handled. It has high strength values, excellent insulation qualities, lightweight construction characteristics, and low cost. Thus these properties assist in various architectural designs to guard against fire, decay, changes of temperature, and shrinkage. Furthermore it provides for almost complete utilization of the log. Great increases have marked the developments in the use of large-sized Douglas fir and other species found in the Northwest, notably ponderosa pine, for plywood. The development of a successful water-resistant glue and other adhesives have contributed largely to the increase in the use of Douglas fir plywood for concrete forms, railroad-car lining, wall and floor construction, automobile and trailer construction, and many exterior forms. It has been widely exported to the tropics and semitropics for partition, insulation, furniture paneling, interior finish, and many associated uses.

Reasons for increased production. Douglas fir plywood has been as successfully merchandised as any forest product. It has been readily accepted by the public, it is relatively inexpensive, and it may be produced in great volume and large sizes from large-diameter, virgin-growth Douglas fir in the Pacific Northwest. Additional reasons for its increased use may be summarized as follows:

1. Increased utilization of plywood for house construction, especially for subflooring, sheathing, wood paneling, cabinetwork,

cupboard doors and drawers, finishing of basements and attic rooms, garages, and refrigerator rooms.

2. Developments in prefabricated units for house construction.
3. Use for concrete forms in many kinds of construction work.
4. Price factor. Plywood is less expensive than most of its competing materials.

FIGURE 30. Typical Gunnison home, prefinished with plywood outside and inside, plywood floors and partitions as well as plywood base for roof. Made in complete prefinished units at the factory, ready to bolt together on foundation at the site. Modest decorative exterior features added to conventional design as shown. *Courtesy Gunnison Homes.*

The recent demand for relatively inexpensive dwellings has made it imperative that prefabrication materials should be available at places of construction at minimum cost.

Some of the specialized uses for plywood are for archways, automobile body parts, automobile trailers, birdhouses, bookcases, boxes, crates, and similar containers, bulletin boards, drafting boards; various cabinets such as medicine cabinets, ice-cream cabinets, and bathroom cabinets; ceilings, chests, closets, clothes chutes, concrete forms, store counters, store-display cases, desk and table tops, drawer bottoms, store fixtures, flooring, furniture, playhouses, ironing boards, supplies for manual-training classes, paneling, partitions, folding screens, shelving, subflooring, tops, trucks, trunks, window seats, and flower boxes.

Size specifications of plywood. Plywood is manufactured in a great many different thicknesses, from 1/32″ to 1¼″. It is manufactured up to 3″ or 4″ in thickness for such special purposes as gusset plates in roof and bridge trusses. A great quantity is produced as ¼″ 3-ply material, although large quantities of ⅝″ and ¾″ are used for concrete form work and in general construction industries. Thicknesses of ⅜″ and ½″ are also important. Stock panels are produced in various sizes up to 4′ × 8′. This is the largest and most popular size and can be readily loaded, shipped, unloaded, and remanufactured. Special panels up to 8½′ × 16′ are also manufactured by certain Douglas fir plywood manufacturers.

Plywood processing. *1. Veneer preparation.* Properly dried and flattened veneers for assembling into plywood must be spliced edge to edge in suitable sizes, leaving a reasonable allowance for trimming rough edges off the resulting plywood. A recent important development for edge splicing, that is in wide use, is the tapeless splicer, which progressively presses together the glue-coated edges of the veneer strips under a heater bar to preserve the necessary flat surfaces. Heat-setting resin adhesives are employed, and the resulting joints are almost imperceptible. In the highly figured face veneers, where the edges tear out easily, gummed tape is still used but is sanded off when the plywood is completed.

2. Glues and adhesives. There are four important plywood glues that have been in use for some years and do not require heat for setting: (*a*) vegetable glue, usually a starch (cassava) base mechanically mixed with caustic and heat, making a relatively thick viscous mixture that has little water resistance but is in the low-cost bracket; (*b*) casein glue, the curds of milk mixed cold with caustic and lime, resulting in a definitely water-resistant bond, but considerably above vegetable in cost; (*c*) soybean glue, based on flour or meal made from the residues of oil extraction, mixed cold with certain other ingredients, which gives a bond of considerable water resistance that is in the lower-cost ranges, and used principally in Douglas fir plywood; (*d*) animal glue, bone and hide derivatives, prepared by moderately heating a solution, which gives a strong bond of little water resistance, but not extensively used for plywood on account of its cost.

The synthetic-resin adhesives, developed chiefly since 1936, are of three principal types: (*e*) urea formaldehyde, including the melamines requiring catalysts for curing either with or without heat, and permitting the generous use of extenders so that the

FIGURE 31. Hardwood plywood production. Left: Rubber roll spreader applying resin adhesives. Immediate front center: Dry veneer and lumber cores before spreading with glue. Center: Laying up assembled veneer direct on aluminum cauls. Rear center: 10-opening hot press ready for loading; pumping equipment at left of press. *Courtesy Plycor Co.*

glue-line cost is quite moderate, but having substantial moisture resistance; (*f*) phenol formaldehyde, available in powder, liquid, or film form, usually hot pressed, and possessing maximum moisture resistance, but considerably above the extended ureas in cost; (*g*) resorcinol formaldehyde, a modified type of phenolic that does not require heat, but is in the higher-price range, and has maximum moisture resistance.

3. Glue preparation and application. Plywood glues and adhesives are usually mechanically mixed in containers with double beaters or paddles. Steam or water jackets are often provided to heat or cool the mixture during preparation. A thorough dispersion of the solid ingredients is highly important.

Glue spreaders usually apply glue on both sides of alternate layers of veneer and are provided with finely grooved or threaded rollers. Metal rollers are customary for heavy spreads, 60 to 90 lb. of liquid glue per 1000 sq. ft. of joint, which is standard for the older cold-setting glues; whereas rubber-covered rollers are preferable for the lighter spreads of the resin adhesives, from

FIGURE 32. Douglas fir plywood production. Far left: Two spreaders with rubber rollers. Near left: Layup stations on conveyer chains. Front center: Dry veneer, to be assembled with glue-coated layers. Rear center: Loading elevator, served by both spreaders. Right center: 20-opening hot press. *Courtesy William S. White & Co.*

30 to 50 lb. In most cases the coated veneers are immediately assembled and placed under pressure.

4. Assembling and pressing plywood. The older method is to press the freshly glued plywood in bundles, some 24″ to 30″ thick, attaching screw clamps while the plywood is still under pressure, and allowing the glue to set overnight before unclamping and releasing pressure. An interval of a day or two is required to evaporate the surplus water introduced with the glue, before trimming and sanding.

The more modern method is the multiplaten steam-heated hot press, in which the resin bond can be pressed and cured in a matter of minutes and the plywood processing continued immediately after cooling, when the plywood is thoroughly dry.

A single unit, for hot or cold pressing, will produce some 10,000 sq. ft. of plywood for furniture work, of assorted sizes, constructions, and thicknesses, per 8-hour shift. The plywood for hot pressing, is assembled between aluminum cauls, several units of the same thickness being allowable in each pair of cauls, for more convenient loading of the hot press.

During World War II considerable impetus was given to the development of radio-frequency heating to cure thermosetting glues. The principal application of this high-frequency treatment has been in edge-gluing lumber core panels.

In softwood plywood, where production and standard sizes are both large, the use of mechanical loaders is customary, since operating cycles are short and the large assemblies are quite unwieldy. Aluminum cauls are seldom used in such large-production programs.

Douglas fir plywood is made in two principal grades: exterior or waterproof, for weather and marine exposures, usually with phenolic adhesives and hot presses; and interior, for limited exposures, in which soybean glues are employed. In the latter instance, with soybean glues, the bundle-clamping method may be employed at room temperatures, although hot pressing is also employed to speed up production.

Plywood adhesives. There are several well-known and generally used adhesives divided into two classes: (1) cold-setting wet glues that harden by the evaporation of the water solvent with little change in chemical form, and (2) heat-reactive glues, in which the application of simultaneous heat and pressure results in different physical form with properties altered from those possessed before hardening. The principal plywood adhesives in each class are:

Cold setting. There are four cold-setting adhesives, namely: (1) cassava starch, (2) soya bean, (3) casein and, (4) animal glue as briefly described above. In addition, some resin adhesives cure (set) at 70°F.

Heat reactive. Blood albumin was the earliest used adhesive of this type and, although difficult to apply, gives an excellent waterproof joint, owing to the coagulation of the albumin under heat. Urea resin, is applied as a wet glue, but most economically set in a hot press. It is highly water resistant in cold water but delaminates in hot water. The urea resin solutions are unstable chemical compounds. Phenol formaldehyde resins are stable in liquid form and wholly waterproof when set under heat. Although most phenol formaldehyde resins are used in liquid

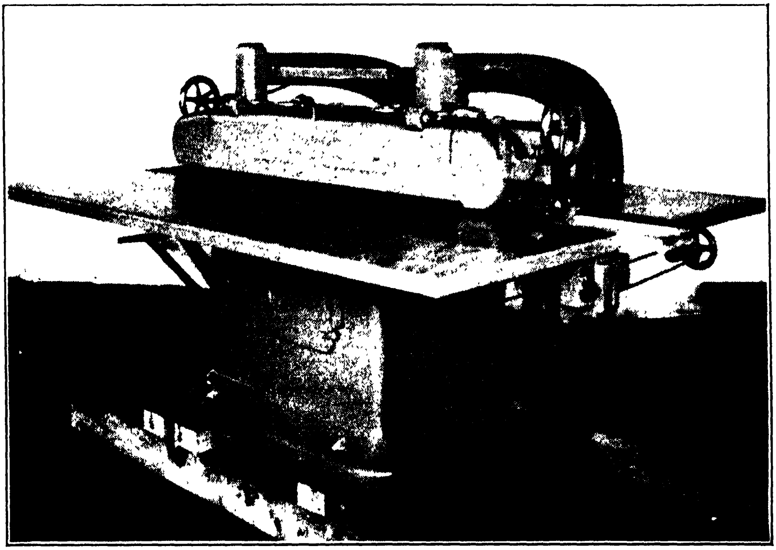


FIGURE 33. Tapeless veneer splicer. This machine splices veneer as narrow as 2″, from 1/30″ to 1/8″ thick, at speeds from 15 to 85 f.p.m. Uses resin adhesives cured under electrically heated pressure bars. *Courtesy G. M. Diehl Machine Works.*

form with water or spirit solvents, there is some used as a resin film. Both types of phenolic resin compare favorably in cost with casein. This film consists of exceedingly thin paper spread on both sides with phenol formaldehyde resin, and it is interleaved between sheets of veneer. Plywood manufacturers find it decidedly advantageous to be saved the trouble and hazard of mixing and spreading and are most appreciative of the opportunity to use plywood immediately on removal from the press. This new film resin adhesive is one of the principal factors in the rapid introduction of plywood into many new forms of utilization.

ELECTRONIC HEATING FOR WOOD GLUING *

Within recent years electronic wood-gluing equipment has come into increased prominence as a production tool in many woodworking plants. An electronic wood-gluing setup usually incorporates a radio-frequency heat generator as well as some sort of a mechanical clamping press. The wood-glue combination to be cured is placed between two electrode surfaces, usually the platens of the press. When the output voltage of the radio-frequency heat generator is placed across this wood-glue load, a certain amount of electric power loss occurs in the load. Since this loss appears as heat, this type of heating is termed *radio-frequency heating.*

There are two arrangements of the electrodes in general use. (1) For the bonding of flat or molded plywood and wood laminates, the electrode plates are parallel to the planes of the glue lines. (2) When lumber is edge-glued for open face or core stock, the electrode plates are at right angles to the glue lines. In this latter case, the electric field between the electrodes will concentrate in the moist glue lines, and a "selective" heating of the glue lines results.

The main application of electronic wood gluing has been for edge-gluing operations. There are two general types of mechanical clamping presses. In the batch-type press, the boards are laid up on an assembly table and automatically fed into the press when the correct panel width has been built up. Top and side pressures are applied to the panel, and a pressure-sensitive switch actuates the radio-frequency heating unit. Upon completion of a predetermined curing cycle, the press automatically opens, and the cured panel is ejected by the new load moving into the press bed. Depending on such variables as panel area, panel thickness, number of glue lines, type of glue and hardener, and output power of the radio-frequency heat generator, a complete curing cycle may range from 20 seconds to 1 or 2 minutes.

In the continuous type of edge-gluing presses, the boards are fed continuously, a flattening pressure is applied, and edge pressure is built up as the boards are carried through the radio-frequency heating field. Depending again on the same variables

* From data supplied by John M. Yavorsky, New York State College of Forestry.

listed previously, a continuous edge gluer can deliver from 4 to 30 lin. ft. of glued-up panel per minute.

Another application of electronic heating which is becoming more widespread in the industry is the assembly gluing of radio- and television-receiver cabinets, silverware boxes, and the like. For instance, the front, sides, top, back, and mounting board of a radio receiver can be assembled in a jig and all the glue lines cured simultaneously in less than 1 minute. This results in a marked reduction in the required number of jigs as well as lower handling and cleanup costs. In addition, the finished cabinets are square and well aligned, and the absence of pins, nails, and fasteners improves their appearance.

The intelligent application of this new production tool will undoubtedly aid the efficient utilization of the lumber and veneer produced from the second-growth trees which more and more are becoming the primary source of raw material for the woodworking industry.

16 · CROSS TIES *

The cross-tie industry is a very large and important one. Although sometimes associated with the lumber industry, it is nevertheless a distinct and separate entity. Cross ties, including both hewed and sawed ties, constituted approximately 8% of all timber cut in the United States, according to the last complete Census of Manufacturers. The amount of wood consumed for cross ties exceeds that employed for mine timber, poles, and cooperage. As to the value of the product, the class I † railroads of this country expended for cross ties, 1921–48, $2288 billion, an average for the whole period of $81,900,000 per year. In 1948 purchases of cross ties amounted to $87,916,000. For the calendar year 1947, the average cost to the railroads of all new wooden ties laid in track was $2.40 per tie.

There has been a marked reduction in the number of ties consumed annually due to the greatly increased use of treated ties since 1912. In 1907, the railroads purchased 153,703,000 ties; in 1910, 148,231,000; and in 1947, only 37,200,000 were placed in track. The present annual requirements will average approximately 50 million ties per year, plainly indicating that the life span of an untreated tie is only a third of that of the treated tie.

The United States is a greater builder of railways, with per capita mileage exceeding that of any other nation. The United States is the most important consumer of cross ties and also exports treated and untreated cross ties to various parts of the world, for the most part to China, Egypt, and South and Central America, although under the European Recovery Program some ties have been sent to the United Kingdom and Europe to aid in the restoration of the railways damaged in World War II.

The length of all tracks used by class I railways is 330,350

* Reviewed and checked by B. N. Johnson, chief procurement officer, Wood Preserving Division, Koppers Company, Richmond, Ind.

† Railways with annual operating revenue above $1 million. They maintain about 93% of the total mileage of the United States and earn about 97% of the total revenue.

miles, including sidings and yards. The era of vast expansion of railway systems has perceptibly slowed down, and relatively little new mileage is being built, while some branch lines are being abandoned. In 1927 there were 1047 million cross ties underlying 352,000 miles of maintained track in the United States. The corresponding figures for 1947 were 993 million ties and 330,000 miles of track. During the intervening two decades, mileage decreased by 6%, and the number of cross ties in track declined by 5%. There are 1,134,296,555 cross ties in the tracks of class I railways of this country and Canada. If laid end to end, these ties, averaging 8′ long each, would stretch 1,720,000 miles, or 68 times around the world. Expressed in board measure, this is equivalent to 43 billion b.f. or nearly twice the total lumber production of the United States in 1939.

In 1898, the total cross-tie insertions in the American railways were about 80 million or 304 per mile. The insertions in 1947 were 44 million ties or 117 per mile. The total conservation of timber due to the preservative treatment of cross ties during this 50-year period (1898–1947) was about 3 billion ties or the equivalent of 125 billion b.f. Based on a cost of $4 per tie as placed in the tracks, the yearly conservation is about 71 million ties or a total value of $284 million.

If we assume a merchantable stand of 5 M b.f. per acre, it would require 25 million acres to produce 125 billion b.f. of cross ties used during this 50-year period, without considering growth.

The most important railway systems using cross ties are the New York Central system with 22,274 miles of maintained tracks, Pennsylvania Railroad with 21,422 miles, the Santa Fe with 19,225 miles, the Milwaukee system with 13,542 miles, the Southern Pacific system with 12,556 miles, and the Burlington system with 11,854 miles. The New York Central system has approximately 68 million cross ties in the tracks it maintains.

The cross-tie industry is distinguished by the following outstanding features:

1. There are generally wide fluctuations in demand. It supplies exclusively one transportation industry, namely the railroads.* It is limited mainly to that one single market. The demand for

* In addition, the trolley, interurban, subway systems, mines, and industrial and construction works use small quantities of ties, but their total number is relatively small. Ties for logging railroads are cut generally

cross ties, therefore, varies with the increase or decrease of railroad revenues, which in turn are a direct reflection of the business condition of the country.

2. There is a decided increase in the use of the treated tie. Owing to the interest of the industry and the railroads in the problem of eliminating the preventable decay of ties, there de-

FIGURE 34. Main line of Pennsylvania Railroad with its 4-line right of way and well-ballasted track with treated ties at Stoopes Ferry, Pa. The Nation's railroads which pioneered in the use of pressure-treated ties are now turning to the economy of treated wood for cars, grade crossings, poles, and general construction.

veloped rapidly in the United States plants for the chemical treatment of cross ties. Proper treatment results in prolonging the life of ties as much as three or four times and has done as much to conserve our forests as any other single factor. In addition to conserving timber, the cost per tie per year of service has been greatly reduced. Formerly, an untreated tie gave 5 to 8 years of service in track. A treated tie will last 20 to 30 years. The

along the track. In the South, spur lines are constructed of round logs or roughly faced by hewing on one side. There are 24,250 miles of track laid with switch and bridge ties, which are generally longer than the usual tie.

proportion of treated ties inserted in track increased from 49.6% in 1923 to 95% in 1947. The treatment of ties has also proportionately prolonged the local source of ties available to individual railroads and has made available for commercial cross-tie use species of wood formerly not acceptable. The preservative treatment of ties is saving the American railroads annually many millions of dollars and has resulted in effecting a significant conservation of the timber resources of the United States.

3. In spite of the attempts to introduce and use substitute forms of ties (more than 2500 patents have been issued for substitutes), no satisfactory substitute form is now being used. Therefore, there is not in prospect use for any substantial quantities of metal, concrete, or composite forms of substitute ties. The metal ties used for railroads in Germany, France, Belgium, England, etc., are gradually being replaced by wooden cross ties.

4. Formerly ties were almost all hewed; now there is a definite trend toward the sawed cross tie. In 1913, 21% of all ties were sawed. For the 10-year period, 1923 to 1932, inclusive, 45½% sawed ties were produced, and now considerably over half of all ties are sawed with the percentage increasing each year. One principal reason for this change is the disappearance of the tie maker. Hewing ties is arduous manual labor, and men skilled in the art are difficult to find except in portions of the South where pine timber is available. Hewing is also a wasteful process, and the constantly increasing price of stumpage has forced the timber owner to utilize it to the best advantage. The tie boards or siding produced in sawing ties are readily purchased by flooring plants and others as lumber.

5. The cross-tie industry is one of very active and keen competition. Some railroads may, at times, almost abandon cross-tie purchases for a period of 3 or 4 years. When the cross-tie business is active, a large number of operators, particularly of small sawmills, may produce 50 to 60 cross ties with four men, up to 120 cross ties per day with eight men.

6. The demand for cross ties must be anticipated. There is a long interval of time—several months or a year—elapsing between the felling of a tree and delivery of the treated ties. The tie logs must be skidded and hauled to a sawmill (or hewed), the ties must be stream-driven, truck-hauled, or transported by railroad to a treating plant and then seasoned, treated, and made

ready for delivery. Therefore excellent judgment must be exercised to estimate properly the trends and developments in the market demand for ties.

7. The period of active railroad building and extension is past; approximately the same amount of mileage is being abandoned as constructed. Therefore the market for domestic use is not likely to expand.

8. Of the total tie production in the United States, conservative estimates show that about 64% are handled and manufactured by tie companies, the remaining 36% being produced (*a*) by individuals who produce locally along the railroad right of way and sell to one road only, and (*b*) as a side line by larger mills whose principal output is forest products other than railroad ties. This latter method (*b*) applies primarily to the Rocky Mountain and Pacific Coast States.

SPECIES USED

For many years, the timber growing adjacent to new railroad developments supplied the ties. With the westward extension of many railroad systems and the cutting of the eastern and southern forests, the sources of supply for cross ties widened beyond the local timber. Oak has for many years been the pre-eminent and outstanding species. Although a much greater variety of species is now utilized, generally in the treated condition, oak still leads in supplying the railroad requirements. The oak is widely grown in the lower Mississippi Valley states and in the Ohio Valley section. On some small railroads, white oak is used untreated where it is desired to hold the financial outlay for ties to a minimum. Red oak is subject to rapid decay without treatment, but it treats readily and when so preserved has an excellent service life. Oak ties are largely produced at small sawmills. Large lumber operators produce a negligible number of oak ties, although they do at times box the hearts of some logs and manufacture switch ties which are 9′ to 16′ in length. Almost 40% of all cross ties produced are oak.

The southern pines are next in order of importance for use in cross ties. There is wide variation in durability among these pines. Second-growth timber with a large percentage of sapwood is preferred because of its ready treatability. Large quantities are cut on separate tie operations as well as in connection with small sawmills. When treated, these pines render very satisfactory service.

Douglas fir has advanced rapidly as a source of cross-tie material in recent years, producing 6 million cross ties in 1945. Cross ties of fir are produced for the most part in the sawmills of the West Coast, but great quantities are also produced in western Montana and other Rocky Mountain states.

Redwood, western red cedar, and cypress are exceedingly durable. They are not, however, sufficiently hard to resist the impact and pressure of high speed and long, heavy trains and, therefore, are not employed for main lines. None of these species is so durable as treated ties of other species.

Tamarack, western larch, western and eastern hemlock, and lodgepole pine are cut locally and used in the treated condition. They are not widely distributed to various parts of the country as are oak, southern pine, and Douglas fir cross ties. Gum (including red, black, and tupelo), beech, and both hard and soft maple are utilized in the treated condition for cross ties. Other species, such as ponderosa pine, birch, elm, hackberry, ash, hickory, sycamore, and locust, are occasionally used where local railroad specifications permit.

The following are the normal percentages of the kinds of wood used for cross ties:

Oak	38
Southern pines	22
Douglas fir	13
Gum	9
	82
All other species	18
	100

REQUIREMENTS OF A SATISFACTORY TIE

The following are the principal qualities desired in a satisfactory tie:

1. Durability. The average untreated tie does not last more than 5 years. In the tie used in untreated condition, durability of wood is of very great importance.

2. Treatability. Within recent years much has been learned about the treating qualities of both sapwood and heartwood of the various species. That a species of wood can be satisfactorily and inexpensively treated may be a more important factor than native durability.

3. Ability to resist impact. The tendency during recent years has been to employ heavier rails and rolling stock and therefore larger sizes. The 7″ × 9″ × 8′ or 8′6″ tie is regarded as standard on some of the main lines of heaviest traffic. A cross tie must be sufficiently hard and strong to resist the crushing effect of heavy and speedy traffic. Cross ties of several species fail more because of mechanical destruction than through lack of durability. Some railroads have reported 10% failures owing to mechanical destruction rather than to decay. Oak is the outstanding species to fulfill the requirements of strength and hardness.

4. Ability to resist spike pulling and lateral displacement of spikes. A few railroads * have adopted screw spikes rather than the usual nail spike. Such hard and heavy woods as oak, maples, beech, and birch are much superior to such softwoods as cedar, spruce, cypress, redwood, and ponderosa pine for this reason as well as for reasons given under 3.

5. Available supply sufficiently large and reasonably inexpensive. Locust, mulberry, Osage orange, and persimmon produce excellent ties, but, growing in insufficient quantities, they may be more valuable for other purposes. Walnut and cherry produce excellent ties but, generally, are entirely too valuable for use as ties.

Table 6 shows the species that may be used untreated and those that should be treated.

SAWED VERSUS HEWED TIES

In the early days of railroad expansion and development, a large percentage of ties was hand-hewed. The percentage of ties sawed has increased gradually until now more ties are sawed than hewed. Hewing is an excessively wasteful process. When a log is faced on each side by the hewing process, there is large wastage in chips; whereas, when the log is sawed to the same size, the side cuts, known as tie sidings and slabs, may be profit-

* Notably the Delaware, Lackawanna, and Western Railroad. Screw spikes are also used on ties at railroad and trolley intersections to lessen the danger of rail spreading.

TABLE 6

CLASS U. TIES THAT MAY BE USED UNTREATED

Group Ua	*Group Ub*
"Heart" black locust	"Heart" Douglas fir
"Heart" white oaks	"Heart" pines
"Heart" black walnut	"Heart" larches
Group Cc	*Group Ud*
"Heart" cedars	"Heart" catalpas
"Heart" cypresses	"Heart" chestnut
"Heart" redwood	"Heart" sassafras
	"Heart" red mulberry

CLASS T. TIES WHICH SHOULD BE TREATED

Group Ta	*Group Tb*	*Group Tc*	*Group Td*
Ashes	"Sap" cedars	Beech	"Sap" catalpas
Hickories	"Sap" cypresses	Birches	"Sap" chestnut
"Sap" black locust	"Sap" Douglas fir	Cherries	Elms
Honey locust	Firs (true)	Gums	Hackberries
Red oaks	Hemlocks	Hard maples	Soft maples
"Sap" white oaks	"Sap" larches		"Sap" mulberries
"Sap" black walnut	"Sap" pines		Poplars
	"Sap" redwood		"Sap" sassafras
	Spruces		Sycamores
			White walnut

ably utilized. Furthermore, the increase in the use of preservative treatment given cross ties has tended to increase the advantage of the sawed tie, as it is more uniform in size than the hewed tie and can be handled somewhat more readily with mechanical equipment. When inserted in track, its regularity of size is advantageous to the track foreman, since the sawed tie does not displace an undue amount of ballast as irregular sizes of hewn ties may. Better utilization of cylinder space is possible with sawed ties. Most of the larger railway systems accept both sawed and hewed ties indiscriminately and make no differential in price between them.

The advantages of hewed ties are that they are cut usually with a straight grain and hence may have superior strength, and the railroad generally receives a larger volume of wood when purchasing hewed ties. The latter theoretical advantage applies, however, only to ties in the untreated condition. Sometimes the producer may be able to hew ties more cheaply than to haul saw logs to a mill and convert them into sawed ties. Furthermore, there is more sapwood in hewed ties and, therefore, greater protection after treatment, because heartwood is more difficult to treat with preservatives.

The principal reasons for sawing ties, on the other hand, are the following:

1. Hewing involves an enormous wastage of good material. More than 200 million b.f. of good wood was wasted annually at one time in hewing ties. From 15″ logs two ties can be sawed, but only one can be hewed from a log this size.

2. More sawed ties, for a given specification, can be loaded on a cylinder tram for treatment than can hewed ties. Thus, with sawed ties, the daily output of a tie-treating plant is increased slightly, and the cost of treatment per tie is decreased.

3. Tie plates and rails on sawed ties have a more even and uniform bearing surface than on hewed ones. All ties should be adzed or bored * before tie plates and rails are spiked.

4. Hewed ties contain much unnecessary volume and weight and are, therefore, more expense to handle, to transport, and to treat.

SPECIFICATIONS

Within the past few decades the larger railroad systems have increased gradually the size of cross ties to meet the demands of increasing traffic, heavier rolling stock, and greater speeds. For many years, some railroads used 6″ × 7″, 6″ × 8″, and 7″ × 8″ cross ties, 8′ long, but the sizes have been increased on most main lines until the standard tie under these conditions is now regarded as 7″ × 8″ and 7″ × 9″ × 8′ or 8′6″ long. Several railroads now use 9′-long ties.

Each railroad system, for the most part, issues its own specifications, giving the species accepted and the width, thickness, and length accepted in sawed or hewed ties. All ties must be free from any defects that may impair their strength or durability in service, such as decay, large splits, large shakes, large or numerous holes or knots. Some railroads insist that some

* At the present time, a large percentage (about 72%) of ties is bored and adzed before treatment.

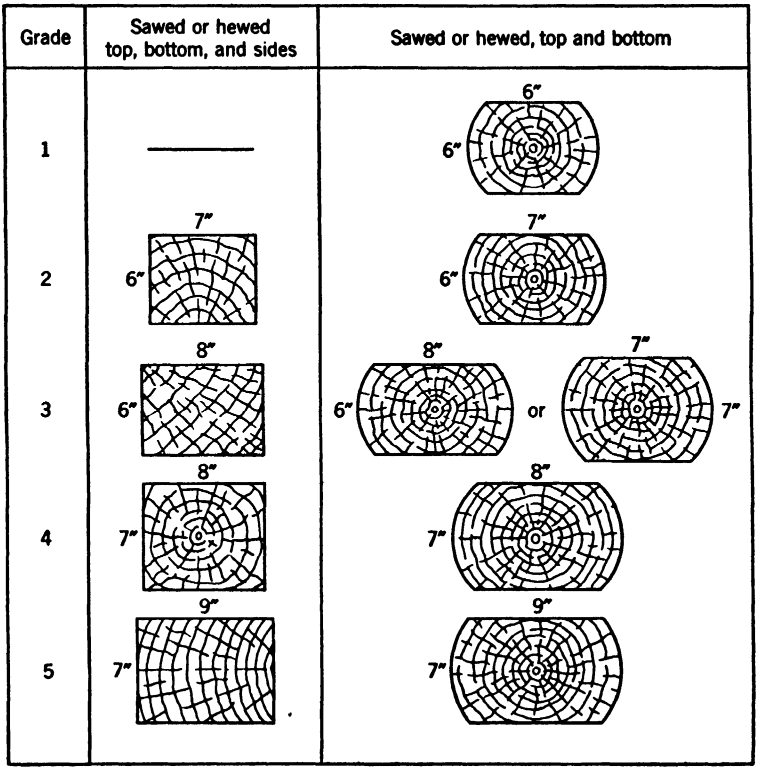


FIGURE 35. Specifications of the five grades of ties acceptable by the railroads. The largest sizes are used by railroads with the heaviest and most frequent traffic. The smaller sizes are used by the smaller systems and for side tracks, branch lines, and sidings. *Courtesy U. S. Forest Service.*

species be felled only during the winter or other special seasons. Bark must be removed, and all ties must be straight, well cut, and square at the ends. Only the kinds of wood named in a group may be stacked together.

CROSS-TIE MAKING

In the early period of railroad history cross ties were produced by individual tie makers and small sawmills. These individual tie makers were, for the most part, farmers, who, during winter months, produced a limited number of ties from their own land, or small sawmill operators who purchased one or more small tracts of timber and produced ties in a relatively small number. In the beginning these individual tie makers were faced with several difficulties. They were scattered throughout the country and had no facilities for marketing their production. Their individual production was not large enough to supply the demand of any one railroad. Their capital was not sufficient to allow them to accumulate a supply large enough for shipment in carload lots, and their individual type of production made it difficult for railroads to obtain uniform ties. As a result of these difficulties, there developed a unit of the tie industry known as the "tie producer." The tie producer, or tie company, is the source of supply on whom a large number of railroads depend for their cross-tie requirements, particularly those railroads upon whose individual right of ways are not produced sufficient numbers of ties to meet annual requirements.

The tie producer maintains tie-buying and concentrating yards and an organization of yard supervisors, laborers, and inspectors. The tie makers and mill men bring their ties to the nearest tie producer who grades and classifies them according to standard specifications and receives cash for his product on delivery.

The tie producer is not dependent on the type of production just named, because as a source of supply he must be in a position to furnish ties at such seasons and in such quantities as the railroads may require them. He is, therefore, prepared to furnish additional amounts of ties when required and, owing to this fact, generally owns and controls extensive timber holdings which enable him to have a fixed and certain supply of raw material for his production.

Stumpage. Stumpage for cross ties is sometimes sold in connection with a saw-log operation. In the Rocky Mountains and some sections of the East and South, there is a stumpage price based on piece rather than on board foot as a unit. White oak stumpage is often worth 25 to 60 cents per tie, southern yellow pine 20 to 40 cents, Douglas fir 5 to 16 cents, and red oak, western larch, ponderosa pine, maple, gum, ash, and hickory 20 to 50 cents per tie.

Suitable size timber for hewing. Trees from 11″ to 15″ d.b.h. are most suitable for hewing. Lodgepole pine is probably the best-sized tree for hewing. Merchantable timber frequently contains 15 to 75 trees per acre of suitable hewing sizes, that is, 10″ to 15″ in diameter, and lodgepole pines are tall, straight, and free from excessive taper, knots, and branches. The average southern pine tree 11″ in d.b.h. produces $2\frac{1}{2}$ cross ties, whereas a 16″ pine will produce 6 cross ties. Tie-volume tables showing the number of cross ties to be produced from each tree diameter

FIGURE 36. Hewed cross ties laid 26″ apart, center to center, on the tracks of the Boston and Maine Railroad in Maine. Note the tie plates used to increase the bearing surface and to prevent the rail cutting into the wood and the use of single-nail spikes. Some railroads formerly used the screw spike. The prevailing practice is to use tie plates with nail spikes. *Courtesy U. S. Forest Service.*

have been prepared for many species in several parts of the country. Tie hackers do not desire trees of very small diameter because the resultant ties may be rejected by the inspector at the railroad landing, whereas, if they are large, the labor involved in felling, limbing, and hewing may be excessive.

Number of ties per thousand board feet. The usual converting factor is 27 ties per M b.f. This means 37 b.f. per tie. Actually the board-foot contents vary widely with each size tie. For example, the 7″ × 9″ × $8\frac{1}{2}$′ tie contains 45 b.f., the 7″ × 8″ tie 40 b.f. and the 6″ × 8″ tie 34 b.f. Sawed ties are sold by the piece for given specifications. The board-foot content of hewed ties is a very variable factor.

Hewing. This includes the felling, limbing, scoring, facing, and bucking of the tree into tie lengths. It is also known as tie making. The tie makers, known as "tie hacks" and "hackers," normally work by contract and are paid by the piece for each tie delivered along a skidway or haulroad. They carry generally a 4- or 4½-lb. double-bitted axe, one 12″ 7-lb. broadaxe, a crosscut saw, iron wedges, sledge hammer, bark spud, a measuring pole of the desired tie length, and a bottle of kerosene to oil the saw. These men furnish their own tools and are assigned to a given area. When the tree is felled, the tie hack stands on the trunk, scores with an axe at an angle of about 45° with the direction of the tree and at intervals of 4″ to 8″. After being scored, the two faces are hewed down with the broadaxe to the desired width and smoothness, the chopper standing on the tree and working and chopping with the grain. The trunk is cut into desired lengths with the crosscut saw. The majority of hewed ties are now hewed on four sides. The cost of hewing depends on (1) ability and efficiency of the chopper; (2) the species of the tree; (3) the condition and slope of the forest floor; (4) size, shape, and condition of timber, number of trees per acre, etc.; (5) specifications of ties. An experienced chopper will make 20 to 25 ties per day in lodgepole pine timber and somewhat less in Douglas fir, western larch, and southern pine. In oak and other hardwoods, a tie hacker may be able to make only 8 to 15 ties per day. Tie hackers are paid rates depending on prevailing prices for cross ties, difficulty of hewing, and other local conditions.

Transportation. Cross ties are hauled, as a rule, from the sawmills or the woods to the railroad or delivery point on motor trucks. Where there is excessive windfall or the topography is very rough, cross ties are skidded to a truck road by team or tractor, 3 to 10 ties or more being taken per trip. Drays or sleds are used both with and without snow for short distances.

In the Rocky Mountains, cross ties are sometimes flumed and stream-driven to destination. In the Ohio Valley and lower Mississippi Valley, cross ties, for the most part, are trucked to destination. Forty to sixty cross ties may be handled on each trip. The number of trips per day varies with the distance, character, and condition of the road, size and weight of ties, efficiency and size of motor truck, and other local conditions.

SAWED CROSS TIES *

More than one half of all the cross ties used by the railroads are now sawed, and there is a definite trend toward a large production by sawing rather than hewing. This change is for reasons given previously and because of the efficient operation of motor trucks for transporting logs to the sawmills and ties from the mills to the railroad loading point. Motor trucks provide a much more flexible source of supply and transportation on an economical basis. Cross-tie stumpage varies normally, from 20 to 50 cents per tie. These costs compare favorably with stumpage prices usually paid for saw-log stumpage, except in dense pine or for cooperage.

Cross ties are sawed principally at small sawmills which have a normal producing capacity of 5 M b.f. per day. Small mills operated by four men may saw 50 to 60 ties per day. Larger mills operated by seven to nine men, capable of producing 7500 b.f. of lumber per day, may produce 150 cross ties per day. None of the large sawmills producing 40 M b.f. to 200 M b.f. or more per day devote practically any of their production to cross ties, which are generally incidental to the main-purpose production.

Small mills producing up to 150 ties per day may be efficiently operated for logs varying in top diameter from 12″ to 20″. Logs of various diameters may be classified into those from which the better grades of lumber may be produced and those that are primarily cross-tie logs. Those from which both lumber and cross ties are sawed are cut usually to 16′ or 17′ with allowance for trimming so that they may produce two lengths of cross ties as well as lumber of the longer lengths. At some mills, notably in Missouri, Arkansas, and the Ohio and Mississippi Valley sections, short-length logs, that is, 8½′ or 9′ long, are cut, and a short carriage approximately 12′ or 14′ in length with two head blocks may be especially advantageous for maximum cross-tie production.

An unloaded saw (revolving free) making 600 r.p.m. will make

* For further information on this subject see Application of Mechanical Power in Cross Tie Production, by C. J. Telford, *Cross Tie Bull.*, St. Louis, September 1936.

only about 450 r.p.m. when sawing with a standard gasoline engine or tractor. When powered with a steam engine, the saw may maintain faster speeds. About 50 hp. is sufficient for this production. Producing 150 ties per day means sawing one tie every 3 minutes. When unloaded, the saw may be run at 550 r.p.m. and when loaded at not more than 520 r.p.m. At least 60 hp. or more is needed to operate the headsaw and edger. This power refers to belt power. Ratings are often confused as to the power developed in various types of engines. These ratings do not always give belt horsepower, which is the important consideration. Most tie mills now use gasoline- or Diesel-power units. There are very few steam mills in operation. Research in improved metallurgy is providing saws that will run for days instead of hours between sharpenings. The new portable mill is being designed to save unnecessary waste in saw kerf as well as to produce much more accurately sawed lumber and cross ties. Some sawmills are being operated in Europe with wood chips or charcoal as a basis of fuel in place of the more expensive gasoline. Recent improvements in cross-tie sawing have been power-slab conveyers, tie conveyers, and loaders operated by tractors and power hoists. One company has recently put out a machine which has combined skidder and loader, mounted on a mobile tractor, for reducing logging costs in the woods. Power saws are rapidly replacing the crosscut saw in timber cutting.

In the large producing areas of the lower Ohio and Mississippi Valleys typical manufacturing costs of an oak tie are approximately as follows:

Stumpage	$0.40
Felling and bucking	0.17
Logging	0.21
Sawing	0.37
Hauling to railroad	0.30
Insurance, etc.	0.03
	$1.48

SEASONING

Cross ties are seasoned before being placed in service on the railroad right of ways or before pressure treatment, for the following reasons:

1. Seasoning generally increases the effectiveness of penetration of the preservative treatment.

2. A decrease of 10 to 17% by weight as a result of seasoning means a corresponding decrease in freight. (Railways do not figure freight when hauling ties to be used on their own right of ways.)

FIGURE 37. A common method of piling switch ties for seasoning. Switch ties should be grouped according to species and length before being placed in seasoning stacks.

3. Seasoning under proper conditions prevents serious checking and splitting. Checking before treatment is preferable to checking after treatment. The rate of seasoning is determined by the structure of wood of each species, season of the year, general climatic conditions, and methods of piling. The hardwoods, oak, gum, maple, and beech, season slowly and with difficulty, compared with the softwoods, pine, fir, cedar, spruce, cypress, and redwood. Winter-cut trees are less susceptible to damage by fungus and insect attack and, when properly barked, season rapidly the following spring and summer.

Various methods of piling are insisted on by railroads, treating plants, and other purchasers. Some of these methods are shown in Figure 37. The principal forms used are as follows:

1. Solid piling, ranging 7 to 9 ties each way, with no spacing and therefore little opportunity for air circulation. Treated ties are often close piled and covered with dirt or other material to prevent fire and check from wind, hot sun, and changes in climatic conditions. Green ties should never be piled solidly for any length of time.

FIGURE 38. Recently developed method of handling and stacking cross ties in storage and seasoning yards. Ties are packaged as shown on lift trucks. This mechanization of handling, stacking, and transporting ties has resulted in reduced labor costs. *Courtesy Spurrier Studio, Grenada, Miss.*

2. Half-open piling, in which about 2″ of space is allowed between ties. They are placed 7 in a tier each way. This is not considered good practice because it is too close for adequate seasoning.

3. Triangular piling. When rapid seasoning is desired and there is sufficient available space for piling, this form may be used, but it is expensive.

4. Open-crib piling, where the ties are placed in alternate layers, that is, 7, 8, or 9 one way and 1 the other. This is known as 7 × 1, 8 × 1, or 9 × 1 piling. Such variations as 7 × 2, 8 × 2 and 9 × 2 are also common. The 7 × 1, 8 × 1 or 9 × 1 piling is the most common practice of the progressive railway systems because the minimum tie area rests on the stringers and adjoining ties. Ten tiers resting on concrete, stone, or treated timber foundations, 9 ties to the tier and 15 tiers high, constitute a common method of piling. These methods permit free circulation of air currents.

Oak ties should be seasoned for at least 8 months after cutting in the winter. Some specifications call for seasoning for 12 months. Other dense and heavy hardwood ties, such as beech, birch, maple, sycamore, locust, and elm, do not require such long periods of seasoning. The softwoods are seasoned generally 5 to 8 months.

LIFE OF UNTREATED AND TREATED TIES IN SERVICE

Until 1912 a large proportion of cross ties was placed in service in an untreated condition. Therefore, white oak and heart long-leaf pine were considered the most desirable species and gave the most satisfactory service. The life of untreated ties depends on a number of factors, as follows:

1. *The native durability of the species itself.* This is by far the most important factor.

2. *Size of tie.* Small ties become shattered under heavy rolling stock much more rapidly than larger sizes.

3. *Amount and condition of sapwood.* Sap species are very important for both treated and untreated ties.

4. *Difference in bearing strength.* From a study recently made at a wood research laboratory of a polytechnic institute, tests made demonstrated that the difference in bearing strength for seasoned and green red oak ties is almost negligible because of the forced moisture distribution within the tie cross section under the bearing plate during load application.

5. *Climatic conditions.* In warm, humid climates an untreated tie of some species may last only 2 to 5 years, whereas in dry, cold climates the same species may last 8 or more years.

6. *Condition of the roadbed,* such as character of ballast, drainage facilities, porosity of underlying soil.

7. *Weight of rolling stock, frequency of trains, and location of ties,* whether they are laid on main or branch lines, sidings, etc.

8. *Protection against mechanical wear* by the use of tie plates, screw spikes, pre-adzing, etc. These are all of material assistance in lengthening the life of cross ties in service.

9. *Care and upkeep of track.*

In the untreated condition beech, birch, maple, hickory, eastern hemlock, and loblolly pine will last only 3 to 5 years; red oak, ponderosa pine, and white pine 3 to 6 years; Douglas fir, longleaf yellow pine, tamarack, and western larch 6 to 9 years; white oak 7 to 11 years; heart cypress and redwood 9 to 14 years.

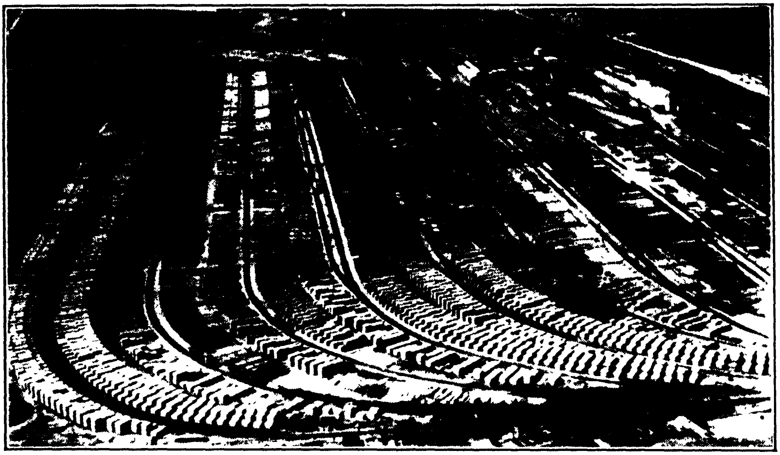


FIGURE 39. Airplane view of large treating plant at Newport, Del., showing storage capacity of more than 3 million ties. This plant is served by 15 miles of standard-gauge track and has an annual treating capacity equivalent to 2,500,000 ties. *Courtesy wood preserving division, Koppers Co.*

Relative mechanical values. Railway maintenance engineers have estimated that between 40 and 75% of all untreated ties that are not protected with tie plates fail because of decay followed closely by mechanical abrasion due to loss of strength. This is especially true of the softer and lighterweight woods, which are readily cut by the rail when heavy axle loads and frequent traffic pass over them. All treated ties should be protected with tie plates.

Some species, as indicated previously, will decay before they wear out, but some soft and durable woods, such as redwood, northern white cedar, chestnut, western red cedar, and southern white cedar, unless protected by tie plates may wear out before they fail from decay. Species arranged in order of their mechanical value as cross ties are as follows: black locust, white oak, red oak, beech, sugar maple, longleaf pine, Douglas fir, shortleaf pine, western larch, tamarack, red gum, hemlock, white fir, lodgepole pine, ponderosa pine, and northern white cedar.

The most recent complete and thorough tests of the average life of untreated and treated ties was conducted by the Burlington Railroad system. Table 7 shows the average life of a variety of untreated ties.*

TABLE 7

AVERAGE LIFE OF UNTREATED TIES IN YEARS

Cottonwood	2.9	Hemlock	4.9	White elm	5.3
Sycamore	3.3	Beech	5.0	Hickory	5.5
Tupelo gum	3.5	Ash	5.1	Pin oak	6.3
Red birch	3.6	Tamarack	5.1	Cypress	8.3
Soft maple	3.6	Loblolly pine	5.3	Chestnut	9.7
Red gum	4.1	Poplar	5.3	White oak	11.1
Hard maple	4.7	Red oak	5.3		

Table 8 is a summary of results of inspection of several thousand cross ties after 40 years' service, as treated by various processes and also in the untreated condition. This involves both eastern and western lines of the Burlington system.

TABLE 8

SUMMARY OF 1949 INSPECTION OF CROSS-TIE TEST TRACKS, C., B. & Q. R.R.

Results of 40 Years' Service *

Process	*Total Placed*	*Total Removed to Date*	*Per Cent Removed Account Decay*	*Per Cent Removed Other Causes*	*Actual Average years Life to Date*
		Lines East			
Straight creosote	2,046	1,977	37	59	25.4
Card process	10,241	10,210	38	62	19.4
Burnettizing	1,578	1,578	55	45	16.1
Untreated	2,046	2,046	90	10	5.4
		Lines West			
Straight creosote	1,236	1,109	27	63	25.0
Card process	5,591	5,519	38	61	18.5
Burnettizing	910	910	50	50	15.0
Untreated	1,226	1,226	91	9	5.8

* Data supplied by H. R. Duncan of the Burlington system.

* From study by H. R. Duncan of the Burlington system based on 1949 inspection of ties and 40 years of experience.

APPLIANCES FOR THE PREVENTION OF CHECKING

To prevent checking, S, C, and other types of irons have been inserted in the ends of hardwood cross ties, timbers, and other products. Two C irons together protect a greater area from checking than the other types used singly. To salvage badly split ties a tie squeezer has been developed with 50,000 lb. pressure, sufficient for pulling together any hardwood ties that have checked. After compression, a band and buckle are applied to hold the tie together. These bands are made of copper-bearing material to resist rust, and are applied while the squeezer is holding the tie together. Many railroads are using these squeezers and the bands without or in connection with antichecking irons. The latest method of preventing checking and splitting that has been developed involves the use of wooden dowels. The ties are put through a machine which bores holes near the ends of the ties or timbers and automatically inserts two dowels in each end. This method requires the purchase or lease of an expensive piece of machinery.

17 · POLES AND PILING

With the invention of the telegraph and still later the telephone as a means of communication, a great demand for poles on which wires are supported was created. Still later street railroad and interurban trolley systems required many thousands of poles. Still more recently electric-light and power-transmission lines have required additional poles so that, normally, between 5,000,000 and 8,000,000 poles valued at about 60 to 70 million dollars are required annually for new construction and renewals of poles broken or decayed. This value is based on an estimated price of $12 each for a class 7–35 * pole which is the size most commonly used.

No official statistics are available showing the production of piling, but it is estimated that as much timber is required for piling as for poles. Enormous quantities of piling are used in all seaboard communities for wharves, docks, abutments, protective devices, holding booms, piers, etc., and in all parts of the country for railroad and bridge trestlework, grade-crossing eliminations, etc. Piling and poles are produced along similar lines and of similar sizes.

In the early days nearly all local available species were utilized for both poles and piling. Accessibility and initial cost were the determining factors. It was quickly discovered, however, that most poles of low-decay resistance decay at the ground line in 2 to 6 years when they are used in service in the untreated condition. Untreated cedar poles often last 10 to 17 years. At the present time only the more durable species are employed in the untreated condition, and there has been a very definite advance in the use of treated poles, notably poles of southern pine.

The telephone poles now in use by the Bell Telephone System are reported to be 70 million. There are 471,770 miles of pole lines in the Bell system. The Rural Electrification Administra-

* This means a pole 35′ long with a 7″ top.

tion has been employing more than 2 million poles a year. They have a total of 750,000 energized miles.

Poles are employed principally for telephone, telegraph, and power transmission. The demand for new or initial installations for various forms of pole lines has advanced within recent years, and there is and probably will continue to be a very steady de-

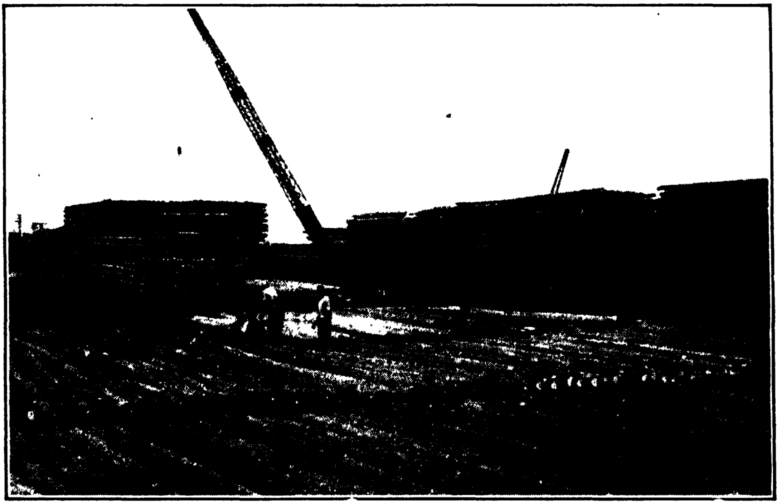


FIGURE 40. Southern pine poles are carefully inspected and framed before being given pressure treatment their entire length. Most of the poles treated in the United States are of southern pine.

mand for replacements. The tendency toward more preservative treatment (both for full length and for butt treatment) may decrease the number of poles used for replacements. More than one half of one company's consumption is of full-length creosoted southern pine poles, the annual requirements being one million poles.

The southern and midwestern states are the most important centers of pole consumption. The producing centers are largely in the southern pine territory and the western red cedar forests of the Inland Empire (principally northern Idaho), where cedar grows to very favorable sizes for pole purposes. Large numbers of northern white cedar poles are used in the Lake States and in Maine. Southern white cedar is employed locally and to a very limited extent in tidewater sections of Virginia and the Carolinas. Probably 90% of all poles are treated.

The heaviest pole-consuming centers are in or near the centers of population and concentration of railroad and power lines. There is a definite trend more and more toward creosoted southern pine poles, which constitute at least 72% of all the poles employed in the East and South and Central States. There is also a definite trend toward the greater use of shaved poles, which give greater symmetry and better appearance through the absence of knots, burls, or other inequalities. The greatest demand is for poles 30′ long with 5″ or 6″ tops.

Pole sizes vary, in general, from 16′ with 4″ tops to 50′ with 11″ tops. Some poles have been cut to lengths of 70′ to 100′, or more, but they are exceptional, exceedingly difficult to obtain, and expensive to erect. They are only required for such unusual and specialized needs as transmission lines where the object is to avoid other lines, buildings or other structures, and lines crossing rivers and streams.

Poles now come usually from small timberlands and farmers' wood lots, widely scattered in the South. The poles are logged in connection with large operations in northern Idaho and generally precede the work of getting out saw logs. Because of the likelihood of breakage, poles are driven separately from saw logs when stream driving is used to bring the primary product from the woods to pole yards, concentration plants, or treating plants. In many parts of the South, timber is being grown intentionally, not only for naval stores and pulpwood, but in connection with them for poles, piling, posts, and other similar products.

Poles are now generally trucked directly from the woods to treating plants. This is particularly true in the South. Poles are hauled on motor trucks for distances up to 85 miles. They are also transported by railroad cars, flat rafts, and on barges, in the tidewater streams, coastal estuaries, and rivers of the Gulf and southeastern states.

Flagpoles and poles for drying clothes are extensively common in the larger cities. They are generally cut from local stands of timber near the cities where used. In the East, especially New York, Boston, and Philadelphia, many spruce poles are employed for these purposes.

Pole production. The demand for poles has steadily increased in spite of the introduction and use of substitute forms. The peak was reached in 1947 with more than 8 million poles. Since the depression years, the demand has steadily increased. Production by species has been notable for the decrease in the number of cedar, chestnut, cypress, and oak poles and the very definite

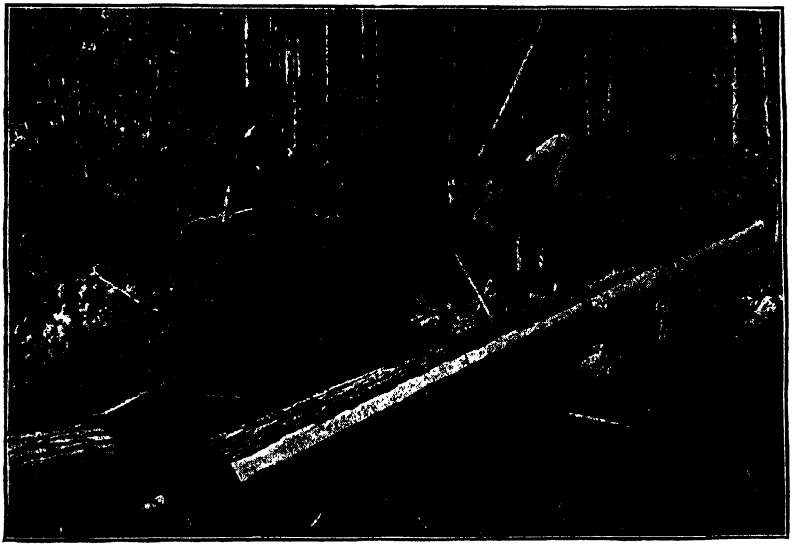


FIGURE 41. Peeling western red cedar poles in northern Idaho.

increase in the use of southern pine poles and an increase in Douglas fir, lodgepole pine, western larch, and ponderosa pine. The peak production of cedar was about 2½ million poles in 1915. In the normal year of 1929 this figure had dropped to about 2 million poles and in 1931 to about 1 million poles. Chestnut poles have decreased in production from a peak of 988,084 poles in 1906 to 503,000 in 1929, and to a lower figure since. Cypress poles have decreased in production from 101,000 poles in 1906, 25,540 in 1929, and still fewer today. The peak of oak-pole production was 265,292 poles in 1910. In 1929 only 6179 oak poles were used. This rapid falling off is due to the excessive weight of oak poles for shipping purposes and the concurrent increase in the use of the inexpensive southern pine poles and the increased length of life in service after creosote treatment. Pine poles have shown an increase from 177,000 in 1906 to 546,000 in 1915 and to more than 3,960,000 in 1948. Table 9 shows the number of poles treated in 1948. Practically all poles are butt-treated or pressure-treated.

TABLE 9

POLES TREATED IN 1948 *

By Species and Method of Treatment

Species	*Full-Length Pressure Treatment, Number*	*Non-Pressure Treatment, Number*	*Total Number*
Southern pine	3,959,662	1,863	3,961,525
Western red cedar	5,752	456,145	461,897
Douglas fir	392,070	64,635	456,705
Lodgepole pine	235,674	159,400	395,074
Larch	2,410	90,682	93,092
Northern white cedar	......	87,070	87,070
Ponderosa pine	48,073	......	48,073
All other	18,714	20,926	39,640
Total	4,662,355	880,721	5,543,076

* From data supplied by U. S. Forest Service.

PROPERTIES DESIRED IN POLE AND PILING TIMBERS

The following properties are the determining factors in the selection of the various woods available for poles and piling:

1. The species when used untreated must be durable in contact with the soil. Decay occurs most readily at the ground line because of the alternate dry and moist conditions prevailing at that point. Practically all poles and piling are used in the round condition, and sapwood, the least durable part of the tree, is exceedingly susceptible to decay in the various forms.

2. Timber used must be accessible and available in sufficient quantities so that the price factor is attractive.

3. The wood should be preferably light in weight to reduce transportation and erection charges to a minimum.

4. Wood should be sufficiently strong to resist stresses and strains incident to carrying loads up to 80 or more wires under the pressure of high winds, sleet, and ice storms, etc. Since there is a considerable amount of breakage of poles in all parts of the

country owing to excessive wind and sleet storms, the wood must not be brash.

FIGURE 42. Section of the 2-mile double-track ballast-deck creosoted-timber bridge built by the Illinois Central system over the Bonnet Carre spillway near New Orleans in 1935. More than 10,000 creosoted piles, totaling 850,000 lin. ft., and 4½ million b.f. of creosoted timber were required for construction of this bridge. The cross ties are also creosoted.

5. Poles and piling should be straight and cylindrical, with gradual taper, and free of excessive checks or defects which will detract from their durability values.

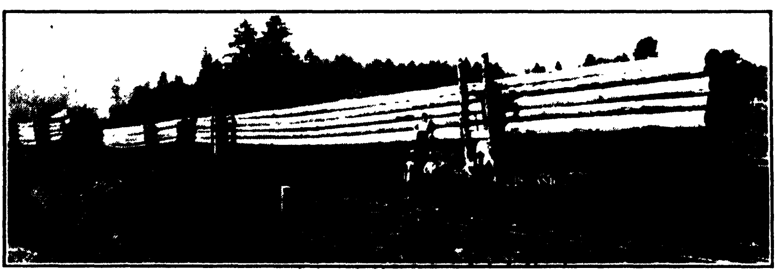


FIGURE 43. Douglas fir piling 100′ to 120′ long loaded on three car lengths. When unusual piling of this type is required, Douglas fir is the only tree available in these long specifications.

6. The surface of poles should be suited to climbing irons. Although this is a minor consideration, workmen sometimes have

difficulty in climbing poles of some species and therefore object to their use.

7. When treated, the wood should be susceptible of penetration by creosote or other preservatives.

In general, the same qualifications as described for poles obtain

FIGURE 44. Piling used in harbor improvements along the Potomac River at Alexandria, Va. At lower left is shown a relieving platform supported by piling. Various types of ferry slips, piers, wharves, and abutments are constructed of or supported by piling. The familiar pile driver is shown at upper right. *Courtesy U. S. Forest Service.*

for piling. However, piling must be capable of withstanding shocks of the pile driver without breaking or splitting. Piling must also withstand heavy loads and be sufficiently straight so that the axis is kept within the pile. Because piling is often driven underground and sometimes double and triple piling are used, piles are not necessarily made from highly durable species. When free from conditions of decay, that is, proper temperatures, moisture, and air conditions, piles will not rot. Hemlock piling has been known to be sound after 56 years of service in swamps where grillage on the top prevented access to the air.

GENERAL SPECIFICATIONS

Poles and piling are generally classified for commercial purposes in 5′ lengths and by top diameters. Sometimes the diameter at the probable ground line is specified, usually 5′ from the butt in the longer chestnut poles. The minimum length is regarded usually as 20′ for both poles and piling. Some lengths up to 100′ are occasionally in demand for transmission lines that must cross ravines, canyons, railroads, and other lines. Practically 70% of all poles are 20′ to 30′ in length; only about 25% are 30′ to 40′ in length; and the remainder are 45′ to 50′ in length.

Specifications are prepared by the various pole producers' associations and the larger companies using poles—the Bell Telephone Companies and the railroad and electric light and power companies.*

With the exception of chestnut, poles and piling must be cut from live growing timber, properly peeled, with knots trimmed flush with the trunk, butts and tops sawed square, and both butts and tops sound. Only a minimum crook or sweep is permitted for the different lengths. Large knots if the pole is sound and if properly trimmed are not considered a defect.

Within the past two decades, under a strong demand for uniformly tapered poles, machines have been devised to surface the poles to uniform diameters and tops, gradually from the butt to the top. This is done before preservative treatment, particularly in southern pine poles.

The specifications † for piling are particularly rigid in the matter of straightness. Straightness is assured by having specifications to control sweep which is the deviation from a straight line between the centers of the butt and the top. The deviation allowed is usually 1″ for each 6′ of length. Piles intended for treatment with preservative shall be free of inner bark wider than ½″ and on more than 15% of any square foot of surface. The top-diameter specifications for piling are more rigid than for poles. For example, piling must have a diameter of not less

* Specifications of the American Standards Association are generally followed.

† Federal specifications MM-P-371, March 31, 1947, are usually followed as a standard for piling. Railroads and highway departments have their own piling specifications.

FIGURE 45. Large quantities of wooden poles are used to support electric-power lines in all parts of the country. Poles that are straight, have little taper, and are durable in contact with the soil are much preferred. Western red, southern white, and northern white cedars produce ideal poles. Much southern pine with full creosote treatment is used because of the scarcity of available cedars. Lodgepole pine, western larch, and Douglas fir have recently advanced as important species for poles. *Courtesy U. S. Forest Service.*

than 7″ at the small end and must be at least 12″ to 14″ in diameter at a point 3′ from the butt.

PRODUCTION OF POLES AND PILING

The logging of western red cedar, northern white cedar, and southern white cedar poles is conducted as a separate operation generally before the logging of saw timber. Usually it is a good example of prelogging to prevent injury in the felling and skidding of the smaller-size pole timber. Most of the western red cedar poles are produced from the Panhandle of northern Idaho, and a large quantity is cut annually from the National Forests of that district. The cedar of this section lends itself in size, taper, and condition better to pole purposes than the same species found on the western slopes of the Cascade Mountains. The logging of cedar poles is one of the most important businesses in northern Idaho. Table 10 shows the number of poles produced and length classes cut in the Northern Rocky Mountain region of the U. S.

TABLE 10 *

NUMBER OF POLES PRODUCED IN 1947

Species	*Northern Rocky Mountain Region*				*Per Cent of Total*
	Montana	*N. Idaho*	*N.E. Washington*	*Total*	
Lodgepole pine	269,141	30,020	52,149	351,310	43.0
Western red cedar	16,984	161,274	52,614	230,872	28.2
Western larch	32,704	124,902	64,384	221,990	27.2
Douglas fir	5,905	568	....	6,473	0.8
Miscellaneous	....	....	6,557	6,557	0.8
Total	324,734	316,764	175,704	817,202	....
Per cent of total	39.7	38.8	21.5	100.0	100.0

DISTRIBUTION OF PRODUCTION BY LENGTH CLASSES

Per Cent of Total

Species	*Length Classes*					
	25′ and Under	*30′*	*35′*	*40′*	*45′ and Over*	*All*
Lodgepole pine	11	33	39	12	5	100
Cedar	20	25	26	13	16	100
Larch	24	20	36	14	6	100
Douglas fir	3	21	35	23	18	100
Miscellaneous	10	27	37	18	8	100
All species 1947	14	25	35	16	10	100
All species 1946	4	13	50	15	18	100

* From data supplied by the Northern Rocky Mountain Experiment Station of the U. S. Forest Service at Missoula, Mont.

Forest Service. It is especially interesting to note the rapid and recent rise in production of lodgepole pine and western larch poles.

As indicated previously, southern pine is cut principally from scattered holdings after logging as well as from farm wood lots and other small timber properties. It is therefore produced from a large number of small scattered bodies of timber and furnishes a very important part of the net cash income from many farms throughout the southern pine states. It is produced largely from shortleaf and loblolly pine in second-growth stands. Timber of this kind has a large percentage of sapwood which lends itself readily to creosote treatment. Timber-treating plants throughout the South are busily engaged in the treatment of pine poles which are used throughout the East, Northeast, South, and Middle West.

Pole and piling stumpage values are based on poles of given sizes as well as on a linear-foot basis and a per-thousand-board-feet basis. Western red cedar poles from the National Forests are sold for 2 cents per lin. ft. for 25′ to 30′ poles up to 6 cents per lin. ft. per 55′ to 70′ poles; thus stumpage prices would be 50 cents for a 25′-length pole up to $4.20 for a 70′ pole. The values of standing timber are greater for poles and piling than they are for saw-log production. Similarly the cutting of standing timber may have a greater value for poles and piling in the South and East than for saw logs or for any other purpose. This is determined by local and regional demand. This factor should be carefully analyzed by foresters to determine which is the most valuable product of a given stand of timber.

Table 11 indicates much higher prices paid for cedar than for lodgepole pine and the premium paid for the longest sizes which are the most difficult to obtain. Cedar usually grows in much taller stands than lodgepole pine.

Poles and piling are considered best cut during the winter, when the sap is down. Peeling, which is required of poles, is least difficult and expensive during the spring. Therefore cutting is done usually during the winter and early spring and peeling from about May 1 to August 1 in the northern latitudes. Most pole-treating plants now have peeling machines, and many of them bring the poles from the woods directly to the plants for peeling.

TABLE 11 *

STUMPAGE PRICES PAID FOR LODGEPOLE PINE AND WESTERN RED CEDAR POLES IN REPRESENTATIVE NATIONAL FORESTS IN MONTANA AND IDAHO

National Forest and State	*Poles*	*Stumpage Price per lineal foot*
Lodgepole Pine		
Bitterroot, Mont.	25′ or shorter	$0.005
	30′ and 35′	0.008
	40′ and 45′	0.013
	50′ and over	0.018
Deerlodge, Mont.	35′ long	0.011
	40′ and 45′	0.016
	50′ and longer	0.022
Western Red Cedar		
Clearwater, Idaho	35′ or less	0.02
	35′–45′	0.03
	45′–55′	0.04
	55′ and over	0.06
Kaniksu, Idaho	25′ and shorter	0.01
	30′ and 35′	0.03
	40′, 45′, 50′	0.04
	55′ and over	0.06

* From data supplied by the Northern Rocky Mountain Experiment Station of the U. S. Forest Service at Missoula, Mont.

In general, peeling of cedar is done with a bark spud; the peeling of other species with a bark spud, draw knife, and axe.

After the tree has been felled, skidding is done, usually by tractors or by horses with a bumper or dray to elevate the front end and decrease the tractive resistance incident to dragging the heavy and bulk log over the ground. Motor trucks, also, go directly into the woods, particularly in the South, and haul poles and piling from the felling area to the loading or other concentration points along the railways, driving streams, or major transportation points.

When poles are stream-driven, as in northern Idaho, they are handled in a separate operation from the saw logs because of the relatively large amount of breakage when saw logs are mixed with poles. Owing to their length, poles and piling are not used, as a rule, in connection with flumes, but they are frequently logged in connection with chutes. More poles and piling are now hauled to treating plants or concentration yards by motor trucks than by any other means of transportation.

Piling is cut throughout the Northeast and South, generally

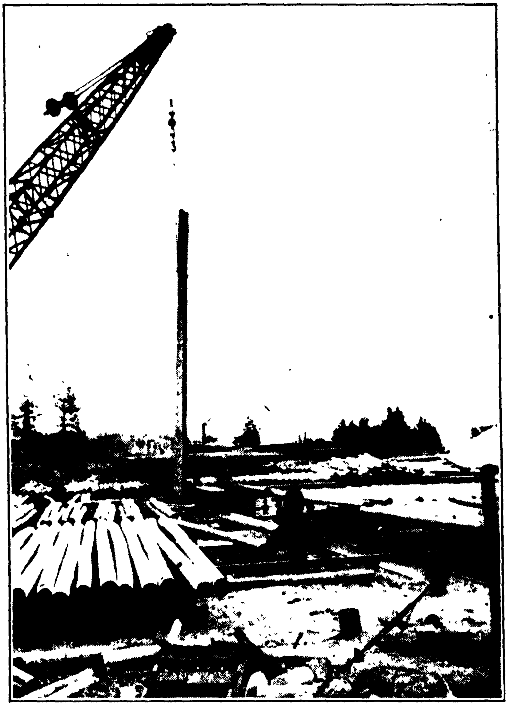


FIGURE 46. Typical view of poleyard where quality cedar, pine, larch, and other types of poles were cut on farmers' wood lots in northeastern Washington, at Newport. Poles are an important cash crop for farmers and other small woodland owners. *Courtesy American Forest Products Industries.*

as a separate operation. Piling is cut as close to the point where used as possible. For example, in the Northeast and East, oak is much preferred, and local oak is usually cut for the purpose, even from scattered wood-lot holdings. In the South, piling is cut by a method similar to that described for poles, that is, from scattered farm wood lots and other small holdings, as a separate operation, and hauled by motor truck and trailers to the point of preservative treatment, or to the point of final use when in untreated condition. In a grade-crossing elimination in a small-sized eastern city more than 250,000 lin. ft. of creosoted piling was used. Piling is extensively favored for bridge abutments; flood dams; trestlework; harbor, river, and other marine improvements; and the tendency is to increase the demand for piling.

Proper yarding and seasoning are of great importance in the pole and piling business. Poles should be air-seasoned or steam-conditioned before treatment. If piled too closely or too high, they are liable to be attacked by fungi before they season properly; but, if exposed too much to the sun and drying action of the sun and wind, they may check seriously. The decrease in weight during seasoning may vary from 20 to 30% or from 180 to 900 lb. per pole. This is an important item in saving freight charges either by motor truck or railroad. Shrinkage in such low-specific-gravity species as spruce and chestnut is much less than in oak and southern pine. When there is serious danger of end checking, poles are protected by the use of S, Z, and other forms of end irons. Usually small poles known as skids or stickers are placed between poles and piling during the seasoning process to permit free circulation of air. When thoroughly seasoned, poles and piling should be shipped at once or a protective roof placed over them. Southern pine poles may badly deteriorate under unfavorable weather conditions in less than 4 months. Therefore the usual practice is to treat these poles without air seasoning by using the steaming and vacuum-conditioning method. Many Douglas fir poles are also treated green and conditioned by the boiling and vacuum process. When untreated, piling is frequently used in the green as well as in the seasoned condition.

Poles and piling more than 40′ in length must be loaded on two flat cars for railroad shipment. There are generally 85 to 225 poles per car, depending on the length and top diameters, which may vary from 6″ to 8″ or more. Lengths, as a rule, vary from 25′ to 40′. On double carloads the number of poles varies from 40 to about 100 poles, depending on length and top diameters.

LENGTH OF SERVICE UNTREATED

The following factors determine length of life:

1. Species. The cedars, redwood, cypress, and white oak are very durable and sometimes are used with only butt treatment or in the untreated condition.

2. Climate, precipitation, etc. It is obvious that poles will decay more quickly in a warm humid climate than in a dry region relatively free from precipitation.

3. Local conditions of soil, drainage, moisture, etc.

4. Breakage due to sleet and ice storms, strong winds, etc.

The life of untreated piling depends on species, size, amount of abrasion, and wear to which it may be subjected, damage by such marine borers as teredo, limnoria, and xylotrya.

PRESERVATIVE TREATMENT OF POLES AND PILING

There has been a notable forward progress in the relative quantities of poles and piling treated. The prevailing practice is to treat more and more of these forms. The most notable achievement has been in the direction of further treatment and utilization of southern pine poles for reasons outlined previously. The use of more and more piling for trestlework, bridges, and for stream, lake, and harbor improvements, as well as directly for docks, wharves, piers, and abutments, has increased the demand for treated piling, particularly in regions where marine borers are prevalent, as in San Francisco Bay and south thereof, throughout the Gulf and South Atlantic ports.

Heretofore many cedar poles have been butt-treated in open tanks to a point above the intended ground line. This policy is being continued except that the demand for full-treated poles has increased to such an extent that the butt treatment is not on the increase. Sapwood decay in untreated tops was found to be serious in some sections of the country, and there has been a trend toward full-length treatment of cedar poles.

All southern pine poles that are treated to extend their life in service are pressure-treated for the full length. More than 85% are treated by pressure methods. Butt treatments are definitely on the decrease. Practically all piling treated with preservatives is treated with creosote or creosote mixtures by pressure processes.

Pressure-treated pine poles have an estimated life of 25 to 40 years. Butt-treated western red cedar poles last 16 to 25 years except in the South where climatic conditions favor decay in the untreated tops. Untreated western red cedar poles last 10 years; although along the Milwaukee Railroad electrification lines in Montana, they showed an average life of 17.4 years.

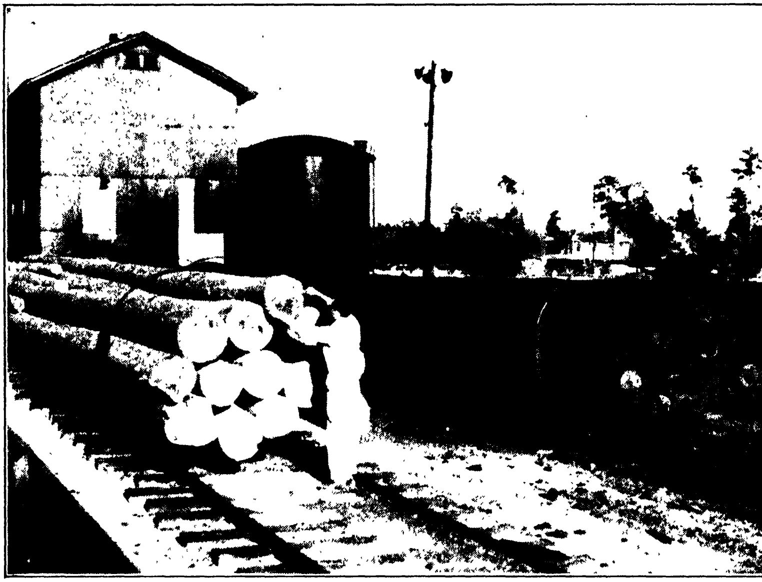


FIGURE 47. General view at large southern pine creosoting plant at Brewton, Ala. At left are untreated poles; at right are shown poles after creosoting treatment. Many of these poles are secured from prelogging operations before being cut for saw logs and pulpwood. *Courtesy American Forest Products Industries.*

Treated poles should be carefully handled when loaded or unloaded from cars. The use of sharp hooks or "dogs" exposes both untreated and treated poles to decay unnecessarily. A considerable amount of damage is caused by allowing poles to drop from cars to the ground. Rope or steel cable slings should be used for this operation.

SUBSTITUTES FOR POLES AND PILING

Some companies have resorted to the use of metal, concrete, and other forms of piling and poles because they give longer service and because the cost of wooden poles has increased. Underground conduits, in places, have replaced telephone and telegraph poles. The latticed steel poles and towers, to some extent, have replaced the wooden poles for high-power transmis-

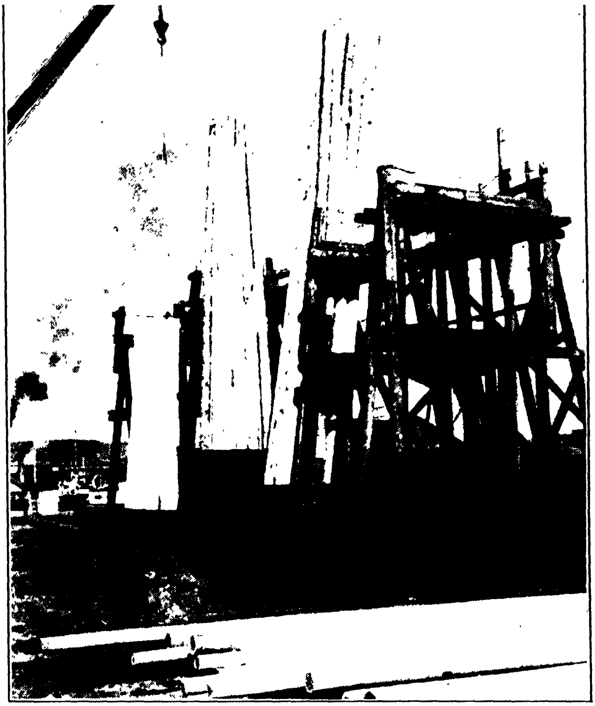


FIGURE 48. Long Douglas fir poles being butt-treated. These poles were cut on prelogging operations from stands of second-growth Douglas fir. Photograph taken at Cascade Pole Company plant at Tacoma, Wash.
Courtesy American Forest Products Industries.

sion lines and lines that cross wide and deep canyons, ravines, rivers, etc.

Relatively little is known, however, regarding the durability, length of life and service, and response to the elements of the various forms of substitute poles and piling. Steel and other metals require frequent and expensive painting. Concrete poles have not definitely demonstrated their durability and length of life. In spite of the substitution of several forms of both poles

TABLE 12

APPROXIMATE WEIGHTS OF PILING OF DIFFERENT SIZES, GREEN AND DRY, FOR DIFFERENT KINDS OF WOOD, ALSO WEIGHT PER CUBIC FOOT OF EACH *

Length, ft.	*White Oak*		*Black Oak*		*Sugar Maple*		*Cypress*	
	Green †	*Air-Dry*	*Green* †	*Air-Dry*	*Green* †	*Air-Dry*	*Green* †	*Air-Dry*
20	610	470	610	440	550	430	470	290
25	770	590	770	550	690	530	590	370
30	920	700	920	660	820	640	710	440
35	1080	820	1080	770	960	750	820	520
40	1580	1200	1590	1140	1410	1100	1210	760
45	1780	1360	1790	1280	1590	1240	1370	850
50	1980	1500	1980	1420	1770	1370	1520	950
	Weights per cubic foot Used Above, lb.							
	62.7	45.0	62.5	47.6	55.9	43.4	48.0	30.0

Length, ft.	*Chestnut*		*White Elm*		*Black Gum*		*Longleaf Pine*		*Increase with Top Diameter of 8″, %*
	Green	*Air-Dry*	*Green*	*Air-Dry*	*Green*	*Air-Dry*	*Green*	*Air-Dry*	
20	540	300	480	340	440	350	490	410	15.3
25	670	370	600	430	550	450	610	510	15.4
30	810	440	710	510	660	530	740	620	15.6
35	940	520	840	600	770	620	860	720	15.7
40	1390	760	1230	880	1130	920	1260	1060	12.3
45	1560	860	1390	990	1270	1030	1420	1200	11.9
50	1730	950	1540	1090	1410	1140	1580	1330	12.3
	Weights per cubic foot Used Above, lb.								
	54.8	30.2	48.6	34.6	44.7	36.2	50.0	42.0	...

* Top diameter, 6″; butt diameter, 12″ for piling 20′ to 35′, inclusive; 14″ for piling 40′ to 50′, inclusive.

† The green weight or the weight of wood before it is air-dry varies widely. The weights here given are based on the weights of logs shipped in by rail to the Forest Products Laboratory, Madison, Wis., for purposes of testing.

Data supplied by the U. S. Forest Products Laboratory, Madison, Wis.

FIGURE 49. Tractor with hyster winch skidding piling to truckloading point in northern Appalachian region in Maryland. The piles are loaded on truck by crosshaul method. About 60 piles are skidded and loaded per day. Note the straight and symmetrical sizes of piling. *Courtesy Caterpillar Tractor Co.*

and piling there continues to be a steady demand for these forest products.

WEIGHTS OF PILING

Table 12 on page 108 shows the weights of piling of different sizes, condition, and species.

18 · POSTS AND GRAPE STAKES *

POSTS

No statistics of the annual production of fence posts are available, but it is estimated that there are about 230 million posts used yearly on farms and ranches, by railroads to protect their right of ways, for fencing along the highways, and for miscellaneous purposes. Fence posts constitute the fifth most important use of wood. The quantity of wood utilized for fence posts is exceeded only by lumber, fuelwood, pulpwood, and veneers. The normal consumption exceeds that of hewed cross ties, mine timbers, cooperage, and poles. Approximately 230 million cu. ft. of wood is used annually for fence posts, which represents 3.3% of the total wood employed. In 1948, 69 million posts were treated.

Posts are produced principally in farm woodlands, although the railroads and state highway departments often purchase posts, treated or untreated, from large lumber companies, which produce them as an incidental phase of their main operations. In California and the Southwestern States redwood is pre-eminently the most popular wood used for posts. In the Pacific Northwest the principal wood is western red cedar. In the Northern Central States and Lake States, white cedar from Wisconsin, Minnesota, and Michigan is used. Throughout the Central West, southern pine posts, especially those in a treated condition, are used in large quantities. Locally produced locust, white oak, catalpa, mulberry, hackberry, and other woods are also employed in the Central West. In the Northeast, northern white cedar, white oak, and locust have supplanted chestnut, formerly the principal wood used. In the Allegheny and Appalachian sections, chestnut, white oak, catalpa, and sassafras are widely used. Chestnut that has been dead for several years is still durable. In the South and Southeastern States, cypress, southern white cedar, southern pine (especially in a treated condition), and eastern

* Reviewed and suggestions made by J. Oscar Blew, U. S. Forest Products Laboratory.

red cedar are employed. Longleaf and slash pines are often used in an untreated condition.

Posts are usually cut to 7′ lengths, although for special purposes they may be cut in 8′ to 20′ lengths. In producing posts, lengths are often cut to multiples of 7′ and then crosscut to the desired length at or near destination. This is done for the sake of

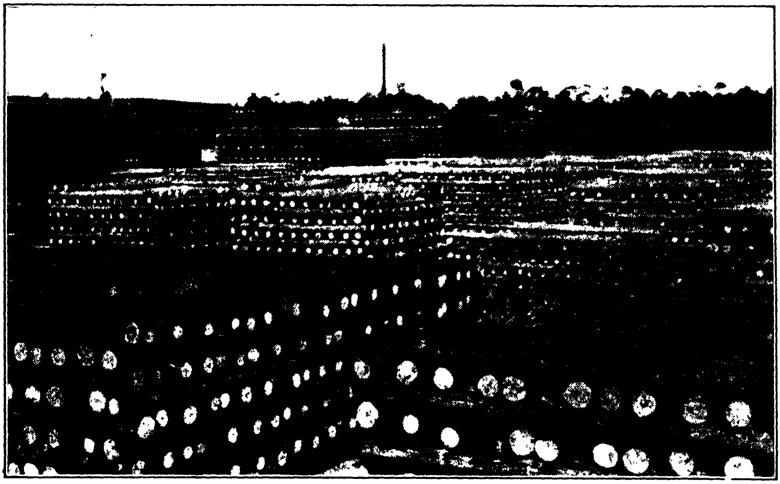


FIGURE 50. Several thousand posts and poles cut from southern pine regrowth stands in thinning operations awaiting treatment at a large plant at Brewton, Ala. Posts in the South are generally made in lengths from 6′ to 14′, those above 8′ being used for brace posts and similar purposes. They are graded in 7 top-diameter size groups from 2½″ to 7″. *Courtesy U. S. Forest Service.*

economy in harvesting and transportation. In the East, South, and Middle West, fence posts are used generally in the round, when they are 2½″ to 6″ in diameter at the top. Larger sizes are split usually into halves or quartered. Western red cedar and redwood posts are often split. Within recent years there has been an increase in the use of sawed posts. Sometimes such sizes as 4″ × 8″, 5″ × 10″, or 6″ × 10″ are ripped in a slight diagonal direction to produce posts that are larger at the base than at the top.

Many cypress, longleaf, and slash pines are also split into posts. With the disappearance of old rail fences in the agricultural sections, there has been a decrease in the use of posts for fences. However, the larger farms and ranches are being divided into smaller ones, and many more highways are being constructed, with a resulting greater demand for adequate protection through fencing. Furthermore, drift fences are common to a larger extent on the National Forests and in public and private grazing areas of the West. All these factors tend to increase the demand for and use of fence posts.

There has been a very definite increase in the demand for creosoted or otherwise preserved fence posts. The increased planting of shelterbelts in the Great Plains both by Federal agencies and by private enterprises has resulted in a large increase in the use of fence posts.

The extensive use of creosoted southern pine posts began in 1916. Some of these posts have been in satisfactory service for 30 years. The standard practice is pressure treatment, full length, with 5 to 6 lb. of creosote oil per cu. ft. with the Rueping process.

The posts are graded in the round in 7 groups of top diameters as follows: 2½″–3″, 3″–3½″, 3½″–4″, 4″–4½″, 4½″–5″, 5″–6″, 6″–7″. Southern pine posts are generally made in lengths from 6′ to 14′. The 10's, 12's, and 14's are employed for brace posts and similar purposes. Some posts are halved in the medium and larger sizes, and the largest ones are sometimes quartered. Southern pine posts are largely produced in Louisiana and eastern Texas as well as in Arkansas and Oklahoma, although they are produced to some extent in every one of the southern pine states.

In a test on regrowth southern pine untreated 4″ size by 4′ length, one post was unserviceable in 2 years, 7 unserviceable in 3 years, and all were so in 5 years.*

Posts are sometimes classified according to use as follows: (1) fencing, (2) guard rail posts along highways, (3) underpinning, (4) stakes, principally those used in vineyards. They are also graded in some regions in two or three classes, depending on size, straightness, taper, and top diameter.

The average life of fence posts, untreated, is estimated to be 8 to 10 years. The life of untreated fence posts depends on the species, seasoned condition, and size (particularly the diameter at the soil line), relative amount of sapwood, soil conditions

* From tests of the Mississippi Highway Department made in 1948 near Jackson, Miss.

where placed, climate and temperatures of the region of placement, and the rate of growth and density of the particular species used. Among the most durable woods employed for fence posts are eastern red cedar, redwood, cypress, western red cedar, mulberry, black locust, Osage orange, white oak, chestnut, northern and southern white cedar, catalpa, and bur oak. Black locust

FIGURE 51. One of many types of wood rail fences as used near Rapid River, Mich. Fence posts are one of the most important uses of forest products. The old rail fences have almost disappeared in favor of wire fences, particularly in the western range country and along railway right of ways. The posts and many of the rails are of northern white cedar. Rustic forms of rail fences as shown here have recently come back into wide favor. *Courtesy U. S. Forest Service.*

and Osage orange have given service of 15 years and more. Western larch, eastern larch or tamarack, red elm, and butternut are also durable, but they represent a third group class. Other woods that should be utilized only in the treated condition are white ash, maple, red oak, birch, cottonwood, Douglas fir and the pines, aspen, beech, and elm. These will last, untreated for only 2 to 7 years. Practically every wood is used for fence posts, but only a relatively few species should be used in the untreated condition. Large quantities of lodgepole pine and ponderosa pine and some Douglas fir and western larch are used in the northern Rocky Mountain region because they are locally available and inexpensive; but there are also sent to this region and the central and southern Rocky Mountains large quantities of western red cedar and redwood posts which give much more satisfactory service and have longer life.

Posts are produced, generally, as an incidental product from large logging operations and from local farm wood lots. The wood lot is the principal source. Posts offer excellent opportunity for efficient utilization, because many of them are produced from

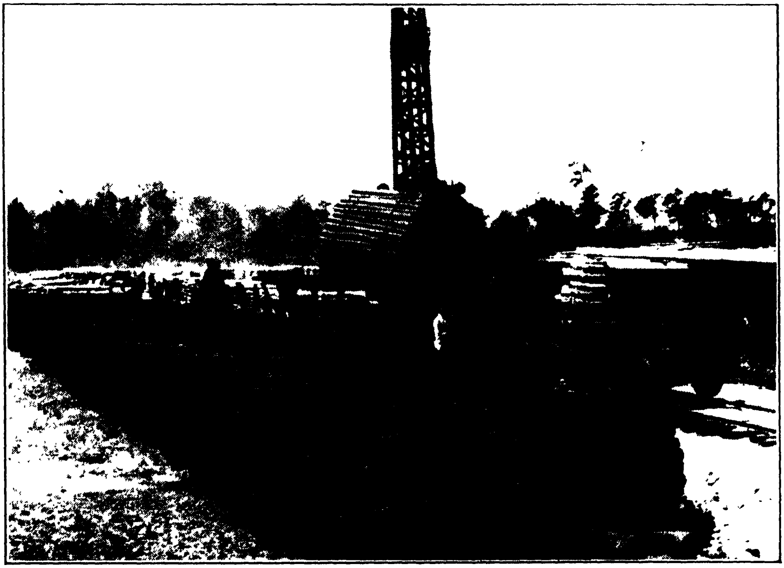


FIGURE 52. Fence posts bundled for shipment after treatment in southern plant. Millions of these posts are used along our highways and railroads, as well as on farms and ranches. *Courtesy American Forest Products Industries.*

top logs or from tops not large enough to produce saw logs, as well as from thinnings, especially in southern pine timber and from species not otherwise profitably utilized. The sound parts of hollow and decayed redwood and western red cedar logs are sometimes rived into posts.

During and since World War II, other materials such as concrete and iron have been substituted, particularly along trunk-line highways. However, with the improved methods of treatment, as well as treatment through pressure methods, the wooden post has not been seriously displaced for general utilitarian purposes. Preservative treatment may cost 15 to 20 cents per post for the open-tank treating process and more by the pressure-treatment method in cylinders. Recent quotations for pressure-creosoted southern pine posts varied from 35 to 44 cents for 2½″ top up to $1.01 to $1.25 for 6″ top, depending on quantity ordered. Minimum prices are for lots of 500 or more posts.

It seems likely that posts will always be used in large quantities and may furnish a medium of much more important utilization of materials otherwise wasted or disregarded in woods operations.

GRAPE STAKES

It is estimated that there are about 4,500,000 stakes used for supporting wires or trellises in vineyards in the United States. The important grape-growing centers are in California, three important sections of New York, and northern Ohio. Actually vineyards are found in nearly every important agricultural state of the Nation.

As for posts, the principal requirements for grape stakes are durability and inexpensiveness. Generally local woods or those produced in near-by regions are utilized. Grape stakes are of various specifications, principally 2″ × 2″ × 6′ in length in California and 7′ to 8½′ long with minimum top diameters from 3″ to 4″ in northern New York and Ohio. The following is a brief description of the conditions in New York and in California. In California stakes are used only in the younger vineyards.

New York stakes. There are 45,000 acres of vineyards in western and central New York and in the Hudson Valley. It is estimated that there are 228 grape stakes per acre, or 10,260,000 stakes, required for the vineyards. If we estimate a 10-year life per stake, the average annual requirements are about one million stakes in New York. If the stakes are valued at 20 cents each, the total annual value is about $200,000. Vineyards vary from 5 to 60 acres, or more, in area. Chestnut that has been dead 10 to 15 years is still sound and can be used for grape stakes. Chestnut formerly constituted 90% of all stakes. Cedar is next in importance, with small lots of locust, oak, cherry, and other miscellaneous species. Chestnut posts last from 3 to 15 years, depending on diameter, sap content, and soundness when cut. Black locust is the most durable, and it is now being grown for grape-stake purposes. Stakes are usually 7′ to 8½′ long, depending on the type of trellis; top diameters are 3″ to 4″, with some up to 8″ in diameter, in the tops. About 200 to 400 stakes are loaded per truck and are transported for distances up to 50 miles.

California stakes. There are 600,000 acres of vineyards in California; and there are 19,000 acres of young vineyards. Stakes are employed, as a rule, only for the younger vines. The number of stakes per acre is about 500 to 600, indicating the total number in use as about 11½ million stakes. The annual requirements are about one million stakes, indicating (assuming the acreage of new vines is stabilized at 19,000 acres) an average life of 11½ years. Stakes are almost exclusively of redwood with a few of incense cedar. The size is usually 2″ × 2″ × 6′, and practically all are split products.

19 · SHINGLES AND SHAKES *

Shingles are thin pieces of wood with parallel sides, thicker at one end than the other. Shakes are rived or split shingles that are as thick at one end as the other. Split shakes and sawed shingles have been used for many years, both as roofing and siding, to protect buildings from the weather. In ancient times they were made entirely by hand, the logs being cut into bolts, rived by hand with a frow or broadaxe, and sometimes shaved at one end with a drawing knife so that they would lie closer and be more wind-tight.

The industry in the past few years, has produced a processed shake. This is a remanufactured shingle with one surface fluted to resemble the split shake. About 25 times as many processed shakes as hand-split or rived shakes are now produced. They are being used on all types of houses irrespective of cost.

Until about 1900, a great variety of species was employed for shingling roofs of American dwellings. There are some examples of properly roofed structures where wooden shingles have given satisfactory service over periods of 50 to 75 years, or more. In the old Colonial homes at Duxbury and other early settlements of Massachusetts and in the home of the author of "Home, Sweet Home," built in 1660 at East Hampton, Long Island, wood shingles have given evidence of great durability. In the South, examples of cypress shingles in continuous use up to 100 years have been noted. On the West Coast, redwood and western red cedar shingles have given good service for as long a time as the white man was settled there.

This important timber product furnishes an outstanding example of adverse prejudice created by a campaign of nation-wide advertising in favor of composition and other types of substitute roofing.

A square of natural or unstained shingles consists of four

* For further information see *Certigrade Handbook of Red Cedar Shingles*, Red Cedar Shingle Bur., Seattle, Wash., 1938. This chapter has been reviewed and checked by W. W. Woodbridge.

bundles and is called a "square" because these four bundles, when applied at the recommended weather exposure for roofs, will cover 100 sq. ft. of roof area. This makes it easy to estimate the number of shingles needed for any roof job—merely figure the area to be covered in terms of square feet, divide by 100, and you have the number of 4-bundle squares required.

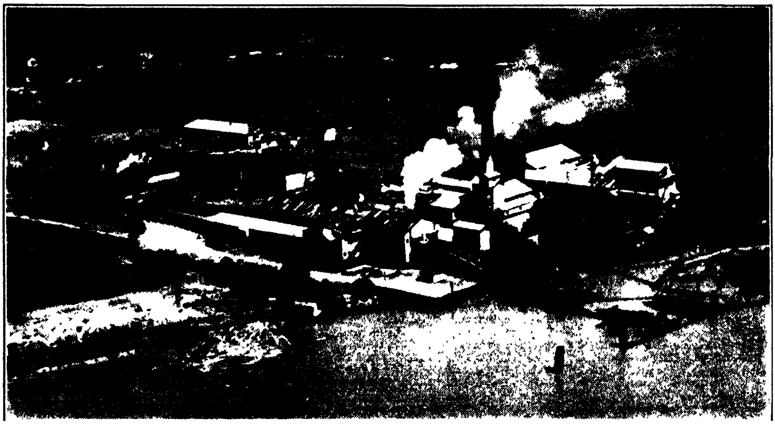


FIGURE 53. Large mill with 24 shingle machines devoted exclusively to the manufacture of shingles. This plant is located on the Fraser River near Vancouver, B. C. An interesting feature is the Pres-to-log plant immediately beyond and to the right of the mill's stack and burner. This uses the waste sawdust and other shingle refuse in the production of these compressed briquettes which are widely used for fuel purposes in diners, fireplaces, ranges, heaters, and furnaces. *Courtesy Bloedel, Stewart and Welch.*

When properly manufactured, seasoned, and laid, the wooden shingle is undoubtedly the best material for roofing dwellings and many other forms of construction because of its relatively low cost, great durability resulting in long life in service, and attractive appearance. Many forms of substitute shingles have invaded the field of wooden shingles, but experience with them has generally indicated that they have failed to replace the wooden shingle in the fundamentally important factors mentioned.

The Red Cedar Shingle Bureau of Seattle, Wash., has conducted a very effective and interesting Nation-wide campaign not only to improve the manufacture, conversion, packing, and seasoning of shingles at the sources of production, but also to show how shingles should be properly laid, how overroofing can be successfully applied, and how the improved shingle nails and other features that have been very helpful in extending the general popular appreciation and understanding of wooden shingles can be correctly used.

FIGURE 54. Western red cedar logs are characterized by their long, stringy bark. This group of cedar logs is being readied for the shingle mill.

QUALITIES DESIRED

Desirable qualities of shingle woods may be summarized as follows:

1. Shingles must withstand quick and extreme changes of temperature and moisture conditions.

2. They must be light of weight for inexpensive transportation to destination and handling by carpenters.

3. They must have ability to resist the effects of strong winds, the weight of deep, heavy snows, and impact from heavy hailstorms.

4. The wood shingle bolt should be straight-grained and of sufficient size to produce quarter-sawed or edge-grain shingles.

5. They should add to the beauty of the roof and sides of buildings.

6. Low-cost features are very desirable.

7. Shingles must hold nails without loosening or splitting.

8. There should be a minimum tendency to warp, shrink, twist, or curl, with varying moisture and temperature conditions.

Western red cedar is admirably adapted to meet these qualifications, and the fact that it constitutes the source of nearly all the shingles made in the United States indicates that it has given very satisfactory service. Other woods, such as northern white cedar, make shingles of excellent quality, as do cypress and redwood. The species first mentioned is small in size and therefore difficult to secure without knots. Cypress and redwood produce very high-grade shingles, but very few cypress shingles are made.

SHINGLE PRODUCTION

The peak year of shingle production was 1905 when 15,340,909,000 shingles were produced. From this top figure, the production gradually decreased to 8459 million in 1915; 7324 million in 1925; 6110 million in 1929; 2110 million in 1932. Since then, owing to the efforts of the Red Cedar Shingle Bureau and the growing popularity of wood shingles there has been some increase in the use of shingles throughout the country. In 1947 the production was 3953 million, a large portion of which came from Washington. In 1949 there were 285 active shingle mills which had a total of 589 shingle machines installed. Western red cedar comprises about 95% of the total shingle production.

PRODUCTION OF RAW MATERIALS

Western red cedar shingles generally come from very large-sized trees. The western red cedar is one of the largest trees in the huge, virgin forests of the Pacific Slope. Logs for shingles are produced usually in connection with large logging operations which provide logs for sawmills.* Cedar, as a rule, occurs in association with Douglas fir, western hemlock, and Sitka spruce. Only rarely are logs cut solely on logging operations for shingle bolts. Large rafts of cedar logs are commonly found in Puget

* For details of logging methods, see *Logging*, by Nelson C. Brown, John Wiley & Sons, New York, 1949.

Sound. Along tidewater in this great inland waterway are found numbers of shingle mills, organized as separate units, or in connection with large sawmills. There are also shingle-producing units in Gray's Harbor, Willapa Bay, along the Columbia River, and in some near-by inland places. Washington is the great center of shingle production. At or near sawmills, cedar logs are bucked into shorter lengths or bolts. These bolts are cut

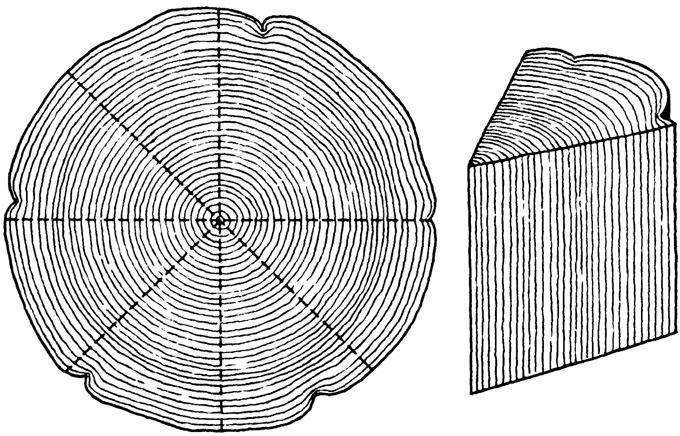


FIGURE 55. Sections cut from the large logs of western red cedar are quartered and requartered to produce choice vertical-grain blocks.

at the shingle mills to 16″, 18″, and 24″ by equalizer saws. Then they are split into bolts for convenience in handling. In some of the lumber-producing centers there may be large separate sawmills devoted exclusively to cedar. During woods operations the cedar logs are sorted from the fir, hemlock, and spruce and manufactured at the mills into siding and other forms of lumber. Butt logs and some others are sent to the shingle mills located near the large sawmill units. Large circular saws up to 10′ in diameter cut the logs into the desired lengths for shingle bolts. Then these large shingle bolts are split into sizes suitable for shingle machines. Logs are quartered, usually, and then split in radial fashion, that is, from the center outward in order to give the largest proportion of quarter grain in the finished shingles.

Manufacture. Shingles are now sawed only in upright machines, each of which is operated by a sawyer who edges and

FIGURE 56. A shingle sawyer is a very busy man. On the table in the foreground are placed the blocks of red cedar wood cut to a certain desired length—either 16″, 18″, or 24″. The sawyer places one of these blocks into the carriage at the left, the block being securely held top and bottom by sharpened rollers. After the block is properly adjusted, the sawyer sets the carriage in operation, and it moves the block into a large circular saw which is whirling at a rim speed in excess of 250 m.p.h. Following this cutting operation the carriage returns, and, as it does so, the rollers automatically move the block outward a certain distance (shingle thickness), at the same time introducing a taper to the shingle. The carriage swiftly moves back and forth, the saw peeling off shingles much like a butchershop bacon slicer. As the shingles come from the saw, the sawyer grasps them with his left hand, swiftly transfers them to his right, and proceeds to trim their edges. In front of him whirls a second and smaller saw, at the top of which is a springboard-like plate on which he places the shingles. He gives each shingle a quick inspection, trimming the edge at the desired spot by pressing down on the plate. As one edge is trimmed, the plate springs back up, and the sawyer flips the shingle over, thus trimming the other edge. At the sawyer's right and just below the far edge of the table are two chutes leading to the shingle packing room downstairs. After the shingles have been trimmed properly, the sawyer inspects them and determines their grade, dropping them into the proper chute. *Courtesy C. Laidlaw.*

grades the shingles as they are sawed from the shingle blocks. These shingle machines are equipped with reciprocative power-driven carriages, which convey the blocks past a thin-gage, razor-sharp circular saw. This saw cuts off shingles at each stroke. The reciprocal action provides for a tapered shingle with a butt, in both up or down directions at alternating strokes of the

FIGURE 57. General view of western red cedar shingle plant after the shingles have been sorted, graded, and packed ready for drying in dry kiln before shipment to market. *Courtesy George Lohr Studios.*

machine. The shingle sawyer carefully examines and grades each shingle as it comes from the saw and places it on a "spring-board." A mechanical guide arranges the edges to be jointed at right angles to the ends. Thus the two sides are made parallel to each other, and the shingle is dropped down a chute which conveys the shingles to the packing bins below. Shingle packers again grade the shingles as they pack them into bundles, as shown in Figure 57, and they are finally inspected by a responsible inspection agency.

Seasoning. Shingles are made directly from green or unseasoned wood with a moisture content comprising about 30% of the weight. In usual commercial practice shingles are kiln-dried. This method of drying reduces the moisture to a proper content and leaves the shingle in good condition for laying and subsequent exposure to varying weather conditions. This process also sterilizes the wood and leaves the shingle in a clean, attractive condition. Owing to shrinkage in the kiln-drying process, bundles must be re-pressed.

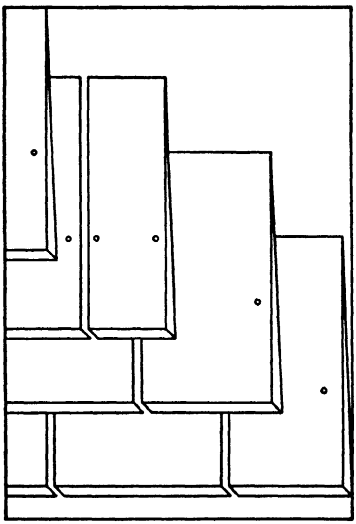


FIGURE 58. The three basic rules of shingle-roof application are shown: exposure, placement and number of nails, and breaking of joints. *Courtesy Red Cedar Shingle Bureau, Seattle, Wash.*

Shingle grading. Shingles are generally classified into three different grades, based upon freedom from knots or other defects, sapwood, and whether flat or quarter sawed. The No. 1 grade is 100% edge-grained, clear, and entirely of heartwood. The present grading rules have been formulated and adopted by the Bureau of Standards of the U. S. Department of Commerce. Most shingles are manufactured in random widths, but experience and tests have indicated that those wider than 10″ will not give the most satisfactory service. As indicated previously, shingles are made in three standard lengths, namely: 16″, 18″, and 24″. The 16″ shingle must be sufficiently thick so that the butt ends of 5 will measure 2 full inches. If it is measured after seasoning an allowance of ¼″ is made for shrinkage. The No. 1 grade 18″ shingles must be strictly edge-grained and all heartwood, and 5 shingles measured at the butt end must be 2¼″ thick. The 24″ shingle is a very expensive and high-grade shingle, and 4 at the butt end measure 2″ in thickness.

Laying of shingles. Shingles are sold, usually, by the square, that is, sufficient to cover 100 sq. ft. of surface with 4 bundles on roofs of not less than one-quarter pitch. On the usual roofs, the 16″ shingles are laid 5″ to the weather; on flatter roofs, this exposure to the weather should be 3¾″; with 18″ shingles, it should be $4\frac{1}{4}''$; with 24″ shingles, usually $5\frac{3}{4}''$. For porch roofs (relatively flat roofs), 18″ shingles are often laid 4″ to the weather. The exposed area should never be more than one-third the length of the shingle.

An important factor is the type of nail used: bright blue or ordinary steel or wire nails should not be used, but only rust-resistant nails: a 6-penny nail for 24″; 5-penny for 16″ and 18″, in case of overroofing; a 4-penny for 24″; and a 3-penny nail for

FIGURE 59. Aerial view of a combination lumber-shingle mill at Hoquiam, Wash.

16″ and 18″ shingles, on new roofs. Only 2 nails should be used per shingle, each one laid near the sides underneath the overlap. This will prevent undue curling, twisting, or nail pulling. Many substitute forms of roofing are now being overroofed with wooden shingles. There is a considerable degree of technique in the selection and use of wood shingles. Advice from experienced retailers or carpenters or from the Red Cedar Shingle Bureau at Seattle should be secured before western red cedar shingles can be used to best advantage. Before redwood, cypress, or northern white cedar shingles are placed, advice should be obtained from some reliable authority.

Many thousands of sidewalls of houses are now being double coursed, that is, with either a prestained processed shake or a No. 1 shingle, superimposed over a shingle of lesser grade and exposed 12″ or 14″ to the weather. This is perhaps the cheapest-quality sidewall that may be had for any home. This type of construction is growing rapidly. There are men in the industry today who believe that the time is not too far hence when practically all of the better class of cedar shingles will be used on sidewalls. This is perhaps influenced by the fact that clear lumber is becoming more and more scarce.

Expected life. There are ample examples of western red cedar shingle roofs that have lasted 30 to 40 years or more. Ordinary, flat-grained 16″ western red cedar shingles which were not properly graded or seasoned, had small amounts of sapwood, and were laid with the ordinary wire shingle nails have lasted 10 to 15 years or more. When properly manufactured, seasoned, and laid, with the right kind of shingle nail and exposure to the weather, edge-grained shingles which are 100% heartwood may reasonably be expected to last 40 years or more, in the north temperate zones, where 40″ to 50″ of rainfall or more are expected and there are extreme conditions of heat in summer and cold in winter.

Shake making. In the early colonial development of the United States shakes or split shingles were rived from the native forests. White pine, chestnut, southern pine, and cypress split readily and were commonly used for shakes in the East and South. With the availability of sawed shingles, the shake has almost disappeared from common use. In sections of California and portions of the Rocky Mountain region and Pacific Coast States, shakes are still made and sold commercially on a small scale. Mountain cabins, fishing and health resorts, rangers' cabins, and similar structures are occasionally still made with shake roofs and siding. For special architectural designs, shakes, although expensive, are sometimes preferred. Frequently large slabs are chopped from sides of trees to determine the splitting qualities of sugar pine, redwood, and other species. In the Sierra Nevada of California 100,000 shakes have been made from 5 sugar pine trees. After sawing bolts to shake length from a felled tree, shakes are diagrammed on the face of the bolt. By the use of a frow, broadaxe, maul, etc., these shakes are split generally in 32″ lengths, 5″ wide and 3⁄16″ thick, and on the quarter grain. Tray shakes for the fruit trade of California are sometimes cut 2′ long and 6″ or more in width. Shakes are now made principally from sugar pine, redwood, and western red cedar.

20 · MINE TIMBERS *

Mines consume large quantities of timbers in the round and smaller quantities of sawed timbers, plank, and lumber. The mines of the United States normally consume about 232 million cu. ft. of round timbers, or about 1.5% of the total wood consumption of the country. Mine timbers are also very important in the many and varied mines of Canada.

Mine timbers represent the seventh most important use of wood. This use is exceeded only by such major products as lumber, fuelwood, pulpwood, veneer, posts, and cross ties. About 80% of the mine timbers are round, hewed, or split. The use of mine timbers centers largely in the coal-producing states of the Appalachian region wherein about 80% of the Nation's coal supply is produced, principally in Pennsylvania.

The timbering of mines is the most important and necessary part of providing adequate safety in the entire mining operation. There are more than 10,000 mines of all kinds in the United States, and all types of mines require timbers. The principal classes of mines using timber, in order of importance, are as follows:

1. Coal, bituminous and anthracite, which represent about 85% of all mines using wood, and approximately the same percentage of the quantity of wood consumed for mining purposes.
2. Iron mines, centralized largely in the Lake Superior and Birmingham, Ala., districts. Owing to the cheaper methods of producing iron ore, chiefly from the iron mines near Duluth, Minn., many of the smaller iron mines scattered throughout the East and Northeast have been abandoned.
3. Mines yielding other metals, principally copper, zinc, lead, silver, and gold.
4. Fire-clay mines, located principally in Pennsylvania and Ohio.

The local available supply of timber has been depended on for many years to supply mine timbers. Within the past several

* Reviewed and checked by J. J. Forbes, U. S. Bureau of Mines.

decades this timber supply has been largely depleted, especially in the important coal and metal regions. As a result, supplies of inferior quality have been used, and the cost of transportation from the nearest available sources has been increased.

Some of the mines in Ontario, Canada, have 120 to 200 miles of underground track and use 3 to 5 M b.f. of mine timbers each per year.

PRINCIPAL MINING REGIONS

The principal mining regions may be summarized as follows:

1. The anthracite field is entirely in northeastern Pennsylvania; the bituminous coal fields are centered largely in Pennsyl-

FIGURE 60. Typical view of bituminous coal mine with 8″ × 8″ props or legs and 8″ × 10″ crossbars or caps. Note fungi on untreated cribbing above the creosoted cap. Increment borings showed creosoted timbers perfectly sound after many years of service.

vania, West Virginia, Kentucky, Illinois,* Indiana, Ohio, Tennessee, and Alabama. Oak was for many years the leading species used in these mines. Timber is now moved from the southern

* See the Illinois Coal Fields as a Potential Market for Treated Wood, by C. S. Walters as presented before American Wood Preservers' Association, Houston, Tex., April 1950.

pineries to these mines by railroad, and as far as 200 miles by motor truck. A wide variety of hardwoods, principally oak, supplies approximately one-half the timber used in these mines, and southern pine and other softwoods the remainder.

The largest single use of timber in West Virginia is in the mining industry for mine timbers including props, caps, and ties. This state annually produces somewhat more than 1 billion b.f. per year and uses over 600 million b.f. of timber in its mines. About one third of all the soft coal mined in the country is produced in the Appalachian region and about 4 b.f., or its equivalent, is required for the mining of each ton of coal.*

2. The Illinois and Indiana soft coal mines are very extensive and secure large quantities of hardwoods from Missouri, Tennessee, Kentucky, and Arkansas, and considerable quantities of southern pine from the South.

3. The Lake Superior copper and iron districts utilize timber hauled for several hundred miles, largely tamarack, hemlock, spruce, red pine, and such local hardwoods as beech, birch, and maple.

4. The Butte copper districts and the northern Idaho lead, zinc, silver, and copper mines consume large quantities of western larch, lodgepole pine, Douglas fir, and ponderosa pine. Montana uses more timber in its copper mines than any other state where copper mines are found. The Butte mines are in the heart of the Deerlodge National Forest, which produces chiefly lodgepole pine. Some of the large copper companies own and operate sawmills to supply their requirements.

5. The Arizona copper mining district employs for the most part sawed timbers of Douglas fir shipped by boat to San Diego and San Pedro from the Pacific Northwest and then transshipped by rail to the mines. They also use large quantities of ponderosa pine and smaller quantities of Douglas fir produced in the Southwest and adjoining states.

6. The Utah copper and coal districts use lodgepole pine and ponderosa pine from the immediate region and Douglas fir shipped in from the Northern Rocky Mountains and Northwest.

* From Prof. W. C. Percival, West Virginia University, Morgantown, W. Va.

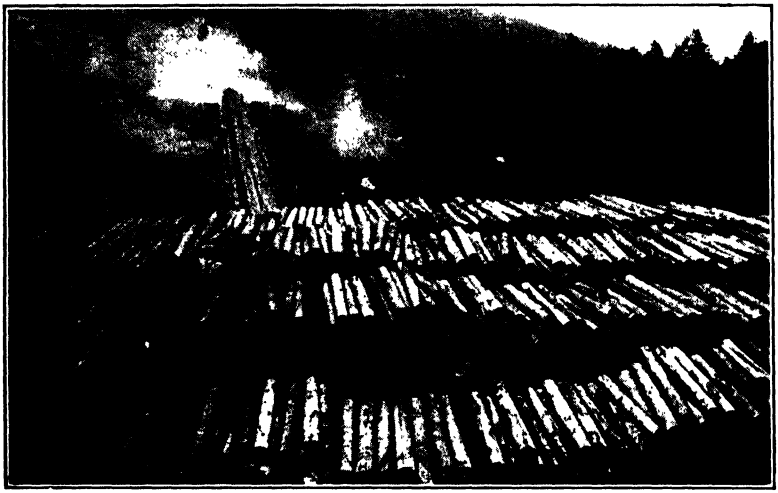


FIGURE 61. Mine props of lodgepole pine piled for loading at a railroad siding. This tree and ponderosa pine, western larch, and Douglas fir are widely used for the important mines in the Rocky Mountain regions.

Principal specifications. The lengths and other specifications for mine timbers, in both the round and sawed forms, vary very widely, according to local conditions and requirements. Even within the same mine, many different lengths, top diameters, and sizes are required. In coal mines and several other mines the principal use is for single props with cap pieces and three-piece sets, consisting of two props known as legs or posts, and a horizontal piece across the top of the two props, known as a cap, collar, or crossbar. There are also two-piece sets, consisting of one leg supporting one end of a crossbar, the other end of which is supported by a niche in the sidewall. This is more often done in room mining than in tunnel or entry mining. Lagging consists of small-diameter poles or sawed planks used on the sides between the props and along the tops between the caps to prevent coal or rock from caving or falling into the mine entry or tunnel. The prop and mine ties comprise the two most important items of mine use. Many of these timbers are employed only temporarily, so that either green or dry wood in the untreated condition is commonly used. In the tops, lagging measuring as little as 2″ and props as little as 4″ are common. Every tunnel or mine opening may require slightly different specifications, and lengths may vary widely, from 2′ to 18′. There is no regularity as to height, width, or distance between props and caps in mine tunnels.*

All mine timbers for the anthracite industry are purchased by the ton weight rather than by the cubic foot or other usual measurement of wood volume. Timber for the bituminous industry

FIGURE 62. Typical view in anthracite mine in Pennsylvania, showing props, caps and lagging, and mines ties.

is purchased by the piece for each specification. Sawed timbers and lumber are purchased by the board foot. In metal mines, permanent drifts or tunnels and shafts are substantially timbered, frequently with sawed planks, lumber, or large-size timbers. Large-size props and caps prevail in tunnels. Hewed ties are

* Many thousand sprags are used especially in anthracite mining. These are small wooden pieces 22″ long with a minimum diameter of 2¾″ and a maximum diameter of 3½″ with tapering points at each end 7″ long. They are generally machined, and oak and hickory are preferred. They must be peeled and straight. Their purpose is to throw in the spokes of mine cars to retard their speed. Their use is on the decrease owing to the use of mechanical belts and shakers. One company employed about 130,000 sprags in the anthracite mining district in 1949.

required in the operation of practically all mines and ordinarily are used in sizes much smaller than those commonly employed on the carrier railroads.

Use of treated timbers. The generally humid and warm atmosphere prevailing in mines is exceedingly conducive to wood decay. Therefore treated timbers or steel and concrete are used in some

FIGURE 63. Preframed air-shaft timbers on tracks ready for pressure treatment with creosote. Owing to the excessive humidity and warm air of many mines, the more permanent shafts and tunnels should be protected by treated timbers to prevent decay.

of the permanent shafts and tunnels. The many branches and temporary tunnels serve for brief periods of time so that most of the timber is not treated. The anthracite mines of Pennsylvania utilize green, partly seasoned wood and thoroughly seasoned wood indiscriminately for temporary timbering. Recently more than 12 million b.f. of mine timbers were treated annually; also more than 5 million mine ties were treated with preservatives.*

Proper preservative treatment can easily extend the average

* At the McIntyre Porcupine Mines, Shumacher, Ontario, Canada, where some tunnels are at the 387-ft. level, it was found that untreated timber lasted only 3 to 4 years, whereas treated timbers showed no failures due to decay in 18 years.

life of mine timbers from 3 years to 12 to 20 years or more while approximately doubling the initial cost. Since the labor cost of installing timbers is two to three times the cost of the timbers themselves, it is economically advisable to use treated timbers wherever the installation is to last more than 3 years. Thus, if timbers cost $50 per M b.f. untreated, $110 per M b.f. when treated, and $100 per M b.f. to install, it is clear that, by the end of 3 years when about 50% of the untreated timbers would have failed, the cost of replacing these decayed timbers would be more than equal to the cost of preservative treatment for all the original timbers.

Wood has certain advantages over steel and concrete for "timbering" of mines. When a mine roof starts to settle, the wooden members bend and "talk" before they collapse, thus warning the miners of danger.

Species used. Hardwoods comprise approximately 80% of all timber in mines in the United States and Canada. Formerly oak furnished about half or more of the mine timbers used. Of the hardwood timbers used in the eastern United States today, about 60% are mixed hardwoods (beech, maple, hickory, ash, locust, poplar, gum, etc.), 30% red oak, and 10% white oak. Of these woods only white oak and locust are highly durable.

Softwoods comprise 20% of all the round mine timbers. They form a large share of the sawed timbers which are classified under the general heading of lumber. Southern pine is the principal softwood used in the mines, especially in the East, South, and Central West. Douglas fir from the Pacific Coast and Rocky Mountains is widely employed in the copper, coal, lead, and silver mines of those regions. Western larch, ponderosa pine, western spruce, and western hemlock are also often utilized.

Leading states in the use of mine timbers. Pennsylvania is the foremost state in the consumption of mine timbers, probably employing about 45% of the total amount. Pennsylvania is followed in order of importance by West Virginia and Illinois, which have extensive bituminous coal mines; next by Montana and Arizona with their extensive copper mines; by Kentucky and Ohio with bituminous coal mines; by Michigan and Minnesota with important iron and copper mines; then by Colorado with its coal and precious-metal mines; and by Indiana, Alabama, and Utah, each having bituminous coal and other mines of special importance.

Use of timbers in the anthracite mines. One of the most important and concentrated centers of mine-timber consumption is the anthracite section of northeastern Pennsylvania, in the neighborhood of Scranton, Wilkes-Barre, and Pottsville. These mines require 0.8 cu. ft. of wood for each ton of coal produced. For mining, in an average year, 50 million tons of coal, these mines use 40 million cu. ft. of wood, the equivalent of about 27,000 carloads. Round timber comprises about 75% of the value of all wood employed in the anthracite mines. Mine props, made of round timbers to support the roofs of the mine tunnels, constitute the greatest single volume. Two props standing on end, one on each side of a tunnel or other mine opening comprise a pair of props. Caps are pieces of round or partly hewed timbers extending across the tops of the props. Lagging, which extends longitudinally between props to protect the sidewalls and roofs of tunnels, is also round timber, 2″ to 4″ in diameter and 6′ to 12′ long. Props are 4″ to 24″ in top diameter and 2′ to 26′ long. The 6″-diameter prop is most commonly employed with lengths of 4′ to 11′. Crossbars (collars) are generally 8′ to 12′ long when used in the round. The height and width of coal veins vary widely, and various sizes are required for the main and branch tunnels.

For tramroads, many mine ties are used. They are generally 4″ on the face and 3′ to 5′ long.

Timbers for anthracite mines are purchased by weight. An average full car contains 40 tons of props; the largest cars may carry 70 tons and the small ones 30 tons. Truck loads are 2 to 3 tons of props, or about 300 lin. ft. of 7″ props for the smaller trucks, and up to 5 to 8 tons of props for the largest-sized trucks.

Many trucks carry coal from this region into New England, New York, New Jersey, and Pennsylvania and return with loads of mine timbers.

Woods production. Mine timbers come largely from farmers' woodlands and scattered timber properties in the East, South, and Middle West adjacent to or within the mine regions. Although usually a separate business, the production of mine timbers is closely associated with the small sawmill operations in the mining districts. Frequently the largest trees are utilized for saw logs, or perhaps the butt logs of the better trees. Then the smaller trees or top logs, down to 4″ in diameter, are used for mine props, caps, and lagging. Sometimes lagging is taken down to 2″ in the tops. Too frequently farm woodlands are cut clear for mine timbers and often at the most rapidly growing period

FIGURE 64. Mine props piled in foreground were taken from otherwise unmerchantable top logs cut on a hardwood selective logging operation in the Southern Appalachians. Note the stumps of some of the larger trees cut and the number of various-sized younger trees, saplings, etc., which will replace the trees cut and quickly grow into merchantable timber. Principal trees in this stand are oaks, yellow poplar, white ash, hard maple, beech, hickory and black cherry. Too frequently entire stands are cut off clean for mine timbers. *Courtesy Appalachian Hardwood Manufacturers.*

of the life of the tree. Altogether, mine timbers provide an excellent outlet for the use of small sizes and short lengths that otherwise could not be salvaged.

Tractors and horses are employed to skid the felled trees to landings or other convenient assemblage points, from which motor trucks haul the round timbers to the railroad sidings or directly to the mines. Timbers are frequently trucked to the

FIGURE 65. Scaling red pine mine timbers in northeastern Minnesota. This is typical of many small logging operations which provide extra income for farmers during the slack winter season and also produce much needed timber crops for local industries. *Courtesy Range Facts, Virginia, Minn.*

mines for distances of 100 to 200 miles. A very interesting feature of the timber industry is integrated utilization; that is, mine timbers, saw logs, cross ties, poles, and piling are sometimes obtained from the same logging operations within the region accessible to the anthracite and bituminous coal mines. For example, the butt log may be used for lumber, the second and third logs may be cut into cross ties or crossbars, and the top log and top above it may serve for props, caps, or lagging. Thus very efficient and complete utilization is practiced on many of these operations.

21 · LATH

Lath for plastering is not nearly so common as it once was. There has been a great decrease in use due to invasion of substitute forms and changing methods of construction in connection with air conditioning and insulation and to the fact that wet plaster when applied to dry or relatively dry lath shrinks and is

FIGURE 66. Bundles of lath cut from white pine slabs formerly wasted. At Cloquet, Minn.

likely to crack. Furthermore, plaster is a poor insulating material. Metal lath, fiberboards, plywood panels, and various coverings for sidewalls, ceilings, and so on, have greatly reduced the use of lath. The peak production was about 15 billion laths in 1905. Six billion were employed in 1929 and only 197 million in 1947. The principal production is in Oregon, Washington, and Idaho.

Lath is made principally from slabs at large sawmills. It is also made from low-grade lumber and occasionally from trimmings, edgings, and miscellaneous waste. It is largely from softwoods, principally the pines, spruces, hemlock, and Douglas fir;

it is also made tq a limited extent from hardwoods. Some cities in the great wood-consuming sections demand special species, such as white pine and spruce lath, and it is difficult to get some builders in these cities to use any other kind of wood.

The standard measurements of lath for most of the pines and spruces are 3/8″ thick, 1 1/2″ wide, and 32″ and 48″ long. Most laths are 48″ long. They are generally made in two grades, No. 1 and No. 2. Every lath must have two good ends for nailing. Southern pine lath when green should measure 2″ in thickness to every 5 laths and must not be less than 1 7/16″ in width. Douglas fir, Sitka spruce, and western hemlock lath must measure 1″ in thickness to every 3 laths and 1 5/8″ in width. Hardwood lath must not be less than 5/16″ in thickness, and 5 laths must measure 2″ in thickness when green.

Three machines are used in making lath: (1) the bolter with ripsaws 2″ apart to cut slabs, lumber, and so on into pieces 2″ thick; (2) the lath machine with several ripsaws 1/2″ or slightly less apart, in which the 2″ pieces are sawed into rough lath; and (3) a bundler and trimmer, in which the laths are held together and tied into bundles and the lengths are equalized (evenly trimmed).

Lath is preferably made of softwoods, which are easily nailed, light in weight, and free from discoloring agents that may affect plaster.

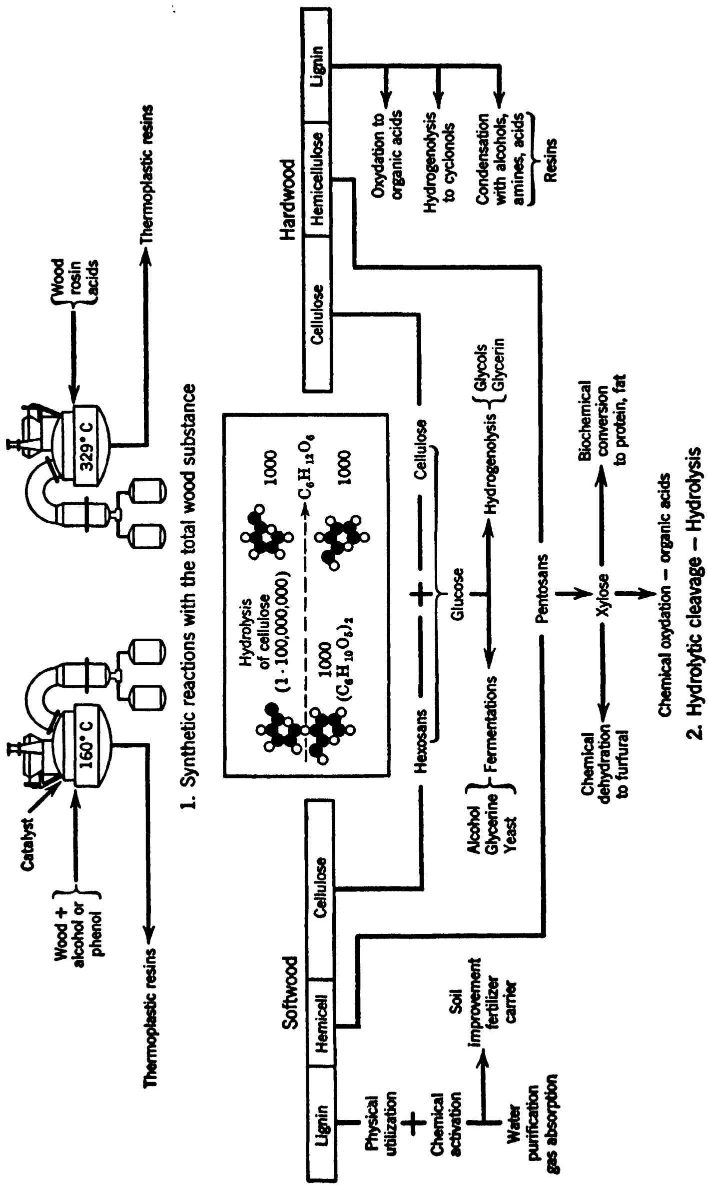
PART III

Chemically Derived Products

The field of chemicals and chemical products derived from wood has grown rapidly in importance among forest industries. Some of the industries, as pulp and its diversified products, are among the most important industries of the country. There are great opportunities for the further development of knowledge which may be applied to the profitable utilization of wood, particularly of various forms of wood waste. Wood consists of a skeleton of cellulose and, in addition, varying amounts of lignin, tannin, resins, gums, and other materials. Cellulose is readily converted into sugars. Lignin, next to cellulose, is the most abundant and widely distributed of the organic substances. The problems of the chemistry of lignin and of cellulose have been of great importance in the pulping of wood and in the conversion of pulp products to various uses. Until recently there was little known or understood about lignin, which is the substance that cements together the wood cells and reinforces the cellulose within the cells. In pulping processes, lignin must be removed before white paper, rayon, Cellophane, or many of the other cellulose products can be successfully manufactured.

Since the first serious study of the chemistry of wood well over a century ago by the French chemist Payen, many scientists have contributed to our present knowledge of this complex subject. Outstanding among them are the English chemists, Cross and Bevan whose fundamental work on cellulose laid the basis for the viscose rayon process, and the Swedish chemist, Peter Klason who is known as the "father of lignin chemistry."

The growing realization of the great potentialities of wood as a chemical raw material for industry stimulated fundamental and technical research in many parts of the world, particularly in Scandinavia, Germany, Canada, and the United States. Indus-



1. Synthetic reactions with the total wood substance

2. Hydrolytic cleavage – Hydrolysis

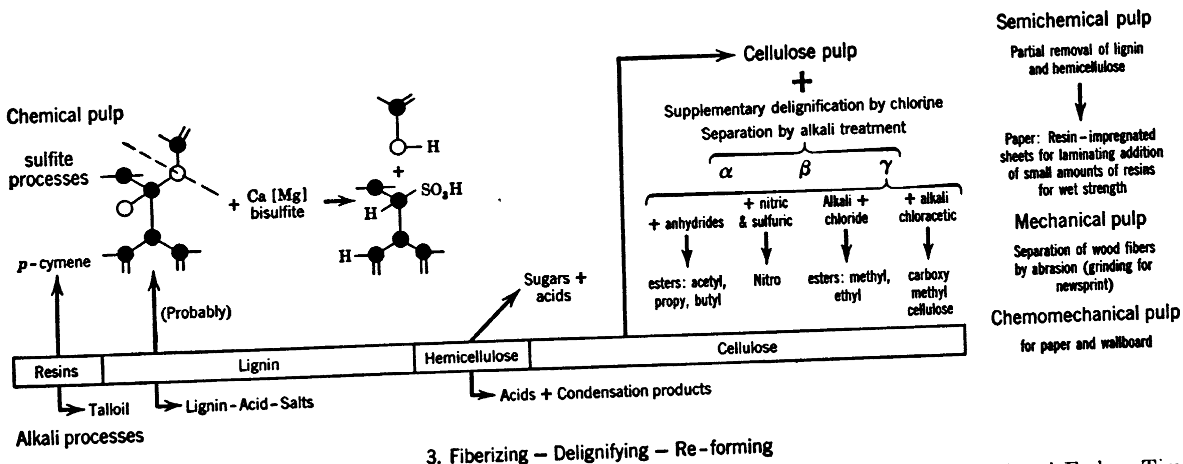


FIGURE 67. Breakdown of the important phases of the chemical utilization of wood as devised by Eduard Farber, Timber Engineering Company, Washington, D. C., and reprinted from *Wood Magazine*, Chicago, Ill., December 1946

try, academic institutions, and government agencies have developed wood-chemistry research laboratories, such as the United States Forest Products Laboratory at Madison, The New York State College of Forestry at Syracuse, the Pulp and Paper Research Institute at Montreal, and the Institute of Paper Chemistry at Appleton. Most recent is the new (1946) excellent Swedish Forest Products Laboratory at Stockholm. Contributions from workers at these and many other institutions and in industry, during the past 25 years, have become evident in the many new developments in processes for making rayon, films, lacquers, plastics, pulp, paper, fiberboards, and other chemically produced forest products.

World War II stimulated developments in wood chemistry as in other fields of science and technology. In Europe these were mainly in the direction of foodstuffs and industrial chemicals, such as sugars, alcohol, cattle fodder, yeast, tall oil products, butanol, glycol, and other organic chemicals. Developments along these lines also took place in the United States, such as the U. S. Forest Products Laboratory method of wood hydrolysis, but in addition important structural and plastic products were produced. These include the newer paper-base laminates, lignin-paper laminates, dimensionally stable chemically modified wood and the combination of synthetic resins with paper, veneer, and wood to make many types of light, strong structural forms for aircraft, boats, and buildings.

The growing appreciation of the lumber and other forest industries for the necessity of a better-integrated utilization of their raw wood material is leading to greater utilization of wood waste. This development is particularly apparent on the West Coast in both the Douglas fir-hemlock areas and in the redwood region. This is the most recent and significant trend in wood chemistry and will lead to better forest management and timber use.

Before the principal features in the conversion of pulp, naval stores, distillates and other wood products into commercial forms are described, Table 13 as prepared by the U. S. Forest Service, is presented. This skeleton outline is intended to show some of the more important chemical and fiber products obtainable from wood. In the processes of chemical or mechanical reduction, woods yield cellulose and lignin wastes, many of which have been developed into useful products as indicated.

TABLE 13

1. PRODUCTS DERIVED FROM CELLULOSE

- Fiber products of crude or refined cellulose
  - Types of paper
    - Newsprint
    - Wrapping
    - Book
    - Print
    - Bond
    - Writing
    - Tissues
    - Wallpaper
    - Parchments
    - Building
    - Cover
    - Industrial
  - Paper products (a few of more than 9000 uses)
    - Ammunition
    - Artificial leather
    - Baskets
    - Boxes
    - Blankets
    - Bottles and caps
    - Cartons
    - Combs
    - Doilies
    - Dolls
    - Dry mat (printing)
    - Felts
    - Flowers, artificial
    - Game counters
    - Hats
    - Jars
    - Lace
    - Lamp shades
    - Lead pencils
    - Napkins
    - Pails
    - Paper twine
    - Paper textiles
    - Plates, paper
    - Ribbons
    - Rugs, paper
    - Shoe counters and insoles
    - Spools
    - Straws
    - Suitcases
    - Surgical dressings
    - Tablecloths
  - Wallboards, such as
    - Masonite
    - Insulite
    - Nuwood
    - Firtex and many others
  - Compound wallboards, wood fiber with gypsum, and similar plasters

TABLE 13 (*Continued*)

1. Products Derived from Cellulose (*Continued*)

Chemical products of refined cellulose (Wood and cotton cellulose are interchangeable)

- Viscose process
  - Rayon, yarns, and fabrics
  - Cellophane
  - Sausage casings
- Nitrate process
  - Rayon, yarns, and fabrics
  - Collodion
  - Explosives
  - Photographic films
  - Celluloid (plastics and shatter-proof glass)
- Acetate process
  - gives these plastics
    - Cellit
    - Cellon
    - Sicoid
    - Sericose
    - Boroid
    - Cellolite
  - Rayon, yarns, and fabrics
  - Plastics and molded products
    - Toilet articles
    - Fountain pens
    - Bottle caps
    - Buttons
    - Buckles
    - Brush backs
    - Lamp shades
    - Napkin rings
    - Artificial hairs and bristles
    - Sponges
    - Imitation leathers
    - Shatter-proof glass
    - Phonograph records
    - Gold leaf
    - Solid alcohol
    - Cigar tips
    - Airplane dopes
  - Hundreds of other familiar articles
- Cellulose ethers and esters, increasingly used in plastics

2. Products Derived from Lignin Wastes

Road-binding materials
Adhesives
Plastics
Fertilizers
Tanning materials
Dyestuffs
Oxalic acid
Binder for lead oxide in storage batteries

3. By-Products of Sulfate Pulping of Southern Pine

Turpentine
Rosin
Fats (pine oils)

4. Products of Acid Hydrolysis of Wood

Sugars
Stock food
Ethyl or "grain" alcohol
Furfural
Plastics
(Xylite, a high-grade, cheap plastic of many uses, developed by the Forest Products Laboratory)

TABLE 13 (*Continued*)

5. PRODUCTS OF DRY OR "DESTRUCTIVE" DISTILLATION OF WOOD

Charcoal	Wood creosote
Methyl or "wood" alcohol	Acetone
Furfural	Wood pitch—used in rubber compounding
Acetic acid	

In all, more than 60 chemical substances have been isolated from the products of hardwood distillation.

Softwoods, in addition to these, yield:

Pine tar—used as disinfectant and antiseptic and for lubrication of cordage

Rosin oil, Pine oil, Turpentine — See also "Products of Steam Distillation"

6. PRODUCTS OF CELLULOSE FERMENTATION

Butyl and higher and lower alcohols
Acetic, lactic, propionic, and butyric acids
Acetone and other ketones

7. PRODUCTS OF STEAM DISTILLATION AND EXTRACTION OF SOUTHERN PINE STUMPS AND THE NAVAL-STORES INDUSTRY

Turpentine, used in:
- Paint
- Varnish
- Synthetic camphor
- Solvents

Pine oil, used in:
- Ore flotation
- Textile industries
- Laundries
- Cleaning compounds
- Disinfectants

Rosin, used in:
- Paper sizing
- Varnish
- Soap
- Linoleum
- Sealing wax
- Adhesives
- Greases
- Matches
- Waterproofing
- and hundreds of other uses

8. EXTRACTIVE MATERIALS

Tannins from:
- Chestnut
- Oak
- Hemlock

Mucic acid from western larch
Dyestuffs from Osage orange
Cascara extract from cascara bark

TABLE 13 (*Continued*)

8. Extractive Materials (*Continued*)

Volatile oils from { Sassafras / Sweet birch / Virginia red cedar }
Storax from sweet gum
Canada balsam from balsam fir
Oregon balsam from Douglas fir
Balsam of poplar buds (Balm of Gilead) from balsam poplar
Leaf oils from many coniferous species

The principal chemical products have been divided into eight major classifications.* They apply to the various products described in Part III of this book, with the exception of rubber, maple sirup, and maple sugar. There are some additional forest products that may be properly assigned to one or more classifications because they may be reduced both by chemical and mechanical processes.

* No attempt is made to describe all products in this book because of limitations of space. Some of the more important ones are briefly described.

22 · WOOD PULP AND ITS PRODUCTS *

The manufacture of pulp and its principal product, paper, is one of the most important North American industries in Canada and the United States. There are 363 pulp mills in the United States and Canada (241 in the United States; 122 in Canada) employing more than 50,290 men in the United States alone, with annual wages more than $148,100,000, making products worth $939,600,000. On the basis of value of products, this industry is classified as one of the 10 largest industries of the country. It is the most important single industry in eastern Canada.

Approximately 90% of all paper manufactured in America is made wholly or in part from wood pulp. The beginning of paper making was in China in A.D. 105. The name "paper" is derived from the Latin word papyrus, which referred to the Egyptian sedges and bulrushes of the Nile Valley. At the present time, about 22 million cords of wood are used for pulp, and it is estimated that, with the increasing demands for paper, Cellophane, rayon or artificial silk, and fiberboards for insulation, construction, containers, packages, and plastics, there will be a continued increase in the volume of wood consumed. If we assume 500 b.f. per cord, the annual quantity used for pulp is equivalent to more than 11 billion b.f.

The industry is still in an evolutionary stage of development in the species of woods used and in the processes of manufacturing pulp, paper, and wood products. A vast amount of research is conducted to determine methods of utilizing various woods and of refining the final product. At first, basswood was employed. Then spruce became our leading pulpwood because of its long, strong fibers; comparative freedom from resins, gums, and other undesirable materials; and its relative abundant supply combined with low stumpage values.

* Reviewed and checked by C. E. Libby, head of the department of pulp and paper manufacture, New York State College of Forestry.

At various times, sporadic attempts have been made to introduce other raw materials, such as waste from the manufacture of cotton, hemp, esparto grass, straw, and cornstalks. These are generally too expensive to assemble, are not available in sufficient quantities, or do not provide the necessary elements for the kinds of paper demanded on the markets.

FIGURE 68. Chain saws used at landing to cut four spruce pulpwood bolts at one time, as found in eastern Canada and in Maine. These tree-length logs have been skidded from the woods to landings along the haulroads. After piling as shown in the background, they are loaded on winter sleds and hauled to the streams for spring driving to pulp mills. *Courtesy Great Northern Paper Co.*

Review of recent developments. Over a period of about 20 years the consumption of pulpwood in the United States has increased from about 7,600,000 cords in 1929 and again in 1935 to more than 22 million cords in 1948. More than 20 million acres of forestland are now owned and dedicated by the industry to the permanent production of forest crops. The annual value of the end products of this industry is more than $6500 million. The consumption of paper in the United States in 1948 rose to an all-time high of about 26 million tons, or about 358 lb. per capita. In 1948 more than $750 million worth of paper and its raw materials formed about 11% of the total dollar value of all forms of imports into the United States. Of this, newsprint accounted for $413 million and wood pulp for $272 million. Thus we are still dependent on foreign sources, principally Canada, for an

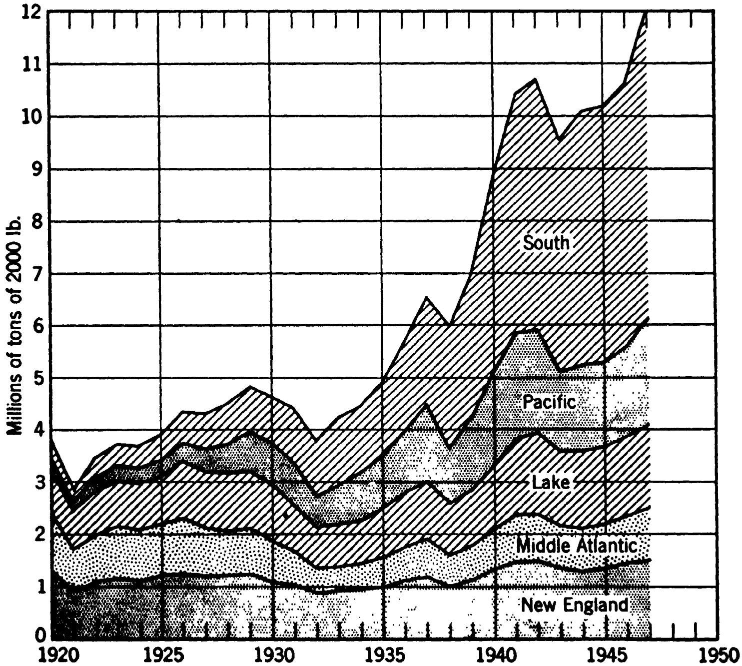


FIGURE 69. Regional wood-pulp production from 1920 to 1947, inclusive. *Courtesy U. S. Pulp Producers Association.*

important share of pulp and paper. More than 80% of our newsprint comes from Canada.

With the increasing demands for all kinds of paper, there has been a rapid shift in utilization from spruce to a variety of woods both softwood and hardwoods and particularly to southern pine which has become the leading wood used for pulp. Within the past 15 years more than $1222 million has been invested in timber holdings and plant construction and equipment in the South. There has also been a considerable increase in installation of plants and use of timber for paper pulp on the West Coast. Sitka spruce and West Coast hemlock are the preferred species in that section. Moreover, great quantities of sawmill and logging waste have been recovered, and increasing amounts are used in the form of shipped material for pulp manufacture. Many hardwoods, notably aspen in the Lake States and several of the southern hardwoods have actively entered into pulp production. Several pulp mills have converted their processes from the use

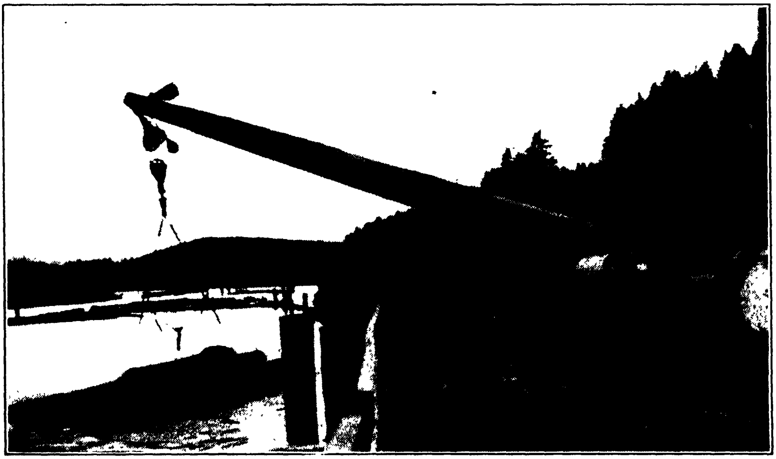


FIGURE 70. Unloading bundled truckloads of pulpwood logs into a stream for towing in "asparagus rafts" in the Northwest. Great progress has been made in bundling of logs since the system was first installed at the Clatsop logging division of the Crown Zellerbach Corporation of Portland. The pulp and paper industry has made great progress in the Pacific Northwest. *Courtesy E. P. Stamm.*

of softwood, notably spruce and hemlock and even some southern pine to the utilization of hardwoods, for example at Berlin, N. H., where a shift from spruce to hardwoods was made. Some of the largest lumber firms in the country have added pulp mills to lumber-manufacturing units, notably at the Crosset Company at Crosset, Ark.; the Camp Manufacturing Company at Franklin, Va.; the Weyerhaeuser Timber Company at Longview, Wash. The production of ethyl alcohol from what was waste sulfite liquor has been an outstanding development by the Puget Sound Pulp and Timber Company of Bellingham, Wash.

Since World War II, the prices for pulpwood and pulp products have advanced materially and there has developed a serious competition for wood in some sections to supply the pulp mills as well as saw logs, poles, cross ties, and piling. This phase of wood procurement has materially aided the use of sawmill and logging waste for paper products.

Many important changes have been made in the paper industry in addition to the gradual shifts in species, the location of mills, and types of processes involved. The first kraft pulp in North America was made at East Angus, Quebec, Canada, in 1907. In 1909 the first kraft paper was manufactured in the United States, but it was at least 15 years later before substantial progress was made in this significant development. Paper was made at a speed of 1000 f.p.m. on a Fourdrinier machine in 1920 in Mosinee, Wis. The first use of southern pine for making paper on a commercial scale was the issuance of the *Birmingham Age-Herald* June 20, 1921, on paper made from this pulp. Among the important developments in this industry were the growth of pulp and paper mills on the West Coast during the 1920's when it was determined that West Coast hemlock and Douglas fir could be used for the manufacture of good grades of sulfite pulp, just as well as from eastern spruce. Meanwhile several mills were established in the South when it was found that the sulfate or kraft process was capable of pulping the southern pine. This process has now outstripped all others, and more pulp is produced by this method than by any other. Another important development which followed by some 10 to 15 years was the discovery that kraft pulp could be bleached for the manufacture of white papers. This gave added impetus to the establishment of more southern kraft mills, and a large tonnage of kraft pulp is being bleached for book, writing, and other papers. The successful bleaching of kraft pulp was just as important in the development of the industry as the establishment of the process itself. A similar and very important development within the past 10 years has taken place with mechanical or groundwood pulp. It was determined that this pulp could be bleached to a satisfactory white color, and this development has added to the importance of the groundwood pulp industry throughout the North. Groundwood pulps are now entering the manufacture of many printing papers, such as magazine stock which heretofore had never used an inexpensive raw material.

The latest improvement in the paper industry, which holds significant promise of widening the source of raw material, is the development of the semichemical process of manufacturing pulp, and this process appears to be particularly applicable to hardwoods. The yields by this process are about 20% better than they are by the conventional chemical process. Furthermore, the pulp may be bleached to a good white color suitable for use in printing papers. This process became the fastest-growing pulp method in the United States and seems destined to accelerate in position until it may rival other pulping methods. The use of the semichemical process is particularly desirable because hardwoods can be pulped by it even more successfully than softwoods. This feature is certain to increase the use of these woods and thereby add to the sources of wood supply for the manufacture of pulp and paper and improve the general utilization of our forests.

Distribution of the wood-pulp industry. Pulp, paper, and other products are made in 37 states of the Union. There are more than 1250 pulp and paper mills in the United States and Canada. The ten states producing the largest amounts of pulp and paper are shown in Table 14.

TABLE 14

PRODUCTION—1946—BY RANK

	Paper Only	*Pulp Only*
1	New York	Washington
2	Michigan	Maine
3	Ohio	Louisiana
4	Wisconsin	Wisconsin
5	Pennsylvania	Florida
6	Maine	New York
7	Louisiana	Mississippi
8	New Jersey	Georgia
9	Washington	Oregon
10	Virginia	Minnesota

Washington and Oregon have recently become important pulp and paper-producing states. The South has probably made most progress in recent years, producing about 45% of the pulpwood of the United States. There are in the South 40 pulp mills using southern pine and 8 pulp mills using hardwoods exclusively. The largest pulp mill in the world, located at Georgetown, S. C., utilizes about 2500 cords (128 cu. ft.) of wood per day, mostly southern pine with some hardwood. The first mill producing newsprint from southern pine was located at Lufkin, Tex. Two more newsprint mills were later established in Alabama. The most important developments in the South have been along the South Atlantic and Gulf Coasts.

The factors that determine the location of these mills are (1) proximity and availability of wood, the principal raw material, in sufficient quantities and at reasonably low cost; (2) proximity and favorable transportation rates to markets; and (3) an adequate supply of process water. Probably no large industry depends so vitally on good water for its successful operation. Therefore, the industry is concentrated along some of the large rivers or wherever a good supply of clean water is available. New York State, the largest producer of paper, concentrates the industry, for the most part, along the Hudson River and its tributaries, the Black River, and the Niagara River.

PULPWOOD CONSUMPTION

Pulpwood normally consumes about 11% of all the timber products of the United States. The peak of production was more than 22 million cords. Much pulpwood is imported and, in a recent year, imports of pulpwood amounted to 2.3 million cords. Of this amount the principal species is spruce from Canada. With the rapid rise in the use of southern pine and western species for pulpwood, imports of both pulpwood and wood pulp are likely to decrease.

Table 15 shows the consumption of pulpwood by percentages for the principal species.

TABLE 15

PULPWOOD CONSUMPTION IN THE UNITED STATES

	Per Cent
Southern pine	47
Spruce and fir	22
Hemlock	13
Aspen	4
Chestnut	3
Yellow poplar	2
Gum	1
Other species	6
Sawmill waste	2

Trends in woods used. The total volume of wood used for pulp has steadily increased during the past half century. Pulp is one of the few forest products which has not had a reduction in quantity consumed, as have lumber, cooperage, fuelwood, and many other forms. The volume steadily increased from more than 2 million cords in 1900 to 22 million cords in 1948. While spruce has been the premier wood in pulp production, its peak was reached in 1920 with 3,487,598 cords. This amount decreased to about 2,380,000 cords in 1935. Southern pine has had the most notable rise, from 69,000 cords in 1906 to more than 10 million cords in 1948. It seems likely that the consumption of spruce will decline further and the use of southern pine, in the South, will continue to increase. Hemlock has had a steady rise in annual consumption, from about 500,000 cords in 1906 to about 1 million cords in 1925 and close to 3 million cords in 1948. This rise is due to the steady increase in use of the western hemlock in the Northwest, where there has been rapid growth in the installation of mills and the use of this wood for pulp purposes.

One pulp mill in Wisconsin consumed 50,000 cords of lodgepole pine from the Rocky Mountains in one year. It is reported that the company even prefers this wood to aspen and jackpine. Considerable Englemann spruce also comes from Colorado to the Lake States for conversion into pulp.

Imports of pulpwood. For many years, large imports of pulpwood have been made, the volume increasing from nearly 1 million cords to more than 1½ million cords in 1927. There was a sharp decline during the depression years following 1930. Since World War II imports have risen to about 2.3 million cords. In addition to pulpwood about 2.2 million tons of wood pulp were imported in 1948, about three fourths of which came from Canada. These imports are largely of spruce from eastern Canada, but importations of some Norway spruce (*Picea excelsa*) have also been made in the past from Russia, Finland, and Sweden.

Production of wood pulp by regions. In order of quantitative production the following regions are the most important: (1) South; (2) Northeast; (3) Pacific Northwest; (4) Lake States; (5) Appalachians. The South and Pacific Coast States are definitely increasing as sources of production; the others are decreasing. In contrast to the present rating, the order of production

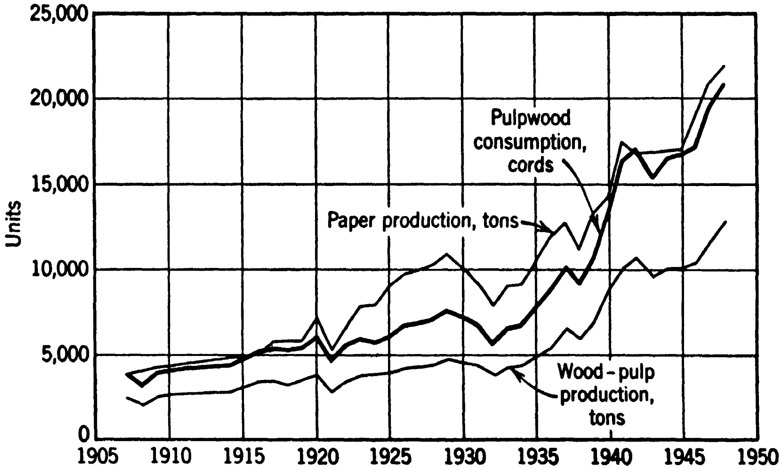


FIGURE 71. Graphs showing progress in pulpwood consumption, paper production, and wood-pulp production in the United States from 1907 to 1948, inclusive. *Courtesy American Paper and Pulp Association.*

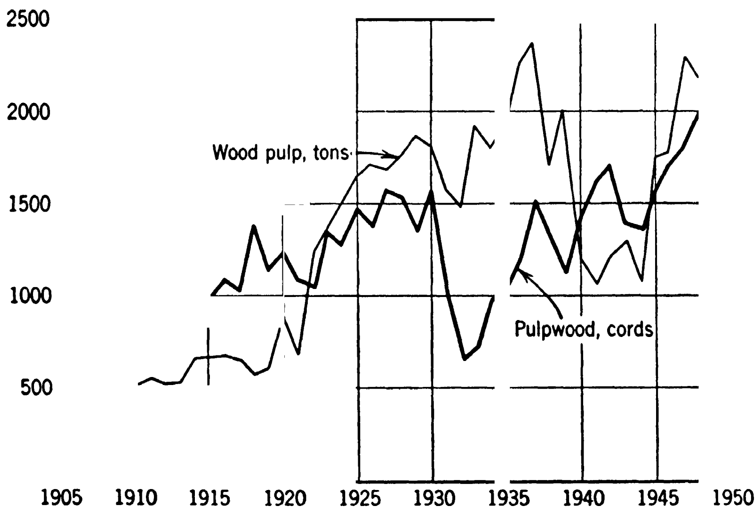


FIGURE 72. Imports of pulpwood and wood pulp. *Courtesy American Paper and Pulp Association.*

in 1927 was as follows: (1) New England; (2) Lake States; (3) South; (4) New York; (5) Pacific Northwest; (6) Pennsylvania.

PRINCIPAL PULPING PROCESSES

There are two distinct pulping methods known as chemical and mechanical. In addition there are a number of processes that combine chemical and mechanical action, and they are generally called semichemical processes. The three principal chemical processes in order of importance are: (1) Sulfate, an alkali process; (2) Sulfite, an acid process; (3) Soda, an alkali process.

The principal woods used for sulfite pulp are spruce, hemlock, and balsam fir, in order of importance; the woods used for sulfate pulp are southern yellow pine, jackpine, and hemlock. The soda process employs largely poplar, Douglas fir, various species of gum, and smaller quantities of beech, birch, and maple. The mechanical process makes use of spruce principally, with smaller quantities of hemlock and balsam fir. The semichemical process is generally used on hardwoods.

The sulfite process. This is an acid process, the active pulping chemicals being sulfurous acid and its calcium salt (calcium bisulfite) in aqueous solution. This chemical dissolves the lignin, or all noncellulose material, leaving the cellulose fibers in the form of pulp. Lignin and the noncellulose products of very complex character comprise more than 50% of the weight of the wood so that the yield of good papermaking fiber is less than 50% in the preparation of the wood pulps by this process. A yield of 42 to 45% of the weight of wood is considered satisfactory. The chemical reducing agent, known as bisulfite liquor, is made at the mill by burning sulfur and absorbing the sulfur dioxide in lime water, or passing the solution of sulfurous acid through towers filled with limestone. Exceedingly careful control must be exercised to obtain proper proportions of chemicals in the processing liquor. The wood from large storage yards, or pulpwood booms, is reduced from the bolt form to small chips by means of a mechanical chipper. These chips are then cooked with the liquor for 8 to 15 hours in large cylindrical steel digesters with pointed ends and acid-proof linings. Cooking is done under 65 to 80 lb. steam pressure and at a temperature of 320°F. Then the wood is blown into pits, where it is washed with water, screened, and either compressed in large, thick sheets, or pumped directly to the paper mill. Sulfite pulp is used with mechanical or groundwood pulp in inexpensive papers to give them greater strength. Waste liquors of this process formerly put into sewers or disposed of in streams are now recovered by several mills in various ways. The Weyerhaeuser Timber Company of Tacoma, is recovering both sulfur and magnesia lime from the liquor and burning the organic matter, thus removing all damage by stream pollution, which has become an important problem in many states.

The soda process. This process depends on the solvent power of caustic soda for converting the noncellulose parts of wood into soluble form. The caustic soda is manufactured at the mill by treating soda ash (sodium carbonate) with quicklime (calcium oxide) in large cast-iron tanks, the chemical mass being boiled together for about 1 hour. This process produces a solution of caustic soda, which is pumped directly into the soda pulp digesters. The soda process is especially adapted to hardwoods, because it yields a soft bulky, but weak, fiber which is well suited to manufacturing book and magazine papers. This pulp is never used alone but is mixed with varying portions of sulfite pulp to give the proper strength values. The cooking operation is done in unlined steel digesters since this soda does not attack metals. After being cooked 4 to 6 hours under a steam pressure of 100 to 125 lb. and a final temperature of 340°F., the pulp is blown into pits, then washed, screened, and compressed into sheets for delivery to the paper mill. Contrasted with the sulfite process, the used liquors are not a waste product but are put through a reclaiming system and used again in the preparation of new liquors. This industry has developed rapidly in the southern hardwood regions, notably in the Appalachian and near-by sections.

The sulfate process. This process is similar to the soda process, but the source of the alkali in the liquor is salt cake (sodium sulfate) instead of soda ash (sodium carbonate). The salt cake must be converted into sodium sulfide before the chemical has any solvent action on lignin. This is accomplished by means of a smelter in the reactive system which reduces the sulfate to sulfide. The final cooking liquor is a mixture of two-thirds caustic soda and one-third sodium sulfide. The action of the cooking liquor on wood is rapid but less destructive to the strength of the cellulose than any other cooking liquor. Steam is admitted to the digesters in which the chips are placed until a pressure of 125 lb. and a temperature of 350°F. are reached. The cooking process requires 1 to 4 hours. The "cook" is then blown and washed like soda pulp and the used liquor put through a recovery

FIGURE 73. Conveyer belt 5′ wide carrying chips made from woods and sawmill waste to bins on top of digester building in large pulpmill. Some of these pulpmills use up to 2500 cords of wood per day. These chips are reduced to pulp through chemical action. The sulfate process has replaced the sulfite method as the leading chemical process of wood reduction. *Courtesy Moulin Studios.*

system similar to the process employed with soda liquor. About 85% of the alkali is recovered and the 15% loss is compensated by adding the crude salt cake at the smelter. This process is well suited to the pulping of resinous woods like southern pines which, because of their resinous nature have not been pulped successfully on a commercial basis by the sulfite process. The sulfate process produces a fiber of great strength which is especially well adapted for the manufacture of strong, tough papers used for wrapping and bag purposes. This process produces the well-known kraft papers which are so strong that they are used in the production of washable fabrics like aprons, overalls, sacks, and even artificial shoe leather. One disadvantage of this process is that the plants must be located, as a rule, in sparsely populated sections because of the extremely disagreeable odors formed during the cooking. Considerable progress has been made in recovering turpentine and pine oils from the waste liquors in the sulfate process. It gives promise of considerable expansion in the future and of competing with the turpentine and rosin produced from gum and wood naval-stores industries described elsewhere under the general heading of naval stores and softwood distillation.

The mechanical pulp process. This process depends exclusively on mechanical disintegration. No chemicals are used. The bolts of wood are cut to 2′ or other desired lengths, after being barked in either the woods or the mill. The bolts are forced by a hydraulic cylinder against the surface of a rapidly revolving grindstone. This whole assemblage of equipment is known as a grinder. The wood is converted into pulp entirely by friction, large volumes of water being sprayed onto the grindstone to lower the temperatures and to prevent burning of the pulp. The grinding process produces "slush," which is screened to remove knots, slivers, and other large fragments of wood. This pulp is then compressed into sheets and shipped to the paper mill, or it may be pumped to the paper mill in slush form if the mill is located near by. The product represents the lowest grade and cheapest form of pulp for papermaking. The mechanical action of the grinder ruptures most of the fibers, thus reducing their length and consequently the strength of the resultant paper. This loss of strength is so great that the pulp must be mixed with sulfite pulp when it is converted into paper. Mechanical pulp is used for such cheap paper as newsprint paper, wallboards, wrapping papers, and wallpapers. Newsprint generally consists of 80% mechanical pulp and 20% sulfite pulp. Newspapers represent the most important outlet for mechanical pulp.

CONVERSION OF PULP INTO PAPER

This is a process entirely separate from the manufacture of pulp. Some of the paper mills of the United States do not manufacture their own pulp but purchase it from other domestic or foreign pulp mills.

All the added materials that compose paper are placed in the beater with the pulp. The pulp fibers pass between two sets of bars and are cut and spread in this operation, the action being regulated to yield a pulp of the desired character for the particular paper. At this time, various chemical compounds such as sizing are added. Sizing is accomplished by adding materials

FIGURE 74. Paper passing through dryers at high speeds to remove the last vestige of moisture. Rolls are steam-heated. *Courtesy Mead Corp.*

that will coat the fibers like a varnish and prevent absorption of the fluids. A rosin soap is the principal material used for sizing. Mineral fillers are added to fill the interstices between the fibers and to make the resulting paper smoother and more nearly opaque. Common clay may be used as a filler. Most papers require coloring. For white papers, a blue dye is used to neutralize the yellow color of the pulp. Colored papers of any particular shade may be obtained by adding the proper dyes to the pulp while it is in the beater. After these materials are added, the final step is fabrication and finishing the sheet of pulp on the paper machine. This machine may be considered to be an aggregation of four machines which operate simultaneously, the most important unit of which is known as the Fourdrinier wire. The first section of the machine forms a web of paper by receiving a thin suspension of pulp in water on a moving endless

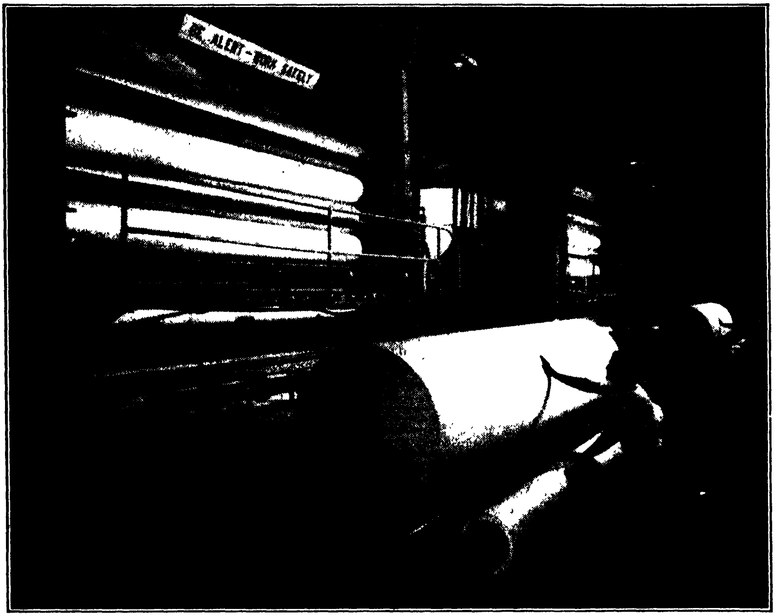


FIGURE 75. Long sheets of paper leave the calender. This is newsprint being wound in 40"-diameter rolls, each of which will contain more than 5 miles in length of paper. *Courtesy Gulf Oil Co.*

belt of wire cloth through which the water drains off, leaving a fine web of matted fibers. The second section compacts this wet sheet by passing it through a series of steel and rubber rolls. The third section of the machine dries the sheet on a series of steam-heated drying cylinders around which the paper passes. Then the sheet passes to the fourth section of the machine, which consists of heavy steel rolls called calenders between which the sheet is passed and given a smooth finish. From the calenders, the continuous sheet of paper is wound on a wooden reel, from which it is rewound into rolls of paper of desired dimensions for the printing presses, or it is cut into sheets for writing paper or various other papers.

CLASSES OF PAPER PRODUCTS

Many different kinds of paper and paper products come from the wood-pulp industry. Actually there are several hundred kinds of paper. They may be classified, however, into 10 separate

FIGURE 76. Typical winter woods scene in northern New England where long piles of 4′ spruce and balsam fir pulpwood are waiting transport by horse- or tractor-drawn sleds or trucks to streams, highways, or railroad sidings for shipment to pulp mills. *Courtesy Great Northern Paper Co.*

divisions.* In Table 16 the examples of the different kinds of paper products included within each of these 10 classes indicate the vast variety of uses to which paper products are applied in the daily lives of our people.

Development of the pulp industry in the Pacific Northwest. Remarkable advances have been made both in the volume of wood used and in the technique of pulp and papermaking in the Pacific Northwest. The mills in Washington and Oregon have rapidly expanded in number and capacity.

* These divisions and the names of the representative paper products in each class were suggested by Professor C. E. Libby. There are 237 different classifications of paper, paperboard, wet-machine-board and construction-paper materials recognized by the Bureau of the Census of the U. S. Department of Commerce for statistical purposes.

TABLE 16

No.	*Classification*	*Products*
1	Boards	Food containers, shipping containers, clothing boxes, paper dishes, tickets.
2	Books	Textbooks, magazines, catalogues, mimeograph papers, lithograph papers.
3	Bristols	Index cards, playing cards, postcards, wedding announcements, photograph mounts.
4	Building	Roofing felts, sheathing papers, plaster boards, thermal-insulating boards, carpet linings.
5	Covers	Manuscript covers, booklet covers, photograph folders, album paper, box covers.
6	News	Sales pads, poster papers, newsprint, adding-machine paper, wallpaper.
7	Tissue	Carbon paper, cigarette paper, napkins, toilet paper, towels.
8	Wrapping	Food wrappings, paper bags, merchandise wrappings, barrel liners, gummed sealing tape.
9	Writings	Bonds, ledgers, drawing paper, envelopes, safety paper.
10	Industrials	Blotting, filter, electrical insulation, photographic, vulcanized fiber.

The following significant developments in the pulp and paper industry of the Northwest have occurred:

1. One mill at Shelton, Wash. (Simpson), has a daily capacity of 350,000 sq. ft. of wallboard per day.

2. New methods of sulfite pulping to solve the waste-liquor and stream-pollution problems by means of the magnesium base process (Weyerhaeuser) and by the ammonium base process (Rayonier).

3. Production of alcohol from waste pulp liquor by the Puget Sound Pulp and Timber Company at Bellingham, Wash., with a capacity of 8000 gal. per 24 hours.

4. Construction of new and modern plants to convert woods and sawmill wastes and to make higher grades of pulps as at the Weyerhaeuser plants at Longview, Wash., and Springfield, Oreg.

The further extension of the pulp industry in the Pacific Northwest seems very likely because of the vast amount of available woods and sawmill waste at relatively low cost. Western hemlock is the principal wood used in these mills.

RECENT SHIFT TO THE SOUTH

Since 1930 southern pine has assumed large importance in pulp production and has surpassed spruce as the premier wood. Most of the total capacity of the southern pulp mills is devoted to producing unbleached sulfate or kraft pulp from southern pine. The production of newsprint in the South is now on a commercial scale and seems likely to improve so that the South will assume a still more important position in the production of both newsprint and kraft papers. The South has more than 100 million acres of cutover pine land which, if properly managed, by adequate fire protection and thinnings, is capable of producing ½ to 1 cord of wood per acre yearly—a volume in the aggregate sufficient to produce five times the total yearly pulpwood consumption of the Nation. Southern hardwoods, such as black gum, red gum, cottonwood, and some other species, are also potential sources of pulp and paper. The use of hardwoods for pulp has increased very considerably.

Southern pine is cut usually to 4″ diameter inside the bark in the tops for pulpwood. One plant takes wood to 3″. It is received generally in unbarked condition, the price for which varies from $8 to $12, or more, with an average of about $11 per cord. The supply comes largely from small, immature, second-growth timber, partly from worked-out naval-stores timber, old field stands of young timber, many farmers' woodlands, and top logs from logging operations. A very small percentage comes from thinnings; but the trend is toward a greater supply from integrated use, that is, a combination of logging jobs including turpentine operations, pole, piling, saw log and cross-tie cuttings, etc. One company has acquired several million acres, several from 150,000 to 400,000 acres or more, and others from 50,000 to 200,000 acres each. The tendency of the pulp companies in the South is to own 200,000 to one million acres or more each as a source of wood supply. Many of these companies, at present, purchase wood in the open wood market rather than cut their own supply. The value of these second-growth timberlands range from $15 to $30 or more per acre, depending on the volume of pulpwood present and potential rates of growth.

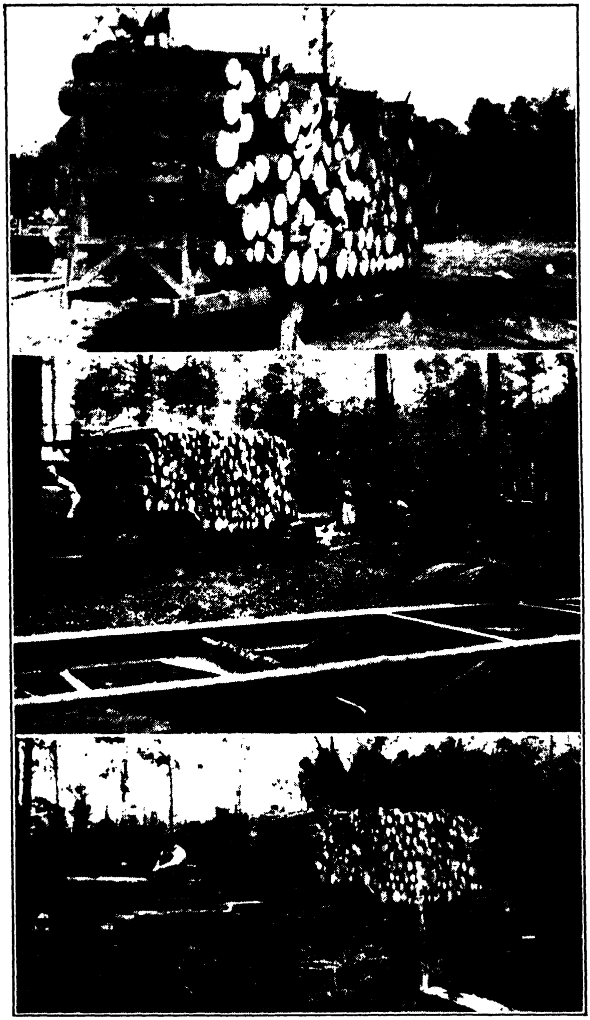


FIGURE 77. At top is loaded trailer resting on front and rear standards ready for attaching either steel Athey wheels for boggy and soft terrain or rubber-tired wheels and axle for highway travel to dock, mill, or railroad loading point. At center is shown trailer with rubber-tired axle and Athey truss wheels for greater flotation. Lower picture shows loaded trailer with Athey detachable wheels, fore and aft, being pulled by Diesel tractor out of swampy location after which the highway rubber-tired axle with Stewart-Warner electric brakes will replace the steel wheels. These represent some efficiency improvements on the largest logging operation in the country to supply about 2500 cords daily for a pulp mill at Georgetown, S. C.

Courtesy International Paper Co.

Most of the pulpwood delivery in the South is by railroad, with about 30% by motor truck and the remainder by barge. Delivery by truck is increasing, however. The general policy is to take the most remotely located wood first. A cord of green wood usually weighs about 4000 to 4500 lb., and the usual truck load is from one to four cords. As a rule, only a few weeks elapse between cutting the tree and delivery at the mill. This is important because it cuts down the inventory of wood supply and results in lower interest charges and fewer losses from insects and disease attacks.

These conditions contrast strongly with those prevailing in the North and in eastern Canada where stream driving is depended on for delivery of pulpwood. The southern mills generally carry 2 to 4 weeks' supply and the western mills a minimum of 1 month's supply.

This strong trend toward new pulp mills in the South has decreased the likelihood of large wood-pulp importations from Scandinavian countries and Canada. Pulpwood can be produced more cheaply than the pulp can be imported.

ADVANTAGES OF THE SOUTH IN PROVIDING AN ADEQUATE SUPPLY OF PULP

These advantages may be summarized as follows:

1. The wood supply is relatively inexpensive. Wood is delivered at the mills for $8 to $12 per cord, compared to much higher prices for spruce in the North.

2. There are in the South several rapid-growing species. Wood sometimes grows at the rate of 1 cord per acre per year without management and up to 1½ cords with management (fire protection, thinnings, planting when necessary, etc.).

3. An abundant supply is available at present, and a future supply is assured.

4. Hauls to the mill are relatively short, with year-round delivery assured.

5. Mills are near sources of important ingredients in the manufacture of pulp and paper, such as sulfur, lime, salt, clay, and rosin sizing.

6. Carrying charges are relatively low, owing to small wood inventories at the mill, compared with periodic (yearly) stream-driving delivery, as in eastern Canada and the Northeast. Deliv-

cry of eastern spruce is in the late spring or early summer, and there are, consequently, higher interest charges during periods of logging and wood storage, at or near mills, pending manufacture. Lower wood inventories naturally result in lower interest charges for carrying wood supplies in the South.

7. There are lower initial capital investment costs in plant construction because of favorable climatic conditions, lower costs

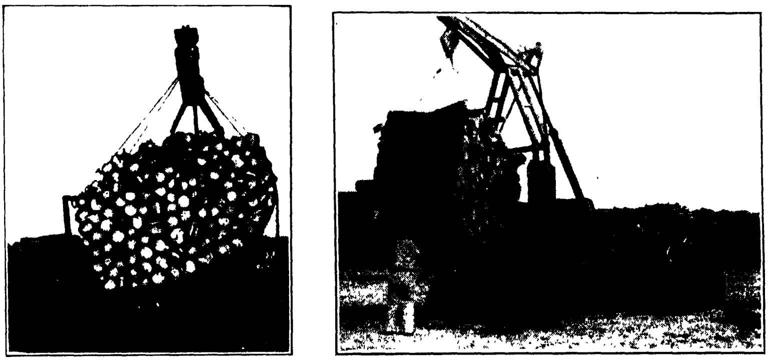


FIGURE 78. At left, high-boom arch with newly developed split bridal slings lifting about 3 cords of pine pulpwood off truck in North Carolina. At right is shown same arch with same load (3 cords) being placed on Athey wheels of arch before stacking in yard or loading directly on barge for shipment to pulp mill. This arch is used for skidding, loading, and unloading. It represents one of the outstanding developments in mechanized logging. *Courtesy T. N. Busch, International Paper Co.*

of timberlands necessary to carry plant requirements, and lower costs of mill sites than in other sections.

8. There are opportunities for integrated utilization as well as prelogging and relogging. Pulpwood production may be closely related to naval-stores, saw-log, cross-tie, pole, piling, and post production. For example, the naval-stores industry may carry timberland investment charges, and pulpwood production or thinnings may be incidental to the major objective of management. Thus the pulpwood may be secured for relatively little or low charges. This contrasts with the single-purpose product in eastern Canada and other parts of the United States. Salvage and sanitation cuttings have materially added to the pulpwood supply.

9. Markets for pulp and paper are based on reasonably attractive freight rates. The bulk of the southern paper is shipped north of the Mason and Dixon line. The competitive delivery rate by rail and water may often determine the profitableness and, therefore, the success of any pulp operation. Low transportation rates are often the deciding factor in competition.

PULPWOOD LOGGING *

The logging of pulpwood constitutes a very large and important industry itself in order to produce the 22 million cords annually consumed. These logging operations are principally in the South, eastern Canada where the logging of pulpwood is one of the principal industries, the Northwest, the Northeast, and the Lake States. Generally these logging operations supply mills requiring from 30,000 to 100,000 cords per year. The largest pulpwood logging job is in the South. In one year, 857,000 cords were brought to the largest pulpwood mill in the world located at Georgetown, S. C. At 500 b.f. per cord, this is equivalent to 428,500,000 b.f. which is even larger than the logging jobs for sawmills of a capacity of 1 million b.f. per day in the West. This pulp and paper mill runs three shifts per day, 7 days per week, and requires 2500 to 2600 cords per day. Wood is brought from distances up to 400 miles from many locations in Georgia, Florida, South and North Carolina. The producing areas of both company and private forests, are largely within a radius of 160 miles in South Carolina and North Carolina. A constant flow of logs is secured by barge, truck, and rail. A Hi-boom arch invented by T. N. Busch and mounted on Athey wheels and hauled by crawler tractor can skid and load about 40 to 50 cords per day. It skids up to ½ mile in sling loads after hand stacking in the woods by the cutters. The usual distance is about ¼ mile of skidding. Sling loads are placed on steel frames of an Evans-Busch trailer combination when parked in the woods on haulroads awaiting tractor trucks to haul the wood to the mill. The company uses 100 Evans-Busch trailer combinations and 15 crawler tractors with 12 large Corbitt truck tractors, Diesel-

* Because of limitations of space, the subject of logging pulpwood is very briefly covered. For further reference on logging, see *Logging,* John Wiley & Sons, New York, 1949.

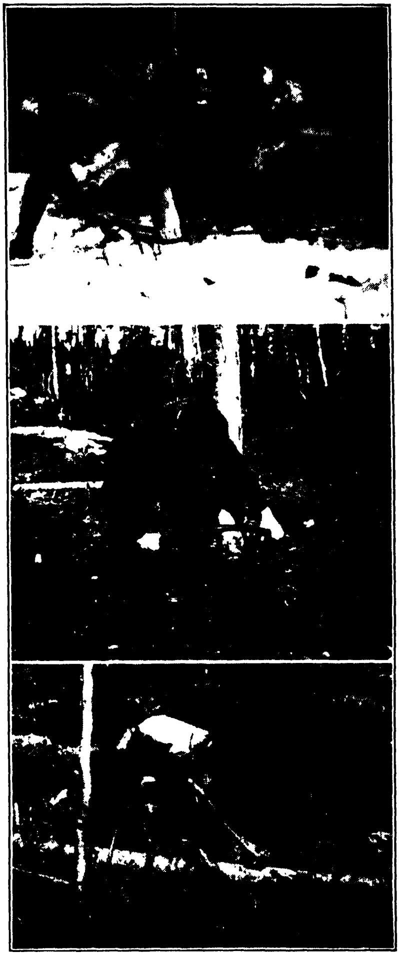


FIGURE 79. Pulpwood felling and bucking in the important spruce-producing areas of Quebec, Canada. Center view shows popular and usual method of felling with bucksaw. At top is demonstration of proper method with same saw to secure low stump. At bottom is the usual and typical method of bucking with the same saw. Mechanical saws have not generally replaced the manual saws in the small timber of eastern Canada. *Courtesy A. Koroleff.*

powered, with four-wheel drive. Each trailer carries six to seven cords of 128 cu. ft. each.

The Wyssen skyline cable system, which has been widely used to bring pulpwood, fuelwood, and other products down steep slopes in Central Europe, has been introduced and successfully employed in the Adirondacks in New York and near Matane, Quebec, in eastern Canada. This cableway system weighs only 5 tons including steel rope and can be set up or moved in 1½ days by five men. It is especially adapted to selective logging because it can be profitably operated when taking only 1½ cords per acre from a stand. It is generally used for a minimum cut of 200 cords at one location. It is anchored to the base of trees at the upper and lower ends. The maximum length of application is nearly 1 mile. It can bring in logs for distances up to 500 ft. along lateral lines on each side of the cable. It drops logs at the lower level where they are bucked up into desired lengths and trucked to pulp mills or other destinations. Five men operate the cable: one is at the winch at the top, there are three choker setters and one man to unhook the chokers from the carriage at the landing and release the chokers from the logs. About 50 loads are delivered at the base of the cable in a 9-hour day. The carriage is the most important feature. It has an automatic stop which makes it possible to stop at any location to attach the load. Logs are attached to chokers. The operating or second cable pulls the logs up to the carriage which conveys the logs by gravity to the landing. Telephone lines connect the winch operator with the choker setters and the man at the landing. A 30-hp. motor pulls the winch to the top of the setting and also pulls the logs to the carriage, serves as a brake on the downtrip, and pulls the carriage to a position where the chokers can be placed on the logs. It is designed primarily for small logs weighing up to 4000 lb. (or groups of logs). In the Adirondacks, 20′ or 24′ logs are generally cut. They are crosscut by chain saws to 4′ lengths at the landings; then piled on trucks for transport to the pulp mill.

FIBERBOARDS

Fiber, or building boards, is a general term applied to products made of many materials and used in many different ways. Whereas wood constitutes the source of many of them and many waste products of sawmills and woods operations are utilized for this purpose, fiberboards also compete directly with lumber, plywood, veneers, cooperage stock, and other commodities made directly from the log.

There are now marketed several hundred different types of fiber and building boards which may be classified as follows:

Wallboards. These are composed of a number of layers or binders or pulpboards molded and pasted together and then sized on the surface. They are also known as laminated wallboards. They are commonly made of wood pulp, straw, and other waste material, and are generally 3/16″ to 1/4″ in thickness.

Gypsum wallboards. These are incombustible boards made of gypsum plaster and reinforced on the surface with a covering of pulpwood or compressed wood, usually 3/8″ to 1/2″ thick.

Insulating boards. These are composed of various fibrous materials, such as wood, bagasse, or other vegetable fibers, which are sized or felted or compressed together to contain a large quantity of entrapped or "dead" air. They are made by compressing together several thin layers of material or forming a nonlaminated layer of the required thickness, which is generally 7/16″ to 1″ or up to 3″.

Insulated blankets or quilts. These are generally flexible materials composed of wood and other vegetable fibers loosely felted so as to contain a maximum quantity of entrapped or "dead" air. They are generally covered on the two surfaces with paper or other fabric and cemented to the fibrous mat. Thicknesses vary from 1/4″ to 1″ or more.

These boards may be used for insulation purposes, or partly so. They are used primarily as covering material, since they usually do not have sufficiently strong structural qualities to provide for necessary strength, rigidity, or protection as solid boards are required to do. Their thinness and compactness prevent their being efficient heat- and sound-insulating materials; but they are used to cover dead air spaces and in connection with other materials to serve these purposes.

The principal objective of insulating materials is to protect from heat, cold, and sound. However, all of these boards, including the so-called insulating boards, have considerable structural strength and often serve to replace sheathing lumber, wood or metal lath, plaster, etc. They are employed as well for general interior decoration, as paneling, and for partitions, ceilings, and similar coverings.

Fiberboards have been made for many years in foreign countries, but their manufacture has progressed more rapidly in the United States than in any other because of the abundant supply of raw material, such as logging and sawmill waste, which may be produced inexpensively.

Because of changes in temperature and humidity, the warping and shrinking of lath and other building materials have presented serious construction problems. These difficulties are also present to some extent in fiberboards. Various oils and waterproofing compounds have been introduced to offset these difficulties. Various forms of pitch, rosin, turpentine, paraffin, wax, glues, and asphalt have been used. Solutions of sodium silicate, phosphate of soda, and sodium tungstate have been used in fireproofing some building boards.

Many of these boards are patented. A maximum number of patents were issued in 1925, when several large corporations, the Masonite Company, for example, were founded. In that year more than 50,000 short tons of building boards were manufactured. In 1948, the production of 1,270,348 short tons was reached. Of this quantity 905,000 tons were insulating wallboard, 364,000 tons were wallboard, and 115,000 tons were sheathing board; the remainder were miscellaneous types.

The fiberboard industry has developed largely in the East and South. New York is the principal port of export. The South has been especially active in the manufacture of fiber and insulating boards because of the vast quantities of inexpensive raw materials available. Many insulating and building-board plants have been established in Sweden, Finland, and England, offering considerable competition to the boards of American or Canadian manufacture. World War II gave a tremendous impetus to the production of fiber, building, and insulating boards of all kinds, because of the necessity of erecting large numbers of structures, more or less temporary in their nature, in the shortest possible length of time. Many warehouses, office buildings, cantonments and similar structures, largely temporary in nature, were constructed with the greatest possible speed. Since then, through expert merchandising and extensive advertising, wallboards have found a large outlet for many purposes aside from interior decoration, partitions, ceilings, and sheathing. Among the miscellaneous uses for wallboards are chair seats, clothes hampers, drafting boards, drawer bottoms, tops of desks, store counters, tables, garage linings, doors, packing cases, radio boxes, showcases, shelving, store fixtures, trunks and wardrobes. Special uses developed for the insulation type of boards have been attic and air-duct linings, auditorium interiors, automobile tops, basement linings, carpet linings, dry kilns, filling stations, garages, icehouses, milk houses, laundries, partitions in buildings, inside or outside sheathing in buildings, portable houses, automobile trailers, refrigerators, roofing insulation, storm doors, tobacco sheds, and tank houses.*

The Stimson Lumber Company at Forest Grove, Oreg., utilizes good wood not suitable for lumber or other products in the sawmill for the manufacture of a new product called "forestboard," which is a 100% Douglas fir fiberboard. No bark, decayed wood, or materials that are not good cellulose are used for this purpose. After chipping, the material is made into a pulp and under high pressures and heat is formed into a hardboard or fiberboard. This process applies to both woods as well as sawmill waste and makes possible a much greater utilization of the tree. It also assists in reducing the fire hazard in the woods. Sound dead wood from fire-killed trees, as well as sound green wood, may be used.

Fiber insulating boards have been made from various wood-waste materials as developed at the U. S. Forest Products Laboratory. These consisted of sifted pine sawdust, aspen chips, and pulp-mill waste from hemlock bark. After being fiberized in an attrition mill, various mixtures including semichemical pulp and repulped newspapers were formed into boards in a suction mold and dried in a hot press. The cost of a plant necessary to produce 60,000 sq. ft. per day was estimated at $265,000 and the unit cost per thousand board feet of ½″ board at $23.26. Production would require 20 tons or more of wood wastes per day.†

* For further information see *Wall Boards and Insulating Material,* U. S. Dept. Commerce Natl. Committee on Wood Utilization, Washington, D. C.

† For further reading on this process see *Small Scale Manufacture of Insulating Board from Wood Wastes,* U. S. Housing and Home Finance Agency, Washington, D. C., 1948, and *Manufacture of Hardboards Out of Wood Waste,* by A. Elmendorf, Chicago, Ill., as presented at the Forest Products Research Society meeting at Durham, N. C., November 4, 1949.

Thermal conductivity. Thermal conductivity of wood is a very important factor in the various types of construction with fiberboards and other insulating materials in air-conditioned buildings and in buildings where changes from heat or cold must be controlled, as in cold-storage warehouses, ice plants, precooling plants, dairies, creameries, fruit and produce warehouses, and butcher boxes. Heat flows from warmer to cooler bodies. The direction of heat flow is always from lower to higher temperatures, or in an upward direction. Conduction is the rate of passage through a body or material when one side is exposed to a lower temperature than the other. The measure of this heat flow is generally expressed in B.t.u.* This measure of heat flow is expressed in B.t.u. per square foot per inch of thickness, per degree Fahrenheit of difference in temperature, or in other ways. In insulating materials, the denser the material, the greater the rate of heat flow and the less value the material has for insulation. The value of insulation materials is also expressed in resistance to conductivity shown as R in Table 17. That is, the larger the number or the greater the resistance, the greater is the insulating value. The column headed K shows the thermal conductivity; that headed D shows the density of various materials per cubic feet.

RECOVERY PRODUCTS FROM SULFITE WASTE LIQUOR

The problem of the utilization of sulfite waste liquor has been a perennial one for a great many years. Many research projects have been initiated to discover and develop methods of utilizing the very large lignin content from sulfite waste liquor. A large papermaking concern at Rothschild, Wis.,† operates a successful recovery system for sulfite waste liquor, consisting of a two-stage precipitation with lime. In the first stage, the inorganic material is precipitated as calcium sulfite, which is settled and returned to the acid system as make-up chemical. Then, by the addition of further lime to the supernatant liquor, the organic matter is precipitated as calcium lignosulfonate. This is the basic raw material for conversion into other lignin products.

* British thermal unit. One B.t.u. is the amount of heat required to raise the temperature of 1 lb. of water 1°F.

† From data supplied by Allen Abrams, Marathon Corporation.

TABLE 17

THERMAL CONDUCTIVITY OF VARIOUS MATERIALS

Material	*D*	*K*	*R*	*Authority*
Balsa wood	8.80	0.380	2.63	Bureau of Standards
Cypress lumber	29.00	0.670	1.49	Bureau of Standards
White pine lumber	32.00	0.780	1.28	Bureau of Standards
Oak lumber	38.00	1.020	0.98	Bureau of Standards
Redwood lumber	25.50	0.570	1.75	G. F. Gebhardt
Corkboard	10.60	0.300	3.33	Bureau of Standards
Regranulated cork	8.12	0.311	3.22	Bureau of Standards
Celotex	16.20	0.340	2.94	Bureau of Standards
Insulite	13.20	0.340	2.94	Bureau of Standards
Firtex	13.80	0.308	3.24	General Electric Co.
Thermax	26.40	0.458	2.18	Peebles
Thermofill	26.00	0.520	1.92	Bureau of Standards
Rock wool	14.00	0.280	3.57	Bureau of Standards
Mineral wool	10.50	0.310	3.22	Peebles
Hair felt	17.00	0.246	4.05	Bureau of Standards
Kapok (dry zero)	0.98	0.240	4.20	Bureau of Standards
"Rock cork"	15.60	0.328	3.06	Bureau of Standards
Asbestos fiber	17.40	0.569	1.75	Randolph
Sheep's wool	8.48	0.338	2.95	Musselt
Balsam wool	2.20	0.270	3.703	Bureau of Standards
Flaxlinum	11.24	0.328	3.05	Bureau of Standards
Palco wool	6.72	0.258	3.88	G. F. Gebhardt (by Peebles)
Planer shavings	8.80	0.410	2.44	Bureau of Standards
Sawdust	12.80	0.410	2.44	Bureau of Standards
Concrete	145.00	8.00	0.125	Average
Cinder concrete	110.00	5.00	0.20	Average
Common brick	120.00	5.00	0.20	Average
Hollow tile	....	3.50	0.286	Average
Wood lath and plaster *		2.00	0.50	Average
Asphalt composition roofing *	...	6.00	0.167	Average
Air film—outside K_2*	...	4.02	0.248	Accepted average values for ordinary calculation
Air film—inside K_1*	.....	1.34	0.745	
Still air	....	0.175	5.70	Motz
Air spaces—1″-8″	.	0.263	3.80	Bureau of Standards
Air spaces—1″-4″		0.338	2.96	Bureau of Standards
Air spaces—more than 3″-4″	.	1.11	0.900	Bureau of Standards (1933)
Aluminum foil—3 spaces per inch		0.310	3.22	General Electric Co.
Cement plaster	..	6.00	0.167	Average
Surface ground (for floors) *	...	2.00	0.500	Accepted practice

D—Indicates density in pounds per cubic foot.
K—Indicates conductivity per inch of thickness except where marked K_1 and K_2.
R—Indicates resistance—$R = 1/k$.
* Indicates values for actual thickness—not per inch of thickness.

By treating the calcium lignosulfonate with the proper quantity of caustic soda and putting through a high-pressure cook, vanillin is formed, which is subsequently removed by extraction, crystallization, and purification. Approximately 50% of the vanillin consumed in the United States is made from lignin.

By converting the calcium lignosulfonate to magnesium or sodium lignosulfonate, tanning materials are produced. By cooking certain lignin salts at approximately 1000-lb. pressure, there is produced a boiler compound employed widely in locomotive and stationary boilers.

Lignin dispersants are used to incorporate carbon black into rubber latex, in cement grinding, for conditioning of mud in the drilling of deep oil wells.

The Rothschild pulp mill produces about 15,000 tons per year of the calcium lignosulfonate.

These products represent significant developments in the more complete utilization of our forest resources through the pulp and paper industry.

RAYON *

Since 1912 rayon or artificial silk has increased in production more than any other forest product. The tremendous expansion in the manufacture of this commodity is the result of a desire to devise a satisfactory substitute for silk. Although various materials have served as the basic source of rayon, it is now almost entirely made from wood, principally spruce and some western hemlock. For some years, cotton linters were used, but these materials have been abandoned largely because wood as a raw material is cheaper and more readily available. The discovery of nitrocellulose by Schoenbein in 1845 laid the basis for the modern rayon industry. Much research and experimentation with raw materials and chemicals followed. The credit for developing a practical textile fiber is given usually to Chardonnet, who produced a fiber by dissolving nitrocellulose from mulberry wood in ether and alcohol. In 1899, the first rayon mill was established at Besançon, France. Various developments and improvements were made in succeeding years.

In 1892, cellulose xanthate was discovered, which soon lead to the development of the viscose process, now the most important method for making synthetic fibers. Nearly 90% of the world's rayon production is now made by this process, and the old nitrocellulose process for rayon filament has gone out of existence. About two thirds of United States rayon is produced by the viscose process. During World War I, cellulose acetate was

* Reviewed and revised by Dr. Edwin C. Jahn.

developed and used in large quantities as a film for airplane wings. From this step a process was developed for making fibers. A third method for making rayon is the cuprammonium process.

The annual production curve for rayon in the United States since 1920 is an almost straight-line curve of rather steep slope. United States rayon production in pounds for several different

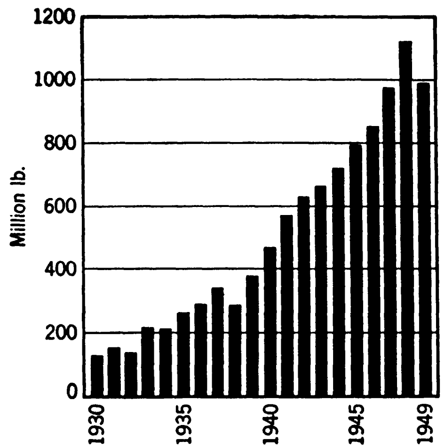


FIGURE 80. Progress in the production of rayon from 1930 to 1949, inclusive. *Courtesy Textile Economics Bureau.*

years is: 1,111,000 for 1912; 10,125,000 for 1920; 127,700,000 for 1930; 471,200,000 for 1940; 723,900,000 for 1944; and 1,124,300,000 for 1948. In 1940 and 1941 the United States production of rayon amounted to about 20% of the world production, and in 1948 it was 45.9% of the world production. The 1948 global production of rayon-filament yarn and staple fiber is estimated at 2450 million lb., which is 23% above the 1947 figure but 13% below the all-time high record in 1941. World War II caused a serious setback in rayon production in such countries as Germany, Italy, and Japan.

Imports of rayon filament have decreased over the years since 1929 but sharply increased in 1948 from a negligible 1947 figure to 10,120,000 lb. Staple fiber imports, on the other hand, have been generally increasing and reached 38,638,000 lb. in 1948. Thus the total United States imports for consumption in 1948 were 48,758,000 lb.

Exports of rayon and products made from rayon, such as garments, tire yarn, cord and fabric, have increased over the years reaching a peak amount in 1947 of 130 million lb. Of this total figure, 31,600,000 lb. represents filament, staple, and spun-yarn rayon.

The manufacture of rayon is an intricate and complicated operation. Many experimental years passed before the industry was able to bring all the operating variables under control. The difficulties of securing a uniform-colored product and of obtaining good strength, especially in the presence of water, have finally been overcome. Filament rayon can be produced with a wide range of predetermined properties and filament thickness (denier). The development of staple fiber has greatly expanded the range of products made from rayon.

Development of a delustering process on a successful basis has materially assisted in improving the product. It has become recognized that rayon can give added strength to satin, silk, wool, nylon, and special combinations of these materials. Rayon in combination with cotton adds strength and luster to the cotton. Worsted fabrics mixed with rayon are stronger and shrink less than pure wool. The principal claimed advantages of rayon are its soft texture, fine and constant color, luster, and drapability. Durability and low prices are important fundamental qualities. Furthermore, rayon does not adhere to other fabrics, nor is it affected by moths. It is resistant to mildew and readily absorbs moisture.

Recent outstanding trends in the rayon industry are the very rapid rise in staple fiber production and in acetate-filament production. Over the years there has been a general increase in the amount of wood pulp used in rayon manufacture, wood pulp now amounting to over 80% of the total cellulose consumed by the rayon industry.

The price of rayon has fluctuated widely during the past 30 years. It reached its peak in 1920. Since then it has greatly decreased with fluctuations reaching 55–56 cents per lb. for 150-denier viscose filament for the period 1942 to 1946. In 1948 the price increased to 75 cents for the same material.

PLASTICS *

Plastics as applied to wood products mean a wide variety of products including cellulose-derivative plastics, lignin plastics, pulp-molded products, paper laminates, and wood particles welded together by a synthetic-resin matrix to form many architectural and structural forms, novelties, fixtures, furniture parts, and trays, etc. The most important group are the cellulose-derivative plastics. Cellulose nitrate is the first material to be used in plastics and reached its production peak in 1919, though it has maintained a fairly steady rate of production since 1925. Cellulose acetate plastics, however, show spectacular growth since 1935. The cellulose ethers and other cellulose esters have also been developed for plastics.

Pulp molding is a relatively new development. It involves preforming an article with wood pulp from a water suspension. The preform is then impregnated with a resin, pressed, and cured. Trays, dishes, miners' helmets and many other articles are made from this material. Large amounts of paper are impregnated with various resins and then laminated under heat and pressure to make a wide variety of articles for the electrical and other industries, for table tops and other structural uses.

Sawdust, lignin from waste pulping liquors, and other forest wastes are receiving wide attention as materials for plastics. It is estimated that the American logging, sawmilling and woodworking industries account for over 60 million tons of wood waste. Furthermore, millions of tons of wood lignin are lost annually in sulfite waste liquors, and over 1.33 million tons of lignin are burned in the soda-recovery systems of the soda and sulfate pulp mills of the United States each year.

Processes for using lignin and wood wastes for plastics are as yet imperfect. Only small amounts of lignin and wood waste are used at present compared to the synthetic resins. A lignin-laminated paperboard is now being successfully manufactured. Also some table-top cores, chair backs, and other items are being made from ground sawdust and shavings bonded with synthetic resins. Large amounts of wood flour enter into many plastic items as a filler or extender. It is possible that in the future many forms used in art, architecture, building construction, and

* Reviewed and revised by Dr. Edwin C. Jahn.

other useful commodities may be manufactured from wood plastics. There is an enormous potential field.

Much research has gone into the problem of converting sawdust and wood waste directly into plastics. Several patents have been granted. The most important work in this field has been done by the U. S. Forest Products Laboratory. They have developed processes based on (1) acid hydrolysis, (2) chemical condensation, and (3) thermal hydrolysis.

1. Sawdust is first hydrolyzed completely or in part with dilute acid under pressure as wood is hydrolyzed for the production of ethyl alcohol from wood on a commercial basis. The solid material is freed from the extraneous liquor and is dried. The dried powder is then mixed with 10% furfural and air-dried. This relatively dry powder is pressed at 135°C. and 3000 lb. per sq. in. A somewhat better board is obtained by the addition of 3½% of aniline to the mixture.

2. The sawdust is subjected to the action of dilute phenol at elevated temperatures of 175°C. for a period of ½ hour. The resulting powder is then thoroughly washed with water to remove excess phenol and sugars and in order to permit the recovery of the excess phenol. It is then dried and pressed dry.

3. The third process is to digest the sawdust at somewhat higher elevated temperature with water alone. The resulting sawdust is then washed free of sugars, dried, and mixed with aniline—about 5%—and pressed at 135°C. and 3000 lb. pressure per sq. in. Several other chemicals seem to give equally satisfactory results.

These processes produce materials that differ somewhat in character, water resistance, and cost. However, they are all rather dense and dark colored and take a brilliant finish. Some of the more recent plastics have a modulus of rupture in excess of 6000. A small amount of chlorine has been found to accelerate greatly the reaction with furfural and phenol, but because of its tendency to etch the molds it has not proved satisfactory.

23 · NAVAL STORES *

Gum naval stores are rosin and turpentine produced from crude gum of longleaf and slash pines by repeated scarring or chipping of the surface and distilling the gum that exudes from the sapwood. Of all naval stores, 46% are produced in this manner, the remainder being obtained from steam solvent and destructive distillation and extraction from the rich heartwood of seasoned pine stumps, knots, and limbs, and from sulfate pulp-mill waste liquors. Naval stores obtained from stumpwood and from the sulfite pulp mills are known as wood turpentine and rosin. The term naval stores dates back several centuries when wooden vessels used tar and pitch from the pine forests of Scandinavia. The demand for tar and pitch from crude gum is now of minor importance.

The gum industry is one of the oldest in the United States, going back to early days in the Virginia and Carolina colonies. Savannah for many years has been the great center of concentration and shipment of naval stores to many parts of the world. Valdosta, Ga., is next in importance. Naval stores are the only world product whose price is based on daily quotations formed by an American board of trade.

The industry is centered in southern Georgia and northern Florida but exists also, to a less extent, in South Carolina, southern Alabama, and southern Mississippi. It is confined to the longleaf and slash pine belts and formerly depended upon virgin timber. Now the industry depends exclusively on second-growth timber.

The naval-stores industry constitutes one of the most important in the lower South and closely follows lumber, cotton, and other agricultural products in its relative importance. In many

* Reviewed and checked by American Turpentine Farmers Association, Valdosta, Ga. For further reference, see *U. S. Dept. Agr. Naval Stores Conservation Program Bulls.*; *Modern Turpentining Practices* by W. P. Everard, U. S. Dept. Agr. Forest Service, 1947; other Government bulletins; and *Naval Stores Rev.* of Savannah, Ga., for current information.

sections of southern Georgia and northern Florida, it is the most important single industry, furnishing employment for large numbers of people. Of the 50 million acres of forestlands in the naval

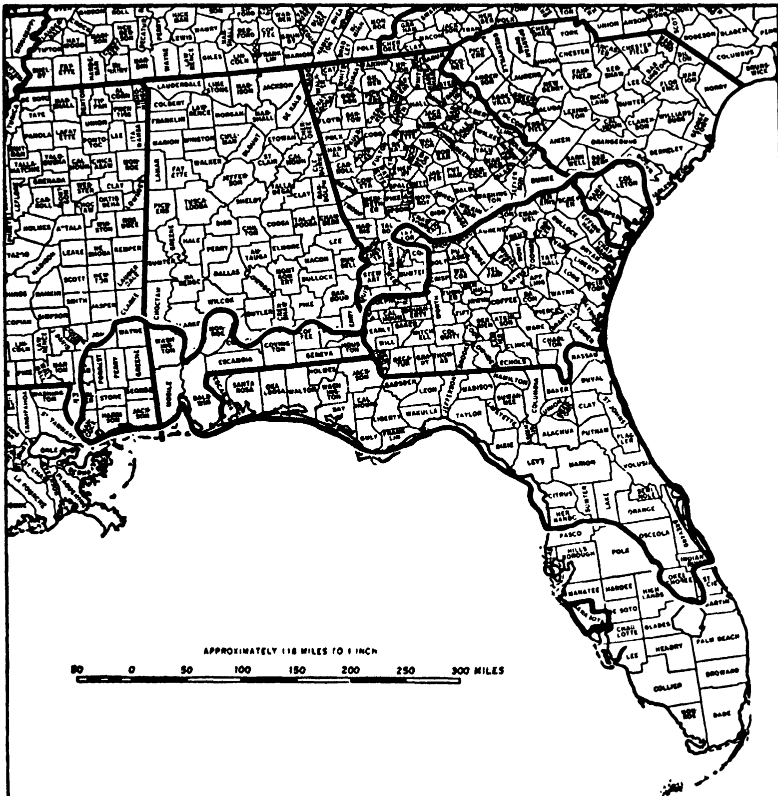


FIGURE 81. Location of naval stores region principally in northern Florida and southern Georgia, showing exterior boundaries. *Courtesy Bureau of Agricultural Economics, U. S. Dept. of Agriculture, Washington, D. C., 1950.*

stores region of the South, about 30 million produce naval stores and nearly 400,000 people depend largely upon this industry for a living.

Large areas of timber are now being managed purposely for naval-stores production, in many sections allied with the production of saw logs, pulpwood, posts, piling, cross ties, etc. The U. S. Department of Agriculture through the Forest Service and the Bureau of Chemistry and Soils has established many improved practices and helped to give permanence to the industry through research. Until about 1890, timber chipped for turpentine was often considered unfit for manufacture into lumber. Many billions of board feet were wasted through windfall, fire damage, insects, and fungi. Worked-out turpentined trees are now widely used for saw logs, pulpwood, poles, piling, posts, and many other products. Turpentined trees are fully as satisfactory for structural timbers, poles, piling, and the like, as those not tapped.

Many advances have been made not only in the management of turpentine forests but also in the chipping of the trees, collection of the gum, method of cupping, and distillation of the resin known as gum into spirits of turpentine and rosin. Formerly, the crude gum was collected in "boxes" chopped in the bases of trees with an axe. Now it is collected in various kinds of clay, aluminum, and galvanized iron cups attached to the tree below the chipped surface.

An important step forward in the industry was the formation of the American Turpentine Farmers Association Cooperative located at Valdosta, Ga. The membership (active gum farmers) represents 95% of the annual production. The 14-year-old cooperative is known as the "Voice of the Gum Turpentine Farmers of the Nation." It represents the producers on many matters, legislatively speaking, sponsoring research, loan programs, and conservation measures. For the first time in the history of the industry, gum turpentine has been available in attractive packages since 1939 through the efforts of the association. It conducts a national advertising program which is paid for by the members' dues. Before that time turpentine was available, but one had to carry one's own container, generally an empty pop bottle.

The naval-stores industry in the Landes region of France is a very important one. There the gum is derived from maritime pine, but the total volume of the product is exceedingly small compared to that of American naval stores.

Resin ducts, which are peculiarly large or abundant in longleaf and slash pines, produce or manufacture gum when the trees are chipped or wounded. These ducts form in the region of the cambium layer immediately inside the bark and occur to a depth of 1″ or more. When exposed by repeated incisions or chipping streaks, the exudation of resin secretion continues throughout warm weather, generally from March to November. The peak flow is during June, July, and August. If cut or chipped, the streak stimulates the formation of other resin ducts in the region immediately above it for an area of 2″ to 3″. About 67% of the total resin flow occurs within the first 24 hours after chipping. Oxidation and crystallization of the resin at the openings of the resin ducts cause them to be clogged so that it is necessary to make fresh cuts, generally each week, to renew the gum flow by opening new resin ducts. At the end of a week, during the summer, practically all flow from the previous cut has ceased. Cold weather tends to retard or completely stop the flow of gum.

A very significant recent development in this industry has been the stimulation of the flow of gum with sulfuric acid applied to the streaks, as well as by bark chipping and by putting the tins in shallow cuts. Better forest management has been practiced in not adhering strictly to the 9″-diameter-limit system of turpentining but using a selective system of tapping depending upon the number and size of trees per acre. Thus, in a dense stand with a good portion of large-diameter trees, tapping of the smaller diameters would be avoided. They would be left for later tapping.

RESOURCES AND PRODUCTION

The active naval-stores belt comprises a total land area of 66 million acres of which 30 million acres are in working groups, 18,600,000 acres in nonturpentine timber, and the remainder in nonforest or nonproductive forest areas. There are about 8745 producers, many of whom are small gum farmers who work only a few thousand faces of turpentine and rosin in the active belt of the five southern states mentioned. Of these, 63 only distil their own gum, and the others sell their gum outright to modern steam-distillation plants. The work is organized in the form of crops of 10,000 working faces. In 1950, there were about 7200 crops or 72 million faces in operation. The work is concentrated largely in southeast Georgia because of the large available quantities of second-growth timber of proper size and age to attract the industry. Originally North and South Carolina were the important sources of production. When the scarcity of virgin timber became apparent after World War I, it was feared that the naval-stores industry would dwindle or entirely disappear. The growth of young timber, however, radically changed the outlook for the future supply.

In the crop year 1948–49, there were 324,330 units* of gum naval stores. Of this, Georgia produced 74%, Florida 18%, and the remainder was distributed among the other three states.

The turpentine orchards are distributed among a large number of owners. The average number of crops worked per producer with woods operations, is about two crops in the entire naval-stores belt. The average yield per crop over the entire area is 42 units and the average number of streaks is 28. The National Forests in Florida conduct an active business in leasing timber for turpentine operations.

The peak of production of turpentine was reached in 1900, when 38,488,000 gal. were produced; the peak of rosin was in 1908, when 4,288,000 bbl. were marketed.†

An important change has taken place in gum naval stores that has given the industry greater prominence and stability. This is the establishment of central distillation plants, the first of which was completed at Jacksonville, Fla., in 1934. The pioneer in this field was Adrian Joyce, head of the Glidden Company. About 33 of these central plants are strategically located throughout the naval-stores region, and they process 95% of all the gum produced. They have replaced all but about 63 of approximately 1300 old-time backwoods fire stills which were in operation in 1933. The Federal Naval Stores Conservation Program under the U. S. Forest Service has been in effect since 1936. Through these programs, many uneconomic practices of turpentining small trees have been eliminated, and substantial progress has been made in promoting better fire protection and better timber-management practices throughout the naval-stores region.

WOODS OPERATIONS

The unit of woods operations, as indicated, is the crop of 10,000 cups or faces. This varies in area with the stand of timber, size of individual trees, and intensity of tapping. About five crops

* A naval-store unit consists of one 50-gal. barrel of turpentine and 1400 lb. of rosin.

† For details of gum and wood naval-stores production since 1850 see Gamble's *International Naval Stores Yearbooks* and *U. S. Dept. Agr. Naval Stores Repts.*

center around a typical turpentine operation consisting of commissary and quarters for the laborers. The organization consists of the manager or owner, and the "woods rider," who is literally the inspector and manager of the woods operations. These are white men, as a rule, the remaining 15 workers being Negroes. The turpentine camp constitutes a community of 60 people, all dependent upon the turpentine operation for a livelihood. The principal centers of community life are the commissary and the church.

There is a tendency on the part of modern progressive operators to own timberlands rather than lease them. This is a trend towards better forest management, permanence of employment, and greater stability of community life.

Cupping and cups. Before operations begin, the trees to be worked are selected and marked. Only good vigorous trees with well-developed crowns are marked. No trees under 9″ d.b.h. are marked by the more progressive operators, and only one face per tree is marked at a time. The lower part of the tree is faced with a broadaxe or a special tool known as a hogal. This gives a flat surface for the gutters, which are used to conduct the gum into the container, usually a round clay cup or rectangular galvanized-iron receptacle. To set the gutters, a slanting cut or gash is made with a special axe on each side to a depth of ½″, the lower ends of the gash being 12″ above ground. Galvanized-iron or zinc gutter strips, as shown in the illustration, are inserted in these cuts. The gutters are 2½″ wide and long enough for the cut with a slight overhang at the ends. A Herty clay cup or other similar cup holding 1 to 1½ qt. of gum is hung on a tenpenny wire nail, left protruding about 2″, and pulled out before the tree is cut into saw logs for sawing. Flat-bottomed cups are supported on sixteen-penny spikes. The Ball system of rectangular or oblong tins for collecting the gum also requires gutters and an apron in addition. There are also one-piece apron and two-piece apron systems with McCoy cups.

The operations of inserting gutters and hanging cups and cutting the advance streak should be done in December and January because early facing stimulates early season gum flow. The former practice of doing it in March is unsatisfactory. The gum continues to flow until November.

Cups likely to become rusty have the disadvantage of producing lower grades of rosin. The cup must be inexpensive, light in weight, easy to dip, durable, and not subject to injurious influences from the changes of temperature. Clay, aluminum, and zinc cups do not discolor gum. On the other hand, galvanized-iron and zinc cups will stand rougher handling. Rusty cups and gutters seriously degrade rosin.

FIGURE 82. On left is shown poor practice of chipping frequently followed by uninformed naval-stores workers. Bark above chip on left should not be disturbed, and face is unnecessarily wide. Tools used in the work, such as maul and hack, are shown. On right, proper method of facing, chipping, and placing cup, apron, and gutter are shown.

Among the notable advances made in this industry has been selective cupping on turpentine farms. For example, in one stand of slash pine containing 210 trees per acre, only 80 trees were cupped. When these cupped trees are worked out for resin, the 130 unworked trees become ready for another selective cupping. In some ways, this is comparable to selective logging so widely applied in the South.

Chipping the trees. The first chipping to stimulate the flow of gum should be done when the cups are hung in midwinter, preferably the early part of January. This chipping, which is also known as streaking, is done with hacks, as shown in the illustration. A 5-lb. weight at the end of a 15″ to 24″ handle facilitates cutting the streak. A good chipper can streak 1000 to 1200 faces per day or 5000 to 7000 per week, in good average timber of 25 to 30 cups per acre. Each week a new streak is cut on each tree above the last one. This streak is usually cut ½″ to ¾″ high and about ½″ deep for healthy longleaf and slash pine. Large crowned, vigorous longleaf pine may be chipped wider and deeper than poorer specimens. Considerable skill is required to secure maximum production of gum. Sharp hacks have produced 10 to 15% more than dull hacks. When the faces have reached 5 or more feet in height, a "puller," a long-handled form of hack, is used for streaking.

FIGURE 83*A*. Removing the scrape from the face of a longleaf pine. This is the last of the season's turpentine operations. The gummy exudation from the tree hardens on the face owing to evaporation but yields good turpentine and rosin.

Collecting the gum. Cups are filled usually in 2 to 5 weeks, that is, after 2 to 5 streaks, depending upon the temperatures and season as well as the condition and size of the tree. When full, these cups are "dipped." The dipper empties the gum from each cup with a wooden or iron paddle into a wooden or galvanized-metal bucket, which he carries from tree to tree. The bucket holds 35 to 55 lb. of "dip," as the soft gum is called. Then these buckets are emptied into 50-gal. barrels placed at convenient locations in the turpentine woods. These barrels, in turn, are loaded on wagons or trucks and hauled to the turpentine still. Six to ten dippings are made during the season, and experienced dippers can fill 2 to 3 barrels per day. Generally 275 to 300 cups are required to fill one barrel.

Collecting scrape. During the season, gum hardens on the face, forming a white sheet of crystallized gum known as "scrape." Scrape includes 5 to 10% of the total yield of slash pine and 20 to 30% of longleaf pine. At the end of the season, in autumn, this scrape is pulled or pushed off with a scrape iron, placed in rosin barrels, and taken to the still. Some progressive operators remove scrape at various times during the season, reducing wastage and obtaining better grades of rosin because of less trash.

Acid treatment. This consists of spraying sulfuric acid on the streaks immediately after chipping. It creates greater gum flow, and the flow continues for about 3 weeks. With ordinary chipping, without treatment, the flow of gum is good for only the first 2 or 3 days; then it slows down perceptibly and stops at the end of 3 or 4 weeks. One treated streak will yield in 3 weeks, almost as much as 3 untreated streaks.

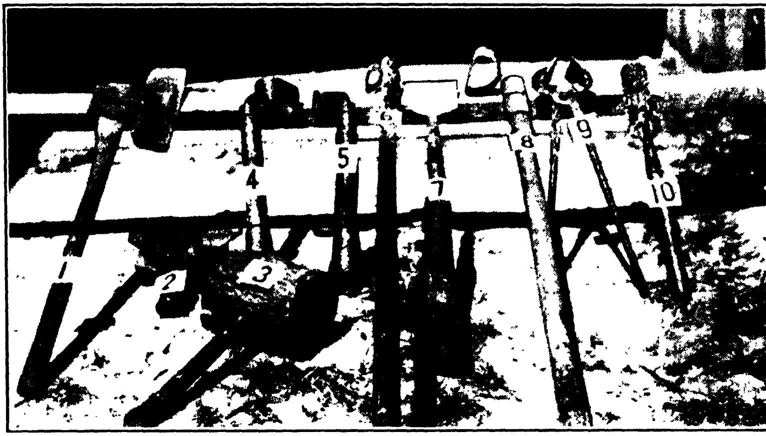


FIGURE 83*B*. Tools used in turpentining. 1. Broadaxe for facing. 2. Pringle axe for setting aprons. 3. Maul, used with pringle axe. 4. Hogal for facing. 5. Hack. 6. Puller. 7. Shove-down scrape iron. 8. Pull-down scraper. 9. Gutter puller. 10. Dip iron.

Chipping and spraying with acid, one man can tend about 4000 faces per week, whereas, without spraying, a man can tend about 5000 faces per week.

Trees have a longer working life with acid treatment. A 40% solution is recommended for slash pine and 60% for longleaf pine. No injurious effects of sulfuric acid are apparent on the health of the trees after several years of tests.

RAISING CUPS

The cups and gutters are raised every year or two so that the gum does not have to spread over so long a face before collection. Rusty tins are usually discarded. These cups and tins are raised to shorten the distance from the streak to the cup and thus reduce the proportion of scrape. To keep the cups free of dirt and caked gum they are collected at the end of the season,

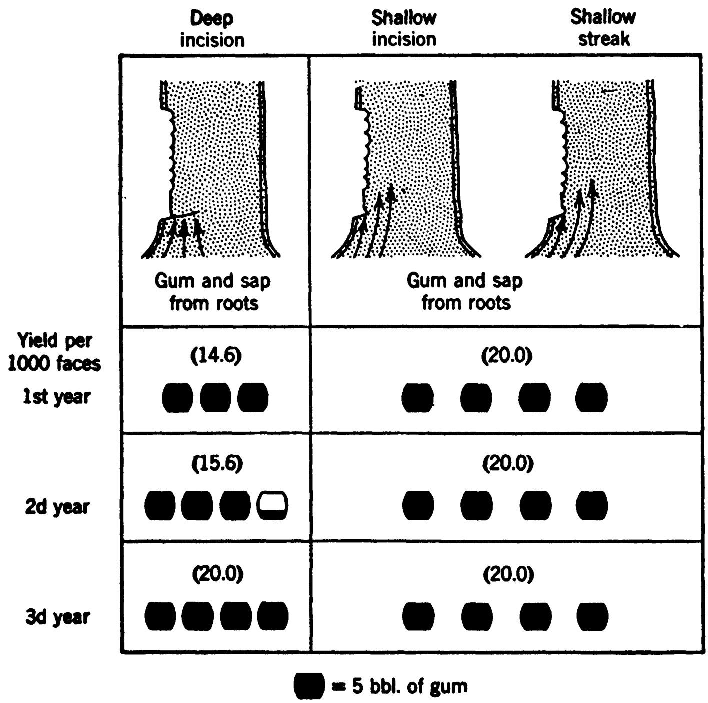


FIGURE 84. Comparison of effect on yield of deep incision and shallow incision or streak. *Courtesy U. S. Forest Service.*

boiled, and cleaned. Clean cups give a better and more valuable product.

The work of chipping, tapping, and gum collection is supervised by a woods rider whose principal duty is to see that the various work is done properly and efficiently. Much of the operation is done by piecework, which he must check.

FIRE PROTECTION

Fire protection is exceedingly important, for the gummy surfaces of the trees are exposed and are very inflammable. The old method of raking the chips, needles, grass, and other debris away for a distance of about 3 ft. from the base of the trees is still common practice. The cost of this operation is generally about $4 per thousand trees. It is done in late fall or during

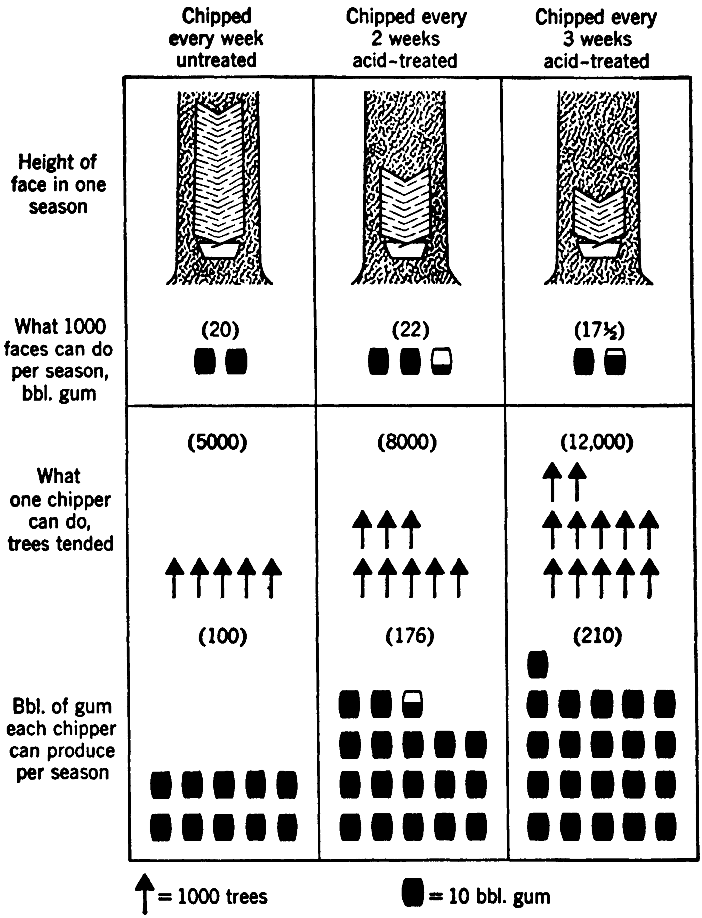


Figure 85. Production by wood chipping at different intervals, with and without acid treatment. *Courtesy U. S. Forest Service.*

winter. Then the remainder of the area is burned, preferably when the forest floor is damp and the fire will do the least damage to turpentine faces. Even with extreme care some faces are burned and cups and gutters ruined. There is a gradual but slow trend toward complete and uniform fire protection, preferably by means of fire lines, which are cut out by a special type of plow hauled by a Diesel tractor. Plowed fire lines are common in protected forests. These plow furrows are usually 4′ to 8′ wide. The cost of plowing a square mile of land into 40-acre blocks by 8′ fire breaks is about $20, which is less expensive than raking and burning.

IMPROVED STEAM-DISTILLATION PROCESS

The old direct-fire still which was used for a good many years for processing gum has practically disappeared. As noted earlier,

FIGURE 86. General view at naval stores still at Valdosta, Ga. Loads of crude gum (resin) are being delivered by farmers from truck at right of picture. Resin is being poured from the barrel into vats in the foreground. A few large modern distillation plants have replaced more than 1300 old fire stills. *Courtesy American Forest Products Industries.*

the changeover came before World War II, and now 33 large modern and improved plants with proper controls have replaced the large number (1300) of small fire stills. These new plants represent an investment of $20,000 to $250,000 each. The first one was built in Jacksonville in 1934.

The distillation process in the old still was more or less haphazard, resulting in discoloration because of scorching the rosin and the consequent degrade of the product. Now the gum from acid-treated trees gives a discolored-appearing rosin unless treated with acid to offset this result. The changeover from old methods of tapping and distilling has resulted in more permanent tree cropping and, together with improved roads and better and cheaper transportation facilities, in a smaller number of large central plants which process the gum by steam distillation. The modern plants dilute and filter the raw gum as brought in from the woods. This gum is treated with acid to produce lighter-colored and therefore more valuable grades of rosin. The gum is washed with water, and any mineral acid sprayed on the scarified face is completely washed out.

The modern steam-distillation plant, therefore, does the work of converting the crude gum into turpentine and rosin much more efficiently and economically, and the resultant product brings a better price, especially for rosin. Thus, properly and permanently maintained woods operations and improved methods of distillation of gum have resulted in a much more stable industry and greater satisfaction for the producers of naval stores.

The procedure in the modern still is simple and consists of distilling off the spirits of turpentine and water in the gum aided by the addition of water. The turpentine and water vapors are condensed in a coiled copper pipe known as a worm, which passes through a "tub" of water and empties into a separator. The turpentine, being lighter in weight, goes to the top, and, by means of an automatic device, water is drawn off from the bottom. Then the turpentine is run into barrels or tank cars for shipment or placed in large storage tanks. The remaining molten mixture of resin acids and resenes known as rosin, together with pieces of bark, needles, dirt, and chips that have accumulated in the harvesting process, is passed in the molten form through a series of wire strainers and layers of cotton batting on a wire screen. The liquid rosin is then run into packages such as wooden barrels, metal drums, tank cars, and multiple-ply paper bags. The amount of foreign material found in the resin determines the clarity and whiteness of the rosin product.

YIELDS

The yields are best summarized in Table 18 as shown in A. R. Shirley's bulletin on Working Trees for Naval Stores and as determined by the U. S. Naval Stores Station at Olustee, Fla.

TABLE 18

YIELDS OF TURPENTINE AND ROSIN FROM CRUDE GUM, SCRAPE, AND MIXTURES *

	100 lb.			435 lb.		
	Turpentine, gal.	*Rosin, lb.*	*Waste,† lb.*	*Turpentine, gal.*	*Rosin, lb.*	*Waste,† lb.*
Average yields for 100 and 435 lb. net						
Longleaf						
April–June	2.78	69.8	11.2	12.1	299.3	48.7
July–September	2.69	69.8	10.8	11.7	303.6	47.0
October–December	2.11	68.8	16.0	9.2	299.3	69.6
Slash						
April–June	2.68	67.8	12.9	11.7	294.9	50.9
July–September	2.65	70.5	10.4	11.5	306.7	50.0
October–December	2.39	69.3	13.5	10.4	301.5	58.7
Yearly average						
Longleaf	2.53	69.1	12.7	11.0	300.7	55.1
Slash	2.57	69.2	12.3	11.2	301.0	53.2
Average yields for varying percentages of scrape						
25%	2.40	67.1	15.6	10.5	291.9	67.9
50%	2.36	68.6	14.4	10.3	298.4	62.6
75%	2.04	66.2	19.1	8.8	288.0	83.1
100%	1.85	68.3	18.4	8.0	297.1	80.0
Average yield of barrel of gum						
Lb. of chips						
6 or less				12.2	304.5	
6–10				12.0	299.7	
10–20				11.9	282.3	
Over 20				11.8	280.4	

* As found by Naval Stores Station, Bureau of Chemistry and Soils, Olustee, Fla.

† Waste includes batting and rock dross, chips and water.

ROSIN GRADING

The best grade of rosin is X with WW or water white next. The poorest grade is D which is very dark brown-red or nearly black. There are 10 intermediate grades making 12 in all. Practically the same grades apply to both gum and wood rosins.

The color of rosin is determined by:

1. The kind and age of cup.
2. The age of the face.
3. Care in distillation.
4. Amount of dirt, bark, leaves, etc., collected with the gum.

There is a wide price range for the different grades, and these prices are subject to rather wide fluctuations.

The first run or virgin dip yields the lightest color and therefore the best prices.

UTILIZATION OF PRODUCTS

Turpentine is principally utilized for paints and varnishes—a large quantity for paint thinning. It is also widely employed for shoe polish and leather dressing, as a solvent for rubber and waterproofing compounds, for many pharmaceuticals such as liniments and salves, and as insecticides. There are a great many minor uses.

Rosin also has a great many uses. Among the important ones are soaps and soap powders, paint dryers, synthetic resins, sizing

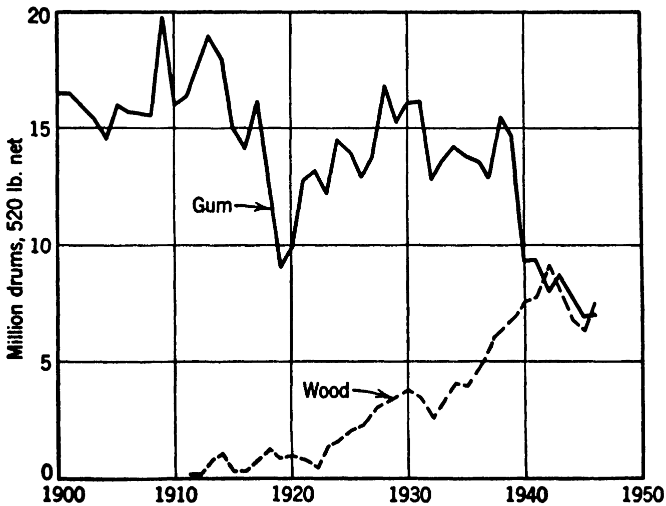


FIGURE 87. Rosin production from gum and wood naval stores, showing the downward trend for gum naval stores. *Data from Naval Stores Research Division, Bureau of Agricultural and Industrial Chemistry, Washington, D. C.*

for paper, paperboard and wallboard, sealing wax, flypaper, matches, munitions, various kinds of cements, plastic wood, wood preservatives, disinfectants, and sheep dip. A familiar use is on gymnasium floors to prevent slipping, especially for basketball games.

The bulk of turpentine is shipped by the large processor to market in railway tank cars of 6000 to 10,000 gal. each. The small processor generally ships turpentine to dealers and for export in stave or metal casks of 50 to 55 gal. During recent years, a good deal of turpentine has been packaged and sold in small cans of 4 oz. to 5 gal.

Daily market prices are established at the Savannah Cotton and Naval Stores Exchange. Savannah is the great port of export shipment.

24 · WOOD-DISTILLATION PRODUCTS

HARDWOOD DISTILLATION *

History and development. The carbonization of wood for making charcoal has been practiced as long as history is recorded. By this process wood is heated until it is carbonized to form charcoal, and the vapors that pass off are the source of by-products recovery in the modern process of distilling wood. There are two branches of the industry, one devoted to utilization of hardwoods, the other to utilization of longleaf and slash pine stumpwood in the South. The hardwood-distillation branch of the industry was developed on a commercial scale first in 1830, when James Ward began making pyroligneous acid at North Adams, Mass. The principal products of hardwood-destructive distillation are wood alcohol, acetate of lime or directly recovered acetic acid, and charcoal, whereas the products of pine-destructive distillation are turpentine, pine tar, pine oils, pine-tar oils, dipentine, and charcoal. Only hardwoods free from an excessive content of gums, tannins, and the like are desirable. The northern hardwoods, principally maple, birch, and beech, are considered most desirable, but hickory and oak are of almost equal value. The industry was formerly located largely in the Lake States, Tennessee, New York, Arkansas, and Pennsylvania. In 1947 there were 9 plants in Pennsylvania, 5 in Illinois, 3 in Ohio, 2 each in West Virginia, Michigan, and Tennessee, and 1 each in New York, Missouri, Arkansas, and Oklahoma. Since World War II many of the plants have gone out of existence. There were 93 plants in 1921 but only 21 in 1947, according to the U. S. Census Bureau.

Changes in hardwood distillation have been principally economic; that is, in the manufacture of products for which wood distillates were used, some synthetic and fermentation processes

* For further reference see *Timber Requirements of the Hardwood Distillation Industry*, by M. H. Haertel, U. S. Dept. Agr. Forest Service, Washington, D. C., 1938, and Hardwood Distillation Industry, by Edward Beglinger (revised), *U. S. Dept. Agr. Forest Products Lab. Rept.* **R738,** 1947.

use raw materials other than wood. For example, more synthetic methyl alcohol is now made than comes from wood. Synthetic acetic acid is also a strong competitor with acetic acid made from wood, and acetone is no longer made from acetate of lime since it has become a by-product in the fermentation of starch for making butyl alcohol. There has also been a considerable decrease in the amount of charcoal iron manufactured, coke iron having replaced it with a corresponding decrease in this market for charcoal. One of the principal technological developments in hardwood distillation has been the introduction and use of the extraction process for obtaining acetic acid directly from the pyroligneous acid. As a result of this change, some of the larger plants which have adopted this process do not manufacture acetate of lime at all. The United States is the world's largest producer and consumer of wood-distillation products.

Necessary conditions. For successful operation there are three definite requirements in the industry: (1) a plentiful wood supply available at a reasonably low price; (2) location near source of fuel, such as coal, natural gas, mill waste, or other materials usable for fuel; (3) reasonable accessibility to a market for the products of the industry. The demand for large quantities of charcoal to supply certain types of iron furnaces in Wisconsin and Michigan resulted in the development of large plants in these states.

Desirable species. Hard, heavy, well-seasoned woods are preferred. Heartwood is preferred to sapwood. Maple is considered best, closely followed in preference by beech, birch, oak, and hickory. At one time, black cherry formed 25% of all wood used in the Pennsylvania district. Other hardwoods are used in some of the plants.

Sources of raw material. Some of the largest and most successful plants have been established in connection with large sawmills where both woods and sawmill waste are available to supply the raw material. This was especially true in the Lake States and Tennessee. In New York and Pennsylvania logging was conducted especially to produce wood in 50″ lengths, which are hauled by motor trucks for distances up to 15 miles. In some centers, the slabs and edgings from sawmills, and woods waste such as top logs and limb wood are used successfully. Sawdust and the smaller edgings and trimmings are not considered desirable because the charcoal made from them forms a dust rather than a solid form. Hardwoods sprout thriftily in New York and Pennsylvania, and areas cut for chemical wood have been handled on 25- to 30-year rotations.

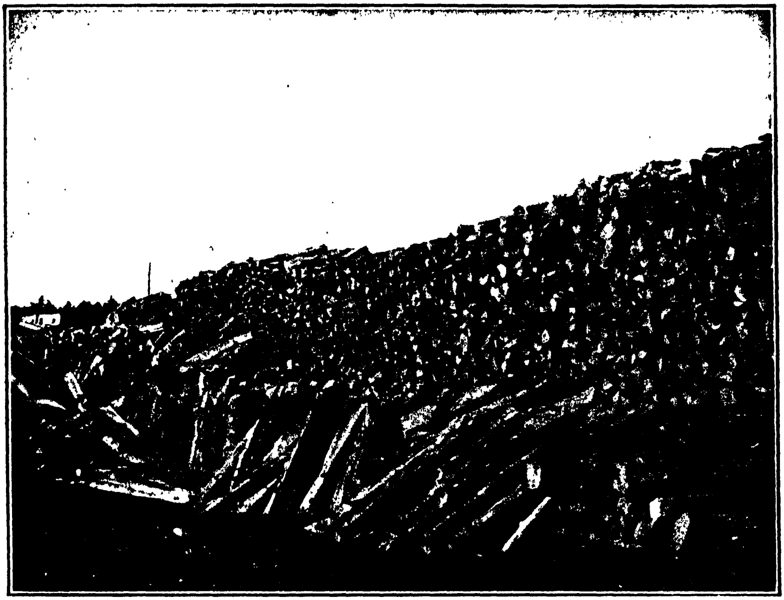


FIGURE 88. Beech, birch, and hard maple cut in 50″ lengths for conversion by dry distillation into wood alcohol, acetate of lime, and charcoal. This wood is always seasoned about 1 year before it is used.

Seasoning and weights. Dry and thoroughly seasoned wood is preferred. Wood is generally seasoned at least one year unless predryers are used, when wood is dried in 2 to 3 days. The average cord of beech, birch, and maple in bodywood and limbwood weighs about 6200 lb. and, after seasoning for a year, about 3800 lb. All-round wood, down to 2″ in diameter, is used. When more than 8″ in diameter, wood is split so that it will season better. Bodywood is preferred to limbwood because the latter contains too much sapwood and, consequently, has excessive moisture content. Hence there is a greater yield from heartwood than from sapwood.

Consumption of wood. The hardwood-distillation industry formerly consumed 500,000 to one million cords of wood annually.

World War I gave great impetus to the industry because of the demand for three products used for war materials. There are no official figures of current wood use in the industry, but the total probably does not exceed 200,000 cords yearly.

Process of manufacture.* At first brick kilns were used to make charcoal and then small iron retorts. The modern procedure

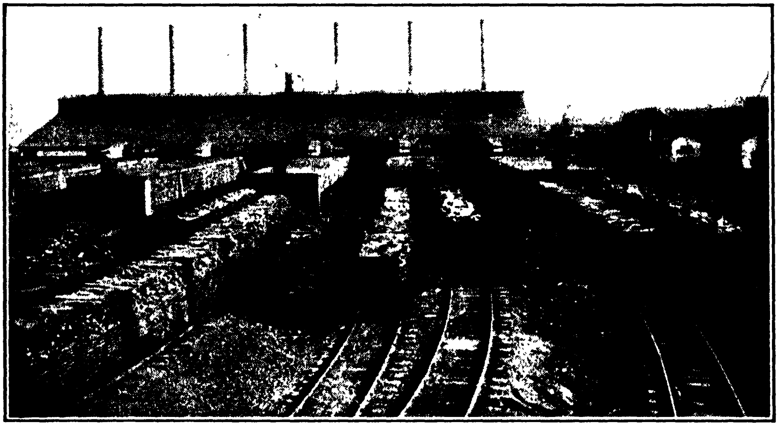


FIGURE 89. Buggies loaded with hardwood entering preheaters at a large hardwood-distillation plant in Tennessee. Beyond the preheaters are the ovens in which the distillation process takes place.

generally requires long, heavy iron ovens 25′ to 60′ long, 8′ 4″ in height, and 6′3″ in width. Small buggies or metal trucks, each loaded with about 2 cords of wood, are run on steel tracks directly into the ovens. A firebox underneath heats the wood after the doors are closed and made airtight. The wood is heated 22 to 24 hours, during which time the vapors pass out from one or two large openings into condensers. The crude liquor is conducted into holding sumps. A series of ovens provides for a capacity of 200 to 220 cords per day in some plants. After the heating process is completed, the charcoal, representing about one-half the original volume of wood and one-quarter its weight, is allowed to cool for another period of 24 hours in a set of coolers similar to the ovens mentioned previously. Then the cars containing

* For recent and complete data on various processes, products, and their utilization see Hardwood Distillation Industry, by Edward Beglinger (revised), *U. S. Dept. Agr. Forest Products Lab. Rept.* **R738**, 1947.

charcoal are drawn into a second series of heat-exchange ovens for a period of 24 hours and then into the open air where they are left for 48 hours. Thus a period of 96 hours elapses between the completion of the heating process and the time when the

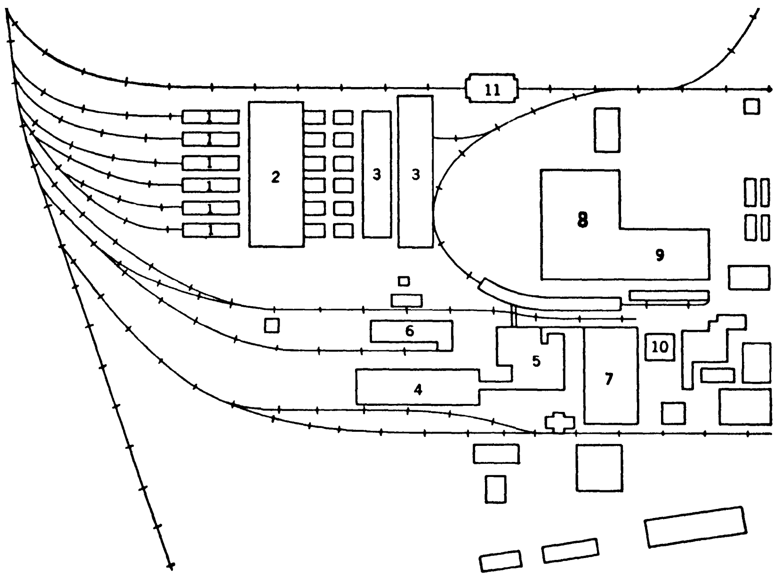


FIGURE 90. Plant layout of typical large hardwood-distillation plant, with a plant capacity of 120 cords of wood per day.

1. Predryers
2. Retort house
3. Cooling sheds
4. Charcoal storage
5. Charcoal screening and storage
6. Storage sheds
7. Acetic anhydride manufacturing building and charcoal-briquette plant
8. General shop and storage
9. Sodium acetate and acid-refining building
10. Tank shed
11. Storeroom

charcoal is loaded on cars for shipment to market. Charcoal must remain on freight cars at least 12 hours before shipment so that 108 hours must elapse from the end of the heating process to final shipment. This precaution is to prevent fire which otherwise might cause a loss of charcoal and cars in transit, or other damage.

1. Distillation. When the wood is rolled into the long ovens on trucks, doors are hermetically sealed and fires started underneath. In 1 to 2 hours the wood is sufficiently heated for water distillation to take place. This distillate contains about 2% acid. Then the so-called "green gas" comes free for 5 to 6 hours. The wood must be heated gradually. The exothermic process, during which the wood fibers break down, does not come until an average temperature is advanced to about 480°F. Eight to ten hours

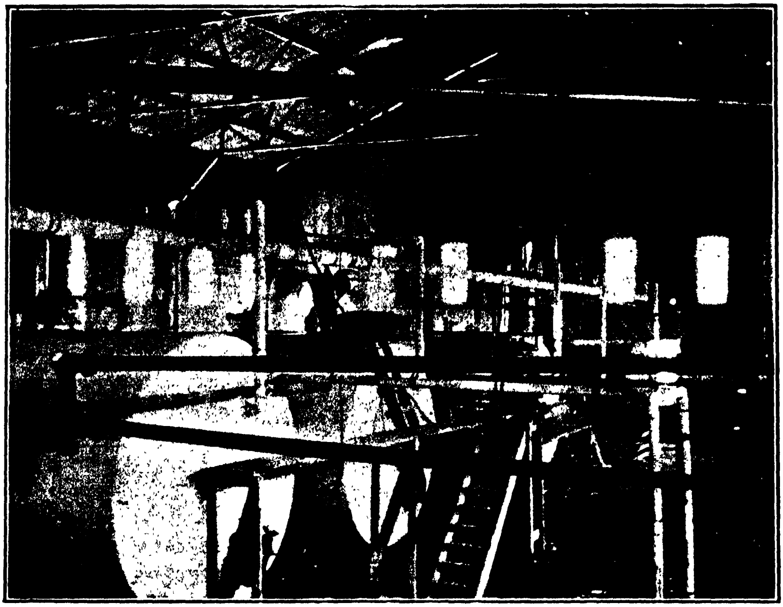


FIGURE 91. Interior of the still house at a hardwood-distillation plant in Pennsylvania.

after the doors are closed the temperature reaches about 600°F. From this point, the temperature is allowed to rise slowly to an end temperature of about 790°F. After about 6 hours of heating the pyroligneous acid begins to flow, and the best production is maintained up to about the 18th hour. After the 18th hour the latent heat in the oven is sufficient to complete the process. As the vapors and gases pass through the outlet of the oven, the vapors are condensed into a yellowish-green, ill-smelling liquor called pyroligneous acid. A copper run conducts this condensate to the raw liquor "sump" by gravity. Meanwhile, the fixed or noncondensable gas is trapped, taken off at the outlet of the condenser, and used as fuel beneath the ovens or boilers, or both. The pyroligneous acid then goes to a series of wooden tubs to settle the tar and heavy oils. The heavy tar is redistilled, and the residue is utilized generally as boiler fuel. The remaining pyroligneous acid is conducted to primary steam-heated copper stills, and the distillate is run into a separate tank, the light oils which rise to the top being taken off. Then follow several processes during which the wood alcohol is distilled from the "lime-lee" stills; the residue, acetate solution being sent to large, shallow, steam-jacketed steel pans and boiled down to the consistency of mortar. It is then spread out on brick or steel floors over the ovens, regularly turned from time to time, and dried. Then it is shoveled into sacks and sold as acetate of lime. The alcohol liquor from the lime-lee stills is drawn into storage tanks and distilled through a copper fractionating column. Thus the more volatile vapors pass through a condenser, the distillate forming the finished 82% crude alcohol. The third product of the process, charcoal, has been described previously.

2. Plant equipment. Ten to sixty acres or more are required for storage yards, trackage facilities, and the plant itself, which may have two to ten or more oven retorts, an open space for two sets of cooling ovens, a shed for the cooling and storage of charcoal, the still house and power plant, usually kept separate from the retort house. Modern plants may cost $50,000 to $500,000, or more, for the initial investment. They may cost $10,000 to $12,000 or more per cord of daily capacity.

Plant operation. Six forms of fuel are commonly used in this industry: namely, coal, natural gas, charcoal, wood, wood tar, and wood gas. Charcoal, wood tar, and wood gas are derived from the process itself. Those in northeastern Pennsylvania and southeastern New York use coal from the anthracite fields near Scranton. Labor is a very important item in the cost of production. Usually the labor is unskilled with the exception of the plant yard manager, still house and retort foreman, a chemist, and an expert engineer. All plants operate day and night. At a four-oven plant with a daily capacity of 40 cords, there are 18 men on a 24-hour shift, with 13 men serving during the day and 5 during the night. This list does not include those hauling wood to the plant by truck.

Owing to the intense heat required for distillation of wood, the acid nature of the products, etc., the depreciation charges on the equipment are exceedingly large. Ovens generally last only 3 to 10 years. The copper apparatus used for distillation lasts, as a rule, 10 to 12 years. The cost of operation depends upon a number of factors such as:

1. Cost of wood delivered to the plant.
2. Cost of fuel.
3. Labor charges.
4. Transportation costs to market.

As the three major products are highly competitive and are produced in widely separated regions, they are frequently transported for long distances. The actual costs vary with the plants and may be about 45% for wood, 21% for fuel, 18% for labor, and the remaining 16% charged to lime, oils, and other supplies, depreciation, insurance, taxes, and general expenses.

Yields. Yields vary widely, depending upon the following factors:

1. *Temperatures* maintained during the exothermic process.

2. *Species of wood.* As indicated, maple is considered the best wood, with beech, birch, oak, and hickory in next order of preference.

3. *Condition of wood.* Wood should be as dry as possible and preferably seasoned for 1 year.

4. *Efficiency of plant operation.* This is determined by the character of the machinery and equipment.

An investigation of 25 plants indicated an average yield of 42.7 bushels of charcoal per cord. The maximum was 50 and the minimum 38 bushels per cord among the several plants. The average yield of acetate of lime was 200 lb. per cord of wood and the range was from 171 to 220 lb. The average yield of wood alcohol was 9.9 gal. of 82% wood alcohol per cord of wood; the range was from 8 to 11 gal. per cord. In addition to these three major products, 23 to 28 gal. of wood tar per wood cord were secured, with an average of 25 gal. Furthermore, 11,500 cu. ft. of gas was secured per cord.

Utilization of products. The largest profits were originally secured from acetate of lime before the use of synthetics. The decline of the industry is due to decreased use of charcoal and the use of substitutes—largely synthetic materials.

Acetate of lime. Formerly about 100,000 tons of acetate of lime were produced each year. Probably about 75% of this product served as raw material for the acetic acid industry. Acetic acid is employed principally for the manufacture of white lead acetate in the rayon, plastics, and leather industries and in a great variety of other commercial manufactures. Other important uses are in the manufacture of cordite and lyddite, two high explosives. Acetone is used principally as a solvent for the cutting of guncotton and in the manufacture of smokeless powder. The manufacture of wood vinegar from acetic acid, common in Europe, is prohibited in the United States.

Wood alcohol (*methanol*). About 10 million gal. of wood alcohol was once produced yearly in the United States. Only a small part of this is now produced. Its principal use is as a solvent, and it is consumed for this purpose largely in the paint and varnish industry. Most of it is refined to a high state of purity before being utilized. It is employed in the aniline-dye factories to make colors, in the manufacture of formaldehyde and photographic films, as an antifreeze in automobiles, and in stiffening hats. A large camera-manufacturing plant once maintained a hardwood-distillation plant in Tennessee, principally for the products used in the manufacture of films as well as for other purposes. Refined wood alcohol of high purity is known as methyl alcohol and is sold under a great variety of trade names, such as Columbian Methanol, Colonial Methyl, and Diamond Methyl. As an extractive agent, wood alcohol is used in the manufacture of nitrocellulose. It is also used in various chemical and medicinal preparations. It is largely produced now by synthetic processes.

Charcoal. Until about 1905 the principal market for charcoal was in the reduction of iron ores. Charcoal, or Swedish iron as it is often known in the trade, is still in demand for such a specialized purpose as the high-grade steel in tools, instruments, car wheels, etc. An investigation disclosed the consumption of charcoal to be: 76% for blast furnaces, 19.5% for domestic fuel, 1.9% for chemical purposes, 1.03% for powder, and the remainder for smelters, railroads, and miscellaneous purposes. Some plants make briquettes from the charcoal dust. Others screen it into five different grades of coarseness. Charcoal is occasionally used for medicinal purposes, for poultry and cattle food, for chemical manufacture, and for fuel.

Wood tar and gas. Practically all wood tar in the industry serves under the ovens as fuel. This constitutes a large potential value which may some day be realized, as great quantities of wood tar are utilized for fuel when the same amount of fuel might be supplied from other sources. Some amount is employed in various chemical manufactures, but this outlet is rather limited at the present time. This wood tar is used to some extent for the preservative treatment of poles, cross ties, posts, mine timbers, etc. Wood gas is used exclusively as a plant fuel. In Germany and Austria wood gas is employed for illuminating as well as for cooking and heating purposes. Many attempts have been made to convert various forms of wood gas into motor fuel, but commercial success has not attended any of these experiments up to the present time.

The hardwood distillation industry prospers during war periods. Since 1945, the industry has decreased in importance.

SOFTWOOD DISTILLATION *

Softwood distillation is an outgrowth of the hardwood distillation industry as originally developed in New York and Pennsylvania. Owing to the structure, nature, and chemical content of the softwoods, entirely different products are derived from softwood distillation.

Softwood distillation in commercial practice is confined to the southern pineries. Although many experiments have been attempted in various parts of the United States, much financial loss has attended the operation of many of these plants, especially the attempt to put laboratory experiments on a commercial basis, in the North and on the West Coast. The industry is confined entirely to the South Atlantic and Gulf States, particularly in the region of longleaf and slash pines where these species are used.

The first commercial distillation of pine wood is usually credited to James Stanley of Wilmington, N. C., in 1872. His was a very crude form of destructive distillation. Between 1900 and 1907, rosin was extracted in addition to turpentine which heretofore had been the primary product of distillation. The first

* Reviewed and checked by Arthur Langmeier, director of naval stores operations, Hercules Powder Company, Wilmington, Del.

plant operated by the steam and solvent process was built at Gulfport, Miss., in 1910. The process of softwood distillation is known as wood naval stores in contrast with gum naval stores

FIGURE 92. A giant stump pusher has wrenched an old longleaf pine stump from the earth near a woods camp in Georgia. These stumps are used in a softwood-distillation plant. The trees in the background are thrifty volunteer regrowth that has sprung up after logging. *Courtesy Hercules Powder Co.*

described in another section. Since 1910, the production of wood naval stores has steadily increased, the methods followed being restricted to the three processes described below.

Raw material. At first only "lightwood" of longleaf and slash pines was used. The practice soon followed of blasting or pulling old stumpwood of these species left after logging of virgin stands. Stumps are generally removed 8 to 10 years after logging so that they may be properly "seasoned." Stumps, although too readily broken up by blasting, are easier to handle when this is done. Recently the more progressive and larger companies began pulling stumps with a special power puller mounted on a 20-ton caterpillar tractor operated by a 150 hp. Diesel motor. Stump pullers usually secure about 250 stumps per day and obtain

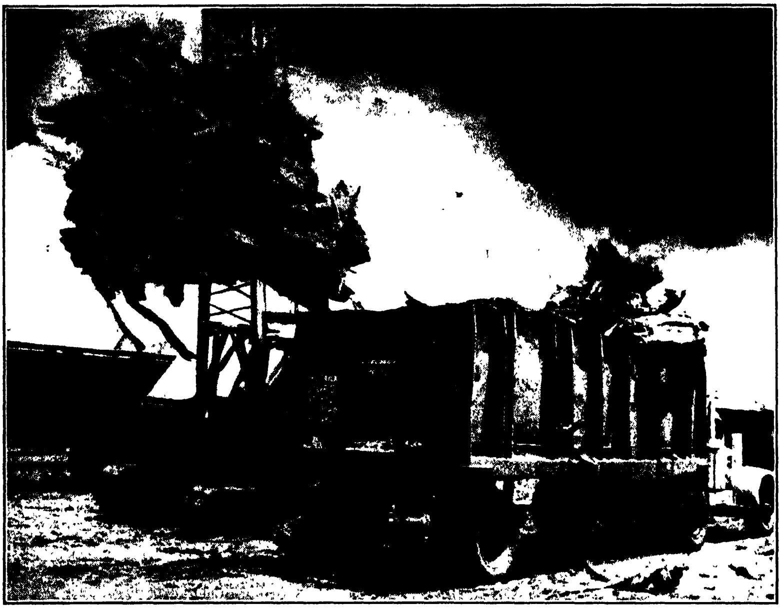


FIGURE 93. Old longleaf pine stumps dug out by tractor being loaded on railroad car by tractor-mounted crane for transport to distillation plant. *Courtesy Hercules Powder Co.*

more volume of wood per stump than is obtained by the blasting process. About 80% of all of the wood now consists of stumpwood and 20% lightwood. Some plants may use one type of wood exclusively.

Distillation processes and yields. There are three processes of distillation, as follows:

Destructive process. The wood, in 4′ lengths, is heated in a retort and the vapors led into a condenser. The liquid, after condensation, goes to a separating tank where oil and water are permitted to separate by gravity. Heavy pitch, or tar, is drawn directly from the bottom of the retort after distillation is completed. Three types of retorts are commonly used, one of cylindrical type holding 1 to 3 cords, charged and discharged by hand, another a large metal oven holding about 10 cords, in which cars are directly loaded with wood, and a third concrete retort heated by pipes along the walls and charged by placing

FIGURE 94. Chips from longleaf and slash pine stumps used in the destructive distillation process. *Courtesy Hercules Powder Co.*

in them cars loaded with wood. The destructive distillation process is accomplished in the absence of air. The products of distillation are wood acids, pinene, turpene alcohols, dipentene, tar oils, pine tar, charcoal, and some others. The destructive distillation process operates on wood of approximately 4′ lengths.

The steam and solvent process. The wood is ground into small pieces by means of a hog and shredder and then steamed to remove turpentine and some oil. The residue is extracted with gasoline, forming a solution of rosin and gasoline. When the gasoline is distilled, rosin remains. There are three basic products from pine stumps, namely rosin, turpentine, and pine oil. From each of these a number of chemical derivatives are made, such as synthetic resins, insecticides, foundry core binders, solvents, chemicals for rubber, plasticizers, sizing for paper, soaps, disinfectants, and textile chemicals. For example, Toxaphene is a toxicant derived from turpentine for agricultural insecticides which quickly destroy the bollworm, boll weevil and other insect pests. Also Resinol assists in making many poorly producing oil wells yield oil profitably again. This process can be controlled chemically and offers large opportunities for sound development and increased utilization of wood. Yields are rather uniform. Per ton of wood, there are 400 lb. of rosin, 8 gal. of turpentine, 3½ gal. of pine oil, and 1½ gal. of monocyclic hydrocarbons.

The entire naval-stores industry processes about 2 million tons of pine stumps a year. This is done by what is called the steam and solvent processes which are (1) steam distillation of chips to recover volatile turpenes with subsequent extraction with a volatile solvent, and (2) the complete extraction of turpenes, turpene alcohols, and resinous matter with subsequent separation and refining. The products of these processes are turpentine, pinene, dipentine, terpinen, turpene alcohols, rosin, and several others.

Sulfate wood naval stores. This process refers to the recovery of certain products in making sulfate pulp. During the cooking of chipped wood in the manufacture of pulp, turpentine and other gases are formed. These are condensed by passing them through coils in cold water. Thus turpentine is obtained from what otherwise are waste liquors. But still more recently, tall oils (resin acids and fatty acids) have been recovered. The turpentine has a very strong and unpleasant odor, which may be removed by distillation with sulfuric acid. The yield by this process is ½ to 2 gal. of turpentine per cord of wood.

In the first two processes described, only the resinous heartwood is used. Heartwood ordinarily weighs about 5000 lb. or more per stacked cord, and a stumpage value of 50 cents per cord is generally paid for top wood that is left after logging operations are discontinued. Somewhat higher stumpage prices (and in inaccessible locations much lower prices) are obtained for stumpwood. There were 32 softwood distillation plants in 1947, mostly in the South, according to the U. S. Census Bureau.

On many old logging operations, there is stumpwood remaining for 30 to 40 years. It still retains very desirable heartwood even if the sapwood has rotted away. The largest plants employing the steam-solvent process are located at Brunswick, Ga.; Pensacola, Fla.; Picayune and Hattiesburg, Miss.; DeQuincy, DeRidder, and Oakdale, La. The plants using the destructive distillation process are widely scattered throughout the longleaf pine belt of the South Atlantic and Gulf States.

All of these processes have been successfully operated under normal economic conditions. The number of plants has continued about stable for the past 10 years. Under subnormal economic conditions, when prices are not so attractive, some of these plants have had difficulty in operating successfully. It is not likely that these industries will furnish a more extended outlet for the utilization of stumpwood, top wood, or other forms of logging or sawmill waste because of the increasing possibilities of producing certain forms of naval stores from the recovery of materials from what have been waste liquors in pulping processes.

All of the raw materials for the first two processes mentioned must come from virgin and old-growth longleaf and slash pines. The virgin timber of these two species has practically disappeared, and second growth does not produce favorable material for pine distillation. However, the supply in sight, owing to extensive logging operations in the past, is sufficient to increase the present production 2½ times, even assuming that the industry is liquidated during the next 25 years.

The resinous wood from which the oils and rosins have been largely extracted has been used, for the most part, as fuel to produce steam and power requirements for plant operation. Several years ago, the Armstrong Cork Company made exhaustive studies of the possibilities of this material for low-cost fibrous insulating and building board. This company's plant at Pensacola, Fla., has a daily capacity of about 100,000 sq. ft. of 1″ fiberboard. It consumes only about one-third of the available supply of extracted wood. The product is sold under the name of Temlok. The process is partly chemical and partly mechanical. The extract wood chips are first screened, and, in the presence of hot caustic alkali solution, the wood is broken down into coarse pulp.

25 · EXTRACTIVES: TANNINS, DYES, AND MISCELLANEOUS

There is a wide variety of wood, bark, and leaf extracts that assume considerable importance as products of the forest. These are principally tanning materials obtained from chestnut wood and from oak and hemlock barks. Domestic dyes are obtained from Osage orange wood, but there is also a variety of logwood and other foreign materials imported for dye purposes. In addition to these principal extractive products, mucic acid is obtained from western larch; cascara, used in some medicinal preparations, from cascara bark on the North Pacific Coast; volatile oils from sassafras, sweet birch, and Virginia red cedar; storax from sweet gum; Canada balsam from balsam fir; Oregon balsam from Douglas fir; poplar bud balsam from the buds of the balsam poplar (Balm of Gilead); and a large variety of leaf oils from several coniferous species, chiefly pine and cedar oils. It is impossible within the scope of this book to describe in any considerable detail the methods of production, manufacture, and utilization of all these products. A few of the more important products are described in this chapter.

TANNINS *

Records of early civilization indicate that the tanning of leather to preserve it was practiced by the Chinese more than 3000 years ago. It is said that the Romans tanned their animal skins with olive oil and alum and occasionally with oak bark. The Indians of our country were found using oak bark to preserve buffalo skins. It is reported that the first tannery in the United States was built in Virginia in 1630, but the industry developed most widely and successfully in Massachusetts. In 1650 there were 51 tanneries in New England. Oak bark was used principally at first and was generally preferred to hemlock. The abundant

* Reviewed and corrected by Dean Williams, editor of *J. Am. Leather Chemists' Assoc.*

supply of hemlock, however, brought it into early and prominent use. Many skins and hides were exported to Europe, and by the year 1810 the value of the products of the American tanneries was about $200 million.

Nearly all the plants of the vegetable kingdom contain an astringent principle known as tannin. This agent has the property of acting upon animal skins to make them strong, flexible, imputrescible, and resistant to decay and wear. Practically all the commercial tannin, however, is derived from a relatively few species of plants and is obtained 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.

Production. The American leather business annually requires large quantities of forest products estimated to be 285 million lb. of tannin for tanning purposes. The three most important domestic tanning materials are chestnut wood, chestnut oak bark, and eastern hemlock bark. Of these, chestnut wood has been the most important but is declining in volume. It did comprise about 60% of the tannin from domestic sources. Chestnut oak bark and eastern hemlock bark are important domestic sources.

These materials are produced largely in the Southeast and East. In California, tanbark oak is the principal source. In the Appalachian Mountains, chestnut wood is widely used, and white oak bark is produced largely in the southern Appalachian Mountains and the eastern states. Hemlock bark is produced in the Northeast, Lake States, and the Appalachian section. Pennsylvania, formerly the leading state, is still an important hemlock-producing state, but Wisconsin and Michigan have become the principal sources of hemlock bark.

Although a blight has caused the gradual elimination of chestnut, it still constitutes an important source of tanning materials. Wood unsuitable for lumber, such as tops and small logs, is used in the southern Appalachian Mountains, where the chestnut reaches its optimum development. Practically all merchantable-size chestnut trees are either dead or affected by the blight. It is possible, however, that an immunity may gradually develop, as the chestnut sprouts persistently from the roots. Trees dead 25 to 30 years are still sound and are used in the tanning industry.

Western hemlock is richer in tannic acid per unit area than the eastern hemlock, but it is very thin and inferior to the eastern hemlock as a source of tanning material.

The most important development in the tanning industry within recent times in the United States came with the discovery of a method of extracting the tannin from the chestnut wood on a commercial basis. The commercial phase of the industry has developed rapidly within the past 33 years, especially in the mountainous sections of North Carolina, Virginia, West Virginia, and Tennessee. In several of the chestnut-extract factories, 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 assured, owing to the growing scarcity of chestnut.

Of our total annual consumption of tannin, 50 to 70% is derived from foreign materials. Of these, quebracho wood is the most important, contributing about 40% of our total consumption. Myrobalan nuts, wattle bark, divi-divi, valonia cups, mangrove bark, and a few others together supply the remainder of foreign imports.

The use of the California tanbark oak has always been limited and confined to the few tanneries located along the Pacific Coast. It is still used by these tanneries, usually blended with quebracho.

The world's supply of tannin materials is apparently very abundant, and it is estimated by authorities that many sources little developed at the present time may be depended on for sufficient 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 not been developed insofar as their tannin resources are concerned, and they constitute an important source of tannin for future use. At the present rate of cutting quebracho in South America which amounts to about 4 to 5 million tons annually, the trees will be depleted in 30 years, although the exact time is uncertain owing to lack of a thorough knowledge of the extent of the quebracho stand. It is thought, however, that with proper care, propagation, utilization of roots, etc., the quebracho industry can be extended 200 years.

TABLE 19

	Tannin, %	Class of Tannin
Domestic		
Hemlock bark	8–10	Catechol
Chestnut wood	4–10	Catechol
California tanbark oak	10–29	Catechol
Chestnut oak bark	8–14	Catechol
Black oak bark	6–12	Catechol
Red oak bark	4–8	Catechol
White oak bark	4–7	Catechol
Western hemlock bark	10–12	Catechol
American sumach—Southern States	25	Pyrogallol
"Staghorn" or "Virginia"	10–18	Pyrogallol
Foreign		
Quebracho wood—South America	20–28	Catechol
Gambier	35–40	Pyrogallol
Myrobalans	30–40	Pyrogallol
Valonia	Up to 45	Pyrogallol
Sicilian sumach—Italy	20–25	Pyrogallol
Divi-divi—Central America, pods	40–45	Pyrogallol
Mangrove bark—tropics	15–40	Catechol
Golden wattle	About 40	Pyrogallol
Kino	Up to 75	Catechol
Algarobilla—Chile	Average 45	Pyrogallol
Pistacia lentiscuc—Sicily, Cyprus, Albania	12–19	Catechol

Table 19 shows the most commonly used domestic and foreign tanning materials with the percentage of tannin they usually contain.

Harvesting and processing chestnut wood for extract. Although chestnut has been largely eliminated from the eastern and southern Appalachian timber stands by the blight, the sound dead trees are still used for tannin. Much extract wood is taken out in connection with the usual logging operations, principally in Virginia, North Carolina, and Tennessee. Chestnut wood is piled separately, split into convenient 4′ lengths, and shipped by truck or rail to the extract plants. In processing, the wood is put through grinding machines of the "hog" type, which grind up 5 cords per hour. Some wood is reduced by disk chippers similar to those used in chipping pulpwood. The chips are then conveyed to the extraction or leach house. Three methods of extraction are in common use, known as (1) open-tank diffusion, (2) decoction, and (3) percolation.*

After extraction the liquor is evaporated to the desired density or concentration. About 1400 to 1800 gal. of water must be evaporated for every cord of wood leached in open extractors. A plant producing 250 bbl. of extract daily consumes 245,000 gal. of water in evaporation to produce this amount.

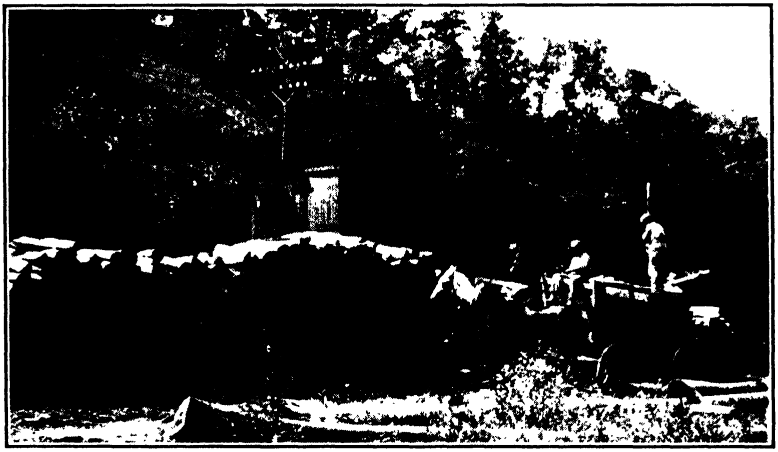


FIGURE 95. Chestnut acid wood for tannin being loaded in railroad cars in western North Carolina. The production of tannic acid wood constitutes an important but waning business in the southern Appalachian Mountains.

In spite of the gradual disappearance of the chestnut tree, chestnut wood extract is now employed for approximately 30% of the total vegetable domestic tanning material in the United States.† It is used largely for heavy leather, such as soles, belting, and harness leathers. Most of the spent chips are consumed in the production of paperboard. It is estimated that about 18% of the spent chips are burned for fuel. There are 7 extract plants engaged in the manufacture of chestnut extract with a potential capacity of 400 million lb. of extract (25% tannin) annually. Of all of the forest products cut from National Forests in the South, chestnut acid wood constitutes 18% of the entire value,

* See *Chemical Distillation of Wood*, p. 103 by H. K. Benson, U. S. Dept. Commerce, Washington, D. C., 1932, for details of these processes.

† From information supplied by E. S. Flinn, manager, tannin extract division, Mead Corporation, Lynchburg, Va.

being exceeded only by the value of saw timber for lumber, veneer logs, and cooperage stock.

Harvesting hemlock bark. For many years hemlock was the principal source of tannin, some of the tanneries using 3000 to 6000 cords of bark per year. The industry was first developed in Pennsylvania, New York, and New England. The large, old hemlock trees with thick bark were considered best as sources of tanbark. About 1900 to 1910, many million hemlock trees

FIGURE 96. Chestnut extract plant at Buena Vista, Va.

were felled for their bark alone. The bark is stripped into pieces 4′ long and in various widths up to 18″. It must be piled and cured before being used. Bark must not have been in water because of the leaching out of the tannin contained, and therefore bark from water-driven logs is not acceptable.

Seasoning requires 2 to 4 days with the inside of the bark exposed to the sun and air. About 1 cord of bark is secured from 1500 to 1800 b.f. of logs, depending on the size. Two experienced men can fell the trees and peel and pile 2 to 3 cords of bark per day. Bark is measured by the cord (4′ × 4′ × 8′). When dry a cord weighs about 2000 lb. Fifteen cords are generally shipped per boxcar by rail. Cutters producing less than 3 cords from a given area have difficulty in finding a market for their product. Usually a carload is considered a minimum quantity for marketing to the tanneries. In 1949 hemlock bark sold for $14 per cord F.O.B. cars in northern Wisconsin and upper Michigan. Here the large, defective, knotty, and top logs are barked and put into pulp, the sound logs going into lumber. In these sections and with small logs it requires about 2 M b.f. Scribner, Decimal C log scale to produce one cord of bark.

Production of oak barks. The barks of several oaks have always been important sources of high-grade tanning material. Oak bark is especially valued for sole leather and is used directly in tanneries as well as for making tanning extract. The principal species used are chestnut oak and tanbark oak. Chestnut oak is found throughout the East, especially in the high, rocky ridges and dry locations in the Appalachian and Allegheny Mountain regions. It grows chiefly in mixture with other oaks and hardwoods. The bark is secured usually on logging operations, when peeling may be done from late March until late June. Chestnut oak extract is used with chestnut wood extract to give strength, tenacity, and greater impermeability to leather.

One man can cut and peel 1 to 2 cords per day, besides felling and crosscutting the tree. Frequently, the primary purpose in felling the tree has been to obtain the bark alone, the remainder of the tree being cut into cross ties or saw logs for lumber.

Tanbark oak is found principally in northwestern California, where it grows frequently in association with redwood and other species. It was first developed shortly after the "gold rush" of 1849 and is the principal source of tanning materials, especially for sole leathers on the West Coast. The average yield is 1¼ to 2½ cords per acre. About 6 average trees will make a cord of bark. Peeling of bark continues from May 20 to August 1, depending on weather conditions. After the tree is felled, it is girdled and the bark removed in 4′ sections, as is done for other oak and hemlock barks. The trunks are left in the woods to rot because they cannot be logged and sawed at a profit.

Other miscellaneous domestic sources. A considerable number of experiments are being conducted in the utilization of western hemlock as a source of tannin. It has important possibilities. The bark is very thin and, whereas the tannin content is relatively large, production has not been placed on a commercial basis because of the availability of other tanning agents. Douglas fir bark is also being tested for the production of tanning materials on the West Coast.

In Europe, Norway spruce bark is the chief native source of vegetable tannins. The barks of spruces contain tannins of varying percentages. These barks are available for development in the United States, should it be necessary to depend on them as a source of tanning materials. Owing to the wide variety of foreign and domestic tanning supplies, it is not likely that our other available sources will be developed for many years to come.

FOREIGN TANNING MATERIALS

Quebracho. Several trees are known as "quebracho," but the real quebracho (*Quebracho colorado*) is regarded as the most important source of tanning materials in the world, furnishing a large portion of the tanning agents brought to the United States. The native habitat of quebracho is along the watercourses and plains of central South America, embracing southern Brazil, southeastern Bolivia, Paraguay, Uruguay, and northern Argentina. It is included within a district of 300,000 square miles. About 200 million lb. of extract valued at $19 million are annually imported to the United States.

The name is derived from the Portuguese meaning "axe breaker." The wood is one of the hardest and heaviest known, the specific gravity being 1.30 to 1.40. A cubic foot of wood weighs 75 to 78 lb. It is extensively used for railway cross ties in Argentina, where it is said to resist decay for more than 50 years.

Tannin is found chiefly in the heartwood (20.24%), although the sapwood (3.4%) and the bark (16.84%) contain small percentages as well. Excepting chestnut, quebracho is the only wood that has been developed and used on a large scale for tannin, all the other materials consisting of bark, leaves, or other parts of the tree.

The trees, after felling and the removal of bark, branches, and sapwood, are bucked into logs 4′ to 16′ in length, or more, and then hauled by oxen to the nearest railway. They are transported, sometimes several hundred miles, to extract plants. Some companies have a monthly output of 500 to 1000 tons of wood. In the process of extraction, the wood is reduced to small chips or shavings and then placed into closed copper extractors. Steam is admitted, and the leaching process is consummated rapidly. Consequently very concentrated liquors are obtained. 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% of water remains. This extract, on cooling, becomes solid. Analysis of quebracho extract shows about 65% of soluble tannin extract, 8% insoluble tannin, and 7% non-tannins.

Practically no quebracho wood is exported from the South American countries, a ban being placed on the exportation of the wood a number of years ago. This ban led to the dismantling of the extract plant of a large corporation at Wilmington, Del. Another company also had an extract plant in Pennsylvania, utilizing quebracho logs, but this plant was also abandoned years ago, owing to the relative costliness of transportation of the wood compared with that of the extract.

Wattle. Wattle is the second most important raw material imported. Wattle or mimosa is the name applied to several acacias of Australia, South Africa, and Tasmania. It is extensively cultivated in South Africa. The black wattle is *Acacia natalitia,* and tannin is also found in commercial quantities in the *Acacia pycnantha.* Both barks are very rich in tannin. About 51 million lb. valued at $1,404,000 are annually imported to the United States.

Mangrove bark. Mangrove bark has reached some importance in the tanning industry in this country. In some years about 3000 tons are imported, which represents a greater value than that of any other imported tanning material except quebracho.

Mangrove bark formerly came principally from Portuguese East Africa, Madagascar, and the East Indies. Since the 1930's, however, large quantities have come from Venezuela and Columbia. Most of the mangrove bark consists of the so-called red mangrove (*Rhizophora mangle,* Linn.).

The yield varies considerably with the regions. Altogether, this variation is said to be from 5 to 45%. The older the tree, however, the greater is said to be the tannin content. The mangrove cut and placed in the market in large commercial quantities usually produces a yield of tannin 22 to 33%.

Myrobalan nuts.* "Myrobalans" is the trade name applied to several species of Indian trees of the *terminalia* genus. The greatest source of supply is the *Terminalia chebula,* which is a tree usually 40′ to 60′ in total height and cultivated in the vari-

* This word is also spelled myrobolan.

ous districts of India for the timber as well as for the value of the nuts. The nuts are harvested by the natives and 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% and is found chiefly in the husk.

Divi-divi. Divi-divi is the trade name applied to the seed pods of a small tree, *Caesalpinia coriaria*, indigenous to the West Indies, Mexico, Venezuela, and northern Brazil. Divi-divi is shipped principally from the ports of Caracas and Maracaibo. Divi-divi has been used for more than 100 years, chiefly by the Germans. It is blended most often with certain tanbarks or other extracts. It readily adapts itself to use in the extract form.

Imported sumach. Sicilian sumach (*Rhus coriaria*), as it is known in tanning circles, contains 20 to 35% of tannin and is regarded as a valuable tanning agent in the Uited States, where the importation has increased since the 1930's. 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. Sumach tannin is used principally for tanning such fine leathers as glove and book leathers and, as a mordant, to fix the basic aniline dyes.

Valonia. Valonia is the usual commercial name given to the acorn of the Turkish oak (*Quercus aegilops*), which grows principally in Asia Minor and to a less extent in the Grecian Archipelago. It is sometimes known, according to its origin, as Smyrna valonia and Greek valonia. These acorn cups contain up to 45% of tannin.

Other foreign tanning materials. Gambier is used for both tanning and dyeing purposes. It comes to the United States from Singapore. Gambier usually contains 35 to 40% of pyrogallic tannin and comes from two species: namely, *Uncaria gambier* and *U. acida*. It produces a brown tannin which is generally favored 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% of tannin. Cutch (*Acacia catechu*) is imported in large quantities, but it serves chiefly for dyeing purposes. It is employed occasionally for tanning leathers in connection with the dyeing operation.

DYE MATERIALS

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 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 on these dyestuffs, but the use of forest-grown materials has decreased very rapidly since the 1920's. The textile industry consumes the largest quantities of dyestuffs for cotton, silk, wool, etc. Other important outlets are for paint, varnish, ink, leather, paper, and wood.

At the present time aniline dyes compose a large percentage of all the dyeing materials used. For certain purposes, however, a few dyewoods are still held in high regard in the textile and leather trades and other trades which consume large quantities of dye materials.

MANUFACTURE OF DYESTUFFS

Most of the natural dyes are now produced from imported woods of Central and South America and the West Indies, the coloring matter being obtained from the parenchyma cells after reducing the wood to the powdered or chip form. Dyewoods generally contain only 5 to 10% 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 in concentrating the solution to the crystal, liquid, or powdered forms.

Raw materials used. A very large share of our natural dyestuffs is received in the log form, 3′ to 8′ long and sold entirely by weight. To be acceptable to the dye manufacturers, the logs must be thoroughly trimmed of all bark and sapwood and freed from any dirt or other foreign material.

Logwood or Campeachy wood constitutes about 75% of all dye-extract materials imported into the United States. Fustic is next in importance; then there is a great variety of foreign woods occasionally used, such as brazilwood, and other redwoods, and sandalwood. Additional forest-grown materials for dyeing purposes are catechu or cutch, sumach, and gambier. Other sources of natural dyes, such as cochineal, indigo, tumeric, and madder, are not classified as forest products.

Osage orange is 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 very limited extent are black walnuts and butternuts, sumach, yellowwood, mesquite, alder, red gum, bluewood, and dogwood.

MISCELLANEOUS

The following are brief descriptions of some of the less important extractives obtained from our forests.

Cascara. The bark of cascara buckthorn, *Cascara sagrada*, found from British Columbia and southeastern Alaska to northern California and east to Idaho and Montana, produces an important commodity used in medicine. The tree generally grows to a height of 20′ to 30′, has a smooth gray bark, and is usually 6″ to 15″ in diameter, although occurring up to 30″ in diameter. Limited principally to the banks of streams and lower moist slopes, it is an important by-product of the forests of western Oregon and western Washington. There are about 15 million acres west of the Cascade Mountains which produce bark in paying quantities. Its growth is more than its annual production. The peeling and drying of cascara bark in the spring is an interesting part of the community life in some sections and constitutes a small local industry.

In removing the bark during the period of sap running in the spring, care must be taken not to girdle the tree completely or injure the roots. Only about one quarter or at most one third of the bark is removed, and it is best not to have the incised portions too close. About seven tenths of a ton of medicinal bark per section of 640 acres in the best region is the annual yield, worth from $150 to $300, depending on quality and widely varying prices. Vancouver is the principal port of shipment for export. Several hundred tons of this useful product are harvested annually.

Extracting pine and cedar needle oil. This industry is old and well established in Europe and at least 70 years ago had made a start in America. In no species of pine is the oil content of the needles very large. Of native trees investigated the longleaf pine ranks highest, the yield averaging 1 lb. of oil for every 250 lb. of fresh needles and twigs. The western pines and Douglas fir have a content very much lower than this. Cedar oil is also extracted to a small extent in the Lake States, the Northeast, and eastern Canada.

The process of distilling the oil is very simple, and the apparatus need not be elaborate or expensive. The leaves and young twigs are collected during a logging operation or cut from young thickets. If oil is the only desired product, the material is run through a feed cutter that chops the needles and twigs into pieces ½″ to 1″ long. This fine material packs more readily and uniformly in the still and accelerates the liberation of the volatile contents. Distillation is by steam. Live steam is passed through the chopped or crushed needles and finds its way out through a water-cooled coil of pipe where it is condensed as in any ordinary distillation process. As hot steam comes in contact with the material, the volatile oil in the leaves and twigs is vaporized and passed out with the steam and is condensed with it. This oil, which is in reality a mixture of several oils, is only about four fifths as heavy as water and accordingly rises to the surface of the distillate. Either it is skimmed off, or the water is drawn off from below. The time required to complete the distillation process varies from 5 to 8 hours.

Needle oil is used for numerous purposes such as perfuming soaps, greases, and other preparations, and for medical purposes. It is claimed to be of value in the treatment of pulmonary and bronchial diseases and for use as a liniment for external application.

The future of the industry in America does not seem very promising. This is largely due to the high cost of production and absence of a good market. Practically the same process is followed with cedar oils extracted from the leaves and twigs of northern white cedar or arborvitae in the Northern Forests and those of eastern Canada.

Mucic acid. When the wood of the western larch is converted into chips, an extract yielding 8 to 25% galactic acid is obtained. On hydrolysis with dilute acids at 100°C., the product may be oxidized into mucic acid. This is the basis of a process developed on a commercial scale. Larch butt logs yield about 10% of mucic acid and 2.25% of oxalic acid. After extraction, the residue of chips may be dried and used for fuel or converted into pulp for wallboards or other products. Mucic acid is used in baking powders and for sulfurizing flour in place of tartaric acid, and for certain dyeing purposes and as an accelerator for the growth of yeast.

Storax. Storax is a yellowish, fragrant, balsamic liquid or gum which exudes from the bark of red or sweetgum (*Liquidambar styraciflua* Linn). It is widely used in medical and pharmaceutical preparations such as adhesives and salves. It is also used as incense, for perfuming powder, soaps, and for flavoring tobacco. Storax for many years has been imported from China and Asia Minor where there are closely related species of the same witch hazel family. When China was invaded in 1937 by Japan, the imports of storax fell off, and consequently the demand for American forms rose. This continued actively during World War II and to some extent since.

Storax is obtained from red gum in its entire range, but the flow is most abundant in the southern part of its range centering in Alabama and notably in Clarke County in that state.*

For many years country boys have used knives to dig out bits of gum from the bark of these trees and used it for chewing gum.

On commercial operations a ring partly around the tree is cut 2 ft. from the ground early in the spring. After the bark is peeled, the gum is scraped from the surface every 14 to 21 days, and a new ring or thin slice is cut preferably ¼″ to ⅜″ thick. This is done with a cutting device similar to the turpentine hack. The gum is collected into a small container and transferred to larger cans and then heated over a slow fire made in a trench in the ground. It is then strained and canned. The product appears like a chocolate-colored gum which solidifies like beeswax. Yields of ½ to 1 lb. per tree are secured with efficient operations. The yield is in direct proportion to the green leaf

* From Sweet Gum from the Sweetgum by C. R. Ross, *Am. Forests*, September 1947.

surface. One man may operate 1500 to 2000 trees per year, and one tree will continue to produce gum for 3 to 5 years. Tapped trees will continue to grow for lumber or pulpwood purposes. The estimated annual value of this product from Clark County, Ala., alone, was estimated at $200,000.

26 · RUBBER *

NATURAL RUBBER

Rubber, in the natural form, is obtained from a variety of trees, vines, and shrubs of the tropics. It originates in the form of a milky juice, called latex, which flows as a result of incising, or wounding, the plant. The function of latex, despite intensive study, is still not definitely known, but recent discoveries indicate that it may serve as a reserve food supply of the plant. The chemical composition of rubber consists mainly of a combination of carbon and hydrogen.

Before 1900, practically all of the world's rubber supply consisted of wild rubber, the bulk of which came from Brazil. With the establishment of the plantations of the Far East, resulting from Sir Henry Wickham's successful transplanting of the seeds of *Hevea brasiliensis* (Para rubber tree) from Brazil to London, and in turn to Ceylon, Malaya, and the Dutch East Indies, plantation rubber rapidly monopolized world markets to such an extent that by the end of the second decade of the nineteenth century Brazil had practically dropped out as a production source. Ironically, an attempt to establish a plantation industry in Brazil, the country of origin of *Hevea brasiliensis*, was defeated chiefly by a disease, called the South American leaf disease (*Dothidella ulei*) which, although relatively harmless to wild rubber growing under natural conditions, at the sparse density of approximately 1 tree per acre, completely devastated the dense plantations. Intensive efforts to overcome this disease by spraying, and bud grafting of disease-resistant crowns, were successful from the pathological standpoint but prohibitively expensive from the economic standpoint. Fortunately, the disease thus far has been confined to the Western Hemisphere.

* Prepared with the assistance of Valentine O. Goodell, formerly of the Rubber Development Corporation and the International Rubber Allocation Board.

PLANTATION RUBBER

After the introduction of *Hevea brasiliensis* to the Far East, plantations were rapidly established to such an extent that by the end of 1940 there existed nearly 9 million acres, almost equally divided between European-owned, relatively large estates, and Asiatic-owned small estates. About 77% of the total acreage

FIGURE 97. Two-year-old stand of bud-grafted rubber on an American plantation in Sumatra. *Courtesy U. S. Rubber Co.*

occurred in Malaya and the Dutch East Indies, and the remainder in Ceylon, Siam, Indo-China, Sarawak, India, North Borneo, and Burma. In addition to the afore-mentioned acreage, approximately 100,000 acres of plantations have been established in Africa (chiefly Liberia), South America, and the Pacific Islands.

The original plantations consisted entirely of seedling trees, yielding an average of about 300 lb. per acre per year. However, efforts on the part of botanists to reproduce the rubber tree vegetatively resulted in successful bud grafting, an operation that happily reproduced the yielding capacity of outstandingly high-yielding parent trees, and, as a result, many of the modern plantations now consist partly or chiefly of budded rubber stands capable of producing up to 2000 lb. per acre of dry rubber per year.

The operation of a modern rubber plantation is a highly technical one, comparing roughly to that of a large-scale combined agricultural-horticultural project. Jungle clearing; soil preparation, conservation, and fertilization; plant breeding, planting, upkeep and pruning; and harvesting and processing of the product are among the many procedures encountered in the rubber-production business.

FIGURE 98. Tapping a 20-year-old seedling tree. The usual tapping system consists of daily tapping for 1 month alternating with 1 month's rest. The length of the cut is one-half the circumference of the tree. *Courtesy U. S. Rubber Co.*

Latex is processed into three main types of crude rubber as follows: smoked sheet, crepe rubber, and latex, described briefly below. The original smoked-ball type of rubber, as produced from the wild Brazilian source and termed Para balls, is rarely found on the world markets today.

Smoked sheet. The bulk of plantation rubber is produced as smoked sheet. The latex is placed in partitioned tanks in order to form the rubber into thin sheets, formic or acetic acid is added as a coagulant, and, after an interval sufficient to allow enough coagulation so that the rubber particles will adhere together in the form of sheets, the sheets are passed through rolling mills which press out most of the water content. They are then placed in drying houses where all except about 1% of the total moisture content is extracted. The sheets are then baled and shipped to market where they are manufactured into many products for which rubber is used, the chief one of which is tires.

Crepe rubber. The processing of latex into crepe rubber is similar to that for smoked sheet except that the rolls in the rolling mills travel at different speeds, causing a slight maceration of the sheet. The product, easily recognizable, is used in its raw form for shoe soles and for special purposes where a light-colored stock is required.

Latex. Latex as a market grade is the most recently developed of the three main types of raw rubber. The name indicates that it is the basic form of rubber. In the early stages of the latex business (the 1920's), latex direct from the tree was shipped to

FIGURE 99. Centrifuges used for concentrating latex. A modern latex-processing plant on an American rubber plantation in Malaya. *Courtesy U. S. Rubber Co.*

market merely with the addition of an anticoagulant in order to prevent premature natural coagulation and, further, to prevent putrefaction. Latex is described as a milky fluid; in addition to its milklike appearance it possesses a further characteristic of milk in that it contains bacteria which multiply rapidly and cause putrefaction unless checked. Therefore, certain chemicals must be added which serve the double purpose of preventing coagulation and putrefaction.

Shortly after the beginning of the latex business it was discovered that it would be highly advantageous from the standpoint of later manufacture to increase the dry-rubber content of the latex, or concentrate it, as it is termed. Therefore, two processes were developed termed *creaming* and *centrifuging,* which again bear a similarity to the processes used in milk production.

Creaming consists merely of allowing the latex to stand in large tanks until the rubber particles, which are lighter than water, rise and concentrate themselves into a smaller volume. An accelerator, or creaming agent, must be used in order to speed up the process. Anticoagulants must also be used in order to prevent premature coagulation and putrefaction.

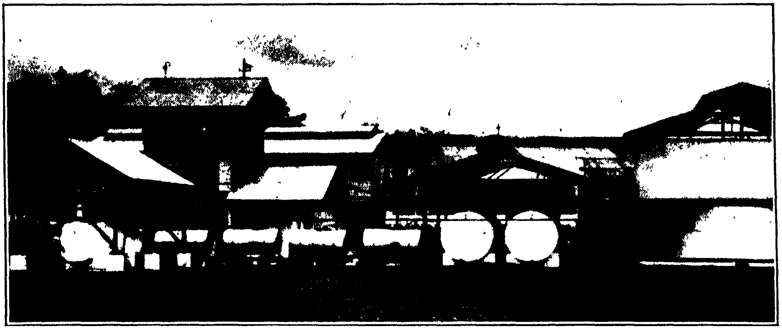


FIGURE 100. Modern latex-creaming plant on an American plantation in Sumatra. Railway tank cars in left foreground, creaming and storage tanks in center and right foreground. *Courtesy U. S. Rubber Co.*

Centrifuging is similar to the separating process for separating cream from milk; in latex, the rubber particles are separated from part of the inherent water, actually resulting in the concentration of the rubber particles.

Both processes result in a concentrated latex averaging 60 to 70% dry rubber, compared with the 30 to 40% dry-rubber content of the original latex. The advantages of the use of concentrated latex are considerable in the manufacture of such items as foam sponge rubber, golf balls, rubber thread, rubber-impregnated cloth and footwear, and surgical supplies.

SYNTHETIC RUBBER

It is realized that the subject of synthetic rubber does not belong in a book devoted to forestry products. However, in order to give an indication of the future of natural rubber, brief mention will be made of its chief competitor.

The story of synthetic rubber has probably made more headlines in a relatively short time than that of any other product.

World War II accelerated the development of synthetic rubbers which had to, and did, act as successful substitutes for natural rubber, 90% of which had been captured at the source by the Japanese. There is little doubt that the development of the synthetic-rubber manufacturing program saved the Allied Nations from defeat, or at least from the agonies of a war which would have lasted many years longer than it did. The Allied supplies of natural rubber were nearly exhausted when synthetic supplies became available in the "nick of time."

The effect of this tremendously accelerated industry on the future of natural rubber is certain to be profound. Briefly, price quality must eventually settle the issue, unless political considerations interfere. It remains for the future to decide.

PRODUCTION AND CONSUMPTION

In order to show the present position of the industry, world production and consumption figures are given for the 10-year

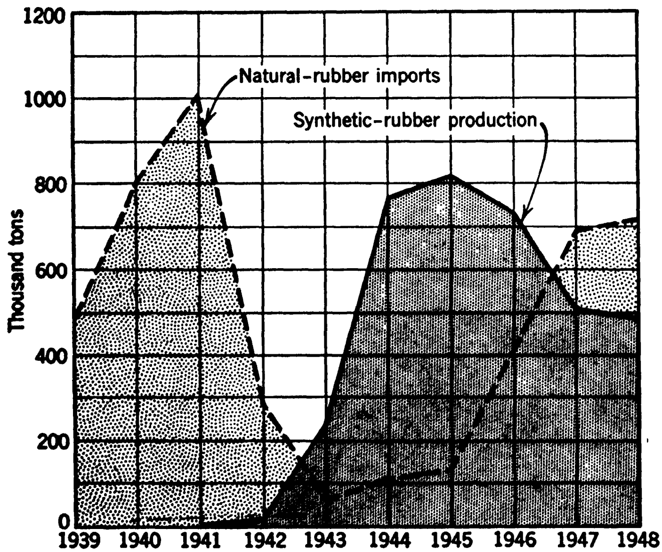


FIGURE 101. Where the United States gets its rubber. The chart shows the wartime rise of the synthetics industry and its position recently. *From Revolution in Rubber by Bernard Jaffe, New York Times, May 15, 1949.*

period 1939–48. Production data are arranged to show the comparison in synthetic production between the United States and the rest of the world (this is unnecessary in the case of natural rubber as the United States, of course, does not produce any). Consumption figures are totals of natural and synthetic, broken down to show a comparison in total consumption between the United States and the rest of the world. Some of the figures are necessarily estimates because of lack of accurate statistics from some countries and difficulty in obtaining data from Russia. Further, during the years 1942–45 production figures of natural rubber in Japanese-occupied countries are based on very inadequate data.

TABLE 20

WORLD PRODUCTION AND CONSUMPTION OF NATURAL AND SYNTHETIC RUBBER, 1939–48, IN LONG TONS

	Production				*Total Consumption*		
		Synthetic		*Total Natural and Synthetic*			
	Natural	*U.S.A.*	*Rest of World*		*U.S.A.*	*Rest of World*	*Total*
1939	1,000,000	1,750	21,998	1,023,748	593,750	526,250	1,120,000
1940	1,415,000	2,560	39,826	1,457,386	651,060	501,440	1,152,500
1941	1,600,000	8,114	69,361	1,677,475	781,259	531,241	1,312,500
1942	640,000	22,476	98,135	760,611	394,442	483,058	877,500
1943	465,000	231,767	118,276	815,043	488,525	418,975	907,500
1944	360,000	764,072	136,453	1,260,525	710,783	414,217	1,125,000
1945	250,000	820,352	45,717	1,116,069	799,009	328,491	1,127,500
1946	837,500	740,026	66,538	1,644,064	1,039,296	428,204	1,467,500
1947	1,255,000	508,702	50,622	1,814,324	1,122,327	612,673	1,735,000
1948	1,520,000	490,434	43,843	2,054,277	1,069,404	823,096	1,892,50C

Table 20 illustrates three main points, among others:

1. The preponderance of the United States in world consumption of rubber.

2. The steady increase in total world consumption of natural and synthetic rubber since the end of the Second World War.

3. The tremendous increase in synthetic-rubber production during the war years, necessitated by Japanese capture of the source of about 90% of the world's supply of natural rubber.

An idea of the economic importance of the rubber industry may be obtained if the 1948 consumption is converted at 20 cents per lb., the approximate average price for crude rubber for that year, equalling $847,840,000. The value of the manufactured products derived from crude rubber was, of course, far greater than this figure.

27 · MAPLE SUGAR AND SIRUP *

This is an important home industry almost entirely confined to farm woodlands in the optimum or best range of the sugar maple tree, which includes New England, New York, Pennsylvania, Ohio, and the Lake States. Vermont is the center of the industry, which has been more intensively developed there, especially along marketing lines, than elsewhere. More than one half of the total cash income of the average Vermont farm is obtained from this industry. All maples produce a sugary sap, and occasionally all species are tapped. The sugar maple (*Acer saccharum*) is usually the dominant tree in the "sugar bushes" so commonly found in New England, New York, Pennsylvania, Ohio, Wisconsin, and Michigan, and, as a rule, comprises 25 to 75% of the total stand. There are 62½ million acres of maple, beech, and birch type in this country. Only a very small proportion of all sugar maples is tapped. Frequently roadside and shade trees about the home are tapped yearly for sap.

Sugar bushes are often known as "cold" bushes or "warm" bushes. A cold bush is one that is exposed to the chilling spring winds and located on a northerly exposure. A warm bush, on the other hand, is one that is protected from chilling spring winds and lies on a southerly exposure. Sap flow begins several days earlier in the latter than in the former, even within the same locality.

Production of maple sugar and sirup. The U. S. Bureau of the Census has kept records of this industry since 1859, when 1,598,000 gal. of sirup and 40 million lb. of sugar were produced. The peak production of sirup was in 1918 when, under the stimulus of World War I, 4,863,000 gal. were produced and more than 19 million trees were tapped for sirup. When the total production is reduced to terms of sugar, there were 52 million lb. pro-

* Reviewed and checked by Charles C. Larson, formerly with the Vermont Agricultural Experiment Station and Extension Service.

The spelling used in Vermont is sirup, although it is often spelled syrup. Both are used in various publications on the subject.

duced in 1859 and approximately the same amount in 1918. Since 1918, there has been a steady decline in production of both sirup and sugar. In 1935, 12,496,000 trees were tapped by 30,000 farmers, and 3,377,000 gal. of sirup and 1,704,000 lb. of sugar were produced. By 1946, the number of trees tapped had fallen to 8 million, and production during this year represented 372,000 lb. of sugar and 1,328,000 gal. of sirup. It is estimated that in 1949 about 1,600,000 gal. of sirup were produced.*

Forest service sales. On National Forests in the Lake States, rights to tap maple trees are sold for 3 to 5 cents per spigot per season. In Vermont, the Forest Service sells these rights for 2½ cents per bucket. Tapping of trees under 12″ d.b.h. is not permitted. One bucket may be hung on trees 12″ to 16″ d.b.h., two buckets on trees 17″ to 20″, and not more than three buckets on trees 21″ and larger.† Sugar maples on the George Washington National Forest in Virginia are tapped under permit similar to sales for lumber, poles, cross ties, piling, or other products.

CONDITIONS NECESSARY FOR COMMERCIAL OPERATIONS

Although a considerable amount of maple sugar and sirup is made in small-scale operations on the farm, a number of enterprices are sufficiently large to be regarded as commercial businesses. A few of the more important factors to consider in undertaking the production of maple products on a commercial scale are listed below:

1. There should be trees enough in the sugar bush for at least 500 buckets, and, in most instances, the development of a sugar bush capable of supporting fewer than 1000 buckets would not be advisable as a commercial undertaking.

2. Sufficient trees should be distributed in the sugar bush to allow hanging from 75 to 100 buckets per acre. Expressed in terms of trees 10″ to 12″ in diameter, this would mean about 100 trees per acre; in trees 14″ to 16″ in diameter, 75; in trees 18″ and over, about 50. Individual trees should be well formed, vigorous, and healthy, with deep wide crowns of good size.

3. The sugar bush should be located on moist but well-drained soil, preferably on slightly sloping ground with a south-

* See page 246 for recent statistics.

† From data supplied by G. S. Wheeler, Supervisor, Green Mountain National Forest, Vermont.

western or an eastern exposure. The ideal sugar bush is one having two exposures, one open to the sun and the other somewhat protected from the sun, in order that both early and late sap runs can be obtained.

4. Sufficient capital should be available to purchase modern, high-quality equipment, such as flue evaporators, tin or aluminum buckets, bucket covers, gathering and storage tanks, and the like.

FIGURE 102. Taking a load of sap to the sugarhouse near Wilmington, Vt. This shows a typical sugar bush with modern and efficient types of buckets and covers. *Courtesy U. S. Forest Service.*

At 1947 prices, the cost of equipping a 1200-bucket sugar operation, inclusive of sugarhouse, approximated $2800, or an investment of about $2.30 per bucket.*

SAP FLOW SEASON

The sugar concentration of maple sap varies from 2 to 7%, depending on the season, the site, and the individual tree. The average is 2.5 to 3%. Sap resembles sweetened water in taste. The other components, besides sugar, are various minerals, such as lime, potash, iron, magnesia, and certain vegetable acids. It is the alternate freezing by night and thawing by day peculiar to the sugar-maple region that is most conducive to sap flow.

* Making Maple Syrup, by F. T. Murphy and W. W. Simonds, *Penn. State Coll. Circ.* **310**, p. 26, 1947.

Temperatures of 25°F. during the night and a maximum of 55°F. during the day, with damp northerly or westerly winds, are conducive to maximum sap flow. Changes of temperature cause expansion and contraction of gases within the wood cells and intercellular spaces. This results in alternate pressure and suction. During the sugar season, this force varies from a suction of about 2 lb. per sq. in. at night to a pressure of 20 lb. per sq. in. during the average day.

Ordinarily sap flows in Vermont from about March 5 to April 15. In northern Ohio, southern Michigan, and western New York the season is usually from late February to early April. This condition is determined wholly by the weather. The number of sap-flow days varies from 9 to 50 days. The longest known run of sap was 57 days and the shortest only 9. The average is 34 days. The season ends generally when the leaf buds begin to swell.

Among the findings of J. L. Hills of the Vermont Agricultural Experiment Station at Burlington are the following:

1. The amount of sap flow is probably in direct proportion to the leaf area and the amount of sunshine the tree receives. A tree 15″ in diameter and 50′ in height had 162,000 leaves with a leaf space equivalent to 14,930 sq. ft., or about ⅓ acre.

2. No more sugar or sirup is obtained by tapping on the branchy or south sides of trees. Apparently the compass direction has no bearing on the yield of sap or sugar.

3. Sap flow comes generally from the first 3″ of the sapwood. Deep holes are not considered desirable, holes should be preferably not more than 2″.

4. Trees should be tapped about 4′ above the ground. This point yields more and better sap than any other part of the tree. Experiments indicate that 51% of the total yield of sugar comes from the tap 4′ from the ground, whereas only 27% comes from the root tap, and only 22% from the highest tap.

5. Best size of tap hole is ⅜″ or 7/16″, since small tap holes heal over quickly and yield practically as much as larger holes. The sharp, short auger bit used in making holes should be left clean of all shavings, dirt, bark, and so on, when the sap season is over.

6. Sap pressure exists on all sides of the tap hole.

7. The sap flow occurs largely between the hours of 9 A.M. and noon. Experiments indicate that 63% of the total sugar is con-

tained in the sap which runs before noon. After 3 P.M. there is little if any flow.

8. Removal of sap does not materially affect the growth or general health conditions of the tree. If an average of 3 lb. of sugar is made per tree, only 4 to 9% of the total sugar content, according to the size of the tree, is removed.

9. "Buddy" sap or "green" sap collected at the end of the season, from which a reddish sirup is obtained, is attributed to the swelling of the buds. Research has indicated, however, that this coloration is caused by the development of certain bacteria.

WOODS OPERATIONS

Two men, utilizing manual tapping procedures, may hang from 400 to 500 buckets per 9-hour day. The use of portable

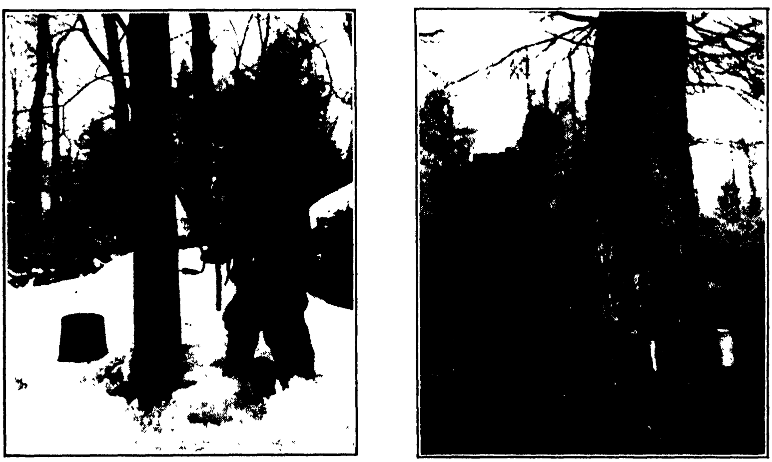


FIGURE 103. Photo at left shows method of boring standard 7/16" hole by manual method in sugar maple. This method is used on most small operations. On right, portable power tree-tapping machine with 1-h.p. gasoline engine, weight about 35 lb., mounted on U. S. Army back pack, as used on most commercial operations. With this machine a crew of 5 men is most efficient, 3 men tapping holes and driving spouts, 2 men hanging 16-qt. buckets. *Courtesy Esso Farm News; and Extension Service, U. S. Dept. of Agriculture.*

power tapping machines in recent years, however, has enabled producers to reduce the labor involved in tapping by as much as 35% or more. One of the leading power tapping machines in use today consists of a 1-hp. gasoline engine mounted on a U. S. Army plywood back pack with regulation shoulder straps and pads. A 4′ flexible shaft attached to the power take-off of the motor is equipped at the end with a device to hold the boring bit. Carrying this unit on his back, one man can tap at the rate of about 250 borings per hour. Efficient crews, consisting of four or five men, have tapped, driven spouts, and hung from 3500

FIGURE 104. One- and two-bucket trees with modern sugarhouse at roadside below orchard in distance. Trees are not generally tapped below 10″ d.b.h., and only one bucket is hung on the smaller trees. This is characteristic of much roadside tapping throughout New England. *Courtesy Esso Farm News.*

buckets in 12 hours to 5000 buckets in 16 hours. The use of power tapping machines not only offers an opportunity to reduce tapping costs, but often enables operators to take greater advantage of early sap runs. There are about 12 different types of sap spouts, spigots, or spiles. They must hold firmly in the tree and be able to support a bucket and cover when full. Buckets should never be suspended from a nail above the spigot.

Rustproof tin buckets of 12- to 16-qt. capacity have superseded the old-fashioned wooden buckets. Covers are recommended to prevent bark, leaves, twigs, chips, and other refuse from getting into the sap. Galvanized iron pails should never be used for collection of sap.

In starting new operations, haulroads are customarily swamped out of the woods so that the buckets may be carried a minimum distance. Sap collection is generally done by hand on small operations, but for the large commercial operations pipe lines often are used. When there are 1000 trees or more, tin tubing is used in sections of various lengths to conduct the sap directly to the sugarhouse. When manual methods are used, a gathering tank

FIGURE 105. Spouts connected with pipeline system by means of "goosenecks" which take sap directly to the sugarhouse. This eliminates the use of buckets to collect the sap. The owner taps 2000 trees and makes 20 gal. of sirup per acre on 200 acres of sugar bush. This pipe system is used on only a few of the largest operations. Production averages ⅕ gal. per spout. *Courtesy Extension Service, U. S. Dept. of Agriculture.*

of about 6-bbl. capacity is placed on a sled and drawn by team. A metal tank with a strainer at the top to remove such impurities as leaves and twigs is preferred. Normally a crew of two men and one team will collect the sap from 500 buckets per day, making two collections. Sap should be collected after 2 to 4 qt. of sap flow. It should never be left overnight.

MANUFACTURE OF SUGAR AND SIRUP

Sugarhouse. On small operations, sap is brought to the kitchen and boiled down. But in an orchard or sugar bush of 500 buckets or more, a sugarhouse is established in the woods, conveniently located with reference to the trees. If a pipe line is used it must be at an elevation whereby the sap may be conducted by gravity into a storage tank.

Generally these sugarhouses are 14′ × 20′ in area and very cheaply and crudely constructed, as they are used only a short time each year. On some of the largest operations, permanent structures with separate woodshed and brick or concrete floors are constructed.

FIGURE 106. A typical sugarhouse in the "sugar bush." A large pile of dry wood is available for heating the evaporator under the shed at the right.

Fuel. Wood is the common source of fuel in concentrating maple sap, though a few operators are currently burning oil. On the average 1 cord of wood will evaporate about 600 gal. of sap to sirup. Thus, at the beginning of the season there should be available at least 1 cord of well-seasoned wood for every 65 to 75 buckets hung. The use of green or wet wood is never satisfactory in that it creates difficulties in firing and reduces the effective operation of the evaporator. There would appear to be no better use of labor during off-days of the sugar season than to perform stand improvement cuttings and thinnings in the sugar bush as a means of securing the next season's fuel supply.

Equipment. Current prices of maple-sugar makers' equipment are comparatively high. Nevertheless, the commercial operator will always find it advantageous in the long run to utilize first-grade equipment. A general list of the major items considered necessary for a 1000-bucket sugar operation are listed below.

Sugarhouse (14′ × 24′) with sheds attached for storage tank and about 15 to 20 cords of wood.
1 Flue evaporator capable of turning out approximately 4 gal. of sirup per hour.
1000 15-qt. sap buckets with covers.
1000 sap spouts or spiles.
1 25- or 30-bbl. storage tank.
1 6-bbl. gathering tank.
1 50- or 60-gal. filtering tank with at least 4 felt strainers.
Miscellaneous equipment such as gathering pails, thermometers, braces and bits.

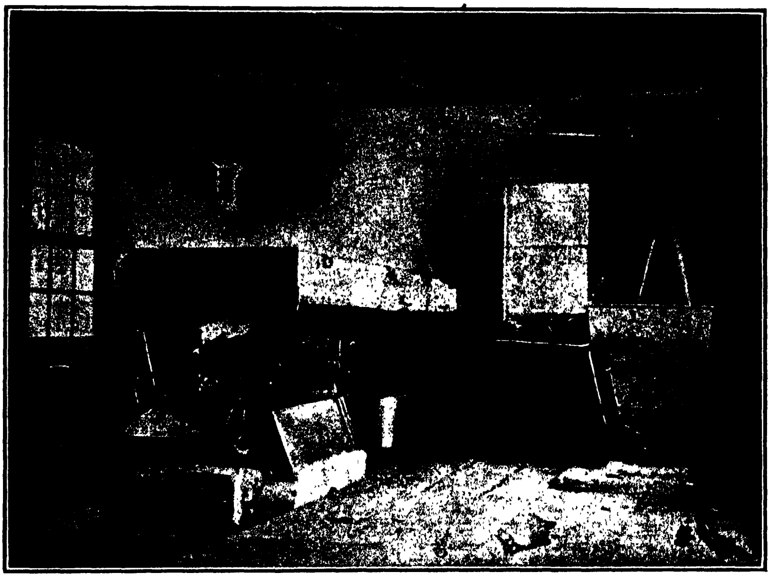


FIGURE 107. Interior of a sugarhouse showing the steaming evaporator at the left and the "sugaring-off" arch at the right.

As stated previously the costs of these items at 1949 prices would total approximately $2800. If a mechanical tapping machine were used, there would be an addition to this cost of about $125.

Studies carried out by the Vermont Agricultural Experiment Station of some 450 maple-sugar operations indicated that about 75% of the producers were utilizing evaporators smaller in size than were required for maximum efficiency. In general, an increase in the size of the evaporator in any given operation would have resulted in savings in both labor and fuel.*

In Table 21 data are presented that can be used as a rough guide in selecting the proper size of evaporator for a given operation.

TABLE 21

Size of Operation		*Evaporator Required*	
Average Production of Bush per Season, gal. of sirup	*Approximate No. Buckets Hung*	*Capacity per hour gal. of sirup*	*Approximate Size of Evaporator*
75	350–400	2	3′ × 12′
125	600–650	2.5	4′ × 16′
175	850–900	3.5	5′ × 16′
225 or more	1100+	At least 4	6′ × 16′

Suggestions for making high-quality sirup. The production of high-quality products may well mean the difference between profit and loss in maple-sugar operations. The efficient producer who turns out a high percentage of Fancy Grade sirup thus reaps the double benefits of low production costs and top prices for his products. A number of factors are of major importance in the production of high-grade maple products.

1. The cardinal rule in the production of high-grade maple products is to keep the sap as free from dirt and bacterial growth as possible throughout the season.

2. Clean thoroughly all equipment coming in contact with sap at the outset of the season. High-quality sirup can be produced late in the season by washing all equipment, including buckets and gathering and storage tanks, during the periods between sap runs.

3. Gather sap frequently, and concentrate it into sirup as rapidly as possible.

4. Keep the sugarhouse and the equipment therein clean and free from unpleasant odors at all times.

5. Produce a standard product by concentrating sirup to the proper density. When the concentrated sap in the evaporator

* Cost and Profit in the Sugar Orchard, by John A. Hitchcock, *Vermont Agr. Expt. Sta. Bull.* **292**, 1929.

reaches a boiling temperature 7° above the boiling point of water at the barometric pressure of the sugarhouse, it will weigh approximately 11 lb. per gal. the standard weight prescribed by law for maple sirup. At 60°F. standard maple sirup will have a Baumé hydrometer reading of 35.6°.

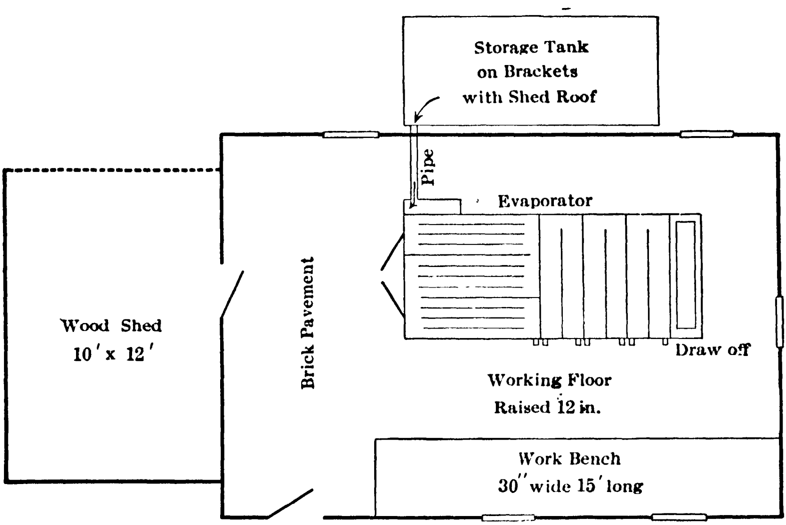


FIGURE 108. Ground plan of a 14′ × 20′ sugarhouse equipped with a modern evaporator.

6. High-grade sirup must be free of all cloudiness and sediment. Thus, as sirup is drawn from the evaporator, it should be strained through felt strainers prepared for that purpose. In many instances, it may be desirable to remove impurities from sirup by placing it in settling tanks for a given period. Draw-off outlets located several inches from the bottom of such tanks enables the sirup to be removed and canned free of all foreign matter.

7. Be sure all equipment used in handling sap is free of materials containing lead. The chemical action of fermented sap will free the lead from solder seams in certain kinds of buckets, tanks, and the like, thus resulting in contamination of the sirup produced.

Other maple products. By carrying the sap-evaporation process beyond the point required for standard sirup, such products as maple cream and maple sugar (hard and crumb) may be produced. When it is planned to make sugar from sirup, a sugaring-off arch and pan are set up, usually in a separate room of the sugarhouse or in one corner of it. The type of equipment used, however, will depend on the size of the sugaring enterprise. The production of maple cream is an art and requires considerable experience to turn out a perfect product. Roughly, the procedure consists of boiling sirup down to a temperature of about 25° above the boiling point of water at the given elevation. The heavy sirup thus obtained is chilled rapidly to a temperature of about 95° and then stirred until it reaches the consistency of a spread. The production of soft and hard maple sugar consists of concentrating sirup down to a boiling temperature of 26° to 28° and 30° to 33° above the boiling point of water, respectively. Both these sugars may then be poured into molds to form cakes of candy size or large bricks weighing 10 to 20 lb.

Yields. Production records obtained for 90 maple bushes in Vermont for a 5-year period revealed the following figures for the average annual operation: (1) number of trees tapped, 911; (2) number of buckets, 1097; (3) sirup produced, 208 gal.* This represents a sirup yield of approximately 0.19 gal. per bucket and 0.23 gal. per tree. If it is assumed that the average sugar content of the sap produced in those bushes was 3%, the sap production per bucket would then approximate 5.5 gal., and per tree, 6.5 gal. These latter equivalents are based on the "86" rule for determining the number of gallons of sap required to produce a gallon of standard sirup. Divide the number 86 by the per cent sugar concentration of the sap, and it will give the number of gallons of sap that will have to be evaporated to produce a gallon of sirup weighing 11 lb. to the gallon. For example, it requires 35 gal. of 2.5 per cent sap to produce a gallon of sirup; 29 gal. of 3% sap; and 17 gal. of 5% sap. In Canada, applying this rule to the Canadian gallon, substitute the number 103 for 86.

There are approximately 40 lb. of sugar per 50 cu. ft. of wood in a maple tree containing this much cubic volume. The same volume of wood contains about 1200 lb. of water, thus making the concentration of the sap approximately 3.3%. The amount of sugar present in a given volume of maple wood will vary,

* The source of this information is The Grazing of Maple Sugar Orchards, by John A. Hitchcock, *Vermont Agr. Expt. Sta. Bull.* **414**, 1937.

of course, with the season of the year, the individual tree, and the site on which the tree is growing.

Grades. Since maple products lend themselves more readily to a direct relationship between the producer and consumer than most other commodities, the Vermont Department of Agriculture has established official grades of maple products. This is primarily to protect those who are unfamiliar with pure maple products from being misled into purchasing inferior sirup, such as blends of cane or other sirups having a small quantity of maple sirup added for flavoring purposes. Vermont producers whose products have been graded and packed in accordance with official state grades are thus given permission to use a distinctive label as a means of identifying their products as pure and up to state standards.

The difference in grading is largely due to differences in color of sirup. The light amber shades, having milder flavor, are of the best quality.

PRODUCTION STATISTICS

Recent figures from the New England Crop Reporting Service show the maple production output, with number of trees tapped and the production obtained in the most important states.

TABLE 22

MAPLE OUTPUT

Sirup Converted to Sugar at 8 lb. per gal.

State	*Number Trees*	*Lb. Sugar*	*Gal. Sirup*	*Total lb.*
Vermont	3,191,000	235,000	549,000	4,627,000
New York	2,563,000	28,000	538,000	4,332,000
Ohio	511,000	....	150,000	1,200,000
Michigan	542,000	16,000	110,000	896,000
Pennsylvania	345,000	21,000	94,000	773,000
Wisconsin	277,000	....	59,000	472,000
New Hampshire	221,000	15,000	41,000	343,000
Massachusetts	159,000	14,000	44,000	366,000
Maryland	32,000	7,000	16,000	135,000
Maine	89,000	5,000	10,000	85,000
Total	7,930,000	341,000	1,611,000	13,229,000

To these totals should be added the estimated output of Maine's northern counties, plus Minnesota and Indiana, together estimated at 565,000 lb.

PART IV

Wood Containers

28 · COOPERAGE—SLACK AND TIGHT

Cooperage is the science of making barrels, kegs, tubs, pails, and other containers of pieces of wood known as staves and heading bound together by hoops. The industry is based on a very ancient art, early historical records indicating 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. There are two broad divisions of the industry: namely, slack and tight cooperage. Each has distinctive features.

Slack cooperage. Slack cooperage is composed of three parts: staves, heading, and hoops. Each part is commonly made at separate plants, although in some of the larger cooperage establishments both staves and heading are made in one plant. The manufacture of wooden hoops is quite distinct, however, and constitutes a separate industry. Tight cooperage is distinguished from slack cooperage in its ability to hold liquids. In general, there are two grades of slack-cooperage barrels. One grade is used for the shipment of flour, sugar, powdered milk, chemicals, etc. These barrels are sometimes made from tongued and grooved staves, particularly those used for powdered milk and fine chemicals. The other grade is used for packing-house products, fruits, vegetables, lime, cement, rosin, hardware, crockery, etc. Tubs, buckets, pails, firkins, and the like are used for dairy and some packing-house products.

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

FIGURE 109. For many centuries wood has been used in the construction of barrels, casks, and kegs. This photograph was taken in a California cooperage storage warehouse. *Courtesy V. Covert Martin.*

portion of the raw material used for slack-cooperage purposes. Furthermore, not only does white oak meet the requirements for tight barrels better than any other wood, but also only the best quality of white oak can be used. Trees less than 18″ d.b.h. are seldom used. In addition to this minimum size, the trees must be straight-grained, sound, and comparatively free from knots, rot, shake, or other defects. Sapwood is not admitted for spirit staves and heading.

Where the seasoning of contents is involved, as, for example, in containers for 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 employed for purposes where seasoning of the contained liquid is not involved, as, for example, in containers for mineral oils, lard, chemicals, pork, turpentine, molasses, and sirup, a limited amount of such other species as red oak, red gum, and white ash 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, barrels of all woods which serve 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 with tyloses.) There is a growing tendency to favor more and more substitute woods in the cheaper grades of tight staves and heading. This condition, moreover, is being aggravated by the growing scarcity of high-grade white oak stock, the increasing demands for the best white oak, and the consequent rise in prices.

Where the seasoning and aging of the spirits contained are involved, as mentioned previously, all white oak barrels are charred on the inside to an average depth of ⅛″ to ⅓″. This has been the custom universally for a long time, especially with whisky barrels.

The pure-food laws passed by Congress, the repeal of the prohibition amendment, 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 strong demand upon the distillers for a 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 cottonseed oil and turpentine, has also tended to enlarge the demand upon white oak and other species used for these barrels.

ADVANTAGES OF WOODEN BARRELS

The advantages of wooden barrels may be summarized as follows:

1. Wooden barrels are generally waterproof, so that water cannot damage the contents of tight barrels.

2. A barrel is a most scientifically designed structure. Every part braces and strengthens the rest. The double arch of the

staves, one of the strongest forms of structure known to science, is the basis of barrel construction.

3. The contents of barrels are protected from heat and cold, because wood is a nonconductor of heat and therefore resists temperature changes. External heat make slow progress through the insulation afforded by the wooden barrel.

4. Wooden barrels are sanitary containers. Only fresh, clean wood that will not contaminate the contents is used, where there is a likelihood of contamination from external sources. The wooden barrel delivers the product, when once filled and closed, in the same condition as it was when packed, and is even proof against moisture if the barrel is tight.

5. Barrels possess great strength. The heads are held firmly in place by hoops. The chime protects the head. Wooden staves are cut with the grain to avoid splitting. Each stave is the keystone of the "arch."

6. Barrels are easily handled in rolling, lifting, and similar requirements in transport operations. Every barrel literally has its own "wheels."

7. They afford protection against theft and pilfering. They offer the best protection for the contents of any form of container.

CONVERSION OF SLACK COOPERAGE

Qualifications and woods used for slack cooperage. Almost any species of wood may be used for slack cooperage. Since this form of container must compete with such other forms of containers and packages as sacks, paper and cloth bags, fiber and wooden boxes and crates, the primary requisite is low cost of raw materials. Therefore, almost any kind of timber which can be supplied for stave and heading materials at relatively low cost is in demand. Lightness in weight to reduce shipping charges is also an important contributing factor. Woods that are easily worked, soft textured, and of uniform grain are preferred to hard, heavy, coarse woods. Those that dry and steam well and retain their form when bent are also in demand. Light-colored woods are in special demand for heading. Basswood is considered the best heading wood because of its light color, workability, lightness of weight, and freedom from gums, resins, etc. Woods that do not contain oils, resins, or discoloring substances likely to taint or affect the contents are considered desirable for both heading and stave material. For hoops, wood that is primarily tough, strong, and readily bent is preferred. Elm meets these requirements best. Formerly oak was the principal wood for staves and heading. With the rapid rise in the value of oak, however, elm, red gum, and tupelo gum came into service in the South, and beech, birch, and maple in the Lake States and in the Northeast. For several years red gum has been the leading stave wood because of its abundant supply and relatively low cost. Many staves and headings of this species are now shipped to European and South American markets. For other low-cost types of barrels, southern pine is widely used. In the West, Douglas fir, the pines, spruce, and hemlock are employed.

Manufacture of slack cooperage. Manufacture of the three component forms to make up slack barrels, namely, staves, headings, and hoops, occurs in separate mills. These three parts are assembled in shops, generally near the location where the barrels are finally used.

Manufacture of staves. For staves, bolts are quartered or halved, depending on their size, and cut into smaller flitches sufficiently large to yield staves 4″ to 5″ in width. Stave bolts were once rived with a maul and wedge, but this exceedingly wasteful method has been practically abandoned. Next, the flitches or bolts are put through a steaming process to soften them sufficiently to shear into staves. Well-steamed wood shears about one third more easily than green or wet wood and yields a brighter-colored and smoother stave. Elm, cottonwood, soft maple, and basswood require less steaming than gum, beech, hard maple, birch, and sycamore. The latter species are steamed usually for 24 hours. The bolts are loaded on trucks and rolled into steam tunnels of wood or concrete, 40′ to 50′ or more in length. Some mills have 15 tunnels arranged parallel to each other with a capacity of 9 cars for each tunnel, or 135 for all. These contain the equivalent of about 100,000 standard length staves.

The bolts then go to the equalizer, after being peeled of all bark. The equalizer cuts off both ends to the exact desired length and also makes them smooth and square. Each equalizing machine can turn out bolts for 50,000 staves daily.

Next the bolts or flitches are cut into staves with a stave cutter. The knives have faces ground to a circle of 20″ to give them the proper curvature. The bolts, placed in a tumbler, are moved against the knife which cuts the staves the desired width. One operator may cut approximately 125 staves per minute. Each stave-cutting machine may turn out 30,000 to 60,000 staves

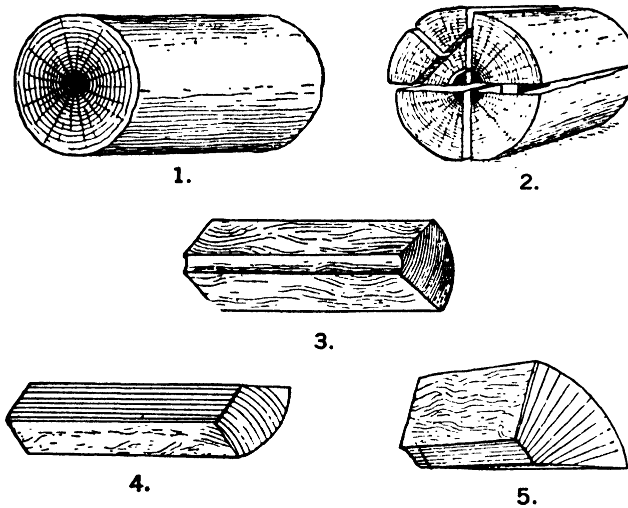


FIGURE 110. Illustrating methods of making staves and heading:

1. A 3′ bolt or log section used for staves.
2. Method of quartering and splitting large bolts. For tight cooperage, straight-grained wood must be used for splitting or sawing.
3. Stave bolt with heart center split off and equalized for length.
4. Method of sawing staves with cylinder stave machine.
5. Method of sawing bolt into heading pieces—usually 1″ thick at sap and ¾″ at heart and 24″ long.

in a 10-hour day. Sometimes woods which are subject to severe checking after the steaming and cutting process are made into staves on a cylindrical saw. The flitches or bolts are fed into the end of the cylinder, or drum saw, which is commonly found in the South. Then the staves are taken to a drying shed for seasoning. For 4 to 6 days they are laid on top of each other, curved sides fitting closely together. The piles of staves are made in the form of a crib and protected from the weather under open-air sheds. Seasoning requires 1 to 3 months, depending on the time of the year.

Next the staves are jointed on a machine driven by power. The jointer shapes the edges of the staves so that the finished barrel will have the required bilge. In staves with ¾″ bilge joints the ends of the staves are ¾″ narrower than the center. A bevel joint is preferred to a square joint to give a tighter package. At each downward stroke of the jointer knife, narrow

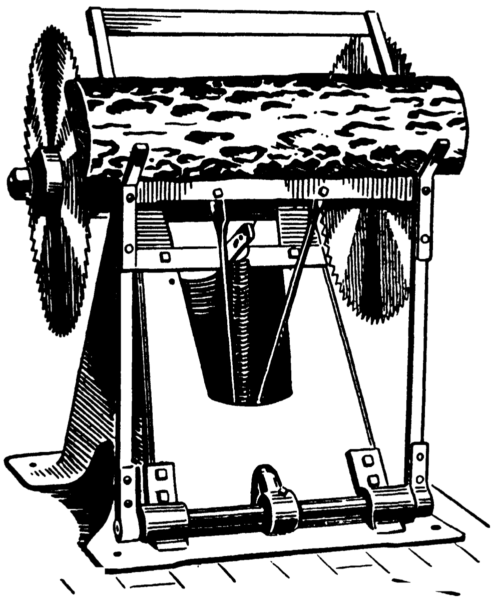


FIGURE 111. The Trevor stave bolt equalizer.

strips or edgings known as "listings" are removed. Each stave jointer has a capacity of about 10,000 staves per 10-hour day. For shipping purposes, staves are bundled in a stave press similar to a shingle, excelsior, or hay press in principle.

In many sections of the South there are separate stave and heading mills utilizing a great variety of hardwoods. In many cases, low-grade logs and logs of the lower-value species may be effectively used for slack staves and heading. There is a large stave mill at Sherard, Miss., which produces about 30,000 barrel staves per 8-hour day from gum, elm, and hackberry logs powered by a 98-hp. Diesel tractor engine. Steam is used for kiln-treating the stave blocks before cutting, and the entire plant formerly powered by steam was converted to Diesel power. This power is installed for the 54″ circular saw, sawdust conveyer, and stave-block conveyer, as well as the jointer.

Manufacture of headings. Bolts selected for headings are cut off (equalized) to the proper lengths, such as 22″ for sugar-

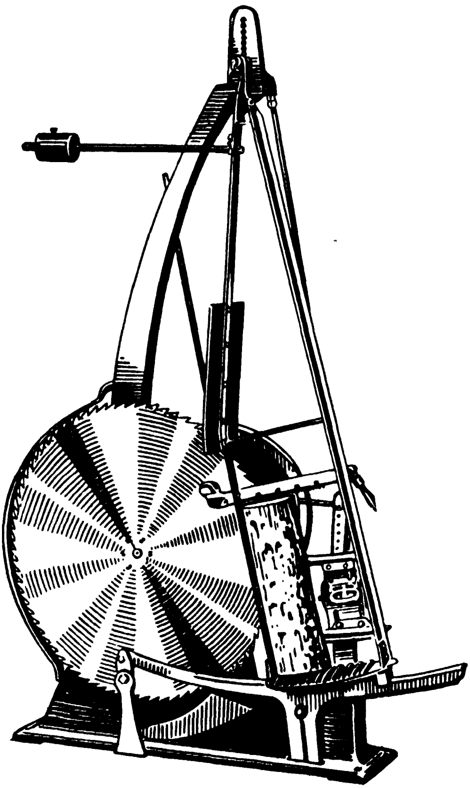


FIGURE 112. Heading sawing machine.

barrel heading, and then rossed to remove the bark or any accumulated sand, grit, etc. Bolts are transferred on live rolls to the heading saw, the larger bolts being quartered or halved. The heading saw is generally an upright, pendulous swing saw. With the harder and denser hardwoods, a 56″ saw with 80 teeth, 50-gage at the rim and 6-gage at the eye, running 1500 r.p.m., will give the best results. The heading saw cuts the stock about $\frac{7}{10}$″ in thickness, which when kiln-dried and surfaced is

$7/16''$ or $1/2''$ in thickness. Surfacing is usually done on one side. The heading boards are then placed on trucks which hold 500 to 1000 pieces and taken to the dry shed, where they remain 10 to 30 days between stickers. From the dry shed they are rolled onto trucks and taken to the dry kilns, of which there are many types, depending on the wishes and skill of the operator. The period of drying continues about 10 days in the dry kilns for northern hardwood, much less time for the softwoods. Then the stock goes to the heading mill where there are three machines: namely, the jointer, heading turner, and the heading press or baler. The jointer makes the edges smooth, but, even so, there will be a tight joint or "fit" when the heading pieces are placed together to form the barrel head. Then the separate pieces go to the matcher or heading turner. Operators assemble the heading pieces into sizes approximately the same diameter as the finished barrel head. Five to six pieces are used for sugar barrels, $19\frac{1}{8}''$ in diameter. These turned heads are piled separately, about 20 sets to the pile. The heading turner circles the finished barrel heading with a beveled edge. The jointed and matched parts are placed in a form or clamp which holds the pieces together. A concave saw cuts the boards in a circle with a beveled edge; the knife cuts the other bevel to meet it. Thus the heading is turned and finished in one operation.

Manufacture of hoops. Elm is the leading hoop wood because of its toughness, strength, and ability to retain these qualities when steamed, boiled, or bent. About 95% of all wooden hoops are made of this species. Occasionally oak, hickory, ash, black gum, and hackberry are used. Owing to the intrusion of metallic hoops, wooden hoops are being gradually displaced. Green sound, straight timber, free from knots and shakes and other defects, is preferred. The standard barrel hoop may vary 3′ to 8′ in length. Hoops are made both by the sawing and the cutting method. In the cutting method a hoop cutter, a lapper, and a jointer, a hoop planer, and a coiler are required. Hoops are made from planks at a sawmill by flitching. Hoops are conveyed to a boiling vat or tank and steamed and then taken to the coiling machines. Coiling is done while the wood is still hot and wet.

Annual production of slack cooperage. The largest production of slack cooperage was early in the twentieth century. The competition of paper and veneer containers has reduced the use of barrels. Before World War II about 22 million slack kegs and barrels were produced annually. The high level of industrial activity since the war has resulted in an annual production of about 35 million units.

Assembling. Assembling of the three parts of slack cooperage is done in shops at or near the location of final use. Sugar refineries, flour and cement mills, fruit and other warehouses

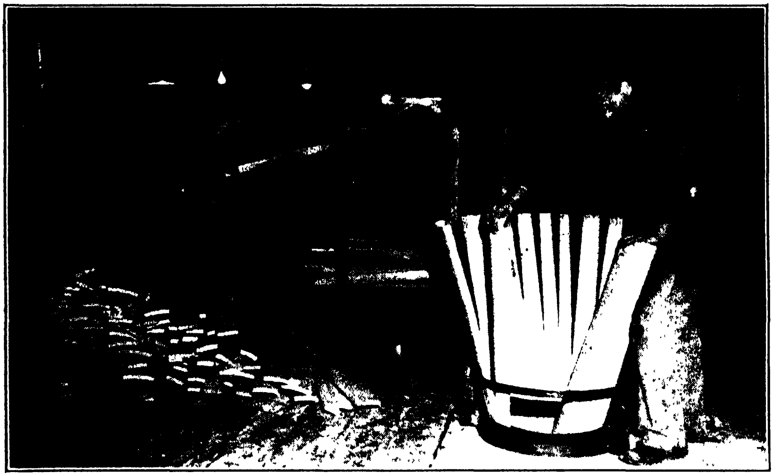


FIGURE 113. Raising or assembling barrels with oak staves cut on the Clark National Forest, Mo. Note the curve of each stave and the shape to provide for the bulge in the barrel. *Courtesy U. S. Forest Service.*

usually have cooperage shops operated in connection with them where large quantities of staves, heading, and hoops are supplied in carload lots and assembled in the final form. The process of putting barrels together consists of the following 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 across the ends of the staves on a bevel, from the groove to the end.

Utilization of waste. The slack cooperage industry offers many opportunities for the saving of woods waste. After an area has been logged, many small trees, tops, crooked trunks, and defective logs may be used for heading and staves. In many operations all

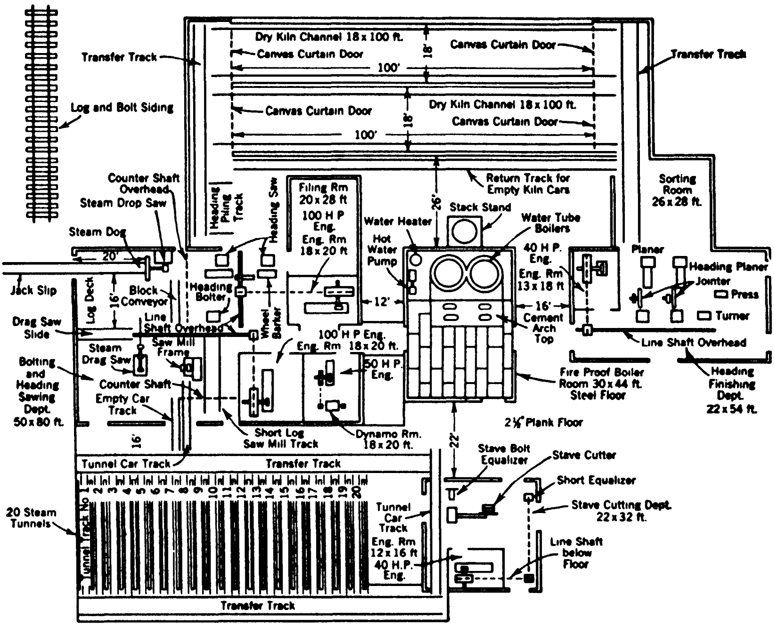


FIGURE 114. Ground plan of slack cooperage plant.

bolts 4′ long and 8″ or more in diameter are used for slack staves and heading. At some of the larger hardwood mills defective ends, trimming, slabs, and small logs are sent to heading mills operated in connection with the main sawmill. These illustrations indicate that this industry may be the means of salvaging large quantities of material otherwise wasted.

The manufacture of heading, staves, and hoops necessarily means the wastage of considerable wood. From 40 to 50% of log contents is lost in the conversion process. There is even a larger loss, up to 60%, in the manufacture of heading. Most of this wastage is unpreventable. The principal sources of waste are:

1. There is sometimes severe checking of bolts and logs due

to long exposure in the woods or at the mills. Green wood brought directly from the woods results in the best stock.

2. Logs suitable only for heading are cut into stave lengths or multiples thereof and in the process of manufacture are found to be useful only for heading. This often results from carelessness or from incompetent inspection or manufacture of the raw material.

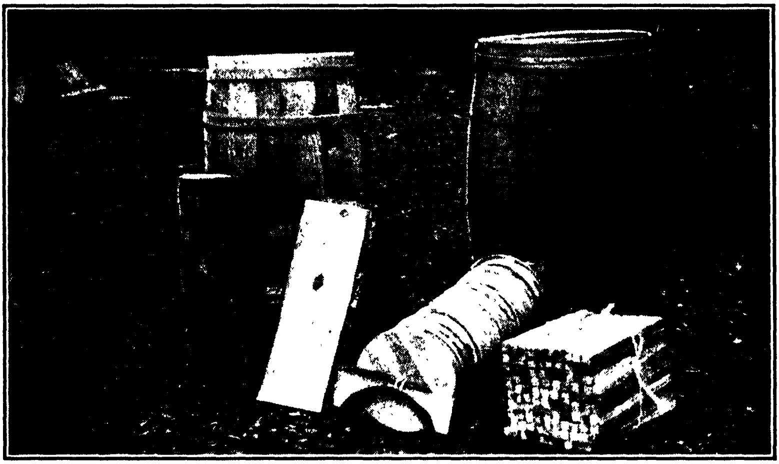


FIGURE 115. Potato barrel on left, fish barrel on right, together with hamper bottoms and cleats made from small-sized southern yellow pine bolts often secured from logging waste.

3. Logs cut for heading or staves of a certain size are later found useful only for staves or heading of shorter length, thus resulting in considerable loss in trimming. Also unnecessarily long lengths are frequently cut, such as 21″ bolts for 17⅛″ heading. Bolts intended for 32″ staves are frequently cut into 28½″ staves, etc.

4. There is sometimes faulty or careless manufacture, such as useless waste in jointing both staves and heading and quartering bolts for both parts.

Some of the larger forms of waste are utilized for trunk slats, crate and cleat stock, furniture parts, chair and ladder rungs, toy and novelty stock, etc. The principal forms of waste occurring in the process of manufacture partly described 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 sends its waste to the distillation plant.

SLACK-COOPERAGE SPECIFICATIONS

Staves—made principally of oak, gum (red, tupelo, and black), maple, ash, elm, beech, birch, cottonwood, basswood, among the hardwoods; and yellow pine, Douglas fir, and ponderosa pine, among the softwoods. Varying specifications for length, thickness, width, bilge, grain, seasoning, defects admitted, etc., for each type of barrel.

Heading—almost all species admitted and used, even different species in some heading. Usually from 14⅛" to 24" in length; in thickness ½" for less dense woods to 7/16" for heavy woods.

Hoops—all are generally of elm 3′ to 8′ long and ¼" × ⅛" × 1¼" up to 9/32" × 5/32" × 1⅜" in cross section.

CONVERSION OF TIGHT COOPERAGE

Special features. The tight cooperage industry is distinguished by the following:

1. Heavy drain on one species, white oak, which lends itself admirably for the purpose and for which no satisfactory substitutes have been devised.

2. Great waste attending the production and conversion of raw materials into finished forms. Formerly nearly all staves and headings were rived. Now only a small portion are produced in this way. Probably 50 to 70% of the raw material is lost in the conversion process. Only good-sized trees and clear, straight-grained boles can be used. Sapwood is considered a defect.

3. Production by small mills, which are frequently moved from place to place to take advantage of the best standing timber supply.

4. Highly specialized industry in that only one or two kinds of staves and heading are made at each mill. White oak comprises probably 80 to 85% of all the material used.

Annual production of tight cooperage. Although the use of wooden barrels is continued in the whisky industry, for most other uses metal containers are replacing tight cooperage. For example, in 1939 4.9 million barrels were used for contents other than beverage alcohol. In 1947 only 3.5 million barrels were used for such purposes. Before World War II about 16.2 million units were annually produced, whereas the annual postwar output has dropped to 9.3 million units. The annual production of whisky barrels and kegs in the same period rose from 1.8 million to 3.1 million.

FIGURE 116. Excellent stand of white oak timber on the Ozark National Forest. This is the largest body of standing white oak timber available for high-grade tight cooperage staves. *Courtesy U. S. Forest Service.*

Woods operations. As indicated, only the best and largest white oak timber is utilized, generally 15″ to 16″ or more d.b.h. Logs are cut up into bolts 2″ or more longer than the final intended length of staves and heading. Only the finest quality of staves are rived, as shown in the specifications.

After the logs are cut into bolt lengths they are sent to a circular drum saw where the staves are cut to the desired bevel or curvature. This saw is generally speeded at 1500 r.p.m., and each sawmill produces 8000 to 12,000 staves per day. The staves are then stacked for 2 to 6 months of seasoning.

Heading mills are operated along similar lines; that is, the logs are sawed into suitable lengths (bolts) somewhat longer than the desired length of heading. The machines commonly used in small 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. The final finishing of staves and heading, including planing, kiln drying, bending, and packing, is accomplished at large plants near or contiguous to the producing timber region.

FIGURE 117. Heading mill at Russellville, Ark. Much of this material comes from cutting area about 20 to 25 miles distant on the Ozark National Forest. *Courtesy U. S. Forest Service.*

Assembling. This process requires great care, experience, and skill because the finished product must be sufficiently tight to prevent leakage. The barrel must withstand transportation for great distances, with much rough handling, and must often resist great internal pressure from fermenting liquors.

The assembling machinery, therefore, must be very elaborate and exacting in its precision and design. Many improvements have been made over the old manual cooper or the machinery in use in the 1920's. Most of the developments have been in the direction of laborsaving devices. The machinery usually consists of the following:

A setting-up form with necessary truss hoops, power windlass, heater, trusser, crozer, which makes a groove in which the heading fits into the staves, head-setting form, lath, thin hoop driver,

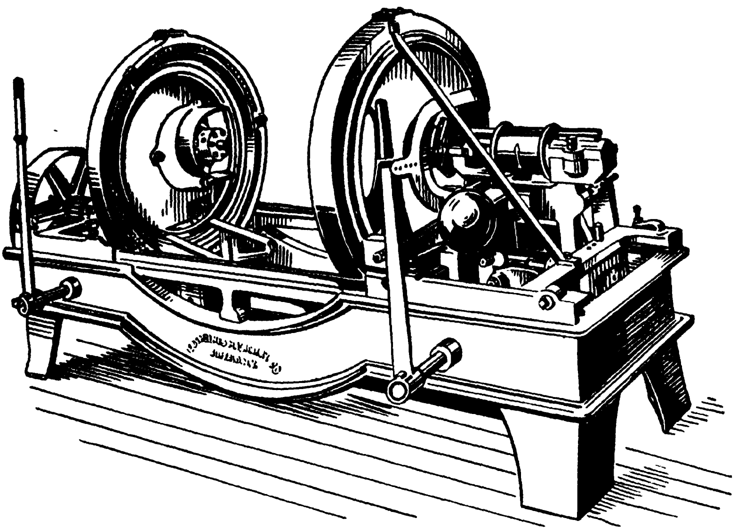


FIGURE 118. Machine for chamfering, howeling, and crozing tight barrels.

FIGURE 119. Assembling barrels with white oak staves cut from the Ozark National forests in the plant of the Chickasaw Wood Products Company.
Courtesy U. S. Forest Service.

heading-up machine, bung borer, and barrel tester. In many plants the heading and staves are delivered in bundles, enough staves, usually 18 in one bundle, for one barrel. First, the staves are planed on both sides and finish-jointed. Then they are set up in a form by a "raiser" or "setter up" who sends them to the steamers where they are heated 3 to 5 minutes to increase their flexibility. Then the truss hoops are driven, both at the head and bilge, in a truss-hoop driving machine. This insures tight joints. Next, the staves are windlassed by power with a wire rope to draw the top or loose ends of the staves together until the head truss hoop can be thrown over them. After drying, the barrel goes to the crozing machine which crozes, chimes, and howels the staves in one operation and finishes both ends at the same time.

National Forest practices and utilization. Excellent standards of close utilization are observed in connection with the felling of white oak on U. S. Forest Service properties, particularly on the Ozark National Forest in Arkansas. Some of the best-quality white oak for bourbon-whisky staves is produced in this section. This white oak is free from the so-called flagworm or ambrosia beetle which degrades white oak found in the southern Appalachians and Alleghany section.

The average-sized white oak on the Ozark National Forest is about 22″ d.b.h., and the merchantable variation is generally 16″ to 36″. The average tree contains about 200 b.f. and there are 1½ merchantable trees per acre, which means a yield of 300 b.f. per acre, the remainder of the stand being composed of black and red oak. Even with this light stand, however, there is a high stumpage value, expressed either in area or thousand board feet. All material that is suitable for staves 30″ or longer may be taken, and any material that will yield heading 19″ or longer must be taken. Not more than 75% of the total stand of trees 16″ and larger is removed, and all trees containing a net scale of 25% of the volume of the tree must be utilized. Three inches is allowed for trimming length on all 16″ logs, and all trees must be taken to a top diameter limit of 12″. Stumps may not be cut higher than 12″.

The Ozark National Forest in Arkansas contains the largest remaining volume of virgin white oak operable for staves in any single ownership. The allowable annual cut on this National Forest is 3800 M b.f. Trees are marked for cutting down to 14" in diameter and require utilization to a 12" top when merchantable. Probably higher prices are paid for tight-cooperage staves than for any other important forest product. Stumpage values advanced from about $16 in 1934 to about $23 in 1939 and $82.85 in 1949. A total of about 50 million b.f. have been cut for white oak staves during the 9-year period 1941 to 1949, inclusive, on the Ozark National Forest, according to P. H. Gerrard, forest supervisor.

TIGHT-COOPERAGE SPECIFICATIONS

Staves—white oak bourbon, 34", 35", and 35½" long, highest grade, no sapwood, largely for export, straight grained, ⅞" in thickness when kiln-dried.

White oak alcohol and whisky, 34" long, ¾" thick when kiln-dried.

White oak sawed spirit Bourbon and rye whisky, 34", 35", 36" long, ¾", ⅞", and 1" thick when kiln-dried.

White oak sawed "half-stave" whisky and alcohol, 26" to 30" long, 11/16" or ¾" thick.

White oak sawed wine barrel, 34" long, 11/16" thick.

White and red oak oil or tierce, 34", 35", and 36" long, ¾" thick.

Turpentine, 34" long, ¾" thick.

Cuban tierce, 35" long, ¾" thick.

Pork (white and red oak and ash), 30" long, ⅝" thick.

Gum (red gum) and several other miscellaneous classes.

Heading—may be circled or square and, in general, must follow rigid or broad specifications to conform to stave material. Thicknesses are 1" kiln-dried for the best and down to ⅝" for pork barrels.

Hoops—all tight cooperage has metal hoops to hold the barrels together.

Plywood barrel staves. Plywood barrel staves are usually made with an odd number of layers of veneer such as 9 or 11. The surface plies are usually of white oak, but the inner plies may be of cheaper hardwood. The center ply and the ply next to each surface ply are generally laid at right angles to the stave, whereas all other plies are laid parallel with the stave. The dry veneers may be moistened before gluing to make them bend more readily. The glue-covered veneers are assembled and placed in a hot press which has the proper-shaped plates to mold the stave into the required compound curvature. The waterproof glue is cured in the press at about 300°F. After removal from the press, the staves are machined to exact size so that 9 staves will join to form a perfect barrel. The resultant barrel if properly made is a very high-quality product, but it is also rather expensive.

29 · BOXES AND CRATING MATERIALS *

The manufacture of boxes, crating stock, and their parts, known as shooks, is one of the most important wood-using industries of the United States. It is very closely associated with the lumber industry because the raw material is usually supplied in the form of lumber, but there are many sawmills and industries that produce these materials as the major product. The volume requirements for wooden containers and crating materials are greater than for any other use except general construction. They exceed the quantities utilized for furniture, car construction, vehicles, and many other products. During World War II, 2400 box plants were in operation in this country, and they consumed one half of the annual lumber production (approximately 15 billion b.f.). Since then, the tendency has been to resume normal conditions with increased competition from fiberboard boxes.

About 14% of the normal annual lumber cut is used for the manufacture of nailed wood boxes and crates. This is equivalent to 5040 million b.f. of lumber. The production of wire-bound boxes and crates consumes 260 million b.f. of lumber and 180 million b.f. of veneer per year. In addition, 625 million sq. ft. of plywood are directly manufactured into wooden containers annually.

Although fiberboard, paper, and other materials have taken the place, to some extent, of wooden containers, the consumption of lumber and other materials for this purpose has steadily increased over a long period of years. Enormous quantities of boxes are annually required for the packing and shipment of citrus fruits (oranges, lemons, grapefruit, and tangerines), canned goods, vegetables, milk, fish, apples, and other varieties of fruits. Twenty to twenty-five million boxes are utilized annually for the California citrus trade and large additional quantities for the shipment of Florida and Texas citrus fruits. Probably the greatest

* Reviewed and corrected by Gordon E. Falkenau, container consultant, engineering department, E. I. duPont de Nemours & Company, Wilmington, Del.

single use is for the shipment of canned goods. Although vast quantities are required for the shipment of fruits and vegetables, still larger quantities are needed for industrial and similar purposes. At one time, more than 50% of the total box-shook production was in the East, but with the increased manufacture of ponderosa, sugar, and Idaho white pines in the West the production of box shooks in the West has increased.

There are about 800 box plants (not including sawmills that have box or shook factories operated in connection with them), employing 44,600 wage earners and turning out a yearly product worth $365,300,000. The annual payroll for production workers at these plants amounts to $85,800,000.

The various types of boxes produced are:

Boxes made of lumber, not wire-bound.
Veneer-panel types, not wire-bound.
Boxes made of lumber, wire-bound.
Veneer-panel types, wire-bound.
Combination wood and fiber.

Veneer and plywood have advanced materially for use in boxes, crates, and similar containers, in addition to vast quantities of hampers, baskets, and so on, not included in this classification. The proportion of veneers employed in box construction is increasing. The number of wire-bound crates and boxes increased in 1949 about 55% over 1944, the peak war year.

Modern materials-handling methods throughout industrial plants, commercial warehouses, and public transportation systems in the United States made tremendous strides in advancing the use of many forms of containers during and since World War II. Consequently, a large volume of lumber is now utilized in the fabrication of pallets, skids, and specially designed tote boxes to expedite the handling of raw materials, work in process, finished goods, and multiple units of packaged items already boxed for shipment. Box plants manufacture a major share of the pallets and skids employed for these purposes.

QUALITIES DESIRED IN WOODS USED FOR BOXES

These may be summarized as follows:

1. Lightness in weight is important because domestic transportation charges are based on weight. For this reason, lumber of low density, veneers and plywood are favored.

2. Strength is vitally important for the shipment of heavy commodities. The proper placement and use of nails and steel strapping will greatly strengthen a box made of comparatively weak wood. Where great strength is required, as for the shipment of concentrated loads, machinery, vehicles, and large metal castings, hardwoods or the high density softwoods are preferred.

3. Nail-holding power is obviously of considerable importance. Hardwoods hold nails better than softwoods.

4. A smooth and attractive surface, preferably light in color, which takes printing, stenciling, and labeling readily, is desirable.

5. Softness and workability are desirable.

6. Sanitary qualities, such as exist in odorless and tasteless woods and woods that do not readily absorb odors are preferred for the shipment of foods.

The pines, especially northern white, Idaho white, ponderosa, sugar, and Norway pines, and Sitka spruce best meet these requirements. Southern pine, especially shortleaf, is also widely preferred. Other woods of relatively light weight and workable qualities which possess other favorable properties are red gum, cottonwood, hemlock, eastern spruce, aspen, and yellow poplar.

SPECIES USED

For many years northern white pine formed a large share of the total amount of lumber used. Until about 1910, this species supplied about one half of all the requirements. Then southern pines became widely favored as well as red gum and spruce. Since the 1930's the tendency has been towards increased use of ponderosa pine, sugar pine, Idaho white pine, and Sitka spruce for box shooks from the far western states, including Oregon, California, Washington, and Idaho. It is estimated that 80% of all lumber for box shooks is supplied by southern pine, ponderosa pine, Idaho white pine, northern white pine, hemlock, and spruce. Large quantities of red gum, black gum, tupelo gum, cottonwood, and yellow poplar are also employed in the South. In fact, practically every wood except black walnut, locust, cherry, ash, and hickory is utilized for box and crating stock.

Large quantities of second-growth timber in the South and North are extensively used for boxboards. As the specifications permit the use of knotty lumber, low grades from the poorer logs, top logs, and the inferior grades from the larger logs are commonly employed. In the large sawmills of the South and Pacific Coast, slabs, edgings, miscuts, and trimmings, as well as lower grades of lumber, are generally utilized for shooks and cleats. From the small mills, tie sidings, the more defective grades of lumber, and sometimes the entire output may be converted into boxboards. The softwood lumber industry of New England, especially those manufacturing white pine and spruce, convert a large part of their output into box shooks. Although the industry in New England has suffered from the invasion of fiberboard, paper, and other types of shipping containers, there are still large quantities employed for these purposes.

The principal producing states are Oregon, Washington, California, Michigan, North Carolina, and Massachusetts. The industry is also very important in New York, Idaho, Illinois, Pennsylvania, Virginia, Florida, and Alabama. The industry is found in every forested state of the Nation to meet the local, regional, or national requirements. The U. S. Forest Products Laboratory at Madison, Wis., and various commercial and private container-testing laboratories have all conducted research programs to determine the best methods of nailing and reinforcing boxes and of improving their design to secure maximum protection to contents during shipment at the most economical cost.

The important consuming centers are California, Florida, Texas, and other fruit- and vegetable-growing sections, Washington, Oregon, Virginia, New York, and Missouri for the apple trade, important canning industries, and other industries using boxes for the shipment of widely diversified commodities.

MANUFACTURE

In connection with the larger sawmills of the Pacific Coast States and Idaho, the box-shook factory is one of the important departments, especially at the pine and spruce mills. An important problem in the industry is to cut up the lower grades of lumber and remove the larger and more serious defects, such as knots, checks, and pitch pockets, with as little waste as possible and with the minimum expenditure of labor and power. Waste in making boxes from the original boards is generally 15 to 30%, or more. If boxes were made with no knots or other defects, it would result in a wastage of 60 to 80%, most of which could not be salvaged. The presence of knots does not interfere with strength or usefulness, provided they do not occur along the edges or in positions where they will be reached by nails.

The specifications as to sizes and thicknesses of the tops, sides, and bottoms of boxes vary widely. Wood boxes and crates may be generally classified as to construction as (1) nailed, (2) wire-bound, (3) cleated plywood, and (4) cleated fiberboard. The wire-bound box has entered the trade prominently, especially in connection with the wire-bound veneer boxes for the citrus and vegetable trade in the South. Cleated plywood and cleated fiberboard boxes are now widely used for shipping industrial products, textiles, thread, and yarn. However, the nailed box is still the most frequently employed and probably constitutes 75 to 80% of all wood boxes used in the United States. Conventional thicknesses are 1″. 1¼″, 1½″, 1¾″, and 2″ in the rough. These are resawed in the box factory to 3/16″, ¼″, ⅜″, ½″, ⅝″, etc., in thickness. The widths vary from 3″ to 12″, or more, although for some purposes there are definite stock widths such as 3″, 4″, 6″, 8″, 10″, and 12″. Lengths range generally from 12″ up to several feet. As a result of the experience gained in designing large crates for heavy vehicles and equipment during World War II, lumber used now for crating automobiles for export shipment is in finished thicknesses rather than in the rough.

A typical fruit crate consists of a top, bottom, and two sides, all 12″ × 24″, and three panels 12″ square, one for each end and one in the middle of the crate. Orange crates are 12¼″ × 27″ with panels 11¾″ × 11¾″ and 13/16″ thick. Formerly they were made of solid wood. The panel ends are often made of a frame of 4 pieces mortised together and covered on each side with veneer. The sides are often made of two or three strips of veneer, fastened together by two or three cleats. This saves lumber and weight. Tops and bottoms are occasionally of solid wood. Many wire-bound veneer crates are used in Florida, Texas, and California.

Some lumber manufacturers' associations recognize definite box grades. Generally Nos. 2 Common, 3 Common, and 4 Common of the pines are chosen for making boxes. In New England, round-edge lumber from white pine is commonly used. A regular box grade is still recognized in the lumber trade of the South Atlantic States, which provide large quantities of shooks for the Baltimore, Philadelphia, and New York box trade.

The details of the specifications, sizes, and methods of manufacture vary so greatly that it would be impossible to treat the

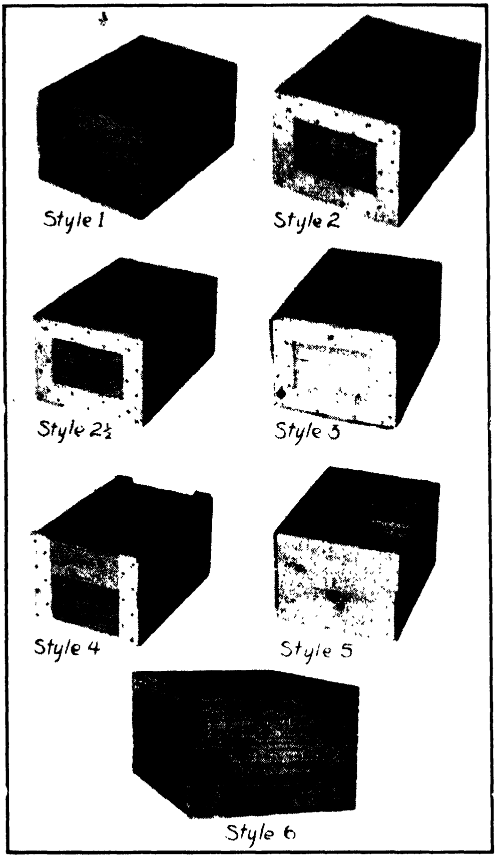


FIGURE 120. Seven different standard styles of nailed wooden boxes. Style 6 is the lock-corner type; the others are of various types of construction and cleat placement. There are literally hundreds of different sizes and specifications required for boxes in various parts of the country.

subject adequately in this book. Of the total costs of production, the costs of lumber delivered at the box factory represents about 70%, the labor costs about 20%, and the remainder of 10% is for overhead expenses, including salaries, insurance, taxes, depreciation, general repairs, and supplies.

OPPORTUNITIES FOR SALVAGING WASTE

This industry is one of the most important in utilizing materials that would otherwise be wasted or completely lost. The lower grades (No. 2 common or lower) represent generally 50 to 70% or more of all lumber produced, depending on the species. Without this significant outlet for low-grade lumber, it would be practically impossible to utilize a large portion of it. Furthermore, box shooks are frequently made from top logs, bolts, and sawmill waste which otherwise might be a complete loss. Vast quantities of slabs, edgings, trimmings, miscuts, cross-tie sidings, rotary-veneer cores, and other materials, such as defective lumber and short lengths, are converted into box shooks in addition to the low-grade lumber. The wooden box has been demonstrated as a superior form of container for the safe shipment and protection of many commodities, and this phase of forest utilization should be encouraged and increased. Furthermore, some species, heretofore little utilized, such as tupelo, black and water gums, the western true firs, cottonwood, and aspen, for which there may be a less profitable outlet, are frequently converted into box shooks and successfully utilized.

PART V

Mechanically Reduced Products

30 · EXCELSIOR

Excelsior consists of narrow, thin strands or shreds of light-colored and soft-textured wood made by the rapid movement of knives or spurs of fine steel teeth against a bolt. The spurs slit the wood and are followed by a knife which pares this slitted material from the bolt in a longitudinal direction.

Excelsior has been made in the United States for more than 75 years. In Europe, it is employed for a much greater variety of purposes than in this country. The term excelsior was at first a trade name used in advertising the product of a single company. Originally used only for upholstering, particularly mattress stuffing, within the twentieth century its use has broadened greatly. Fruit, glassware, pottery, furniture, and many other commodities are packed in excelsior to be shipped, although its principal outlet is still the manufacture of mattresses and upholstery work. Other miscellaneous uses are kennel and stable bedding, decoration, and the stuffing of toys, dolls, and novelties. In Europe it is used as a substitute for absorbent lint and for filtration.

Properties desired. Resilience, the ability to expand readily after compression, is the most important property of excelsior. It must also be light in weight and straight grained. The fibers should be strong and tough, but soft and resilient. Thus excelsior must possess the quality of tending to resume its original condition after compression. Moreover, it should be free from odor or undue quantities of resin, gums, and similar constituents which are likely to affect or discolor any material with which it comes in contact.

Woods used. Basswood best fulfills the necessary qualifications for excelsior. This wood brings the best prices on the market, but, owing to its limited supply, its demand for other uses, and the availability of other cheaper woods, basswood represents only a small part of the total quantity used. Cottonwood, including various species of poplar and aspen, comprises about one half of all the wood used for excelsior. The other species in order of importance are yellow pine which makes up about one third of the total production, yellow poplar, basswood, and very small quantities of white pine, willow, and northern white cedar. Peeled excelsior wood costs $10 to $21 per cord delivered at the plant. The total consumption of wood for excelsior was 135,949 cords in 1947. This produced 153,766 tons of excelsior.

An experienced man can fell the trees, peel the bark, cut into bolt lengths and pile about one cord per day. Spring cutting is preferred when bark peels most easily.

Manufacture and use. Wood used for excelsior is produced in the form of bolts 4″ or more in diameter, cut to 38″ and 55″ lengths. Machines are designed for 18″ or 24″ bolts. The bolts

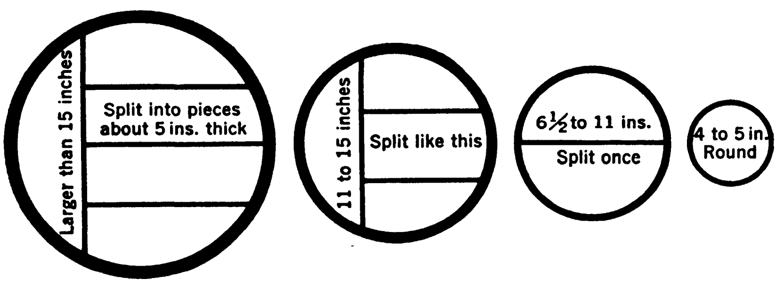


FIGURE 121. Method of splitting various size bolts for use in excelsior machines.

should be free from knots, straight grained, sound, and devoid of bark or burned wood. The wood is generally peeled and well seasoned. After being seasoned, the bolts are cut to 18″ lengths. Bolts that are too dry are not desirable, and so they should never be seasoned more than 2 years. Bolts seasoned 6 to 18 months are preferred. Bolts 7″ to 11″ in diameter are usually split once. Those 11″ to 15″ and more are split into four pieces; those above 15″ are split into pieces about 5″ thick.

The capital expenditure required for the installation of excelsior machinery is relatively low. A 20-machine plant produces about 12 tons of excelsior daily and normally costs about $20,000.

There are two types of machines: namely, upright and horizontal machines, which can be purchased in single units or in blocks of any desired number. A complete plant consists of a battery of these machines, a wood splitter, trimming saws, balers, conveyers, knife and spur grinder, and other miscellaneous tools and equipment.

FIGURE 122. Excelsior being made on upright or vertical machines from southern yellow pine and hardwood veneer cores. This represents a recent and efficient development in the utilization of materials formerly wasted.

Excelsior is graded commercially according to thickness and width of the strands, as well as kind and quality of the wood. Standard grades are 18″ long and $\frac{1}{100}''$ thick and are divided into width classes of $\frac{1}{26}''$, $\frac{1}{8}''$, and $\frac{7}{32}''$. The finest and most expensive grades, often known as wood wool, sometimes are made as fine as $\frac{1}{200}''$ thick and $\frac{1}{32}''$ wide. Approximately 80% of the total output of excelsior is from the medium and coarse grades, in thickness and width.

Aspen excelsior is produced largely in Michigan and Wisconsin, where the industry is centered. Virginia is the center of production of yellow pine excelsior, which is also made in Mississippi, Arkansas, and Louisiana. Basswood excelsior comes chiefly from Wisconsin.

The number of plants making excelsior has experienced a certain amount of fluctuation. There were 95 plants in 1919, 66 in 1929, 48 in 1935, 53 in 1939, and 56 in 1947.

Excelsior is sold by the ton and packed in bales weighing about 100 lb. each. The average price is $38 per ton, but high-quality excelsior when sold in smaller lots may bring as much as $3.50 per hundredweight, which is equal to $70 per ton. Sometimes bales of 200 lb. or more, are made. A standard cord of 128 cu. ft.

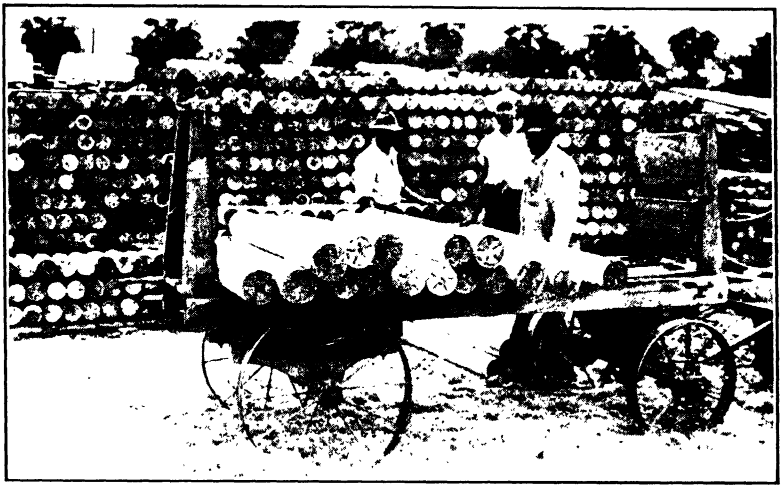


FIGURE 123. Cores left after manufacture of rotary-cut veneers piled before manufacture into excelsior at Ocala, Fla.

makes about a ton of excelsior, although the amount ranges from 1800 to 2200 lb., depending on the size of the bolts, size of the strands, volume of loss due to defects, and the kind of wood used. The normal loss to be expected in excelsior manufacture is about one fourth of the original wood volume. The average normal production is about 150,000 tons annually. Such a production calls for 150,000 to 170,000 cords of wood annually. A representative plant, equipped with 4- to 8-block horizontal machines, uses 20 to 24 cords of wood per day, with an output of about 20 tons of excelsior in 10 hours. The following employees are required: 4 machine operators, 2 balers, 2 helpers, 2 tiers and 2 weighers, 1 sawyer to square blocks, 1 assistant, 1 truck driver to bring in the bolts, 1 man to load cars or pile the product in the warehouse, 1 fireman and 1 engineer, 1 general helper to look after oiling and repairs, and 1 foreman to supervise the entire operation. This makes a total of 20 men in a representative plant.

In determining costs, purchase of wood comprises roughly about one half of the total, the remainder consisting of cost of superintendence, selling charges, and such overhead expenses as taxes, interest, insurance, and depreciation.

Excelsior is a staple article used by upholsterers and manufacturers of carriages, automobiles, mattresses, and furniture. It is also used for packing and shipping glassware, china, bottled goods, toys, hardware, furniture, and other articles where a material that is elastic, odorless, and free of dust and dirt is required.

31 · WOOD FLOUR *

Wood flour is a fine flourlike substance composed of finely divided wood particles. It is generally produced from the dry sawdust or planer shavings of such species as white pine, aspen, spruce, and hemlock. For certain products basswood, cottonwood, yellow poplar, willow, redwood, and maple may find limited use.

There are four general methods of producing wood flour:

1. By recovery of sander dust or by segregating the finer particles from sawdust.

2. By grinding between two stone disks like a cereal flour mill or in a modern attrition mill which employs corrugated metal disks in place of grinding stones. If the disks revolve in opposite directions, it is called a double-attrition mill; if only one disk revolves, it is called a single-attrition mill.

3. By impact fragmentation in a hammer mill, which usually consists of a shaft with loosely mounted hammers that barely clear a containing cylinder when the shaft rotates at high speed. The hammers pound against the particles and break them up.

4. By high-pressure crushing between a moving roller and a stationary surface called an anvil.

The flour is generally separated by air screening or by mechanical screening into different sizes to meet the various commercial specifications and then packed in bags or in bales for shipment.

Wood flour is generally graded into three grades: granularmetric, technical, and nontechnical. As the names implies, granularmetric flour must meet rigid requirements as to particle size. It is a special grade of technical flour and must be very uniform in technical properties. The regular grades of technical flour must meet definite specifications as to size, species, color, specific gravity, resin content, absorptiveness or other properties. Nontechnical flour is a common grade, with less rigid specification as to properties and species. It is usually coarser and is used in cheaper products. Prices for wood flour range from $20 per

* Reviewed and checked by H. C. Jack, president of Wood Flour, Inc.

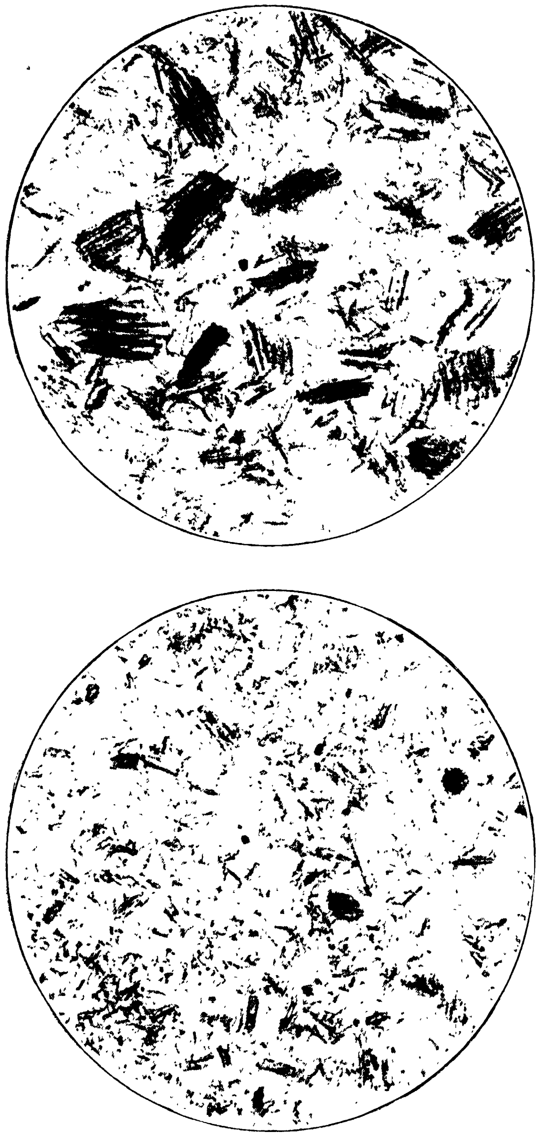


FIGURE 124. Microphotographs showing magnification of 30 times the normal size of two types of wood flour. Above is a coarse-fibered wood flour and below a much finer grade. The one above shows fibers not completely separated; also the fibers are of greater length. This type of wood flour forms a high percentage of the total production.

ton for the cheaper grades up to $85 per ton for the finer sizes of granularmetric flour.

The annual consumption of wood flour in the United States is about 80,000 tons. The bulk of this production is in the lower grades and goes into composition flooring and roofing, linoleum, plastics and other molded products. In addition it has many other uses in which it plays the part of an absorbent, a reactive substance, an inert filler, or a mild abrasive. In certain ceramic industries it is used as a "burnout" material to control porosity. It also finds use in dynamite, wallpaper, artificial wood boards, fur cleaners, hand cleaners, and in a multitude of molded products and plastics.

The manufacture of wood flour involves an explosion hazard that requires special handling. The grinding of wood in the form of shavings, sawdust, or wood blocks creates a dust that is subject to explosion. If the dust concentration is very heavy, no explosion can occur, but, when the dust concentration and moisture conditions are suitable, and if at the same time there should be a spark, a dust explosion will occur.

32 · SAWDUST, SHAVINGS, AND WOOD MOLASSES FOR STOCK FEED

There is an enormous volume of sawdust and shavings produced in the conversion of raw materials, such as logs and bolts, to the ultimate useful forms. In normal years there is an equivalent of 4 to 6 billion b.f. of good wood produced in the form of sawdust and a vast additional amount in the form of shavings, when rough lumber is reduced at the planing mills to the finished or dressed form of lumber. The possible use of this material has always been a problem in the American lumber industry. Until recently, considerable expense was incurred in the disposal of large quantities of sawdust by means of waste burners. Some of it was consumed underneath boilers to generate steam or electric power. Many state laws prohibit the dumping of excess quantities into streams.

Within recent years much study has been devoted to this large problem, and considerable advances have been made in profitable utilization. There is a dearth of supply in many sections and a huge surplus in others. The problem of profitable use is largely one of transportation and concentration of material at supply centers. In one city alone more than 12,000 carloads, or 360,000 tons, are sold annually. Many industries, including linoleum, plastics, and explosives, consume large quantities of finely ground sawdust and wood flour, which is generally manufactured from sawdust. The profitable utilization of sawdust is closely related to the use of various forms of wood pulp and its products, as described in Part III. The profitable marketing and use of sawdust are limited by the following factors: (1) assembling and storage charges, (2) transportation charges to consuming centers, and (3) quality and quantity of sawdust available. Many outlets require sawdust to be of only one species and of uniform texture. In mills that produce several different species and perhaps both hardwoods and softwoods, it is impossible to separate the product as required by some users.

At the large Weyerhaeuser sawmills at Longview and Everett, Wash., and Springfield, Oreg., there is literally no waste. All materials formerly wasted such as bark, slabs, edgings, sawdust, shavings, miscuts, and defective wood are completely recovered and utilized. Much additional material is secured from logging

FIGURE 125. A typical view of sawdust pile found at many of the 60,000 sawmills in the United States. At some of the large western mills the disposal of sawdust is an important and expensive problem. More and more of this sawdust is being utilized for industrial processes. In this illustration blowers take sawdust out to these piles. At large sawmills at Springfield, Oreg., and at Longview and Everett, Wash., there is complete utilization of the primary product: logs including sawdust and materials usually lost or disposed of at great expense. *Courtesy K. S. Brown, Seattle.*

operations by prelogging and relogging of materials that would otherwise be wasted. No waste burners are in use. The mill at Springfield, opened in 1949, is a complete and modern example of integrated and efficient utilization of the raw material.

PRINCIPAL USES OF SAWDUST

Uses of sawdust may be classified in a number of groups. Among the principal ones recognized are the following:

1. As an absorbent and for insulating and packing purposes. Large quantities are used in butcher shops, packing houses, and stables; in nursery work; in the cleaning of metal products and utensils and the conditioning of furs and leather; in packing of grapes and other commodities; in curing cement and smoking meat; and in various forms of insulation. Many plants, shrubs, trees, and other nursery products are shipped in moist sawdust. The leather industries consume 1100 tons annually. The California grape industry uses 4000 tons or more of sawdust annually, sawdust having replaced cork dust for this purpose. Spruce sawdust is preferred for grape packing because it is odorless, tasteless, and possesses excellent absorptive qualities.

2. Fuel. The most important single use of sawdust is for fuel. When mixed with hogged or chipped wood from sawmills, it is widely employed for domestic heating purposes as well as for the heating of industrial plants, apartment houses, and so on, in the Pacific Northwest. Special furnaces have been designed to use enormous quantities, estimated to be the equivalent in heating value of more than 200 million gal. of crude oil. Many thousand sawdust burners are used in Portland and an equal number in Seattle and vicinity. Sawdust may be consumed in hot-air, hot-water, or steam furnaces with relatively low additional cost for special grates. Sawdust is also a principal source of power, in combination with other materials, for sawmills and other industrial enterprises. Many attempts have been made to convert sawdust into various forms of briquettes. No wide development of this kind, however, is in commercial use except with Pres-to-logs of which more than 300,000 tons are annually produced as described elsewhere.

3. Chemical products. Destructive distillation and steam distillation of sawdust have been attempted, but not on a commercial scale. Several plants have been built for production of ethyl alcohol from wood waste, but they have not as yet proved economically profitable in a competitive peacetime market. The use of shavings for making briquettes has been developed successfully, however, as is described under a separate heading in Part VI.

4. Miscellaneous products. The most important developments in the use of sawdust have been in the manufacture of wood flour, plasterboards, composition flooring, certain forms of plastics, concrete-floor tiles, roofing, slabs, clay products, and abrasives. Wood flour is a finely ground substance made of sawdust. A large quantity is also consumed in the manufacture of gypsum plasterboards. Sawdust supplies resilience in several forms of composition-flooring material and fiberboards. It sometimes comprises 50 to 70% of the total volume of materials used for these purposes. Concrete made with a cement-sawdust ratio of 1:3½ can be nailed and sawed. When employed in concrete and stucco, it increases the lightness and porosity and thus contributes to the insulating qualities of these materials. It is added to clay for the production of porous tile which, when burned, leaves cavities or air spaces which in turn add to its insulation value and light weight. Sawdust is widely favored in many sections of Europe for composition flooring. Hardwood sawdust is used in various forms of fabricated or patented shingles. Sawdust of low moisture content is preferred for this purpose, especially sawdust of oak, ash, and similar dense hardwoods. Approximately 7000 tons are utilized in the manufacture of abrasives, principally as an accessory during the manufacturing process.

5. Minor uses. Sawdust is also widely favored as a filler or stuffing material for dolls, toys, furniture, cheap mattresses, and other products where a filler of this type is needed. It is employed in the manufacture of hand soaps and, when treated with chemicals, is used as a moth deterrent, a filtrant for oil and gas, and in the manufacture of explosives, railroad signal rockets, torpedoes, etc.

EXAMPLES OF SAWDUST UTILIZATION

One concern specializing in the sale of sawdust in the Northeast uses 1500 to 2500 tons of dried sawdust per year. This is exclusively birch, beech, and hard maple sawdust; that from ash, oak, soft maple and softwoods cannot be used for these specialized purposes. The sawdust is dried immediately from the headsaw to prevent oxidation and discoloration in large rotary steam-tube driers. A series of gyrating screens separate it into 7 different grades. These are put into burlap or multiwall paper bags and shipped to final users for cleaning, polishing, and drying in such industries as furs, metals, and electroplating. Machinery for this process costs $15,000 to $20,000. Some attempts to season, grade, bag, ship, and sell sawdust properly have met with financial failure because of shipping charges and high handling and selling expenses.

Prespine.* Prespine is a synthetic wood panel made largely from shavings, sawdust, and wood particles accumulating from the manufacture of millwork at one of the largest woodworking establishments in the United States located at Clinton, Iowa. This material, formerly used to fire the mill's boilers, is processed under heat and pressure and bonded together by a synthetic resin. From the cutoff saws, molders and ripsaws, as well as planers and other woodworking machines, there is a steady flow of shavings, sawdust, and waste from this large mill established in 1866. All accumulating wood waste, including knots and pitch pockets, are sent through a hogging machine. This finely ground material is mixed with a bonding agent known as Resinox, fed into trays, and under heat and pressure compressed into panels ¼″ thick. The resultant panel can be sawed, planed, nailed, and painted. The wood that goes largely into this material is ponderosa pine with a very small quantity of other species. The total production of Prespine, approximately 2,500,000 sq. ft. per year, is employed only in the manufacture of company products such as kitchen units and panels for interior and exterior doors.

A concern in Gardner, Mass., utilizes waste material, such as sawdust, shavings, and defective wood, from the manufacture of furniture in that important woodworking center. This is largely hardwood waste of beech, birch, and maple. It is hogged and passed through a 20-mesh screen. It is then compression-molded in dies of original form and construction. The sawdust is previously mixed with a modified type of phenolic resin which serves as a bonding agent. The pressure varies from 500 to 2000 lb. per sq. in., depending on the type of product to be made and especially on its desired density. A special process of making dies has been developed which provides for lower costs than are incurred in the plastic molding dies. This company makes a great variety of products including boxes for small tools and furniture parts, various kinds of trays and products that may use the material of this kind to good effect. The product has a very attractive outside finish as well as special linings. In some cases, furniture parts are decorated by compound molding in

* From data supplied by F. F. Beil, Clinton, Iowa.

which a decorative laminate is bonded to the sawdust at the same time the sawdust is molded into shape.*

One concern in New York City handles about 500 carloads of shavings and sawdust per year. Sources of supply extend from the pine mills of South Carolina to the spruce mills in the Lake St. John and Chicoutimi districts of Canada. Destinations of these shipments are mostly in the large centers of the Atlantic Seaboard such as Boston, Philadelphia, New York, Baltimore, and Washington. Shavings are always baled and used largely for bedding. Sawdust is shipped in bags and loosely in bulk in boxcars and is used for a wide variety of packaging, as an absorbent on floors, for insulation, and for miscellaneous purposes.

Sawmills throughout the East and North sell large quantities of sawdust for cow- and horse-stable bedding. Farmers often prefer it to straw and other materials formerly used. Many small mills sell all they can produce for this purpose at 5 cents a bushel or $5 a truckload. Large trucks carry 200 to 300 bushels each. Pine sawdust is preferred to hardwood because of its pleasant odor; it also serves as a partial disinfectant and deodorant. As one large farmer-user of sawdust described it, pine sawdust "makes everything smell better and generally improves the situation."

Two factors have influenced the use of sawdust in the North and East. Formerly ice was harvested in large quantities from frozen ponds and streams in the winter. Large quantities of sawdust, because of its insulation value, were utilized to store the ice until summer. Now, owing to wide use of house refrigerators, less pond ice is required. Also much straw was formerly harvested from wheat, oats, and barley. This straw was used for bedding in stables. Now wheat, oats, and such products are grown to a less extent, so that many farmers have turned to the use of sawdust and shavings for bedding—and many find it easier to handle and more satisfactory as a fertilizer. Now the many small sawmills (generally 500 to 1500 in each of many forested states) find no difficulty in disposing of sawdust and shavings for local purposes as described; as well as an absorbent in meat-packing plants, butcher shops, and barrooms; for shipping breakables and heavy materials in barrels and boxes; as a soil mulch; and for many other purposes.

* From information supplied by R. R. Smith, Pressed Wood Company.

One of the largest meat-packing concerns in the country has contracted to purchase all the oak sawdust from a sawmill at Blair, Wis. This is used in smoking meats.*

Eastern red cedar shavings are bagged and sold in 5-lb. bags for 75 cents at retail as Permacedar, used for kennel bedding. The aromatic cedar odor is a natural insect repellent. It is a moisture absorbent and serves as an effective soil mulch for perennial flower beds and evergreens and keeps the soil slightly acid.

WOOD MOLASSES FOR STOCK FEED †

Sawdust has been used to some extent in Europe as a cattle and stock food. Experiments have been conducted at agricultural colleges at Corvallis, Oreg.; Durham, N. H.; Bozeman, Montana; Pullman, Wash.; Madison, Wis.; Amherst, Mass.; and several southern colleges, to develop a cattle food from sawdust.

Because of the small capacity of the pilot plant at the U. S. Forest Products Laboratory at Madison to turn out wood molasses, the plant has been able to supply only a few of the many requests for wood molasses for experimental tests, feeding cattle, milk cows, sheep, swine, poultry, etc. In all experiments so far, silage preserved with wood molasses was preferred and consumed while silage with blackstrap molasses was frequently left. Little conclusive evidence for its wide application and use with domestic animals is so far available. It is an interesting development, and after many more experiments have been conducted and continued some satisfactory conclusions may be drawn.

E. E. Harris in the first bulletin referred to has stated as follows:

> Future tests with wood molasses, as well as those to be made with fodder yeast grown on wood sugar, should make it possible to decide whether to build plants for molasses or yeast production from wood for stock-feeding purposes. Feeding tests should disclose whether it is necessary to purify the sugar concentrate. If not, the price would be lower and its chance of being used would be enhanced. If tests show that

* From *Forest Digest,* American Forest Products Industries, Washington, D. C., April 1950.

† For further information see Wood Molasses for Stock Feed, *U. S. Dept. Agr. Forest Products Lab. Rept.* **R1731,** 1948, and Fodder Yeast from Wood Hydrolyzates and Still Residues, *Ind. Eng. Chem.,* July 1948.

purification is needed to improve palatability, it will be necessary to determine the constituent responsible for the "off flavor."

Future tests should include metabolic studies to ascertain: (1) the actual digestibility of molasses; (2) its nutritive value; (3) its value for milk production; (4) its value for fattening hogs, sheep, and cattle; (5) its suitability as a constituent of feed for wintering range animals; (6) its use as a preservative for silage; and (7) its value in improving palatability of roughage.

As a result of extensive experiments in Europe to develop a satisfactory method of manufacturing sugar from wood, Finland has established a factory at Uleaborg, with a daily production of 1000 lb. of sugar. The product is similar to glucose. It is white and has a pleasant taste, and the price does not exceed that of domestic sugar.

During World War II, a large and expensive plant was built by the U. S. Government at Springfield, Oreg., for manufacturing alcohol from woods and sawmill waste available at the important near-by lumber centers of that part of Oregon. Recently a firm has secured control of this plant to use it for the manufacture of molasses from sugar derived from sawdust and wood chips.

33 · HARDWOOD DIMENSION AND RELATED PRODUCTS

HARDWOOD DIMENSION *

Hardwood dimension consists of pieces of hardwoods of varying thickness and length, usually cut from No. 2 Common and Better lumber. It is produced from any hardwood species. The largest production is from red gum, followed in popularity by yellow poplar, oak, maple, cottonwood, and to a lesser extent by ash, birch, beech, tupelo, black gum, black walnut, and mahogany. These are used chiefly by manufacturers of furniture. There are more than 200 separate products utilizing hardwood dimension. A large quantity of ash and maple dimension is now being employed for station wagons. Hardwood dimension is also widely favored for radio cabinets, kitchen cabinets, toys, bobbins, stepladders, shuttles, agricultural implements, handles, musical instruments, clock cases, industrial wooden parts, and many other products. In size, the parts range from the smallest sizes suitable for toys to complicated wood fabrications requiring some 40 wood-fabricating steps for huge truck-body frames for supporting metal exteriors.

In general, there are two kinds of hardwood dimension classified as to ultimate use: namely; (1) rough air-dried dimension which consists primarily of squares, and (2) kiln-dried dimension which may be rough, or semimachined, or completely machined. A large share of the products consists of kiln-dried dimension. Louisiana, Mississippi, Arkansas, North Carolina, and Michigan are important sources. It is impossible to produce dimension from slabs and edgings under the conditions of high labor and handling costs. Furthermore, the present conversion of No. 2 Common lumber into hardwood dimension, flooring, and similar wood products is only possible at the source of production, since

* In the preparation of this chapter P. A. Hayward, managing director of the Hardwood Dimension Manufacturers Association, and C. D. Dosker, president of Gamble Brothers have been of assistance.

in this way the waste is left and the maximum utility is obtained from the individual pieces of lumber.

Within recent years, there has been a very progressive and active improvement in the hardwood-dimension industry. The products of this industry offer important advantages in utilization over those of regular hardwood lumber because the users of the finished products receive stock cut to sizes required by them. Therefore, waste is greatly reduced, the production of the finished product is made less expensive, considerable economy results from not shipping defective lumber in the final article, and less space is required in the assembling plant—generally a furniture plant. Furniture plants in some instances can increase their production of finished furniture 20 to 30% by purchasing kiln-dried dimension. Also, conservation of our forests is furthered by more intensive and complete utilization.

This industry is often referred to as a "feeder" industry to the furniture manufacturers. It is concentrated largely in the production of furniture parts including kiln-dried rough, semi-machined, and completely machined parts. In particular, the parts made for the furniture industry are largely furniture tops, cores, drawer sides, fronts and backs, bed rails, hardwood upholstered frames, radio and television cabinets and sets. The principal producers of hardwood dimension are organized in the Hardwood Dimension Manufacturers' Association of Louisville, Ky. Many members produce specialty kiln-dried furniture dimension lumber, either flat stock or squares, or cut and equalized to furniture manufacturers' specifications. Some members produce other specialties, such as dimension stair treads and risers, hardwood interior trim and molding, and hardwood panel stock, according to specifications and standards set up by the U. S. Bureau of Standards in Washington.

The use of hardwood dimension results in definite economies and represents a signal advance in forest utilization; therefore, its use is steadily increasing. This industry is concentrated in the 16 important hardwood-producing states; the area is widely scattered from Michigan to Pennsylvania to Florida, and from Kentucky to Texas. It developed principally in the southern hardwood regions close to source of production in an effort to reduce the use of waste wood containing knots and other defects and excess water (some water is found in all wood), and to meet the specific requirements of large users of small parts. The many large furniture-production areas are found at or near the centers of hardwood lumber production. Some hardwood-dimension plants of the companies have been producing kiln-dried hardwood dimension for 50 years.

The industry is notable for (1) highly skilled labor, (2) the finest of woodworking equipment and machinery, and (3) the latest refinements in operating and gluing techniques. This is in contrast with the early development of air-dried dimension for furniture squares, wagon rims, spoke stock, rocking-chair flats, single trees, double trees, etc. With the disappearance of hickory spokes for wagon and automobile wheels, many changes have been necessary. Years ago, much of the hardwood dimension came from sawmill edgings, slabs, and low-grade lumber. Now, high-quality semi- and completely machined dimension cannot be produced from wood waste, low-grade lumber, slabs, etc. The principal source of dimension is from No. 1 Common and Better grades of hardwood lumber, and the utilization must be 60% or better from the boards. There is currently an ample supply of hardwood lumber and mill capacity to meet the demands made upon the industry for its product.

The general classification of hardwood dimension falls into two major groups for grading purposes: flat stock and squares, either rough or kiln-dried. The principal grades of flat stock are: clear, clear one face, paint, core, and sound. Squares are graded as clear squares, select squares, paint squares, and sound squares. Clear stock is generally specified. However, other specifications may be developed by the producer and his customer if desired. Sizes of dimension are of varying thicknesses and widths. Maximum length usually is 8′.

The prospects for hardwood dimension are becoming brighter from year to year. This is the direct result of increasing transportation rates, higher labor and dry-kilning costs, higher lumber costs, and more particularly smaller per cent cut of high grades of lumber and increasing cut of No. 2 Common grade and poorer. Manufacturers of assembled and finished hardwood products, notably furniture manufacturers, can materially lower their own costs by the use of hardwood dimension, since it gives them maximum production within minimum plant space. Also the use of machined hardwood dimension relieves them of buying and operating expensive woodworking machinery and equipment.

Since World War II, the annual consumption of hardwood dimension * has reached about 1 billion b.f. of which one third goes into furniture and cabinetwork and the remainder into many products mentioned previously.

Pricing hardwood dimension based on rough lumber costs. There are a number of fundamental basic methods of determining production costs for all items of forest products. Although this subject of cost accounting is a very large and important one, it has not been discussed previously in this text. The following items must be carefully considered in any accounting system in pricing hardwood dimension in order to arrive at a proper and accurate analysis and summary of production costs. The important rough lumber costs include: (1) freight; (2) degrade found in lumber; (3) waste and loss in cutting lumber into hard-wood-dimension items; (4) depreciation on yard and kiln equipment; (5) yard and kiln supervision; (6) repairs to yard and kiln equipment; (7) electric power and lights for yard and kiln; (8) yard and kiln inspection labor; (9) cost of inspection and grading; (10) kiln operators; (11) boiler costs including fuel, repairs, water and firemen; (12) kiln sticks and sills; (13) insurance and property taxes; (14) maintenance of yard, grading, drainage, etc.; (15) demurrage. In addition to rough lumber costs which apply to all operations, a large number of items are included under general administrative expenses and selling expenses.

MISCELLANEOUS MECHANICALLY REDUCED PRODUCTS

The following is a summary of the principal requirements of species and the specifications of some of the leading forms of small logs, blanks, and stock,† used for products in this category.

* This is a very brief treatment of a "feeder industry" for furniture and many other end products of lumber which are too numerous to describe in a book of this coverage. For further information regarding industrial uses of lumber, see various publications of the U. S. Forest Products Laboratory and *Wood-Using Industries of New York*, by R. J. Hoyle and J. R. Stillinger, New York State College of Forestry, Syracuse, N. Y., 1949.

† Owing to the limitations of space, it is impossible to present in this book the details of the species, rough and finished, and sizes and quality specifications required for all of these products.

Tool, handle, and implement stock. Ash and hickory are the premier woods for tool, handle, and implement stock because of their strength, hardness, and toughness. The general specifications covering ash and hickory logs to be manufactured into these products are summarized as follows: the logs must be tough in texture, of second-growth timber (old forest growth not admitted), straight grained, and free from rot, limb knots, and blind knots. Not more than one third of the diameter must be heartwood. The logs must be properly stored. They must not be top logs.

Specifications for maple handle logs, in general, are summarized as follows: the wood must be tough textured of hard, white sugar maple, straight grained, free from rot, limb knots, and blind knots. Trees that have been tapped for sap are not desired; there should be a large percentage of white sapwood, and so virgin or old-growth trees are not acceptable. Logs are produced especially for these products, and ordinary saw logs or lumber are not desired for these purposes.

The specifications for handle dimension stock are summarized as follows: the wood must be tough textured; of second-growth origin; straight grained; contain no punk, decay, or poor heartwood; be free from knots, burls, bird pecks, checks, splits, mineral streaks, worm holes, or blue stain. When large old-forest-growth trees are cut on logging operations in connection with the production of tool, handle, and implement stock, they are sold or delivered to sawmills for conversion into lumber. The sawing of ash lumber is altogether different from the sawing of ash logs for handle and implement stock, because lumber is generally made without regard to straightness of grain. For example, in sawing a tapered ash log for handle purposes, it is first made into planks by sawing parallel to the bark instead of parallel to the center line or pith. Thus a wedge is taken from the heart and discarded. These straight-grained planks are ripped parallel to the bark in order to give straight grain. Those parts of the logs which do not produce straight grain or conform to the other specifications are discarded; thus there is considerable waste in the manufacture of these products.

Ash and hickory logs differ widely in their characteristics in the various regions where they are produced. Trees from river bottoms or mountain tops differ widely in their rates of growth and the character of the wood produced. Wood produced in the North is much preferred to that from the South, and handle and tool authorities even recognize two kinds of ash grown in southern swamps Some swamps contain black acid water and produce ash wood so weak in texture that it is considered unfit for these purposes. Some swamps periodically overflow and contain alkaline water and a heavy mud silt. Ash wood growing in swamps produces wood satisfactory for pulling tools, such as rakes, and hoes, but the wood is too weak in texture to serve for lifting tools, such as shovels and forks. Northern-grown ash is preferred for the lifting tools. Overflowed swamps of the South often produce two kinds of ash trees, one having a straight trunk from the ground up, the other a swollen butt extending to the high-water line. The latter is known as "pumpkin" ash, and this kind of tree is not considered suitable for handle or tool stock.

The sizes produced for the different kinds of handles, tools, etc., vary so widely that it would be impossible to list all of the blanks by length and cross section for the various products. Table 23 shows the species used for the principal types of handles and tools * produced in this industry:

TABLE 23

Tools and Handles	*Species Used*
Poles	Ash, Douglas fir
Hoes	Ash, hickory, maple, southern pine
Forks	Ash
Shovels	Ash, hickory, maple
Spades	Ash
Peavies	Hickory, maple
Cant hooks	Hickory
Sledges	Hickory
Picks	Hickory
Tampers	Hickory, maple
Snow shovels	Ash
Diggers	Ash
Push brooms	Ash
Rakes	Ash, hickory, maple

* These uses have been selected because of their relative importance. Other forms of dimension stock are not described because of the limitations of space. Each has its own specifications of sizes, species, grades, and other requirements.

TABLE 23 (*Continued*)

Tools and Handles	*Species Used*
Shepherd crooks	Ash, basswood
Window brush rods	Ash, basswood, Douglas fir
Hammers and hatchets, high grade	Hickory
Hammers and hatchets, low grade	Ash, oak
Axes, high grade	Hickory
Axes, low grade	Ash, oak

A very large volume of blanks is used for turning, tool, and implement handles. It is estimated that the normal annual demand is 22 million b.f. of ash for what is known in the trade as farming tools. This includes hand tools such as fork, hoe, rake, shovel, and other handles. For hammer handles, and for use with adzes, axes, hatchets, and various forms of striking tools, the normal annual demand is about 10 million b.f. of hickory. Close-grained regrowth ash and hickory are preferred for these purposes. Wood must be straight grained and free of defects. Northern white ash is preferred for farm tools, and the raw material is secured from the middle western states: Kentucky, West Virginia, Pennsylvania and New York. Hickory handles are secured from a wide range of natural growth of hickory. The shagbark hickory is preferred as a source of this material, although the other hickories are used to some extent as well.

Wood turnings. Many turnery products are made directly from primary forms of forest products. Altogether there are a great many varieties of wood turnings. They are particularly devoted to spools, dowels, small tool and implement handles, gummed tape plugs, adding-machine roll cores, sprayer plugs and handles, shovel handle grips, toy turnings of all types including balls, tops, drum sticks, and heads, in addition to those described heretofore. This industry is found in practically all of the important hardwood forest regions of the United States and Canada but is probably centered more in the Northeast than anywhere else. Maine is traditionally the center of wood turning because of the availability of good quantities of excellent wood used for turnings. This is the paper birch. Some of the most important industries in New England utilize this wood very extensively in their turning operations. Other woods extensively employed in this industry are close-grained, diffuse porous, and hardwoods that may be uniformly seasoned, such as hard maple, the other birches, beech, and black cherry. Occasionally ash is used, especially for handle stock.

One company operating in Maine and Georgia consumes several million board feet annually for cotton spools—about 80% being produced from white birch in Maine and 20% from tupelo and black gum in Georgia. Spools vary in size from ¾″ × ¾″ up to 2⅝″ × 3⅝″.

There are many sizes and specifications for spools alone. Logging for the bolts generally takes place in the winter. In some cases parts or certain types of logs are devoted to wood turnery. Much of this stock is air-seasoned followed by kiln drying to a uniform moisture content. After the logs have been reduced to the various-sized blanks, they are turned on various types and sizes of lathes. In the field of dowels alone, there is a very large variety of diameters and lengths.

Production of this class of material is given particular emphasis in the northern hardwood region from Maine and northern New England to New York, Ontario, Pennsylvania, Michigan, and Wisconsin. Many wood turnery products are also manufactured in the hardwood regions of the South.

Match blocks.* In spite of the competition from paper matches, wooden matches are still used in enormous quantities in the United States. There are 24 establishments which produce annually about 287 billion wood matches. These are in addition to the 240 billion paper matches or 12 billion books of 20 paper matches each. A few companies own large timber tracts and conduct logging and sawmill operations primarily to produce satisfactory match blocks from which matches are made. White pine produces the best wood for the purpose because the soft texture and resinous content makes it readily inflammable, and, further, it does not splinter or split easily. Idaho white pine is the chief source of the "king-size" or kitchen match known also as the round match. The square or strike-on box or safety match is made of aspen by the veneer process.

Many of these match companies produce large quantities of lumber in addition to the selected stock of western white (Idaho)

* From information partly supplied by Stuart Little, an authority on the manufacture of wooden matches.

pine, the principal species used for manufacture of matches. Aspen or popple in the Lake States is also converted into matches by the veneer process.

Some of the sawmills producing material primarily for matches have a capacity of 100 to 200 M b.f., or more, in an 8-hour

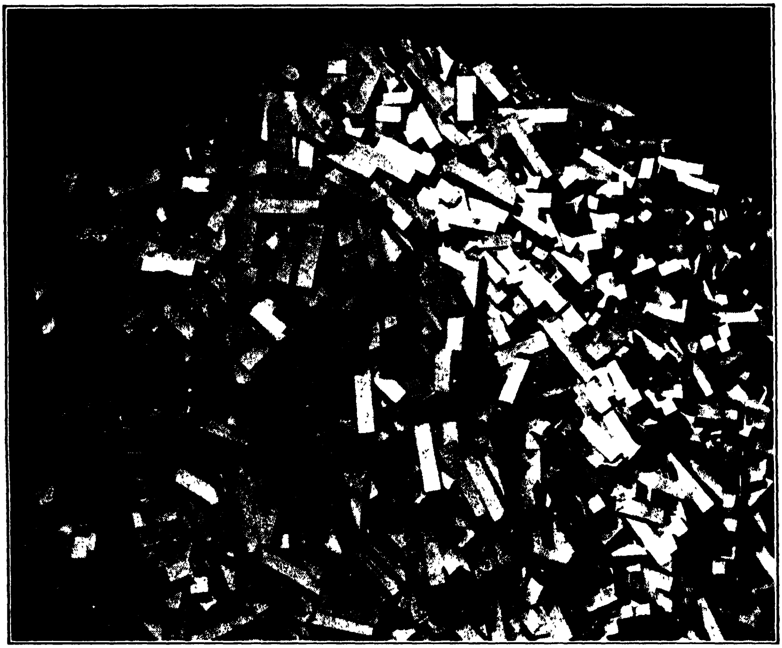


FIGURE 126. Storage bin containing match blocks from Idaho white pine. These blocks are as wide along the grain as the length of the match splint. Only clear blocks may be used for matches.

working day. After the logs have been sawed into 2″ planks, the lumber is piled in the yard to dry 12 to 18 months so that the wood is thoroughly seasoned and the matches made from it are smooth, thoroughly dry, and strong. Then these planks are taken to a factory, surfaced on both sides, and cut up by the gang saws into blocks 2$\frac{3}{8}$″ long, which is exactly the length of the longer wooden matches. The blocks are carried on endless belts to tables where trained choppers remove knots, cross-grained portions, or other defects, and the good blocks are separated from the inferior ones. The selection of the proper grade of lumber to obtain clear blocks, care in seasoning, and proper manufacture of the match blocks are very important phases of the business. The blocks are then taken to the match warehouse, subjected to climatic conditions, and dried to the proper moisture content before going to the match machines.

Blocks are fed into the match machines by trained block tenders so that the grain of the wood meets the cutting head of the machine in the proper manner. This cutting head is set with 40 knives and operates up and down at a speed of 300 strokes a minute. The downward stroke cuts 40 sticks from a block and the upstroke forces the match sticks into holes in an iron plate. These plates are 4″ × 16″ in size and have space for 500 sticks. There are 2400 plates on a complete match machine, hinged together in the form of an endless chain. Approximately 1 hour is required to complete a cycle from the time the stock is inserted into the plate until the matches emerge in finished form. Each machine holds approximately 600,000 matches and produces about 6 million matches a day. After the sticks are placed in the match plate by the cutting head, brushes take out all the weak and imperfect sticks. Later they are passed through melted paraffin, which penetrates the stick and acts as the medium for carrying the flame from the match head to the stick itself. A process is then used to treat the stick chemically so that it will not glow after the flame has been extinguished. The matches are automatically fed into boxes and wrapped six boxes in a package. Thus, from the time the match blocks enter the machine until they come out in the finished package they are not handled by the workers. One company produces 350 million matches a day. If laid end to end, these matches would reach halfway around the world.

Pencil slats. Eastern red cedar is considered by manufacturers to be the best wood for pencils because of its soft, uniform, straight grain. The wood must be free of knots, rot, black specks, or other defects and must be straight grained. About 70% of the pencil cedar purchased is wasted on account of the exacting nature of the process. Because of decreasing supplies, the pencil companies have turned to incense cedar from California and Oregon. Port Orford cedar from western Oregon, western red cedar from Washington, redwood from California, and some of the junipers found in the Rocky Mountain region have been used.

The junipers produce good wood but the trees are of poor shape and grow in small and scattered bodies so that harvesting is difficult and expensive; therefore they are not important sources for pencils. Red and sap gum of the south are also used.

Only the old-growth incense cedar trees having a fine and straight grain are utilized for pencil slats in California and Oregon. In one plant in Roseburg, Oreg., approximately 4500 M b.f. of incense cedar lumber sufficient to produce 216 million pencils are annually manufactured into slats. The finished product is a slat $\frac{3}{16}''$ thick, $2\frac{5}{8}''$ wide, and $7\frac{1}{4}''$ long. This material is carefully sorted, and only straight-grained slats are selected and used. Two of these slats when glued together make 7 pencils.*

Slats are manufactured principally in the southern states and in California and are shipped to the pencil factories. There are generally three grades, the first being dark red and entirely clear in texture, used for the best grade of pencils. The second grade permits a few defects; the third grade may contain white sapwood. In manufacturing pencils, the slats are run through a grooving machine which provides for the lead cores. Then the lead is laid in these grooves and a coat of glue applied. Another grooved slat is then laid above the first one, the grooves fitting over the lead centers. The combined piece is then run through another machine, which rips it into six separate pencils. They are then polished, painted, stamped, and graded.

According to an estimate of woods used for pencils and penholders, the total quantity of wood consumed for these two purposes was about 42 million b.f., subdivided as follows: western cedars, principally incense cedar and some Port Orford cedar, redwood, and western red cedar, $36\frac{1}{2}$ million b.f.; eastern red cedar, $3\frac{1}{2}$ million b.f.; the remainder red and sap gum and birch. There are no U. S. Census figures for pencil slats.

Briarwood pipe blocks. It is estimated that about 14 million blocks are consumed annually in the United States for smoking pipes. For many years, the root burls of tree heath (*Erica arborea*), as found on the shores of the Mediterranean Sea, have served for pipe bowls; in fact, since about 1860. This industry was largely developed in southern France, where the wood is

* From information supplied by C. M. Saar, Roseburg, Oreg.

commonly known as bruyère, and then spread to Italy, finally to Algeria, and to a less extent to other countries along the southern border of this sea.

The important properties and characteristics required in a good pipe wood are: (1) resistance to charring, (2) absence of disagreeable odor in charring, (3) resistance to checking under heat, (4) strength, (5) attractive figure, (6) reception to coloring with stain, (7) ability to take polish.

The rather distorted fiber structure of burl wood is an attractive feature of woods employed for this purpose.

During World War II, because the supply was cut off from the Mediterranean section, native supplies were developed in the United States. These largely consisted of the following: (1) burls found in the root systems of mountain laurel (*Kalmia latifolia*) and rhododendron (*Rhododendrom maximum*) as found in the southern Appalachians, (2) various manzanitas as found in California. Some of the manzanita and Italian briarwood belong to the heath family or *Ericaceae*.

Several plants have been established in both the southern Appalachian mountains and southern California to manufacture pipe blocks from the burls of these woods. Owing to the fact that the supply of native stock as found in the Mediterranean section is being depleted faster than its rate of growth, it is likely that substitute woods must be developed to meet the demands. Of the various manzanitas developed for pipe bowls in California, the best is *Arctostaphylos sp.* which produces a burl and kind of wood that is not so dense as the Italian briar or French briar but is entirely satisfactory in smoking quality and beauty of the grain and figure.

This industry has developed both in the South and West. In California there are small local concerns where men work with grub hoes and axes to cut out the burls at or beneath the soil.

34 · WOOD DENSIFICATION *

Wood densification is a process of improving wood to make it more useful for specialized purposes. At first, this product was known as improved wood—also as modified wood. It consists of filling or closing the voids in the cellular wood structure accompanied by compression under heat. This process adds hardness, increased strength, greater durability, and dimensional stability. In some forms, however, the process reduces toughness, and in all cases it makes the wood much heavier. Compression of wood fibers is generally accompanied by impregnation with phenolic resins and urea resins. By some methods, compression of wood is done without impregnation. Impregnation with phenolic resins is usually in veneer sheets, 1/8″ thick and laid up with parallel grain direction before pressing. Impregnating thick, solid wood is a very slow process. Variable density may be secured by tapering down the length of alternate layers and pressing to a uniform thickness. In other cases, impregnated veneer layers may be placed outside an assembly when surface hardness and light weight are required; or they may be placed inside where a readily gluable surface is essential. Commercial products are of the resin-impregnated type variously known as Compreg,† Pregwood, Pluswood, and, when pressures do not exceed 200 to 500 lb. per sq. in., the product is known as Impreg. In England, it is known as Jicwood. When various types of paper layers are used instead of layers of wood veneers, the final product is known under various technical and trade names such as Papreg, Consoweld, Formica, Micarta, Panelyte and others. Many kinds of densified wood and fiber were especially valuable for military equipment during World War II where costs were not considered an important factor. Some of these products have found useful

* From data supplied by Thomas D. Perry, Moorestown, N. J.

† For further information see "Compreg-Resin-Treated Densified Wood," by George K. McLean, Parkwood Corp., Wakefield, Mass., *Ann. Proc. Forest Products Research Soc.*, Madison, Wis.

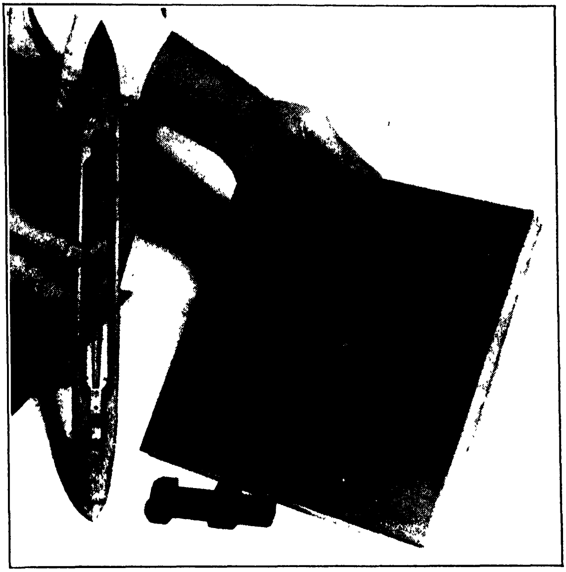


FIGURE 127. Illustrations of densified wood known as Compreg. At left is shown a shuttle used in textile factories; at right is sample of Compreg used as facing on flooring and below is shown a bolt to demonstrate machinability. *Courtesy U. S. Forest Products Laboratory.*

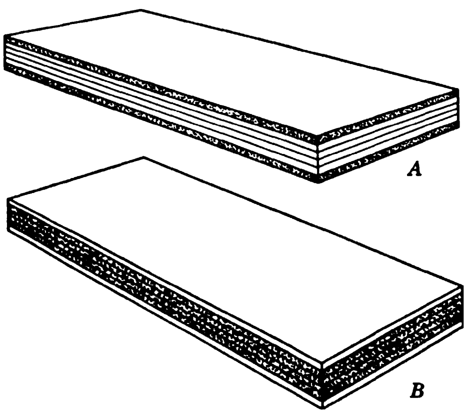


FIGURE 128. Illustration of the use of combination assemblies of low and high density. *A* illustrates outer layer of high-density veneer and *B* illustrates the inner layers of high-density veneer. These are examples of some of the very technical features in the development of densified wood used in connection with plywood assemblies.

outlets in several branches of industry. One form of this product is known as Densi-wood. Another is known as Staypak. The principal feature of Densi-wood is a heat-pressure-hardened surface over shallow areas previously heated to make them com-

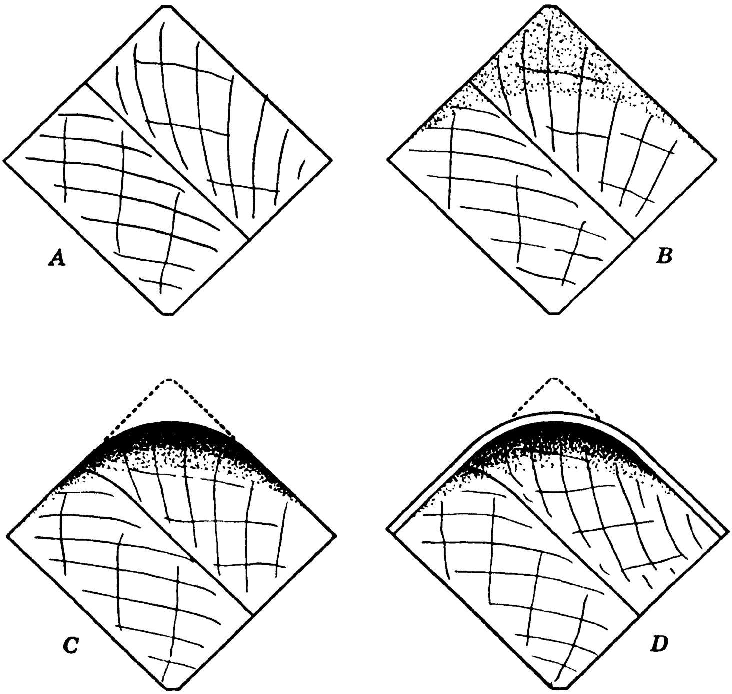


FIGURE 129. Illustration of Densi-wood corner post as recently devised to protect tables, desks, etc., subject to excessive abrasion, wear, and hard usage. *A* shows a normal desk post before treatment, *B* shows same post after plasticization, *C* shows the exterior round corner after treatment by pressure and heat, and *D* shows the same corner with a veneer layer glued to the round corner after densification.

pressible which serves to lengthen the life of furniture parts exposed to severe usage and wear. Each of the several products coming within this classification has developed a market for its particular product. Some are featured by their density, hardness, use for facing other materials, etc. In general, most of these forms are used in the furniture trade and for specialty products. Although an entire piece of furniture may not be made from densified wood, certain parts such as table tops, legs, and exposed portions subject to rough usage are made from them. A market has been developed for shuttles, golf heads, flooring, and highly specialized uses where a heavy, dense, hard and durable surface is required.

PART VI

Wood as Fuel

35 · FUELWOOD

At one time fuelwood constituted the most important product of the forest. It has always played a vital part in the domestic economy of all rural sections. In addition to its value for heating and cooking purposes it was widely employed in the manufacture of brick and later as a source of steam and electric power and even of electric lighting. Sargent estimated that 146 million cords were consumed in the Nation in 1880. Since that time there has been a steady decrease in the use of fuelwood because of substitutes, first coal, then fuel oil and natural gas, and finally electricity and artificial gas for heating and cooking. Some farm homes have had electricity for cooking since 1910. The Tennessee Valley Authority employs electricity for heating many homes built under its jurisdiction. The increasing use and decreasing cost of electricity in our rural electrification program seem likely to affect still further the consumption of wood for fuel.

Next to lumber, fuelwood is the most important wood product of our forests, and it comprises 12.6% of all wood products. This is equivalent to about 2 billion cu. ft. Before World War II fuelwood comprised about 24% of all wood products including lumber. Now pulpwood consumption is nearly as large as the amount of wood for fuel.

Fuelwood is primarily a farm woodland product. It is estimated that some 85 to 90% of all fuelwood is used on farms and in small rural communities. The average farm family burns about 17 cords. It is never hauled long distances because of the excessive cost of transportation. Generally, it is hauled only a few miles, up to 10, and occasionally 60 miles by truck. Many barge loads of fuelwood are hauled from the Virginia rivers to New York City and other greatly populated centers.

Fuelwood furnishes an important outlet for material otherwise wasted, such, for example, as tree tops, branches, defective logs, and other parts left in the woods from small logging operations. Large quantities are also used from such sawmill offal as slabs, edgings, and trimmings. Unfortunately much good, young, grow-

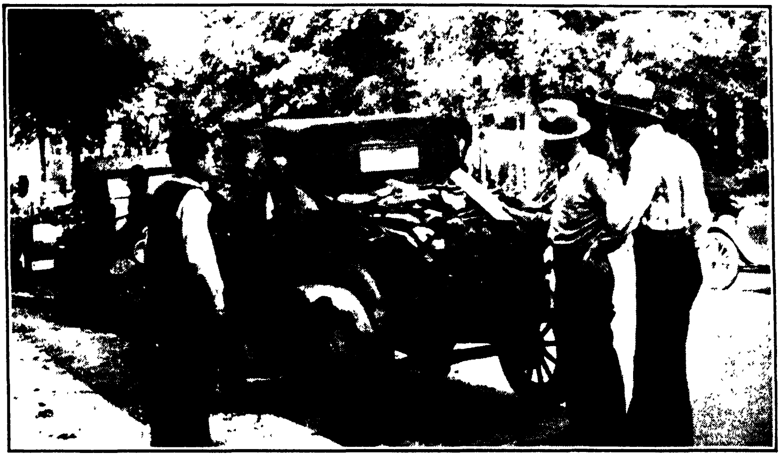


FIGURE 130. A common sight in southern communities where fuelwood is widely used. This is lightwood often known as "lightered," which is heartwood made very pitchy by repeated woods fires and sold for kindling or fireplace wood throughout the South. Truck loads are commonly sold in the streets of all towns and cities. This kind of wood furnishes a quick, hot flame.

ing timber, that is, bodywood, is cut directly for fuel rather than being reserved for increased growth and later use as saw logs, poles, posts, pulpwood, piling, etc. Hodgson * has estimated that several million cords of sawmill-waste and woods-waste fuelwood were yearly utilized in the Northwest (Washington and Oregon). The consumption of hogged fuel has grown into large proportions in the Pacific Northwest, where a useful outlet for large quantities of sawmill and logging waste is found annually. Some of this material would otherwise be destroyed in sawmill refuse burners.

* A. H. Hodgson has contributed much knowledge of the importance and use of woods and sawmill waste in the Pacific Northwest to trade journals and Government and private publications.

Ordinarily, potential fuel is left to rot or burn in the form of defective logs, tops, branches, and materials too small to be utilized on logging operations. Assembling and transportation costs present important problems to be solved. Literally millions of cords of wood annually are left to rot in the Adirondacks, the White and Green Mountains of northern New England as well as in Pennsylvania, and many sections of the East comparatively near large cities which could well use this fuelwood. The cost of assembling and hauling this wood to market with high labor charges however, is prohibitive.

Amount used. It is estimated that 100 million cords of fuelwood were burned in 1923 and that now about 20 million cords are burned annually. The trend of consumption per capita is definitely downward for reasons given previously.

Principal use factors and centers of consumption. The principal determining factors of use are:

1. Availability and cost of competitive fuels such as coal, fuel oil, natural and artificial gas, and electricity. Fuel oil and gas have eliminated the use of wood in many parts of the South and Southwest, as well as in West Virginia, Pennsylvania, and adjoining states.

2. Climate and heating devices that are commonly employed in relation to it. Both solid wood in 4′ lengths and hogged fuel are widely consumed in the Pacific Northwest. Coal and oil are transported at considerable cost to this section, and therefore wood serves widely as a fuel. In the South, there are relatively few cellars and furnaces in farm and rural homes, so that wood is depended on as the principal source of fuel.

3. Transportation facilities and cost. Wood may be abundantly available, but reasonably low-cost transportation may be lacking. Wood is a bulky and heavy commodity and is handled and shipped at considerable cost. In many sections where natural gas and soft and hard coal are available, wood is seldom used, even when produced at relatively low cost.

The South is the principal user of fuelwood, expressed both in total consumption and in per capita use. The following states are the highest consumers, both in total volume of wood and cords used per farm: Alabama, Georgia, Tennessee, Mississippi, North Carolina, Arkansas, and Texas. The Pacific Northwest, the Lake States, and the Northeast are also important burners of fuelwood, but the southern states listed use about 50% of the total fuelwood consumed in the Nation. Since there are few furnaces in dwellings in rural sections in the South, wood is employed both for heating and cooking.

PRODUCTION

Farm labor generally supplies fuelwood except that obtained from sawmills. One experienced man may cut and pile a cord

FIGURE 131. Typical scene in most of the well-forested regions where woods and mill waste, tops, and small defective trees are bucked up by crosscut saw into fuelwood.

of average-sized hardwood per day in timber of favorable size (1 cord equals 128 cu. ft. of sticks 4′ long and piled 4′ high and 8′ long). Axes, crosscut saws, power saws, bow saws, and wedges are the principal tools used. Round wood 8″ or more in diameter is usually split into two pieces or quartered, if above 12″ in diameter. Gasoline engines or farm tractors are commonly employed in connection with cutoff saws to buck up tops, branches, slabs, and edgings in connection with small sawmill and logging operations where there is a good market for fuelwood. Two men can cut up 4′ cordwood into 12″ stove lengths at the rate of 1 to 2 full cords per hour. In many rural farm homes in the North, it is a common custom to have a "buzzer saw" generally a circular saw to cut up the winter fuel supply for one or several homes from near-by wood lots. Fuelwood is almost exclusively hauled by motor truck. In the Rocky Mountains, fuelwood from dead and down timber in the National Forests is often hauled

40 to 100 miles to distant ranches and villages for the winter fuel supply. In farm woodland regions, fuelwood is seldom hauled except on a downgrade haul. Cordwood is occasionally hauled on railroad cars, which carry 12 to 16 cords each. The increasing installation of small sawmills and the trend from steam to gasoline or tractor power to drive them have increased the production of slab wood for fuelwood. When logs average 5.2 per M b.f. for 16′ logs, M b.f., log scale, will produce about one-third cord of slabs for fuelwood in addition to lumber. At one sawmill, used primarily to cut cross ties, it was determined that 30 ties and 1 cord of slabs for fuelwood were produced from 1 M b.f. of hardwood logs. Slabs were cut thin in the first case and liberally in the second, which accounts for the wide differences of slab production.

It is estimated that in sawing 1 M b.f. of northern hardwood lumber, about two thirds of a cord of fuelwood can be cut from the tops after saw logs are taken down to 10″ in diameter. Also in southern hardwoods, about three quarters of a cord of fuelwood can be cut from the tops after saw logs are taken to 10″ in diameter. This is assuming that northern hardwood tops are taken to 4″ and southern hardwoods to 3″, for fuelwood.

The relationship of fuelwood that can be taken from tops of trees cut for cross ties and poles, are shown as follows:

For every 10 cross ties about 1 cord of wood can be obtained from trees 10″ to 15″ d.b.h.

For every 10 poles (various sizes) about 1 cord of wood can be obtained from trees 12″ to 24″ d.b.h.

FUEL VALUES

Fuel or heating values are directly in relation to weight or specific gravity except in resinous woods, which have proportionately greater heat values. The factors determining fuel values are:

1. Density or weight. The heavy hardwoods such as oak, beech, birch, maple, and hickory are considered best for fuel.

2. Dryness. Green wood may have practically no heating value. Wood should be thoroughly seasoned before it can have its maximum heating value.

3. Construction and draft regulation of stoves and furnaces where it is used. The development of new types of stoves in

Europe has vastly increased the efficiency of wood as a fuel. Some of these new types of stoves have been introduced in the United States.

4. Rapidity of burning. When some woods are burned too rapidly full heat values are not derived. The average heating value of dry wood is 4600 cal. per kg., or 8028 B.t.u. per lb.

One pound of good coal is equivalent to about two pounds of seasoned wood. A cord of the following woods is equivalent to one ton of coal: ash, hickory, oak, beech, birch, hard maple, and longleaf pine. About 1½ cords of the following woods are equivalent to one ton of coal: shortleaf pine, Douglas fir, red gum, western hemlock; and two cords of the following are equivalent to one ton of coal: cedars, spruces, white pines, redwood, cypress, poplars, and basswood.

Hodgson has reported that the heat-producing value of one unit (200 cu. ft.) of hogged fuel, or sawdust, is equal roughly to that of 2¼ bbl. of crude oil.

Improved wood-burning stoves. Improved wood-burning stoves have been introduced in the United States from Europe, where they have proved successful. Many residents in large cities have changed from coal or coke fuels to wood because it is cheaper and cleaner than either of the others. These stoves have been developed principally in Germany, France, Austria, Switzerland, and Sweden. The slow combustion of wood in iron and tiled types continues 24 hours with two filling changes, that is, once in the morning and once in the evening. The heat produced by these stoves is even and agreeable, and little ash is produced, so that relatively little labor is required except for stoking. They are designed for solid chunk wood of rather uniform sizes. The flue and sections must be larger than for coal or coke, and the joints must be thoroughly tightened, owing to the volume of wood gas given off. Certain structural alterations are required in the grate.

TABLE 24

QUANTITY OF FUELWOOD CONTAINED IN TREES OF DIFFERENT SIZES

Diameter of Tree, Breast-High, in.	Number of Trees of Each Size Required to Yield 1 cord — Hardwoods		
	Northern	Southern	Softwoods
2	....	170	....
3	....	90	....
4	....	50	....
5	35	25	....
6	20	17	....
7	15	13	20
8	11	9	13
9	8	7	10
10	6	6	8
11	5	5	7
12	4	4	6
13	3.5	3.4	4.5
14	3.0	3.0	3.7
15	2.5	2.5	3.0
16	2.0	2.2	2.5
17	1.7	2.0	2.1
18	1.5	1.8	1.9
19	1.3	1.5	1.6
20	1.2	1.3	1.5
21	1.0	1.2	1.4
22	0.9	1.1	1.2
23	0.8	1.0	1.1
24	0.7	0.9	1.0

For every 1 M b.f. of northern hardwoods cut, about 2/3 cord can be cut from the tops.

For every 1 M b.f. of southern hardwoods cut, about 3/4 cord can be cut from the tops.

For every 10 ties, about 1 cord of wood can be cut from the tops.

For every 10 poles about 1 cord of wood can be cut from the tops.

Softwoods taken to 4″ top diameter. Northern hardwoods: Beech, birch, and maple to 4″ top diameter. Southern hardwoods: Chestnut, oak, hickory, basswood, ash, etc., to 3″ top diameter.

36 · CHARCOAL

Charcoal is carbonized or charred wood, resulting from partial or incomplete combustion. It is made by charring or heating wood in a kiln or pit from which air is excluded. It has been made for many centuries in various forms of the so-called beehive open pit. For many years charcoal has been the principal source of fuel in Italy and Spain and many parts of France, Germany, Austria, and Poland where coal is not available or is very expensive. The manufacture of charcoal reached its height in the United States many years ago when iron ore was converted into iron or steel in New York, Pennsylvania, Connecticut, New Jersey, and other sections of the country. There is a large demand for charcoal where it is manufactured in the Lake States and in the South. It is now made locally in only a few sections of the country and for specialized uses in very limited localities in New York, Connecticut, New Jersey, and Montana. Practically all charcoal is now produced by processes of hardwood and softwood distillation described in a previous chapter. Because charcoal weighs about one-quarter the original dry weight of wood and occupies one-half the space of wood it is very cheaply transported.

Production. The production of charcoal, by all processes, was 47 million bushels in 1923 and 34 million bushels in 1935. Since then no accurate figures are available. These figures show that the demand for charcoal is decreasing. In 1935, only 672,000 bushels were made by the open-pit processes described in this chapter.

Woods used and yields. Wood of great density, such as hickory, hard maple, beech, birch, and the oaks, are the best kinds of wood for making high-grade charcoal. The softwoods and lightweight hardwoods produce less charcoal and a production of lower quality for general-utility purposes. However, lodgepole pine is used in connection with the copper industry in Montana and shortleaf and Virginia scrub pines in southern New Jersey for specialized types of charcoal. Approximately 100,000 tons of lodgepole pine charcoal were produced annually at one time in western Montana. For special metallurgical work, charcoal derived from mixed hardwoods and softwoods is sometimes preferred. For explosives, disinfectants, and filtering purposes, specialized forms of charcoal are required.

The yield depends upon the method and rate of burning, the

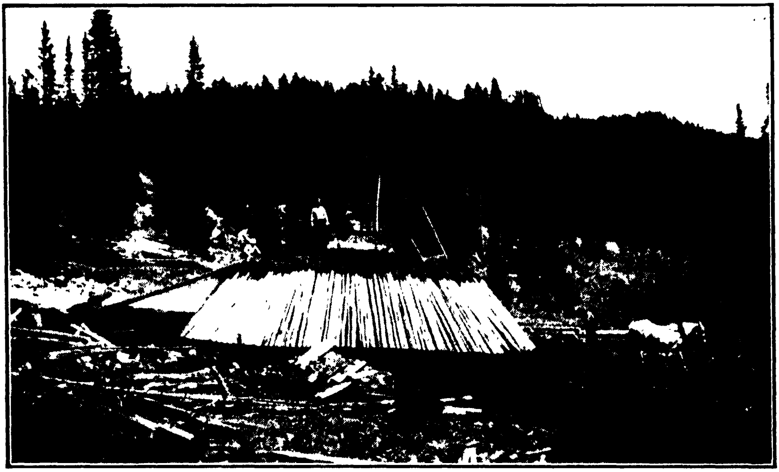


FIGURE 132. Lodgepole pine wood placed in a charcoal pit. First it is covered with straw or fine pine boughs to prevent a 4″ to 6″ layer of earth above it sifting down into the pile of wood. An 18″-diameter shaft is left in the center for carbonization. Twelve to twenty days are required to burn a 50-cord pit. *Photograph by V. T. Linthacum.*

intensity of heat, the kind of wood, its moisture content, and size of raw material. Oak, hickory, and the denser hardwoods yield about 30 bushels per cord. When charcoal is made in a brick or metal retort, yields may be greater because of increased efficiency in operation; but this process has been practically abandoned.

Processes of manufacturing charcoal. The open-pit method of making charcoal consists of the following operations. Billets of wood, 2′ to 4′ or more in length and 2″ to 6″ in diameter, are piled on end in a conical form. Triangular cribbing is built to the height of the pit in the center for a chimney and the wood ranked two tiers or more high, in the shape of a beehive or truncated cone, to the desired height. There may be 8 to 55 or more cords in each charcoal pit. Openings are left around the periphery at the base to serve as drafts. The pieces of wood are piled compactly together. After piling is completed, the pile is covered with grass, leaves, moss, branches, needles, or other local material to a depth of 3″ to 5″, and then with soil and turf to a depth of 2″ to 5″ in addition. The pile is ignited

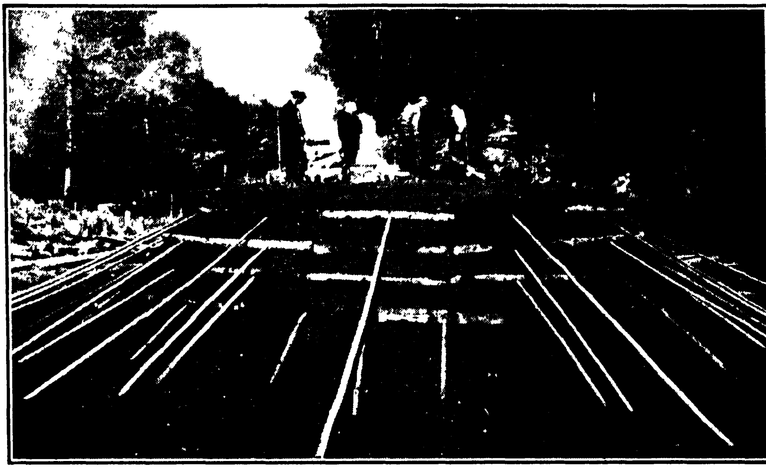


FIGURE 133. Igniting or firing a pit. When the process is completed the charcoal is "drawn." From 12 to 20 days are required to burn a 50-cord pit, depending upon moisture conditions of the air, wind, and other factors. When ready for drawing, the charcoal is a glowing mass and must be wetted down with water as it is uncovered to prevent complete combustion. Charcoal is pulled out of the mound with long-toothed rakes, allowing the covering of soil to settle down and keep the main body covered. *Photograph by V. T. Linthacum.*

by means of a torch at the base of the center flue or cribbing. Thus the pile gradually chars upward and outward, extreme care being taken neither to burn the wood too rapidly nor to permit the wood to become inflamed. Only a sufficient amount of air is admitted to cause partial combustion. The time required depends upon the kind of wood, its size and dryness, the method of piling, size of pile, temperature and weather conditions, and the character of the ground. Experienced colliers control the rate of burning by opening or closing the draft holes around the entire circumference of the pit. It requires about 8 days to burn an 8-cord pine pit in southern New Jersey. Specially designed kilns have successfully been used in Connecticut. About 21 days of average weather conditions are required to complete the carbonization process of the average 55-cord pit of lodgepole pine in Montana. On completion, the pit is "drawn" or "keeled." Quiet weather conditions are necessary when the pit is drawn.

FIGURE 134. Charcoal kiln made of cinder blocks with a capacity of 1½ cords. White pine tops left after logging operations yielded about 25 to 28 bushels of charcoal per cord. This is sold to campers, picnickers, and summer cottage residents near Lakeville, Conn. *Courtesy U. S. Forest Service.*

A strong wind may result in the pit's burning up after igniting the charcoal. In Sweden and Austria, pits contain up to 80 cords of wood. Those in France, Spain, and Italy generally contain only 10 to 40 cords. In Austria and Rumania are beech forests which can be utilized only by conversion of the wood into charcoal because of the inaccessibility of these forests and the difficulty of transportation in the raw wood condition. New pit locations do not give such good results as when the old places are reused. The accessibility and convenience of the wood supply generally governs the location of charcoal pits. The space selected for burning should satisfy the following conditions: (1) a minimum of expense in clearing and preparing the ground;

(2) a flat, level location; (3) accessibility and convenience to wood supply as well as inexpensive transport to market; (4) a convenient and adequate water supply available; (5) good protection from the wind; (6) preferably a clay soil which is dry and soft.

FIGURE 135. Drawing a charcoal pit in southern Ohio. The charcoal is being raked away from the slowly burning pile. This charcoal pit has burned for 7 days and is about one-third its original size. In this section the average pit is made with 25 to 30 cords of hardwood and produces about 1000 bushels of charcoal. Each cord of wood produces about 33⅓ bushels of charcoal. Each bushel weighs 20 lb. *Courtesy U. S. Forest Service.*

A charcoal kiln constructed with cinder blocks has been built and used in Connecticut.

Utilization of charcoal. Many years ago the principal outlet for charcoal was in the manufacture of charcoal iron. Then the principal outlet was in the manufacture of gunpowder and explosives. Charcoal also served extensively as a reducing agent in medical preparations. The increased consumption of coke and improvements in the methods of reducing iron ores have decreased the demand for charcoal. It is now widely used as a filtrant for medicinal purposes, for chicken food, and for fuel. At many parks, recreation centers, and picnic areas, it is sold in bags and small packages for a quick-burning fuel. It is utilized in the great copper smelters of Utah, Arizona, Montana, and other centers for testing ore and for treating some ores. Some of the larger iron furnaces have consumed as much as

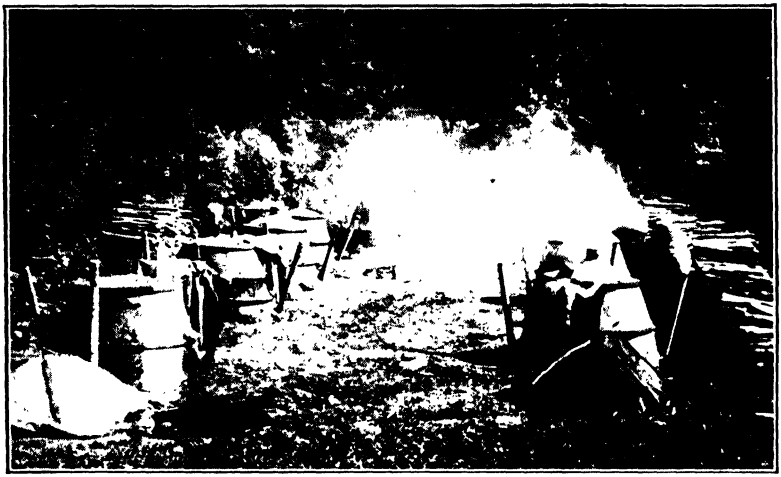


FIGURE 136. The Black Rock Forest portable charcoal kiln, as developed by Tryon in New York. This shows 12 kilns in operation, wood ranks on left and right, brick floors, and kilns cooling while others are being loaded and in process of burning. *Photograph by H. H. Tryon.*

750,000 to 1 million bushels annually. Fifty to seventy-five bushels of charcoal are required to reduce one ton of ore. The price of charcoal has been the determining factor in the industry. During World War I, when there was a great demand for charcoal, prices rose 7 cents to 9 cents per bushel. Considerable quantities of charcoal are still used by tinners and roofers for heating soldering irons. It is employed in the pulverized form for metallurgical work in Philadelphia and in other mints. Recently there has been a strong vogue for charcoal-broiled steaks, creating an increasing demand for charcoal for cooking purposes in many sections of the country. To a small extent, charcoal has been compressed into briquettes and sold for fuel.

Black Rock forest charcoal kiln.* In order to avoid the wastage and the impurities in the manufacture of charcoal by the open-pit method, a process was devised in which was used a light steel portable kiln in two sections, with a coned lid. It is 5′6″ in height and holds a full half cord of wood in its 100-cu. ft. capacity. Eight 4″ holes are cut equidistant from each other on the exterior side to provide adequate draft. Four-foot sticks of dry wood are used. The average yield per cook by an experienced crew was 327.7 lb., or 32.7 bushels, of charcoal per cord. The average time per cook was 24 hours. Two men are required for the battery of 12 kilns for 6 days and two men for 3 days in packaging, storing, and handling the product. This process has also been used at Orland, Me., and in other parts of New England and New York.

* See A Portable Charcoal Kiln by H. H. Tryon, *Black Rock Forest Bull.* **4**, Cornwall-on-Hudson, 1933.

37 · BRIQUETTES *

Many attempts have been made for several decades to use sawdust, shavings, hogged and chipped mill refuse, and other offal in the manufacture of compressed fuel forms known as briquettes. Some measure of success has attended these attempts in Europe. There is an enormous quantity of mill refuse, largely in the form of sawdust, shavings, slabs, edgings, trimmings, defective logs, and lumber, which at one time went to the boilers of large sawmills to supply power or was sent to the refuse burner and eliminated at some expense. One of the largest items of waste is in planer shavings.

FIGURE 137. Each "Pres-to-log" is 4⅛" in diameter × 12¾" in length and weighs about 8 lb., or about 3 times the normal weight of wood from which it is made.

A large company at Lewiston, Idaho, began experimentation in 1930 in briquetting shavings and dry mill refuse. Commercial production started that year but the machines were redesigned and rebuilt in the following years. There are 100 Pres-to-log machines installed and operating mostly in the Northwest and four in Canada. One is operating in Newark, N. J.; one in Memphis; two in South America; two in South Africa; and one in the British West Indies. In 1949 over 300,000 tons of the product were made and sold.

* Information partly supplied by Roy Huffman, manager, Wood Briquettes, Lewiston, Idaho.

A screw-auger type of machine compresses shavings under heavy pressure into cylindrical briquettes 4⅛″ in diameter and 12¾″ long, each briquette weighing about 8 lb., which represents three times the density of normal wood used. The three main

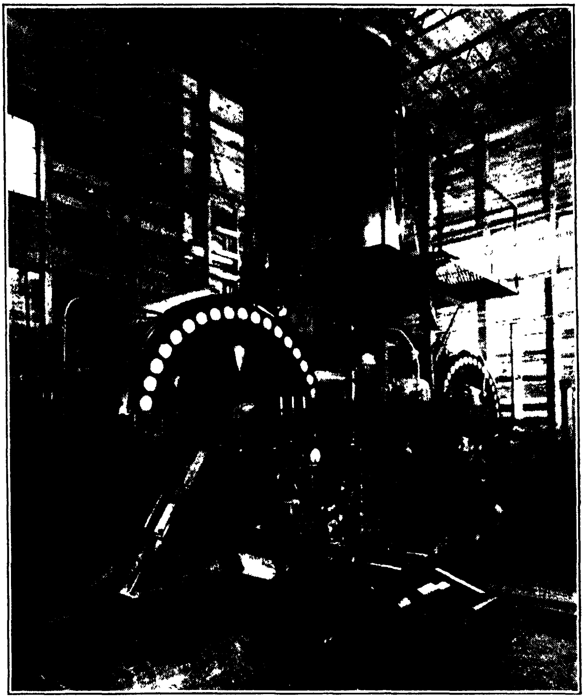


FIGURE 138. A twin-machine installation for making briquettes from shavings. Each machine produces about 12 tons of briquette logs per day (4⅛″ in diameter × 12¾″ in length). One man may operate two machines with consequent laborsaving cost. These two machines produce about 8000 tons annually. Each briquette weighs about 8 lb. *Courtesy Roy Huffman, manager, Wood Briquettes, Lewiston, Idaho.*

elements of the machine are the pressing screw, the die, and the pressure-regulating cylinder. The friction developed in filling a die creates temperatures of 350° to 450°F. It requires 20 minutes to fill and compress the die, which revolves and is water-cooled. This product is commercially known as "Pres-to-log." These briquettes are sold on a competitive price basis with other forms of fuel, including wood. The advantages, aside from fuel economy which has been proved, are cleanliness, convenience, freedom from ash, and relatively small space required for storage. They are used wherever solid fuels are used, in furnaces, fireplaces, heating stoves, and cook stoves. More specialized uses are for fuel in kitchens of diners and lounge cars, and in buffet-car ranges on the western streamlined trains, and for rolling and field kitchens of the Army, automobile trailers, and many intercoastal vessels. More than 12 of the larger railway systems have adopted them for diners. Apparently the market will absorb the product readily. The machine will utilize only dry refuse, but excessive moisture content can and is being successfully removed from newly sawed or partially dried mill refuse. The present capacity of each machine is 12 tons per 24 hours. The briquette industry furnishes a new and thoroughly practical outlet for the utilization of large quantities of planer shavings and, when properly dried, other forms of mill refuse. The total annual production in recent years has been about 225,000 tons of briquettes. Briquetting the refuse of planing mills, box factories, and remanufacturing plants, where dry refuse is available, has met with great success. The estimated production in 1937 was 90,000 tons, and in 1950 it advanced to 300,000 tons, indicating that this type of machine is a distinct commercial success where dry sawmill refuse is available in surplus quantities at low cost, power costs are not excessively high, and there is a good market for domestic solid fuels.

In 1949 a machine was developed to turn out smaller-size briquettes at the same plant at Lewiston, Idaho, where machines are made for manufacturing the larger-sized briquettes described above. The smaller briquettes are intended for use in stoker-type furnaces in place of coal. It has been demonstrated that these small briquettes make excellent stoker fuel.

The Letts' Lumber Company of Northville, N. Y., has developed a process of converting sawdust and other sawmill wastes into briquettes to be used as fuel. These materials are dried and put through a pounding process and then conveyed to a machine which compresses the material into approximately round briquettes about 1″ in diameter and varying in length from 3″ to 6″. It was determined that sawdust up to 2 years from the saw could be converted into these products. Some of the briquettes are packaged and sold for fuel as charcoal has been packaged and sold for some time.

38 · WOOD GAS

Many experiments have been conducted in several European countries to secure gas from wood or charcoal which may be used as a successful substitute for gasoline. Gasoline is not produced naturally in western and central Europe and frequently costs from 5 to 10 times as much as in the United States. Much of the development in Europe is under heavy government subsidy to make those countries independent of foreign gasoline supplies. In these experiments, charcoal is more satisfactory than wood, and both wood and charcoal have displayed definite advantages in cheapness over other forms of fuel.

Wood-gas generators have been devised for both mobile and stationary uses. Sawdust, chips, wood waste, and sawmill refuse may be utilized for stationary plants, but wood used in mobile generators must be of a special kind, preferably the size of a matchbox, well seasoned, and hardwood. Beech has been successfully used in Europe for some time. Greatest progress has been made in Germany where there are 800 stations providing motor vehicles with wood-gas fuel. Considerable developments have also been noted in Italy, Sweden, Austria, Switzerland, and France. According to one test 0.8 to 1.3 kg. of charcoal, or 2 to 4 kg. of wood, produce the same power as 1 liter of gasoline. In Rome, motor buses are running on this type of fuel. Most of the motor lorries and buses in Italy have been run on producer gas within the past few years. There are several thousand vehicles operating on wood gas in Germany.

Experiments are now being conducted to provide illuminating and heating gas as well as motor fuel from wood. This gas has the advantage of high calorific value and is unusually pure so that it may be utilized for various industrial purposes for which ordinary coal gas is not suitable. The French type of motor generator used with *charbon de bois,* or charcoal, ranges widely in price and weighs 80 to 300 kg.

It seems necessary to give the users of this fuel special training in the lighting of the generator, the methods of keeping it clean, and the causes and cures for stoppage in the production of gas.

Much actual driving experience and technique must be acquired before a driver can operate successfully a car using producer gas.

The Forest Products Laboratory at Vancouver, Canada, has conducted experiments in the production of fuel gas from sawmill waste. A motor truck using a producer gas generator has been successfully operated. A company in Brooklyn, which originally operated in France, has developed a successful gasogene to use wood blocks as fuel. To date, however, when the current price of wood gas is compared with the current prices for gasoline, there is no incentive for using wood gas as a source of power to drive trucks and automobiles.

PART VII

Miscellaneous Product

39 · BARK (OTHER THAN FOR TANNIN)

CORK *

Cork is the protective outer bark of an evergreen oak (*Quercus suber*). The inner bark contains the vascular bundles, or sap-carrying ducts. Although the tree grows over a wide territory, the commercial production of cork is restricted to an area bordering the western Mediterranean Sea, between the thirty-fourth and forty-fifth degrees of latitude, north.

The Iberian Peninsula is the great center of cork production and supplies nearly two thirds of the world's supply of cork. This tree also grows widely in southern France, Italy, 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, with Spain next in importance. Both countries are leading producers and exporters of wine corks and natural cork specialties. In addition, the manufacture of insulation board and other cork products has materially increased in the last few years. 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 million acres in Algeria, and 200,000 to 250,000 acres in Tunis. The total area of cork oak forests is estimated to be between 4 and 5 million acres. The richest and most productive forests are in Portugal and Spain.

The cork oak. The cork oak is generally a small, irregular tree 25′ to 50′ in height and 8″ to 18″ in diameter, at breast

* Reviewed and corrected by W. R. Compton, Jr., Secretary of the Cork Institute of America, New York City.

height. The clear trunk is seldom more than 12′ to 15′ in height, and the crown is usually somewhat dense and spreading. The cork oak forests resemble to some degree the live oak forests in the Southeast of the United States and in California, with the exception that individual cork oaks do not generally reach such large sizes as the live oaks of the United States.

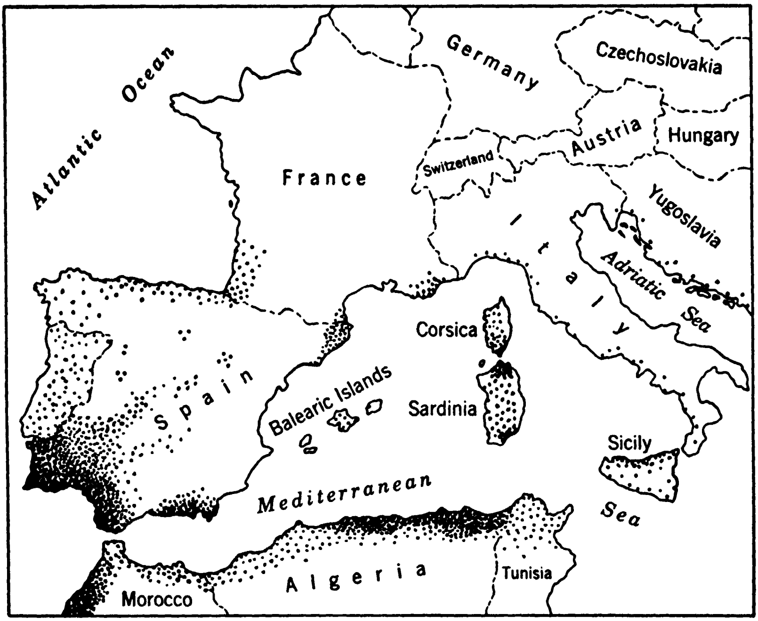


FIGURE 139. Map showing principal cork-producing regions of southeastern Europe and northern Africa. Frequency of small dots indicate most active areas. *Courtesy Cork Institute of America.*

The forests are very open, and there are ordinarily only 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, usually not attaining a size suitable for stripping until 20 to 30 years of age. In Spain, the only important Government regulation concerning the conduct of this industry is the stipulation that no trees under 40 cm. in circumference (about 5″) at a point 1⅓ meters above the ground can be stripped for their bark.

The trees commonly attain an age of 100 to 150 years but may reach 200 to 500 years. 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.

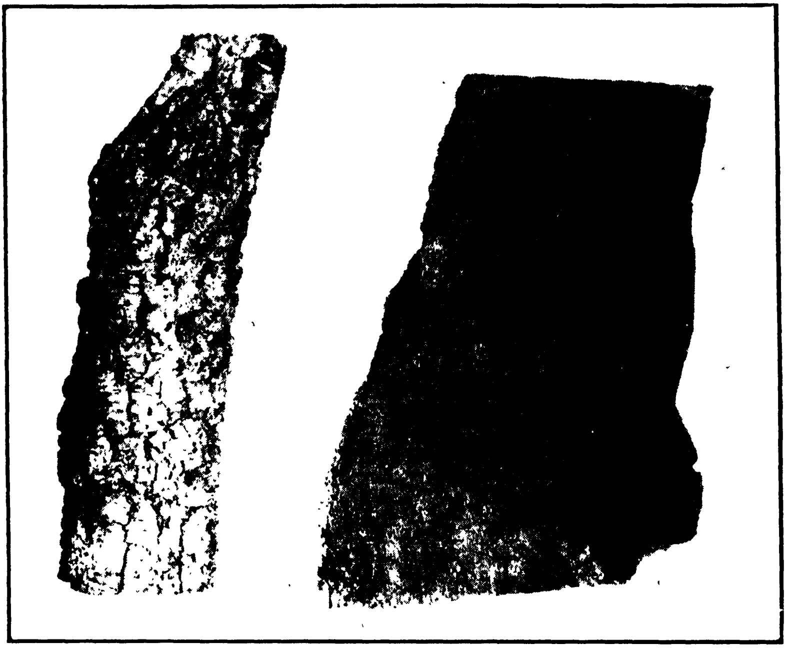


FIGURE 140. Virgin cork from the first stripping shown on the left and better grade of cork from subsequent stripping shown on the right. Cork generally varies in thickness from 1½" to 2½". Each tree may yield 45 to 500 lb. of cork, depending upon its age, condition, and site where grown.

For more than 160 years attempts have been made to grow cork trees in the United States. In 1858 the Government became interested and cork acorns were obtained from Spain and distributed in California and the southern states. Only a few trees survived these early plantings, but there are some magnificent specimens remaining. Beginning in 1904 the University of California made substantial plantings and is still interested. Early in 1940, a new project to promote the growing of cork trees in the United States was started by C. E. McManus of Baltimore, Md. About 60 old, mature trees in the southern states, 40 in Arizona, and some 4000 in California were found, and a vast research program was started. Acorns were collected for planting, and trees were stripped of the cork bark for experimental

FIGURE 141. Cork oak in its prime in southern Portugal being stripped by 5 men of some 500 lb. of high-quality cork which is manufactured into a wide variety of products ranging from the humble cork stopper to vital parts of a dive bomber. *Courtesy Cork Institute of America.*

purposes. Much of this cork proved to be of excellent quality and has been satisfactorily manufactured into cork composition and insulation corkboard. Subsequent strippings have yielded fine-quality cork ranging from 3/4″ to 1 1/2″ in thickness. Although considerable progress has been made in the first 8 years of this project, the growing of cork trees is a long-range program, and it will undoubtedly be many years before any possible commercial quantities of cork can be grown in the United States.

Harvesting the bark. All trees that are vigorous and healthy, 5″ to 6″ and up in diameter, are stripped. Trees are stripped of their bark every 8 to 10 years, and in Portugal recent restrictions call for every 10 years in order to preserve the forests and maintain a high-quality cork. In the lowlands, where the soil is richer, the cork is thicker and more spongy and, therefore, of

FIGURE 142. Cork bark drying in the open field in Algeria, North Africa. *Courtesy Cork Institute of America.*

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 grinding to produce granules for the manufacture of insulation board and similar cork products. It is usually hard, thin, dense, and tough, and very irregular. Trees as young as 20 years have, in special cases, been subjected to the stripping of their bark, but, ordinarily, the age of the first stripping is much greater than this, for the trees in Spain grow very slowly, so that it is often 30 to 50 years before trees attain a diameter of 6″. The first stripping does not injure the growth; on the other hand, it seems to stimulate further development of both bark and wood growth. Each successive stripping produces a better grade of cork.

Yield. The thickness of the bark varies from ½″ to 2½″, depending upon the age of the tree, the part of the tree, its condition, the character of the soil, etc. Each tree will yield 45 to 500 lb. of cork, depending on the same factors.

Ordinarily, the bark is allowed to season 3 to 8 days in the forest, and then it is weighed and sent to some central point to

FIGURE 143. Cork being brought to market on pack mules from remote districts where roads for truck haul are not available. A common sight in some of the rural districts in southern Spain. *Courtesy Cork Institute of America.*

be scraped. The scraping process may be done either in the forest or at the shipping center. In large operations, it is done at some large, central manufacturing point.

Utilization of cork. Cork possesses a number of properties that 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.
6. High coefficient of friction.

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 other special devices for the prevention of drowning.

Its impervious and compressible qualities bring it into wide popularity for bottle stoppers, 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.

The second largest use of cork is cork composition, a truly remarkable material developed as the result of the ingenuity of American cork manufacturers through long research. It is produced by combining pure cork granules with various glues, synthetic resins, and a plasticizer, such as glycerin. This mix is then placed in block-shaped or rod-shaped molds under pressure and baked into blocks or rods, which can be cut or sliced into sheets or disks of required sizes. Also, both rods and tubes are produced by the extrusion process. By varying the size of the cork granules, the binders, amount of compression, and other processing methods, widely different characteristics can be obtained suitable for an unlimited number of applications.

Perhaps the best-known and one of the largest uses of this material is to seal bottled liquids effectively by means of a composition cork disk inside the bottle cap. Another important use is for counters, insoles, innersoles, box toes, and platforms in shoes.

Cork composition played an important part in the success of mass production of automobiles. By means of gaskets and oil seals made of this material, the use of light-metal stampings was made possible instead of the former heavy-steel castings, which had to be machined in precision manner to make a tight fit. Now cork composition has many highly important industrial uses as a seal or gasket to retain grease, oil, and other liquids, as a dust seal, and as a friction material.

A new material has been developed in recent years, known as cork and rubber composition, which combines cork granules with synthetic rubber and resins. This is employed in special applications, many of which are in the same industrial fields as cork composition.

Cork's use for insulation has developed very broadly in the past 35 years. Probably more than 50% of the total cork product of the world, measured by weight, is utilized for this purpose. The percentage is even higher in the United States. Cork insulation used today is primarily in board form made by baking cork granules in molds under compression, thus releasing the natural resins of the cork to act as a binder. Cork is unique in possessing to a remarkable degree all of the principal qualities so important to efficient low-temperature insulation. These are:

Inherent moisture resistance.
Low thermal conductivity.
Resistance to infiltration of air.
Good workability or ease of erection.
Structural strength.
Resilience and flexibility.
Lightness in weight.
Freedom from odors.
Fire resistance.
Unattractiveness to vermin.

The primary purposes for which cork insulation is used are: (1) refrigeration for processing and storage of foods, chemicals, and medicines, and for an evergrowing number of manufacturing processes, (2) air conditioning, (3) prevention of moisture condensation, and (4) maintenance of exact temperatures.

The demands upon cork products have greatly increased during the twentieth century. It is estimated that, in the manufacture of solid articles from cork, there is a primary waste of 55 to 70%. This waste, however, is always collected, ground up, and ultimately used for a great variety of purposes.

Utilization of cork in the United States is summarized in Table 25.

TABLE 25

Uses	*Amount, short tons*	*Percentage*
Insulation	85,000	58.62
Cork composition (gaskets, seals, bottle cap liners, shoe products, etc.)	45,000	31.03
Bottle stoppers and natural cork products	8,000	5.52
Floor covering, marine goods, and miscellaneous	7,000	4.83
	145,000	100.00

PALCO WOOL FROM REDWOOD BARK *

Palco wool is shredded redwood bark used as an economical insulating material, particularly where cold storage demands constant, low temperatures, uniformly maintained. It has a thermoconductivity of 0.255 B.t.u.; is a relatively low-cost material; and is durable, odor-proof, vermin repellent, and moisture- and fire-resistant. Furthermore, it is a means of profitably utilizing a material—bark—which is otherwise wasted or disposed of at considerable cost. Several thousand tons of Palco wool are made each year. Redwood logs before going through the sawmill are peeled in a special bark-peeling plant. The bark slabs are then passed through a shredding process followed by steps in refining and condensing it for the production of two types of bark fiber.

(1) It is used as a loose-fill insulating material principally in low temperature locations; (2) the fiber-A product is used for many industrial purposes. One of the more important of these is in the manufacture of oil filters for Diesel-engine operation where fiber is blended with stripper cotton waste as a combined filter medium. Its very low factor of conductivity in British thermal units makes it very desirable as an insulating material.

SHREDDED HARDWOOD BARK

The department of poultry science of Ohio Agricultural Experiment Station in Wooster reports that shredded hardwood bark has been successfully used for floor litter in poultry brooder houses. Day-old chicks were started on this material with no precautions against eating it if they desired. No harmful results were experienced, and the chicks thrived well on this brooder material the same as other groups did on planer shavings litter which is the material generally used. This shredded hardwood bark makes a good product for litter purposes and has a color resembling peat moss.†

Other forms of bark are pulverized and employed as a mulch and for various other purposes. Many experiments are under way for its use as a filler in plastics, floor coverings, and fiberboards.

* From information supplied by C. L. Thompson, Pacific Lumber Company, San Francisco.

† From information supplied by D. C. Kennard, Wooster, Ohio.

SILVACON

The name Silvacon which includes several products of shredded and refined Douglas fir bark is derived from the Latin word *silva* meaning woods or forest and the word "economical." This implies that these are low-cost materials produced from the forest. Silvacon is one of the outstanding developments in bark utilization. One of the largest timber companies with 2,170,000 acres of timberland containing 40 billion b.f. of standing timber established plans in 1941 "to increase the realization from each acre of forestland harvested."

A laboratory has been established at Longview, Wash., where more than 1 million b.f. of logs arrive daily for a large sawmill. Of this volume, about 800 M b.f. consist of Douglas fir, of which bark accounts for approximately 12% of the weight. Therefore, the daily output of Douglas fir bark available for utilization is about 200 tons.

After many experiments in pilot-plant operations, one of the outstanding products of this Douglas fir bark is Silvacon, which is broken down, in turn, into a number of products. The Silvacon plant is built near a large plywood plant at Longview, Wash., through which 40 M b.f. of Douglas fir logs pass daily. Removal of the bark from these peeler logs provides about 10 tons of Douglas fir bark which is used as raw material for the adjoining Silvacon plant. One product of the latter is an ingredient used in the manufacture of plywood adhesive. Thus, material formerly wasted is utilized in a major product at the same plant.

At first, the bark is removed by a heavy hydraulic barker and then is shredded to a size satisfactory for grinding. The ground bark is conveyed to storage bins. Then it is dried and screened for various products. As manufactured, the various Silvacon products are automatically conveyed to individual storage bins, then bagged, and made ready for shipment.

Silvacon 383 has a high extractive content which suggests utility as a source of wax and tannin and now finds wide use as a soil conditioner. It is employed in flooring materials, cork products, adhesive formulations, rubber products, etc. Silvacon 508 consists largely of stiff spindle-shaped bast fibers in which the lignin content is 34%. It is adapted for use as reinforcing filler in the manufacture of hard, high-density products where it improves strength and minimizes shrinkage. Thus, it is available for the large plastics field. It is also utilized in automobile underbody coatings. Silvacon 490 is a finely powdered material which

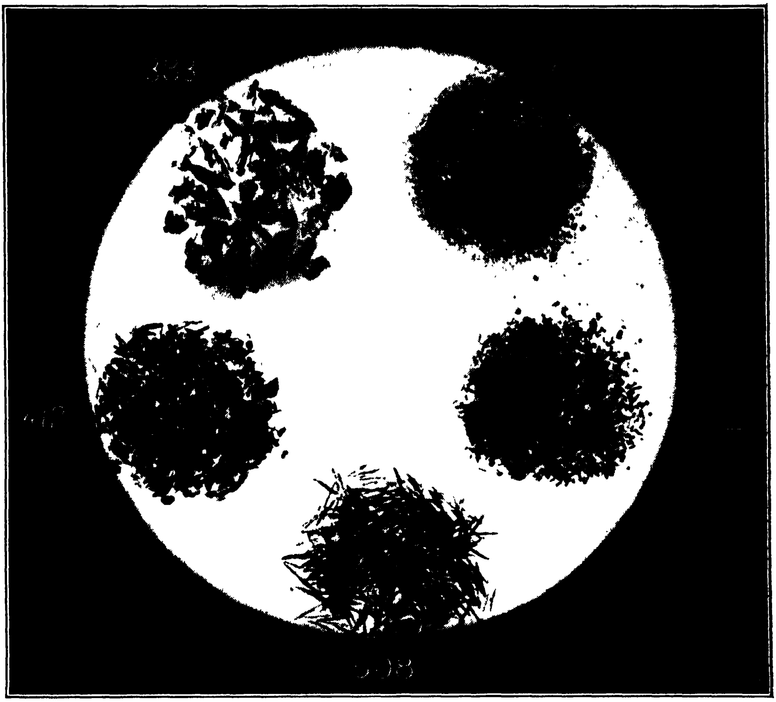


FIGURE 144. Microphotograph of five different fractions processed from bark in the production of Silvacon. This is made from Douglas fir bark transformed into valuable products used in the manufacture of plastics, glues, soil mulch, insecticides, and others. These were developed at a large laboratory at Longview, Wash. *Courtesy L. T. Ordeman.*

contains 65% lignin and may be useful for thermosetting molding compounds. Silvacon 412 is a mixture of cork particles similar to Silvacon 383 but smaller in size which may be uniformly blended with fiber. It may be used with cold-molded plastics. It is used in rubber outersoles, sponge rubber, and a variety of other rubber products. Silvacon 472 is a blend of the individual compounds of Douglas fir bark: namely cork, fiber, and powder. It may be combined with phenolic resin to give a high-quality exterior grade of plywood adhesive at relatively low cost. Silvacon 472 also finds use in oil-well drilling and in the manufacture of asphalt tile.*

* For further reference see Development of Bark Products, by Weyerhaeuser, *Paper Trade J.*, April 7, 1949, originally presented before Northeastern Wood Utilization Council by W. G. Van Beckum.

40 · CHRISTMAS TREES AND DECORATIONS

This industry has assumed large proportions and resulted in the annual cutting of about 25 million trees which, conservatively priced at 50 cents per tree in the woods, would yield $12,500,000. Coniferous forests are very fortunately located with reference to supplying a great variety of native trees desirable for Christmas tree purposes to the great centers of population. In the North and Northeast, balsam fir is very desirable because of its pleasant odor, lustrous dark green leaves, symmetry of crown, and the fact that its leaves do not quickly fall when the tree is placed in warm houses. Spruce makes an excellent tree and is probably most widely used in Canada, the North, and the Northeast. In the Rocky Mountains and on the West Coast, Douglas fir and other firs are considered most desirable. In the South, several varieties of pines, cedars, and other species are used for Christmas trees. When small trees are clear-cut on large areas, serious injury is done to the forest; but, if a careful selective thinning is followed, the forest may be improved. Many Christmas trees have been planted in reforestation projects in New York, the Lake States, Pennsylvania, and New England. They are cut at 6 to 11 years from planting. Some of these have proved to be very profitable. In some sections of the East, Scotch pine and red or Norway pine are sold. Excellent thinnings are conducted on the Pike National Forest in Colorado and in the Northern Rocky Mountains, from Douglas fir stands to supply the annual demand in the Plains and Central Western States. Many hundred thousand pounds of boughs are cut from National and private forests for Christmas decorations. For the purpose of supplying Christmas trees and boughs for Denver, 400 to 600 acres of forest are profitably thinned annually. A net income of $0.50 to $1.50 per acre per year has been obtained from thinnings for these purposes. The Forest Service in the Southwest (Arizona and New Mexico) sells about 50,000 trees from the National Forests.

The season for cutting trees and greens lasts only about 5 weeks, extending usually from November 1 to December 10 for carload lots. Some companies however have extended this cutting season by dipping or spraying small trees with paint and treating them chemically to retard needle fall and prevent mold. Trees treated

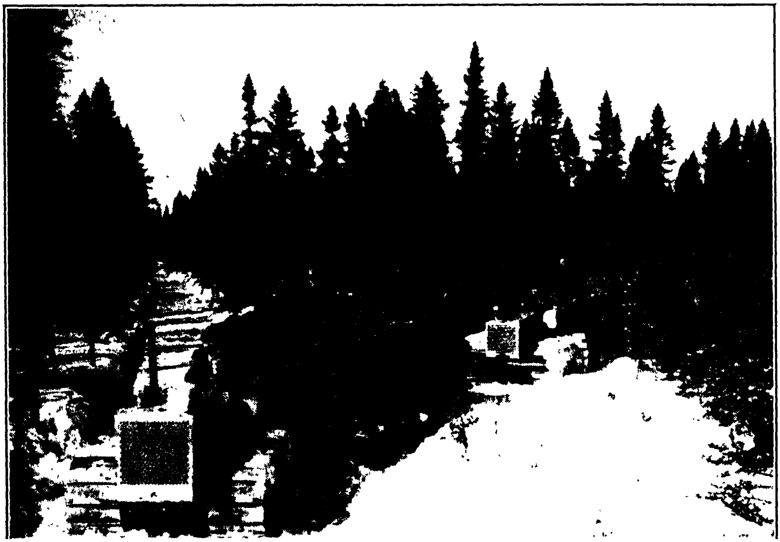


FIGURE 145. Specially built barge-type dray loaded with 3000 black spruce Christmas trees and hauled by Caterpillar Diesel D2 tractor on tract of Halvorson Trees 18 miles southwest of Big Falls, Minn. The D4 tractor in the background is pulling a similar load. At left is a snowplowed haul-road for bringing out trees. More than 1 million of these Christmas trees are annually harvested from the extensive spruce swamps in Minnesota. *Courtesy Halvorson Trees.*

in this manner can be held in cold storage for more than a year.

One concern in Minnesota cuts and ships annually more than 1 million black spruce Christmas trees, generally in yard lengths and processed in a protective chemical bath and mounted on a liquid-containing steel base. About 40% of the output is produced in the spring months, then stored in cold storage to await November or December shipment. About one half of the autumn output is also placed in cold storage, as the cutting of trees starts in the latter part of August. These trees are shipped to many parts of the country. The chemical used colors them in white, aluminum, and green colors. This black spruce grows very slowly in the swamps of northern Minnesota and is not useful for any other important product. Cutting is done so that the forest, which grows exceedingly slowly, is renewed, and thus good forestry is practiced.

California annually uses about 3 million Christmas trees of which about 600,000 come from within the state. Of these about

FIGURE 146. Christmas tree sales yard where various firs from the Sierra region are unloaded and sold in Oakland, Calif. On the left are trees dipped in white chemical. *Courtesy U. S. Forest Service.*

90,000 come from the National Forests. The out-of-state trees come largely from Oregon. The principal trees used are Douglas fir, red fir (*Abies magnifica*) and white fir (*Abies concolor*). The California red fir is highly regarded and is locally sold in the state as a "silver tip Christmas tree." *

The National Forests of California have been selling Christmas tree stumpage for about 18 cents per lin. ft. This amounts to about 90 cents for the average 5-ft. tree. The retail price of trees may vary from 25 to 50 cents per lin. ft. for Douglas fir, and some of the white and red firs bring from $0.60 to $1.50 per ft. About 90,000 trees are annually sold to local cutters from California National Forests. In Washington and Oregon, the annual crop is estimated at 5 million trees, which are shipped throughout the West and Middle West.

* From data supplied by Wallace I. Hutchinson, U. S. Forest Service.

More than 6 million trees are shipped annually from the Rocky Mountain region eastward as far as Pittsburgh in carload lots. Almost all these trees are Douglas fir. From Montana alone, more than 3 million trees are shipped annually. In one year, they were shipped to 33 states. About 81% went to the Central

FIGURE 147. Symmetrical and well-formed spruce table trees cut with Sandvik saw. Many prefer small trees for the table or for a corner of the room. *Courtesy Halvorson Trees.*

States, and 3 carloads went to Cuba. There are about 4500 trees per carload, or 800 per average truckload.

Concurrently with Christmas trees, a large number of evergreens are cut for wreaths and general decorative purposes. Conifers, ferns, mosses and other forms of greens are commonly cut in many parts of the United States. Mistletoe in the South, Southeast, and Southwest, holly and laurel in the eastern and southeastern states, and Oregon grape and salal and toyon in the Pacific states are harvested in large quantities for Christmas decorations. Kinnikinic (*Arctostaphylos uva-ursi*) is used for Christmas decorations in the Southwest and West.

Holly has become an important forest crop especially in the sections of its important growth, such as Maryland, Delaware,

FIGURE 148. Harvesting the annual spruce Christmas tree crop. About 25 million trees are annually harvested for this purpose. Evergreens throughout the country are used, but the spruces, balsam fir, western firs, and Douglas fir are generally preferred. *Courtesy Halvorson Trees.*

Virginia, and the Carolinas. In Maryland, a label entitled "Maryland Certified Holly" is attached to box shipments of holly. In 1949 approximately 600 tons of forest greens, including holly, were shipped from the forests of one district (Salisbury) in eastern Maryland.* This material goes directly to the buyers, as well as through jobbers and wholesalers. Shipments are generally made up until December 10 of each year. The use of Christmas greens, holly wreaths, and other decorations has been

* From data supplied by J. J. Mohr, District Forester, Salisbury, Md.

widely developed, especially in the East, and to some extent in all parts of the country in recent years. Some of the larger cities have fire regulations requiring the treatment of forest greens before they can be used in the interior of homes, shops, etc., where there may be a fire hazard. Many of the holly wreaths are treated with lacquer before shipment. Holly with large clusters of red berries is much preferred and bring higher prices than wreaths with few or none of the characteristic berries. Unfortunately only a small percentage of the natural-grown trees produce berries. Some operators actually grow orchards of the berry-producing trees in order to supply the Christmas trade. They may sell holly sprigs with berries for as much as 60 cents a pound.

41 · ORNAMENTAL AND DECORATIVE PLANTS *

Included in the forest products of wooded sections are many plants used for aesthetic treatment in home, school, park, and other grounds as well as for window or home plants. Within the past two decades there has been a wider appreciation of the value of ornamental trees, shrubbery, and plants to improve the appearance of home grounds, parks, and public buildings. Although these are sometimes considered within the general field of horticulture, many have a definite value as forest products and are sold from National Forests, state forests, and privately owned timberlands.

From the mountain forests of the southern Appalachians, many carloads of rhododendrons, azaleas, mountain laurel, and other ericaceous plants are obtained. The native forests of New York, New England, Pennsylvania, and the Lake States also produce many desirable ornamental plants, considered a valuable part of the annual produce which brings in revenue to some of the timberland owners. In the lower Catskill regions of New York and adjoining areas of Pennsylvania, large numbers of rhododendron, mountain laurel, hemlock, white pine, and many other species are shipped for planting on large estates, around homes, and in parks in the New York, Boston, Philadelphia, Baltimore, and Washington districts. Young longleaf pine trees 6″ to 2′ in height are potted and sold for house plants in several sections of the South.

In 1949 more than 17,000 leucothoe plants were removed, under permit, for a nominal sum from the Unaka National Forest in Tennessee and more than 37,000 other plants, principally rhododendron and mountain laurel, were sold at a value of $3434 from three National Forests in the Appalachian region. Removal of rhododendron and mountain laurel helps in the reproduction of

* For an interesting summary of many minor products of the lush evergreen forest of the Northwest, see *Minor Forest Products of the Pacific Northwest,* by E. W. Shaw, Pacific Northwest Forest and Range Exp. Sta., Portland, Oreg., Dec. 1949.

desirable timber species. If severe cutting or removal of some of these plants results in extermination, the practice may be objectionable, whereas, if the forest is properly thinned, they may furnish a permanent source of revenue and income for the forest owners.

Rooted wildling stock of Colorado blue spruce and Rocky Mountain cedar are sold from National Forests in Colorado for 14 cents to $1.60 cents for trees 4″ to 6′ in height. About half these prices are obtained for wilding ponderosa pine of the same sizes. Wildings under proper regulation are sold from several National Forests throughout the West.

The Denver office of the Rocky Mountain region of the U. S. Forest Service reports that 10,000 lb. of arnica blossoms were sold in 1949 from the National Forests.

The Albuquerque office of the same organization reports the sale of 3200 wildlings (ornamental transplants), 4000 bushels of pine cones for both decorations and seeds, 10,000 lb. of greens for decorations including kinnikinic, 100 cu. yd. of leaf mold (humus) and 22,000 lb. of agave used in making distilled alcoholic drinks such as mescal and tequila.

The Milwaukee office of the north central region of the U. S. Forest Service reports the sale in one year (1949) from two Wisconsin National Forests of 288 young trees (wildlings), 123 tons of coniferous boughs, and more than 90,000 Christmas trees.

42 · WILD FRUITS, EDIBLE NUTS, AND TREE SEEDS

WILD FRUITS AND NUTS

Edible wild fruits are an important pay product of the forest in several sections of the country. The principal ones are wild blueberries and huckleberries, which are gathered on a commercial basis in New England, the Blue Ridge section of Virginia, and in several localities in Washington, Montana, and Oregon. There are more than 30 species of the blueberry genus. Five species of huckleberries are found in the eastern states. They furnish employment and enjoyment to many thousands of people. These fruits are picked annually for sale to the canning trade. On one National Forest in the Northwest, an annual crop of 30,000 to 60,000 gal. of huckleberries is harvested. Pickers receive 60 cents to $1 per gal.

In some localities of southwestern Oregon and northern California, the Pacific plum is an important product. This excellent fruit ripens in summer and constitutes an important food item for the Klamath Indians.

The native forests of the United States produce large quantities of edible nuts which play an important part in local employment and as a source of food. The pecan crop derived from about 5½ million wild and cultivated trees in the South and Southwest produces annually more than 26,000 lb. of nuts. More than one half of the trees are wild and are found principally in Texas.

The pinyon pine nut industry (from three species of pinyon: namely, *Pinus cembroides, Pinus monophylla,* and *Pinus edulis*) is very important in the Southwest, from western Texas to the Pacific Coast. The juniper-pinyon pine type of forest, including about 100 million acres, or more than three times the total area of Pennsylvania, is found largely in the National Forests and Indian reservations. The annual nut harvest varies with the precipitation, which is very uncertain in the Southwest. In a recent year 7 million lb. were harvested in New Mexico and Arizona alone. The gathering of these nuts furnishes employment and food, especially for the native Indian and Mexican people. The nuts are sold to trading stores near the forests, and large quantities not used locally are shipped to the eastern cities. Native pickers receive 9 to 20 cents per lb. The Forest Service makes no charge for the privilege of nut gathering from National Forests.

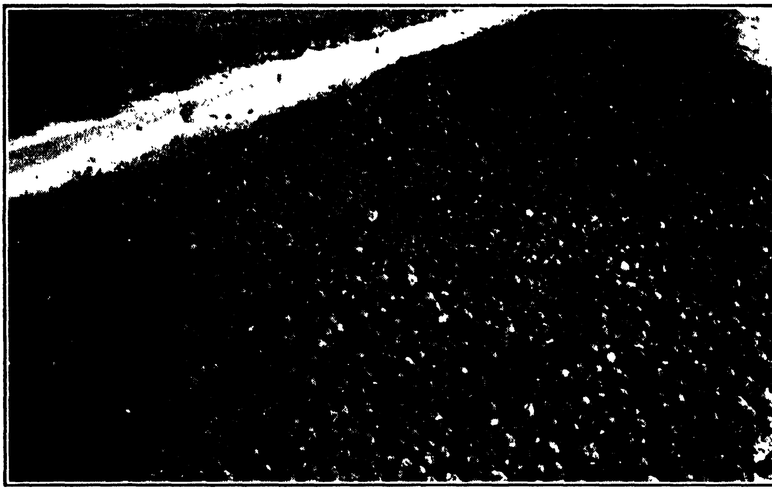


FIGURE 149. About 80 bushels of black walnuts hulled and ready for stratifying and storage at the Illinois State Forest Nursery. The harvesting, preparation, and storage of seeds to meet the enlarged reforestation programs has become an important business in several sections of the country.

The gathering of hickory nuts, walnuts, butternuts, chestnuts, and other kinds of nuts is not done, as a rule, on a commercial basis, but the nuts constitute an important item of food and considerable recreation and pleasure to many people in the East and South. The American Walnut Manufacturers Association of Chicago is promoting the planting of black walnuts in many sections of the middle western states. Although the chestnut tree is about extinct, chestnuts are still gathered in the Appalachian region, and chestnut sprouts sometimes produce nuts in the East and Northeast. In Italy about 600,000 tons of chestnuts are annually harvested. These constitute an important part of their food supply, especially during and since the last World War.

SEED HARVESTING AND EXTRACTION

With the rapid increase in the reforestation program to meet the needs of the new Federal, state, and private conservation policies, tree seeds have assumed an important position as a forest product. For several years seeds were collected in various parts of the United States for the British and other European reforestation programs, as well as for those in New York, Michigan, Pennsylvania, and other leading states in the reforestation movement. Within recent years large seed extractories have been established in the Lake States, the South, the Northeast, and the Northwest, to which large quantities of purchased and collected coniferous cones are shipped for the purpose of extracting seed. After extraction, the empty cones are often sold to novelty manufacturers at prices ranging from 15 cents to 26 cents per bushel. There are estimated to be 50 million acres in need of planting in the United States and Canada.

During its existence, the Civilian Conservation Corps planted more than 2 billion trees. During a 4-year period, 1936 to 1940, some 308,577 bushels of coniferous cones and 2,191,097 lb. of hardwood seeds were collected by the Civilian Conservation Corps. Large additional quantities were collected by private individuals and companies and by various Federal and state agencies for general reforestation, soil erosion, and the Plains Shelterbelt project. The Tree Farm, Trees for Tomorrow, and other private programs have greatly stimulated and encouraged the tree-planting programs in many parts of the country.

Logging operations furnish excellent opportunities for seed collection, especially from felled trees during seed-harvest time. Squirrel hoards are also widely used as a source of supply. Sometimes individuals climb trees to clip off cones or collect hardwood seeds. Hardwood seeds are frequently collected directly from the ground. Several companies in the Northwest and South do an important business in seed collection.

The principal species collected are eastern and western white, Norway, jack, lodgepole, sugar, and ponderosa pines; red, white, and black spruce; red cedar; longleaf, slash, loblolly, and shortleaf pines; hemlock, and Douglas fir among the conifers; and black and honey locust, cottonwood, yellow poplar, white and red oak, red gum, ash, black walnut, and black cherry among the hardwoods. In many localized sections, the harvesting, extraction, and storage of tree seeds are an important business. Much Norway pine and Scotch pine seed was formerly imported from Europe; it is now obtained from reforestation areas in New England, Pennsylvania, New York, and the Lake States. Some of these plantations are 20 to 40 or more years of age and produce viable seed of good quality. Much emphasis is being given to harvesting seed from vigorous and healthy trees.

43 · ATHLETIC GOODS, SHUTTLES AND BOBBINS, AND MISCELLANEOUS PRODUCTS

ATHLETIC GOODS

There has been a greatly increased demand for many forms of wood for athletic or sporting goods concurrently with the expanding interest in athletics and games since World War II.

Few forest products present as diversified problems in design, tooling, and fabrication as those developed in the manufacture of athletic equipment. Sporting goods must be produced to meet constant and extreme abuse while in service whether from impact, torsional strains, abrasion, and other severe tests. In spite of these strains and abuse, these goods must retain their original uniform characteristics of size, shape and life for long periods of time. The problems of weight versus strength and weight versus size are particularly important. This is equally true for wood used in the aircraft industry. Therefore, uniformity of specifications to meet dimensional limitations, resiliency, rigidity, rebound, and other features must be maintained within the closest of tolerances.

These techniques must be particularly considered in the manufacture of tennis, squash, and lacrosse rackets; skis; golf heads; hockey sticks; snowshoes; baseball bats; and yew bows. Ash has fulfilled the qualifications better than any other species, particularly for tennis and other forms of rackets and baseball bats. The pre-eminent wood for golf heads is persimmon, although dogwood until recently was also utilized to some extent. Hickory is the outstanding wood for skis, and elm for hockey sticks. The western or Oregon yew is the chief wood employed for bows in archery.

Among the many forms of athletic goods dependent on wood as their basic raw material, those listed in Table 26 are typical. Many other products in this group are not included because of lack of space. Among them are billiard cues; ping-pong, billiard, and similar tables; hockey and lacrosse sticks; gymnasium equipment; shuffleboards; playground, recreational, and amusement equipment.

TABLE 26

Classification	*Annual Production*	*Principal Woods Used*
Tennis, badminton, and squash	1,000,000 rackets	Ash
Skis	335,000 pair	Hickory
Golf heads	1,100,000 woods	Persimmon
Baseball and softball bats	4,500,000 bats	Ash
Yew bows	5,000 bows	Yew
Bowling pins	3,250,000 pins	Hard maple

Tennis and other rackets.* These have been manufactured for more than 150 years. They have been made from well-known and long-fibered hardwoods such as ash, hickory, and oak and for years were steam-bent from one piece of stock. After many tests both in the laboratory and in play, the laminated ash racket from second-growth, northern and mountain ash has proved to be the best material developed to date. Ash cut from logs having 6 to 12 annual rings per inch produce the strongest and most resilient frames. Only about 33 to 40% of the logs cut for this purpose measure up to the strict specifications. The modern laminated rackets for tennis, badminton, and squash are made of ash and also of hickory, maple, birch, beech, and oak, with decorative or trim laminates of mahogany, walnut, gum, cane, and bamboo. Sawed laminations rather than rotary or spliced veneer are used. Straight-grain laminations are required, having full continuity of fiber and resulting full strength. This is an exceedingly expensive and wasteful process, but the best results are obtained by this method. Generally 8 to 10 laminations are used in the different types and grades of rackets.

Skis.† The use of wood for skis has made great progress during the past 15 years, concurrently with the greatly increased popularity of this sport. In 1931 the value of the total output of skis was about $163,000. It advanced to $1,078,000 in 1939, and in 1949 the estimated volume was about $6,500,000.

* From information supplied by W. T. Brown, vice-president, A. G. Spalding & Brothers.

† From information supplied by John Maxwell.

Hickory is the prime wood employed for skis. About 50% of the hickory skis are of solid wood, and about 50% are laminated. Some foreign companies have promoted the use of ash and birch and other woods, but hickory continues as the outstanding wood. Juvenile skis are made of several pines, maple, and other woods. Metal has been promoted but has not been accepted generally in the trade. A combination of hickory and plastic of nitrocellulose type has been promoted in the past few years. However, they sell for about $65 a pair whereas laminated hickory skis sell for $25 to $35, depending upon whether they are equipped with metal edges. The lamination of hickory is necessary in order to produce a ski that will hold its camber and remain straight. Camber is the belly of the ski that is seen when two skis are placed bottom to bottom. When there is a contact of the tip and tail tangent points, there is a space of 1″ to 1½″ in the middle. This camber is pressed into shape during the setting of the glue on a special press. Skis range in length from 4′ to 5′ in pine, 5′ to 6′6″ in maple, and 6′ to 7′3″ in hickory. The width varies with length. Width at shovel or tip tangent point is 3½″ to 3¾″. Width at foot plate or balance point is 2⅞″ to 3″; at tail tangent point, 3¼″ to 3½″. The thickness varies also, depending on length: At shovel, 5/16″ to 11/32″; at balance point, ⅞″ to 1″; at tail, 5/16″ to 11/32″. Almost all skis now feature a ridge top which reduces weight and improves the beauty of the ski.

Flexibility of a ski is most important, and hickory provides this better than any other wood.

Golf heads. With the continuing popularity of wood for golf heads, there has been increasing difficulty of getting good stock, although it is estimated that the available supply of persimmon in the lower Mississippi hardwood region will last for many years to come. The annual demand is for about 1,100,000 golf heads. The industry is centered about Memphis.

Blanks for fashioning into golf heads are at least 10″ in width in order to make quarter-sawed flitches from which the golf heads are sawed. The golf blocks are approximately 6½″ long and 3½″ wide, and the thickness varies from the neck to the main part, depending on the finished size of head. In all cases the grain on the face must be parallel with the ground line. Persimmon best meets the qualifications for a hard, resilient wood which retains its shape in spite of varying weather conditions and severe use. Dogwood has been used in the past, but it does not reach sufficient size to produce golf heads in quantity. Technically, dogwood produces a very fine golf head, but the natural size of available timber does not meet the size specifications for wide use.

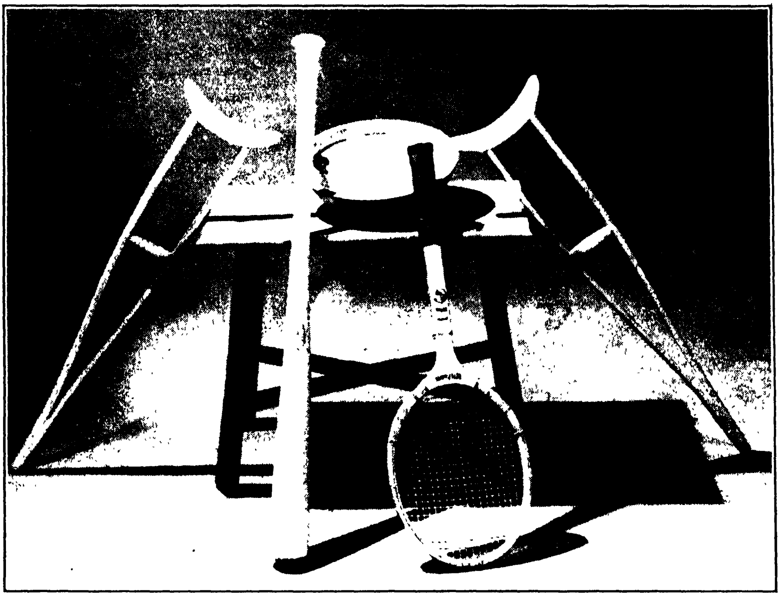


FIGURE 150. Various products made from hardwood. Much of the raw material for these products comes from farmers' wood lots. Various articles are crutches, wooden salad bowl, baseball bat, and tennis racket. *Courtesy American Forest Products Industries.*

Baseball bats. The raw material for baseball and softball bats is produced in round, square, or split ash billets generally from small mills located in Pennsylvania, southern New York, Kentucky, West Virginia, Mississippi, and Alabama. These billets are usually 45″ long and 4″ thick, and, when manufactured on lathes, the finished bats vary from 31″ to 40″ in length and are usually 2¾″ in diameter at the thickest end. Baseball bats when finished are equal in weight (in ounces) to the length of the bat in inches. For example, a 33″ bat weighs 33 oz. Ash is the pre-eminent wood used for bats and probably comprises 90% of the total production. However, hickory, beech, and hackberry are also used. Second-growth ash is much preferred, especially straight-grained and slow-growing stock with uniform rings.

The billets are air-seasoned for 2 years and then are turned into rough form on lathe knives. Then they are sanded and lacquered, and the brand is burned on the top face. Many ballplayers, especially the outstanding ones in the major leagues use autographed bats; that is, they select a bat to their specifications and receive a shipment from the manufacturer with their name burned or painted on the large end. Softball bats are much smaller in size and vary depending on the local requirements.

Yew staves and billets.* Ever since yew wood from the mountains of Spain and Italy was used for warfare before the use of gunpowder, yew has been widely used for bows in archery. The industry in the United States is supported largely by Pacific yew (*taxus brevifolia*) on the National Forests on the western slopes of the Cascade Mountains in Oregon, and to a less extent on other public and private operations in that state. The best qualities are found at about 2200 to 2500 ft. in elevation, and the industry is centered about Eugene, Oreg. This industry has been continued for about 25 years during which 125,000 staves and billets have been produced. The Pacific or western yew is a small tree less than 60′ in height and is found as an understory in scattered locations in the heavy, dense stands of Douglas fir, hemlock, and cedar. The wood is subject to many defects, principally knots, windshakes, bear scratches, and woodpecker holes. Cutting is done in inaccessible locations, generally up to 5 miles from a passable road with horse trails for transporting the staves. Yew staves must be cut before logging which has already destroyed much good yew material. Yew staves are generally seasoned 5 to 7 years and have been priced at $5 to $12 per stave, 5′6″ long to 6′ long, 2″ wide, and of various thicknesses with sapwood and heartwood intact.

Miscellaneous. Among the many other forms of athletic goods and equipment requiring wood may be mentioned lacrosse sticks, snowshoes, gymnasium equipment, rowing shells, canoes and oars,

* From data supplied by E. A. Ullrich, Roseburg, Oreg.

bowling alleys and pins. The following is a brief treatment of bowling pins and alleys.

*Bowling pins and alleys.** Since World War II, bowling has greatly increased in popularity. Large quantities of wood are utilized for both pins and alleys. The annual consumption of bowling pins is about 250,000 sets of tenpins, 50,000 sets of duck pins, and 25,000 sets of candle pins. As there are 10 pins to the set, the annual consumption of all kinds of pins is about 3,250,000.

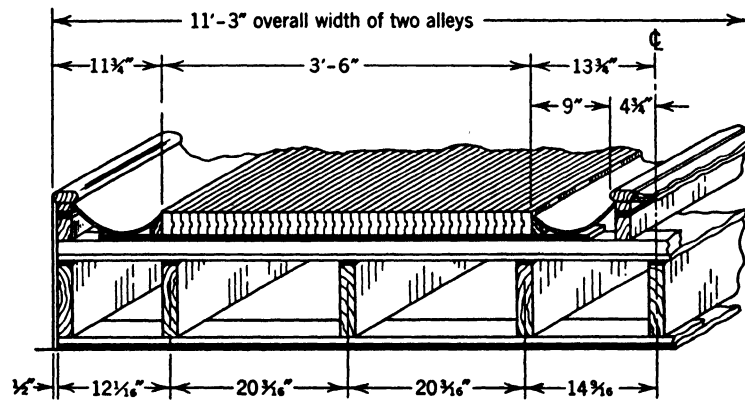


FIGURE 151. Cross section of bowling-alley construction showing flooring laid on edge. *Courtesy Brunswick-Balke-Collender Co., Chicago.*

Hard maple is employed exclusively, and the supply comes largely from Wisconsin, Michigan, and New York, with Pennsylvania, New England, and Ontario supplying important quantities.†

There are about 70,000 alleys of all kinds. Approximately 1 M b.f. of hard maple and 800 b.f. of southern pine are used for each alley and approach. The approach and first part of the alley are built of hard maple to withstand the abrasion of the bowlers' shoes and to meet the impact of the falling ball. The rest of the alley is of southern pine. Including the supports such as stringers, gutters, and accessory equipment, each bowling alley requires about 4200 b.f. Thus, for the 70,000 alleys in use, some 294 million b.f. have been required.

* From information supplied by C. E. Weiskopf, Chicago, Ill.

† A leading manufacturer of tenpins and bowling-alley bed stock reports that the best maple, in order of quality, comes from upper New York, Wisconsin, Pennsylvania, Michigan, Maine, and Canada.

Owing to the difficulty of obtaining a good supply of maple to meet the rigid specifications for pins, two or more laminations have been employed. Improved adhesives have made this possible. However, the demand is still strong for solid rather than laminated pins in spite of the greater expense involved.

The average set of first-quality tenpins will last through 1500 to 2500 lines of play. Duck pins last for 600 to 800 lines and candle pins for 400 to 600 lines of play.

Bowling pins are turned out from blocks as split from short-length maple bolts directly from woods operations. Alleys are made in flooring plants separate from or in connection with sawmills. Bowling balls formerly made of lignum vitae and other woods are now made of composition materials.

SHUTTLES AND BOBBINS *

The annual production of shuttles and bobbins is each about 3 to 6 million per year, depending on textile business activity and partly on the volume of the export market which is very important, especially to England, Italy, and France.

A wood highly resistant to impact, shock, and splintering is required. Shuttles operate at a rate of 100 to 200 or more strokes per minute, depending upon the kind of textile fabricated. Therefore they must be hard and able to resist shocks and rather violent and constant use in the textile business. To some extent, plastics, densified wood, and composition materials and wood in combination with them are used.

In the North, hard maple is principally employed for bobbins as it seasons and machines very well. In the entire Nation, persimmon is favored chiefly for shuttles, and, to a less extent, dogwood and boxwood. Persimmon enjoys the properties and characteristics of an ideal wood, better than any other.

The principal sizes of blocks are $20'' \times 2\frac{5}{8}'' \times 2''$ and $20'' \times 2\frac{1}{2}'' \times 2''$. Many other sizes are used from $12\frac{1}{2}'' \times 1\frac{5}{8}'' \times 1\frac{3}{8}''$ for silk shuttles to $30'' \times 3\frac{5}{8}'' \times 3\frac{1}{4}''$ for carpets. The blanks

* A shuttle is a boat-shaped piece of wood which carries a bobbin containing the yarn or thread used in making cloth. The shuttle passes the thread of the weft from one side of the web to the other between the threads of the warp. The bobbin, known also as a reel or spindle is generally made of wood and is set in the shuttle, releasing the thread or yarn as the shuttle moves rapidly back and forth.

or rough blocks, from which the final shuttles are turned and finished, are larger than the above finished sizes. For example, many are 21″ long × 3″ × 3″ so that, when they are seasoned and then finished, there is ample wood to take care of surface checks or inequalities of rough manufacture as well as shrinkage in seasoning for the above first two sizes.

Manufacture of shuttles and bobbins. *Shuttles.* The billet, or sawed-out blocks from which shuttles are made, come from only three species of wood. There are 47 sizes of dogwood and 13 of persimmon, all these sizes being carried to reduce waste in manufacture.

During conditioning, the billets or blanks must be carefully inspected. When the proper moisture content is reached, they are moved from the drying room to the accumulating room where the process of seasoning is completed.

Transforming the rough billet into a shuttle blank is the first process in making shuttles. After squaring two sides and sawing off the ends, the billets are inspected and graded and all defective blocks are eliminated.

Eighteen machines perform the precision operations. The billet is molded and shaped, spurs are inserted and ground, ends turned and polished, edges rounded, pocket for the bobbin cut and finished, and the blanks are twice machine-sandpapered and buffed. Meanwhile these blanks have been oil-soaked three times and lacquer-finished.

Seven hand operations, which include sanding with steel wool after the machine sanding and the finishing touches incidental to numerous inspections, come in at proper stages to give a practically perfect product.

When shuttles have fiber-covered walls, the extra operations are taken care of in this department. All machines are capable of being set up to do with utmost precision the shaping or cutting required for the particular blank being made. The profiling machine is an interesting precision machine. Its purpose is to cut the bobbin chamber in the shuttle blank.

Of the fittings that go into a shuttle, making the eyes takes the greatest variety of machines and workmanship. Accuracy is the keyword of shuttle making. In the making of shuttle eyes, springs, covers, and other fittings, the parts for each shuttle pass through 35 to 59 machines and 36 to 66 expert hand operations.

Next is a row of 44 specialized machines each of which makes one of the 44 cuts required to prepare any standard shuttle blank to take fittings of the particular shuttle on order. Only two hand operations are needed to supplement the work of these machines in preparing the blanks for the final assembling of the fittings.

Every shuttle must pass through the hands of 161 to 219 machine operators and skilled workers and through 96 to 124 machines. The price range varies from $1.35 to $2.30 each, according to size and specifications.

Bobbins. Maple, beech, and birch make the best bobbin blanks. Black cherry is also used. To be assured of perfection they should always be sawed, never split. First, these blanks are seasoned; this is of great importance if the bobbins are to give long-time service. The blanks are seasoned to a moisture content of 8%.

In a process known as equalizing, the blanks are sawed to measure and the ends squared. All rough or damaged stock is discarded. Records show that by this and previous inspections, more than 60% of the log stock is rejected.

All processes, especially the turning which must favor the direction of the grain, depend upon the drilling of the hole to fit the spindles of the lathes. The turning is accurately done by the cutter heads especially prepared for the order in process.

The freshly turned bobbin immediately gets one of two types of treatment: they are either enameled or finished with shellac.

Machines called rattlers clean them, and a sanding machine finishes them. Bobbins to be shellacked are given an oil bath by dipping or soaking and are dried at high temperatures to drive the oil into the wood. They are again "rattled."

Bobbins that are to have an enamel finish go from the sanding machine to the enameling room. Here, after a filler has been applied to close the pores of the wood, the enamel is applied by dipping and baking in special ovens. Two to six coats are applied. Next the bobbins are removed for a perfect spindle fit followed by the work of placing rings, bushings, shields, and tip shields. Bobbins that are to be shellacked are ready for their final coat after these operations. Each bobbin is then machine-tested and finally given several careful hand inspections.

MISCELLANEOUS PRODUCTS *

In addition to the forest products previously described, there is a wealth of herbs, seeds, roots, berries, tubers, mushrooms, and other edible fungi which in some sections become of considerable importance. Some species known as honey plants are the principal source of honey in parts of California and the Southwest. Matting and basketry, upholstery, stuffing, soapberry, and other plants are obtained from the forest. Manzanita roots for pipe bowls are dug in California, and many other apparently incidental products assume considerable importance in restricted areas. Many thousand pounds of sphagnum moss are removed annually from our forests to be used in the shipping of plants for reforestation purposes and for other shipping needs. Cherry bark for medicinal purposes is collected in the Southern Appalachian region. Peat is sometimes dug in the Northeast and in the Lake States. It is sold for $1 to $3 per ton or more from some of the western National Forests.

A unique product which commands high prices and occurs largely underground is the walnut burls from the native walnut (*Juglans rupestris, major* and *Juglans nigra*) of the Southwest. In fact underground burls are more common than uptree burls.† This product is used in Europe and to some extent in the United States for high-quality figured veneers. Some magnificent burls have been produced from *Juglans nigra* in the Caucasus Mountains. Burls vary in weight from 200 lb. to several tons each and sell for 2 cents to 5 cents per lb. on the stump. They must be literally "mined." About 100 tons are produced annually from inaccessible locations along watercourses and canyons below 7000 ft. elevation. Cost of extraction and transport are therefore very

* There is a very large variety of foreign forest products imported to the United States. They include lac, waxes, and various vegetable fats and oils used for medical and allied chemical purposes. The carnauba wax is of considerable commercial importance. In addition to tropical forest fruits, palm kernels, and oils, there are many tropical tree seeds the oils from which are produced on a commercial scale.

Within the limited space of a book of this type it seems inadvisable to attempt to include all forms of forest products from foreign sources. The book treats such products as cork and rubber of foreign origin, because they are articles of wide use and large importance in the United States.

† Data supplied by Burdett Green of the American Walnut Manufacturers Association.

high. The U. S. Forest Service reports the sale of 54,000 lb. of walnut burls for fancy veneers.

Cactus is used in the Southwest for making novelties such as lamp bases, bookends, and trays. Roots, burls, and knots for ornamental lights, bookends, and rustic benches are produced and sold from some National Forests for 4 cents to 20 cents apiece.

Among the miscellaneous, minor products which assume some local importance are the following:

Spanish moss (*Tillandsia usneoides,* Hortus) furnishes a product valued at $6 million per year. Some 18,000 people are employed in gathering, preparing, and manufacturing it in various forms. It is also known as Florida moss, New Orleans moss, long moss, black moss, and vegetable moss. It grows throughout the South at low elevations, especially in the "piney woods" and cypress and hardwood areas. It is especially prolific near the South Atlantic and the Gulf Coasts, from the Dismal Swamps of Virginia to eastern Texas. It is an epiphytic growth (surface or air plant) with no roots and relies solely on its host for support. Thus it grows also on telegraph poles and barbed wire fences. The Indians made braids of it, and, from the braids, baskets, hats, mats, and many other articles. Later harness was fashioned from it, as well as stuffing for horse collars, saddles, and saddle blankets. Now it is gathered and shipped in bales of 150 lb. each and used generally for mattresses and horse collars. More than 4 million lb. are produced annually. Many gatherers follow logging operations to harvest it. It is put through a gin similar to the process of cotton ginning, cleaned, dried, sorted, and graded. The supply is practically inexhaustible, as it thrives and reproduces readily. The demand for it is increasing.

Tung nuts and oil.* Commercial production of tung nuts and oil started in the United States in 1932 when two full cars of tung oil, each of 150,000 lb., were shipped from the first tung oil mill located near Gainesville, Fla. In 1936 about 2 million lb. of oil were produced in the South, and, in 1946, there were 66,700 tons produced principally in Mississippi and to a less extent in Louisiana, Florida, Georgia, and Alabama.

* For further study and more complete data see Tung Oil by R. S. McKinney, U. S. Department of Agriculture, Gainesville, Fla.

American tung oil is generally regarded as superior to that produced in China which is the original source. The ripe tung fruit contains about 65% moisture. The fruit drops to the ground from September through November, depending upon the variety of the tree, location, and seasonal conditions. The nuts are stored in specially constructed and ventilated drying bins in which the tung fruit slowly dries from a moisture content of 30% to about 13%. The air-dried tung nuts are hauled from the storage to the tung oil mill to be processed through a decorticator which removes the hulls and a portion of the shells from the kernels. The nuts then go over shaker screens where the hulls and broken shells are separated from the kernels and seeds. The yield of tung oil is about 310 to 390 lb. per ton of air-dried fruit.

Tung nuts are not processed on the individual farms where grown. They are shipped to oil mills which are provided with special equipment for expressing the oil from the fruits. The cost of such a plant may be $25,000 to $75,000 or more, depending upon its size and location.

Most of the tung oil is used by paint and varnish manufacturers; the linoleum industry is the second largest consumer. It is also employed in the manufacture of certain insulating compounds for the electrical industry and for printing inks. It is important in the manufacture of some automobile brake linings and in the gaskets of steam pipes, pumps, and engines.

Because the supply from China was shut off during World War II, imports fell off. In 1937, the imports reached a peak of 174 million lb. The price per pound of tung oil has varied from about 7½ cents in 1931 to 39.6 cents in 1942. Since that time the price has declined. The total acreage of tung trees is reported at 195,000 acres of which 146,000 acres are located in Mississippi, and the others in Louisiana, Florida, Alabama, Georgia, and a small quantity in Texas. The total value of tung nuts was estimated at $3,384,000 in 1949.

Many of the tung groves have been disappointing because of improper knowledge of tree spacing, planting on poor soils and subsequent management. Originally trees were spaced 20′ to 30′ apart, or 72 trees per acre. This method produces a maximum number of nuts up to 10 to 12 years. Trees spaced 30′ to 40′

apart are considered the best spacing. Maximum production is generally at 24 to 28 years of age and thereafter.

Spruce gum. One of the minor activities of the North Woods is the gathering of spruce gum—an oleoresinous exudation found in the sapwood ducts of spruce in the Northeast and eastern Canada.

Crude gum is formed as the result of injury to red and black spruce trees. Hedgehogs feed upon the inner bark of the trees, and the injuries they cause are fruitful sources of gum. Lightning scars, frost cracks, old blazes, and abrasions caused by falling trees, and even sapsucker drills are other occasions for gum formations. Around the edges of such wounds, little nodules appear and gradually develop into lumps or teats. A wide scar heals slowly and may produce gum around the entire wounded area, whereas a narrow seam closes so quickly that only a single row of these nuggets is possible. At first, these are mere pitch exudations that become sticky when placed in the mouth and are of unpleasant taste. It requires at least 5 years to transform this material into the hard and brittle amber-like gum. If it remains on the tree too long, spruce gum deteriorates and becomes very dark colored.

Gum gathering has been confined to virgin forests as the yield of cutover tracts and second-growth stands were too meager. A territory once gummed is ready for a second gumming in 5 to 7 years. Gathering gum proceeds the year around, though the favored time is when the leaves are off the bushes and undergrowth, thus facilitating travel and making the gum easier to find. The best time is March when the deep snow covering the underbrush is crusted over. Some operators use a special gathering tool: a chisel inserted in the end of a pole and a tin receptacle fastened just beneath the chisel.

Crude gum is divided into two principal grades, lump and chip, lump being the better grade of the two. Lump is subdivided into grades according to its clearness (color) and weight.

Spruce gum is used as chewing gum being either mixed with sugar and chicle or chewed by itself.

Pine straw. Gathering the accumulation of pine needles on the forest floor constitutes an important and growing industry in several parts of the South. This is especially true of strawberry-growing centers, such as Hammond, La.; Starke, Fla.;

Picayune, Miss., and other centers where large quantities of pine straw are employed for (1) mulching the plants to conserve moisture and prevent weed growth, (2) protection from possible frost damage, and (3) fertilization of the soil. Pine straw also serves in large quantities for packing purposes and for mattress stuffing, horse collars, and many similar purposes. It is sometimes submitted to a chemical treatment to remove the resinous nature of the needles. In some sections, the timberland owner obtains $1 to $5 per acre for the straw or pine needles that may be raked together and sold for these purposes. Leaf litter (pine-needle mulch) is gathered and sold from some western national forests at $3 to $8 per ton.

Anise root. This is an herb of the carrot family (*Pimpinella anisum*) which yields anise oil. It is gathered in the Pacific Northwest, where 7000 lb. were reported from one National Forest. It is sold for 40 to 50 cents per lb. It was formerly shipped chiefly to Japan and China, where it was in demand for medicinal purposes.

Ferns. Sword fern leaves for decorative use by florists are obtained from several national forests in the Pacific Northwest. Sales are made at $1 to $5 per ton or truckload. In some years 70 tons and 190 truckloads are collected. Each bale contains 53 to 55 leaves not less than 24″ in length. Leaves must be perfect for 8″ back from the tip. They are picked principally in virgin stands west of the Cascade Mountains and shipped East in refrigerator cars.

Miscellaneous minor products. The manufacture of battery separators from Port Orford cedar has been replaced by the use of Douglas fir for the same purpose. At least 90% of the American consumption of wood battery separators is now produced from Douglas fir.

In the Northwest, a system of building loghouses from logs averaging 10″ to 12″ in diameter has been developed whereby the logs are slabbed on three sides and cabins are built with the unslabbed side turned out. This is a variation of the log-cabin type, and a very appreciable amount of construction with this form has been developed throughout the Pacific Northwest. A company at Forest Grove, Oreg., has been very active in this development. This provided a profitable outlet for thinnings and small regrowth timber. Some of these small-diameter trees may also be removed in prelogging operations.

Novelties are being made from the burls and otherwise figured wood of myrtle, redwood, and Sierra juniper on the West Coast. Production is largely in small shops and woodworking plants. There are four plants in Eureka, Calif., making ashtrays, bowls, woodenware, trays and souvenirs from redwood burls which have an unusually attractive figure and take a high polish.

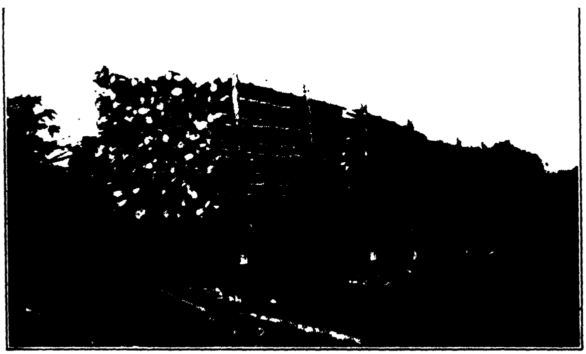
"Cut stock" is being produced from slabs and edgings at sawmills in the Northwest which ordinarily has been sent to the burner. This cut stock as produced from the outside of logs is largely sapwood and free of growth defects such as knots. It is finding profitable uses in the furniture and container trade where, in the latter, it is being glued to corrugated liners to obtain high-grade strength crates.

Utilization of thinnings. Good examples of integrated utilization of thinnings are found in many parts of the South and Northeast. Thinnings in the South are utilized largely for pulpwood and for fuelwood. A good example of the utilization of thinnings in the Northeast is found on the Luther Forest near Saratoga Springs, N. Y., where several thousand acres of red pine were planted on abandoned farmlands. It was found that trees 18 to 25 years from planting were of sufficient size to sell profitably for use in small fish pails, boxboards, box cleats, pulpwood, and brick-kiln fuelwood. These trees are 5″ to 9″ in diameter at the butt and 16′ to 26′ long as taken to a 3″ top. When employed for tight cooperage, only knot-free wood is suitable for staves. Pulpwood, boxboards, box cleats, and fuelwood, however, are low-grade uses, and therefore prices for these are not as attractive as for cooperage stock.

In central New York, thinnings were cut from Norway spruce and Scotch pine plantations 32 years old. Small logs 5″ to 6½″ in diameter inside bark at the small, were halved, then edged and splined and dried. The pieces were used for vertically arranged log-cabin siding. It was learned that 25 butt logs 9′ long from plantations would have yielded 50 cu. ft. or about ½ cord if used for pulpwood. As cabin siding, these logs yielded 282 lin. ft. of 2″ siding and 78 b.f. of lumber varying from ¾″ to 8/4″ thick. Many cabins, barns, small homes, summer cottages, gasoline stations, and refreshment stands have been made from

A. General view of red pine plantations on the Luther Forest, New York. The clear lengths between the nodules are used for tight cooperage kegs 16″ to 27″ in height. Thus, thinnings from 18- to 25-year-old plantations are coming into use for specialized products including cooperage stock, small boxboards, or cleats, pulpwood, brick-kiln fuelwood and ordinary fuelwood.

B. Logs being loaded on motor truck by means of mechanical loader.



C. Carload of thinnings from red pine plantations 18 to 25 years of age. This illustrates the improved utilization of material from plantations in many parts of the country. These are adding definitely to the wood supply of the Nation. More than 300 carloads of these thinnings were shipped to one plant. *Courtesy Thomas F. Luther, Luther Forest, Saratoga Springs, N. Y.*

FIGURE 152. Utilization of red pine plantation thinnings near Saratoga Springs, N. Y.

this or similar material in the forested vacation sections of northern Michigan and Wisconsin as well as in New York and New England.

An enterprising concern in Memphis makes a specialty of

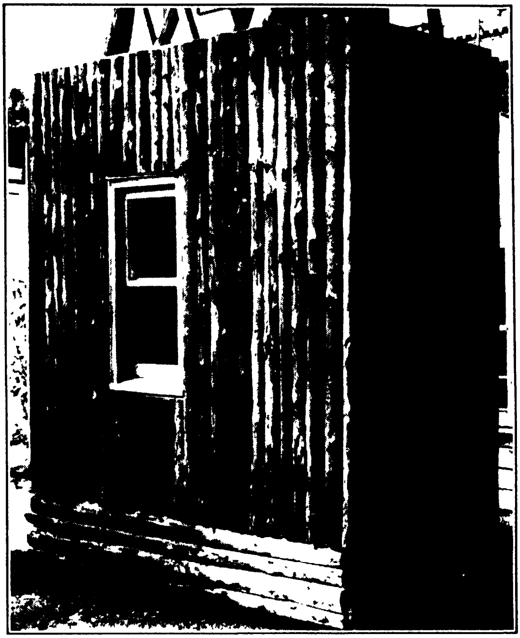


FIGURE 153. Exterior corner of log cabin. Siding made from thinnings from a 32-year-old Norway spruce plantation in New York. Top diameters of 9′ logs were from 5½″ to 6½″. The 25 logs were equivalent to 50 cu. ft. or about ½ cord. As sawed these logs produced 282 b.f. of 2″ log-cabin siding and 78 b.f. of lumber. *Courtesy H. L. Henderson.*

hickory wood flakes obtained from the manufacture of skis, wood trimmings, tool and implement handles made from hickory. This is an excellent example of the utilization of otherwise waste material. These hickory wood flakes are put up in 2½-lb. paper bags and successfully used to barbecue 75 to 100 lb. of meat, chicken, fish, or wild game. They are intended for use on any grill or pit with any type fuel. This package sells for 89 cents retail. The hickory smoke flavor has been well established for curing hams, bacon, and other meats.

A chipper for converting otherwise waste material was developed in 1948 on the National Container Corporation property near Tomahawk, Wis. This machine has two units, namely, (1) the chipper and (2) the semitrailer conveyer truck. It is powered with a 100-hp. Diesel engine, belted to a Murray 10-knife blower-type disk. It will handle up to 20 cords of hardwood under 4″ in diameter per hour as well as edgings, veneer cores, and veneer mill waste. The chips are delivered directly on trucks which have a capacity of 8 to 10 tons. On one trial demonstration in 1949, 21 cords of wood were removed from a 2-acre plot. About 12 cords of this wood could be sold as marketable pulpwood, and the remaining 9 cords would ordinarily be wasted. With this mechanical chipper, the 9 cords were also turned into usable cellulose chips. In doing this, some 140 Norway or red pine trees were released from an overstory of poplar and white birch. The fire hazard was also reduced by salvaging one third more of the stumpage from the area.

GLOSSARY OF SOME TERMS AS USED WITH FOREST PRODUCTS*

ACID TREATMENT. In turpentining, the technique of spraying 40% to 60% sulfuric acid on a fresh streak to stimulate gum-resin flow.

ADHESIVE. A substance used to join two or more pieces of wood into a solid piece. The term adhesive has been applied mainly to the synthetic-resin products used for gluing wood. The term "glue" has been used for many years in conjunction with the naturally occurring adhesives such as starch, soybean, and animal glues.

ADZED TIE. A cross tie which has the place for the tie plates or rails smoothed out to give a better bearing surface. As the name implies this was formerly done with an adze but now is usually done by machine before the tie is treated.

AIR-DRIED. Seasoned below 18% moisture content by exposure to the atmosphere.

ANTISPLITTING IRON. A piece of flat iron, sharpened on one edge and bent into one of several shapes, used for driving into the ends of ties or timbers to prevent splitting. Such irons dependent upon their shape are called S irons, C irons, Beegle irons, or crinkle irons.

BAG MOLDING. See Molded Plywood.

BALLAST. Gravel, crushed rock, or other material used to surface a railroad bed. The cross ties rest in the ballast.

BARK CHIPPING. A technique of chipping pines for naval-stores production. The bark is removed in a narrow strip and the sapwood exposed. This technique is more successful when the streak is sprayed with sulfuric acid to stimulate gum flow.

BATCH PRESS. An air- or hydraulic-operated press for the edge gluing of lumber core stock or solid panels.

BEEGLE IRONS. Irons driven into the ends of ties, poles, etc. to decrease end checking.

BIRD'S-EYE. A small central spot with the wood fibers arranged around it in the form of an ellipse so as to give the appearance of an eye.

* For glossary of terms used in wood preservation, see Rept. of Committee R-10 of the Am. Wood-Preservers Assoc., Washington, D. C., April 1950, especially as applied to cross ties, poles, piling, posts, and other treated materials. For comprehensive definition of terms as used in naval stores see *Working Trees for Naval Stores,* by A. R. Shirley, Georgia Agr. Extension Service, Athens, 1946. For further study of terms see various publications of the U. S. Dept. Agr. Forest Products Lab. and *Forestry Terminology,* Soc. of Am. Foresters, Washington, D. C., 1944.

BLEED THROUGH. The penetration of an adhesive through a veneer or ply to the surface of the panel.

BLEMISH. Anything, not necessarily a defect, marring the appearance of wood.

BLISTER. The area on a veneered surface that bulges due to uneven spread of the adhesive or to too rapid release of press pressure.

BOLT. A short log, generally less than 8′ in length and not used for lumber or cross ties.

BORED. See Prebored.

BOXED HEART. The term used when the pith falls entirely within the four faces anywhere in the length of a piece.

BRASHNESS. A condition of wood characterized by low resistance to shock and by an abrupt failure across the grain without splintering.

BUCKERS, TIE. Men who unload cross ties from cars or trucks by hand and stack them in treating yards (commonly used in Pacific Northwest).

BURL. A large wartlike excrescence on a tree trunk. It contains the dark piths of a large number of buds which rarely develop. The formation of a burl apparently results from an injury to the tree.

CAMBIUM. The layer of tissue just beneath the bark from which the new wood and bark cells of each year's growth develop.

CAP OR CAP COLLAR. The horizontal mine timber which is supported by the props and which in turn supports lagging.

CATALYST. A substance that accelerates a chemical reaction but remains unchanged. The term hardener is more inclusive.

CAUL. A separation of 1/16″ to 3/8″ wood, metal, or other material inserted between uncured plywood assemblies to facilitate loading and to assure undamaged faces.

CELLULOSE. The carbohydrate that is the principal constituent of wood and forms the framework of the cells.

CHAIN DRYER. A veneer dryer in which the veneers are carried between belts, chains, or endless coil springs.

CHAMFER. The chime on a barrel stave.

CHARCOAL. Charred or carbonized wood. It is a soft black porous material composed chiefly of finely divided carbon.

CHECK. A separation along the grain of the wood, the separation occurring across the annual rings.

CHIME. The bevel at the tip of a barrel stave which allows the heading to be forced into position more readily.

CHIPPING. The process of making a new cut or streak on a turpentine face to stimulate the flow of gum resin.

CLAMPING. Providing pressure on pieces of wood being glued together by means of clamps.

COLD BUSH. A sugar bush located on a northerly exposure and subject to chilling spring winds.

COLD PRESSING. Gluing wood in a clamping device or press at room temperature.

COMPREG. One of several forms of densified or modified wood.

CONNECTORS, TIMBER. Devices such as metal rings and plates and wood disks, which, when embedded in each member, increase the efficiency of a timber joint.

COOKING LIQUOR. The solution of chemicals in which the wood chips are cooked.

COOPERAGE. The science or art of making barrels, kegs, tubs, pails, or similar containers from pieces of wood known as staves and headings bound together by hoops. Also used to mean the barrels, etc., produced by this art.

CORNER WOOD. Odd corners left after barrel staves or other staves are made from bolts.

CREOSOTE. A dark oil, derived from the distillation of coal tar. It is the most widely used preservative employed in pressure treatment of wood.

CROP. A unit of work and organization for naval-stores operations. It contains 10,000 turpentine cups or faces.

CROSSBAND. To place the grain of layers of wood at right angles in order to minimize shrinking and swelling and consequent warping; also the layer of veneer at right angles to the face plies.

CROSS TIE (British, "sleeper"). A structural member, usually of wood, which supports and holds in position the rails of a railroad.

CROZE. The notch in the end of a barrel stave into which the heading fits.

CUPPING. The process of preparing a new turpentine face and hanging the cups.

CUPS. Containers of clay, aluminum, zinc, or other material which are fastened to a tree to collect the gum (in naval stores).

CURE. The setting of an adhesive or glue to provide a bond or joint between two or more pieces of wood.

CUT STOCK. Small-dimension stock cut from softwoods and hardwoods.

CYLINDER SAW. A saw in the form of a cylinder with teeth at one end of the cylinder. It is used to saw barrel staves, thus giving the correct curvature to the staves.

DECAY. Disintegration of wood substance through the action of wood-destroying fungi.

DEFECT. Any irregularity occurring in or on wood that may lower its strength or value for the purpose intended.

DENSITY. The mass of a body per unit volume. When expressed in the metric system, it is numerically equal to the specific gravity of the same substance.

DESTRUCTIVE WOOD DISTILLATION. A process in which the wood is heated to the charring temperature in the absence of air. Various volatile substances are driven off and collected in a still, and charcoal is left in the retort.

DIELECTRIC HEATING. See Radio-Frequency Heating.

DIELECTRIC MATERIAL. See Insulator.

DIFFUSE-POROUS WOODS. Hardwoods in which the pores are practically uniform in size throughout each annual ring, or decrease slightly toward the outer border of the ring.

DOTE. "Dote," "doze," and "rot" are synonymous with "decay," and are any form of decay that may be evident as either a discoloration or a softening of the wood.

DOUBLE SPREAD. The application of an adhesive or glue to both surfaces of a glue joint.

DRYER. A kiln or oven in which veneer may be dried either in batches or on a continuous-flow basis.

DRIFT. In naval stores, an area marked or designated for a worker, usually 2000 to 5000 faces.

DRUM SAW. See Cylinder Saw.

DRY ROT. A term loosely applied to many types of decay but especially to that which, when in an advanced stage, permits the wood to be easily crushed to a dry powder. The term is actually a misnomer since all fungi require considerable moisture for growth.

DURABILITY. A general term for permanence or lastingness. Frequently used to refer to the degree of resistance of a species or of an individual piece of wood to attack by wood-destroying fungi under conditions that favor such attack. In this connection the term "resistance to decay" is more specific.

EDGE GLUING. The gluing of boards together at the edges to form a panel.

ELECTRODES. The platens of an edge-gluing press or other metal surfaces for applying radio-frequency heat to wood-glue combinations.

ELECTRONIC WOOD GLUING. See Radio-Frequency Wood Gluing.

EXCELSIOR. Thin strands or shreds of wood shaved from bolts and used for packing and stuffing.

EXTENDER. An additional substance used to extend the volume and thereby cheapen the cost of glue lines.

EXTRACTIVES. Substances in wood, not an integral part of the cellular structure, that can be dissolved out with hot or cold water, ether, benzene, or other relatively inert solvents.

FACE. See Turpentine Face.

FIBER. A wood fiber is a comparatively long (1/25- or less to 1/3-in.), narrow, tapering cell closed at both ends.

FIGURE. The pattern produced in a wood surface by irregular coloration and by annual-growth rings, rays, knots, and such deviations from regular grain as interlocked and wavy grain.

FLITCH. The sawn segment of a log from which veneer is cut.

FROW. A sharp-edged tool used in splitting hand-made shakes. Also spelled froe.

GAIN. A notch or mortise. The notch in a telephone pole into which the crossarm is bolted is a gain.

GLUE. See Adhesive.

GLUE LINE. The layer of adhesive substance used to effect a union or joint between two pieces of wood.

GLUE-LINE HEATING. See Parallel Heating.

GOOSENECK. In cooperage, the piece of waste from a barrel-heading turner.

GRAPE STAKE. A post or support for wires or trellises in vineyards. In California, they are 2″ × 2″ × 6′, in New York 7′ to 8½′ long with a 3″ or greater top diameter.

GREEN. Wood having a moisture content above fiber saturation.

GUM. The exudation from a tree wound, especially gum resin in naval-stores production.

GUM NAVAL STORES. Naval stores produced from the crude gum resin which exudes from living pines when they are scarred or chipped through the bark into the wood.

GUM RESIN. The exudate of longleaf or slash pine which is collected for production of naval stores.

GUM ROSIN. The residue left after the distillation of gum spirits of turpentine from the gum (oleoresin) of living trees.

HALF-MOON TIE. A tie with the tree pith at or very near one of the wider surfaces.

HARDENER. A substance that accelerates the curing of the adhesive and becomes a part of the final product.

HARDWOOD DIMENSION. Kiln-dried hardwood processed to a point where the maximum waste is left at the dimension mill and the maximum utility delivered to the user (National Bureau of Standards).

HARDWOOD DISTILLATION. The destructive distillation of hardwoods (largely birch, beech, maple, oak and hickory). The principal products are wood alcohol, acetate of lime, and charcoal.

HARDWOODS. The botanical group of trees that are broadleaved. The term has no reference to the actual hardness of the wood. Angiosperms is the botanical name for hardwoods.

HEADING. The top and bottom member of a barrel. The heading is a circular wooden member that fits in the croze of the staves and thus tightly closes the barrel.

HEART, HEARTWOOD. The wood, extending from the pith to the sapwood, the cells of which no longer participate in the life processes of the tree. Heartwood may be infiltrated with gums, resins, and other materials which usually make it darker and more decay-resistant than sapwood.

HEART AND BACK TIE. A tie with the tree pith at or very near one of the narrower surfaces.

HEWED TIE (or hewn tie). A cross tie produced by hand by use of a broad-axe and other hand tools.

HIGH FREQUENCY. See Radio Frequency.

HONEYCOMB. Checks, often not visible at the surface, that occur in the interior of a piece, usually along the wood rays.

HOT PRESSING. Gluing wood or other material in a clamping device or press having heated plates or platens to accelerate the curing or setting of the adhesive.

INSULATOR. A material, such as oven-dry wood, which offers great resistance to the passage of electric current.

INTEGRATED UTILIZATION. The use of a given tract of timber or even the various parts of the same tree for different products for which they are most valuable.

JOINT. A union between two pieces of wood usually obtained by the use of an adhesive.

KILN. A chamber or room for drying lumber at elevated temperatures and controlled humidities. See also Dryer.

KNOT. That portion of a branch or limb that has become incorporated in the wood.

LAGGING. Small-diameter poles or sawed planks used along the walls and tops of tunnels or rooms of a mine to keep loose rocks from falling in. Lagging down to 2″ diameter may be used in the round.

LAMINATED WOOD. A piece of wood built up of plies or laminations having parallel grain joined with either glue or mechanical fastenings.

LATH. The structure on which plaster is spread. Wood lath are thin strips of wood generally 3/8″ × 1½″ × 48″ (or 32″ long) which are nailed to the studs and ceilings of a house to serve as a plaster base. Softwoods are preferred.

LATHE. See Veneer Lathe.

LIGHTWOOD. The highly resinous heartwood of various hard pines. Also the resinous knots, snags, and stumps of hard pine which are left after the less resistant wood has been removed by decay or recurrent fires. Commonly used in the South.

LIGNIN. Lignin is one of the principal components of the cell walls of wood. Lignin is an amorphous inert brownish substance which has found no large-scale market. It comprises about 25% of wood substance and is closely associated with cellulose in the cell wall.

LISTINGS. Narrow strips of wood removed by a barrel-stave jointer.

LOAD. In radio-frequency wood gluing, the material located between the electrodes which is heated by electric energy produced by the radio-frequency generator.

MAPLE SUGAR. The sugar produced from the sap of the maple tree. Chemically it is (sucrose) the same as cane sugar.

MAPLE SIRUP. A sweet distinctive-tasting sirup produced by boiling down the sap of the maple tree.

MATCH BLOCKS. Blocks from which wooden matches are produced; white pine is preferred.

MATCHING. The placement of face veneers to form various patterns or designs.

MECHANICAL PULP. Pulp produced by a mechanical process.

MECHANICAL PULPING PROCESS. A process in which wood is ground into pulp by the action of a large grindstone. Produces a coarse, weak, poorly colored, bulky pulp, but yields over 90% of the wood substance as pulp.

MEGACYCLE. One million cycles per second. See Radio Frequency.

MESH DRYER. A veneer dryer which holds the veneer between jointed wire-mesh belts while carrying it through a heated chamber.

MINE PROP. An upright supporting member in a mine tunnel which supports a cap or crossbar. Usually used in the round and 4" and up in diameter.

MINE TIMBERS. Timbers used in mines, especially mine props, lagging, and caps.

MIXER. A device for mixing or stirring glue or adhesive mixtures.

MOISTURE CONTENT OF WOOD. Weight of the water contained in the wood usually expressed in percentage of the weight of the oven-dry wood.

MOLDED PLYWOOD. A material produced when various curved surfaces are made of veneer, either in an appropriately shaped press or by using a rigid form and a flexible bag to exert fluid pressure. In the latter case the process is referred to as bag molding.

NAVAL STORES. Rosin and turpentine produced mostly from longleaf and slash pines. So called because of the early use of tar and pitch on wooden ships.

NAVAL-STORES UNIT. One 50-gal. barrel of turpentine and 1400 lb. of rosin. Usually 4½ barrels of gum of 50-gal. size will produce one unit.

NOVOPLY. A three-ply core made of wood waste used in door and other panels. Developed in Switzerland and now manufactured by the U. S. Plywood Corp. in the United States.

OSCILLATOR. A radio-frequency generator.

OUTPUT. As applied to radio-frequency wood gluing. It is the electric power delivered by a radio-frequency generator.

PAPER PULP. Fibers, principally wood pulp, from which paper is made.

PARALLEL HEATING. The selective absorption of radio-frequency energy by a glue line parallel to the electric field between two electrodes.

PEELER LOG. A log of such size and quality that rotary-cut veneer can be produced from it, especially large Douglas fir logs suitable for rotary veneer production.

PENCIL SLATS. Small flat pieces of wood (generally cedar) from which wooden pencils are made.

PERPENDICULAR HEATING. The absorption of radio-frequency energy by a glue line whose plane is at a right angle to the electric field between two electrodes; i.e., glue line is parallel to the electrodes.

PILE. A long round timber driven into the ground to carry a heavy load, or along waterways for erosion protection, or as bumper or moorage for vessels.

PILING. Piles collectively. Also a group of piles together in a structure.

PITH. The small soft core occurring in the structural center of a log.

PLUG, TIE. A wood plug used for filling an old spike hole, usually treated with preservative.

PLYWOOD. An assembly of wood made of three or more (odd number of) layers of veneer joined with glue and usually laid with the grain of adjoining plies at right angles.

POLE. A long slender piece of wood, especially when used in the round. For commercial purposes a pole is such a piece 20′ long or longer. Shorter members are generally called posts. Most poles are used for either communication or power lines. See also Pile.

POLE TIE. A tie with the top and bottom flattened but the two sides still in the round.

POWER FACTOR. In radio-frequency wood gluing, the power factor is the ratio of the electric power in watts used to cure the glue lines, compared to the total apparent power available in volt-amperes.

PREBORED TIE. A cross tie with the holes for the spikes or screws bored in the wood before being laid in the track. This is generally done before preservative treatment.

PRELOGGING. The operation in which certain products are removed from a stand beforehand to prevent their damage in the main logging operation. An example is the removal of poles before a saw-log operation.

PRESS. A mechanical, air- or hydraulic-operated device for applying pressure to wood-glue combinations during the time when the glue is curing.

PULP. A mass of fibers or fibrous material. See Wood Pulp and Paper Pulp.

PULPING. The process of converting wood or other material into pulp. This is generally done by chemical means or mechanical means, or by some combination of the two.

PULP LAP. Large thick sheets of loosely packed pulp. Pulp is usually manufactured into pulp lap when it is to be shipped from a pulp mill to be manufactured into paper elsewhere, or if it is to be stored for long periods.

PULPWOOD. Wood for use in the production of wood pulp.

QUARTERED TIE. A tie with the tree pith at or very near one corner. This name comes from the fact that a large log is quartered. It will yield 4 ties, each of them being referred to as a quartered tie.

RADIO FREQUENCY. Any frequency at which a rapidly alternating or oscillating electric field causes electromagnetic radiation. For the heating and curing of wood-glue combinations, the radio frequencies employed, range from 1 to 100 megacycles.

RADIO-FREQUENCY GENERATOR. An apparatus for generating a rapidly alternating electric field suitable for radio-frequency heating applications.

RADIO-FREQUENCY HEATING. The heating of nonconducting materials (dry wood) and poor electric conductors (wet glues) by the application of a rapidly alternating electric field.

RADIO-FREQUENCY WOOD GLUING. The curing or setting of glue lines by the application of radio-frequency energy to wood-glue combinations.

RAISING. Setting up a barrel.

RECOVERY LOGGING. See Relogging.

RELOGGING. The logging of an area to obtain products left after the main logging operation. An example of this is the logging of pulpwood left after a saw-log operation. Also referred to as recovery logging.

RESIN. A synthetic compound used to formulate water-resistant and waterproof adhesives.

RIDE. In naval stores, an area, usually 4 to 10 crops, supervised by one woods rider.

RIFLE TIE. A tie with the tree pith in the center and containing no sapwood.

RING, ANNUAL GROWTH. The growth layer put on in a single growth year.

RING-POROUS WOODS. A group of hardwoods in which the pores are comparatively large at the beginning of each annual ring and decrease in size more or less abruptly toward the outer portion of the ring, thus forming a distinct inner zone of pores known as the springwood and an outer zone with smaller pores known as the summerwood.

ROLLER DRYER. A veneer dryer that carries the veneer through a heated chamber by means of a sequence of paired live rolls.

ROTARY CUT. The cutting of veneer by mounting a log in a lathe and turning it against a broad cutting knife.

SALVAGE CUTTINGS. A logging operating to cut and save from further losses timber injured by fires or attacked by insects or fungi. It is also applied to blowdowns from hurricanes.

SANITATION CUTTING. The removal of deformed, diseased, crooked and poorer trees from a stand to improve its condition for future growth and cuttings.

SAPWOOD. The layers of wood next to the bark, usually lighter in color than the heartwood, ½″ to 3″ or more wide that are actively involved in the life processes of the tree. Under most conditions, sapwood is more susceptible to decay than heartwood; as a rule, it is more permeable to liquids than heartwood. Sapwood is not essentially weaker or stronger than heartwood of the same species.

SCARF. An angle joint for splicing two pieces of wood together.

SCRAPE. In turpentining, a white sheet of crystallized gum which forms on the surface of a face owing to the evaporation of the gum resin.

SCREW DOG. A dog or metal tooth which is screwed down onto a flitch to hold it in position while the veneer is cut.

SEASONING. Removing moisture from green wood in order to improve its serviceability.

SEGMENT SAW. A saw that is thick at the center but tapers out toward the rim. The actual cutting edge is very thin and is composed of a series of thin segments bolted to the central part. Hence the name segment saw.

SEMICHEMICAL PULP. Pulp produced by the semichemical pulping process.

SEMICHEMICAL PULPING PROCESS. A process employing both chemical and mechanical means. After being reduced to chip size, the wood may be given a mild cooking treatment and then be further refined by some form of mechanical pulping. The yields are high, often over 80%. The future of this method is very promising, particularly for hardwood pulping.

SETTING. The curing or hardening of a glue or adhesive to form a strong union between two or more pieces of wood.

SETTING UP. The process of assembling the proper number of barrel staves in a form before bending them into the final barrel shape.

SHAKE. A separation along the grain, the greater part of which occurs between the rings of annual growth.

SHAKES. Split shingles generally produced by hand with the aid of a frow and maul; also certain types of splits in a tree trunk.

SHOOKS. The wooden members of boxes, crates, and similar containers.

SIDE CUTS. Lumber produced in slabbing or sawing a log for cross ties.

SLACK COOPERAGE. Cooperage not designed to hold liquids.

SLASH GRAIN. Flat grain, tangential grain.

SMALL-DIMENSION STOCK. Small-sized pieces of wood cut to some specific dimension to fit some subsequent step in manufacture. This is in contradistinction to the general lumber term dimension, which applies to various wood pieces 2″ to 4″ thick such as 2″ × 4″. See Cut Stock and Hardwood Dimension.

SODA PULP. Pulp produced by the soda pulping process.

SODA PULPING PROCESS. A pulping process which employs an aqueous solution of the strong alkali, caustic soda (sodium hydroxide), for dissolving out the noncellulosic parts of wood. The cook is generally made at higher temperature and pressures than in the sulfite process. This process is particularly adapted to the pulping of hardwoods, which yield a soft, bulky, weak fiber. The chemicals can be recovered from the waste liquors.

SOFTWOOD DISTILLATION. This process is confined to "lightwood" and stumpwood of longleaf and slash pines. If the destructive process is employed, charcoal, pine tar, and wood turpentine are produced. If the steam and solvent process is used, the principal products are rosin, wood turpentine, pine oil, and extract-free chips. These extracted chips are generally burned for fuel, but they can also be used to produce coarse pulp for making fiberboard.

SOFTWOODS. The botanical group of trees that have needle or scalelike leaves and are evergreen for the most part, cypress, larch, and tamarack being exceptions. The term has no reference to the actual hardness of the wood. Softwoods are often referred to as conifers, and botanically they are called gymnosperms.

SPECIFIC GRAVITY. The ratio of the weight of a body to the weight of an equal volume of water at some standard temperature.

SPENT LIQUOR. Waste liquor.

SPIGOT. Same as a spout when used in connection with a maple-sirup operation.

SPILE. Same as a spout.

SPOT GLUING. The curing of glue in a spot or small area by localized stray field radio-frequency heating.

SPOUT. A hollow metal device inserted in a hole bored in a maple tree to conduct the sap into a pail. In addition, the spout generally is formed so that the collecting pail may be hung from it.

SPREAD. The amount of glue applied to a joint. It is usually given in terms of pounds of liquid-glue mixture applied per thousand square feet of single glue-line surface.

SPRINGWOOD. The inner, usually softer and more porous portion of each annual ring.

SQUARED TIE. A tie with all four sides surfaced.

STARVED JOINT. A glue line having an inadequate amount of glue.

STAVE. The wooden members which extend in the direction of the axis of the barrel or tub. They are curved in a troughlike manner so that each stave forms a small segment of the arc of the finished round container. In barrels and kegs they are wide at the center and tapered at the ends so that when properly assembled they give the characteristic barrel shape.

STAY LOG. That portion of the veneer slicing machine to which the flitch is bolted to hold it in position for cutting.

STAYPAK. One of several forms of densified or modified wood.

STRAY FIELD HEATING. A method of applying radio-frequency heating by the use of bar electrodes.

STREAKING. Chipping the face of a tree in turpentining.

STUMPAGE. Trees before being felled, that is, as they stand "on the stump." This term is also used to mean stumpage price or the price per unit measure (generally thousand board feet) paid to the owner for the standing tree.

SUGAR BUSH. A wooded area in which there are many sugar maple trees (*Acer saccharum*) that are tapped for their sweet sap each spring. The sap is boiled down to produce either maple sugar or maple sirup.

SUGARHOUSE. The building where maple sirup and sugar are produced from maple sap.

SULFATE PULP. Pulp produced by the sulfate process.

SULFATE PULPING PROCESS. An alkali pulping process similar to the soda process. The cooking liquor is two-thirds caustic soda and one-third sodium sulfide; 85% of the chemicals are recovered from the waste liquor. This process is especially good for pulping southern pine and certain hardwoods. The pulp is strong but brownish colored and is used extensively in kraft paper.

SULFITE PULP. Pulp produced by the sulfite pulping process.

SULFITE PULPING PROCESS. A pulping process which dissolves out noncellulosic parts of wood by cooking wood chips at elevated temperatures and pressures in an aqueous solution of calcium bisulfite, and acid salt. It produces a high-grade pulp, but its yield of pulp is only about 45% of the weight of the wood. Generally employed only on spruce, hemlock, and balsam fir.

SUMMERWOOD. The outer, usually harder and less porous portion of each annual ring. Syn: Late wood.

SUNKEN JOINT. A depressed line occurring in the surface of a veneered or plywood panel.

TANK CIRCUIT. The main oscillatory circuit of a radio-frequency generator.

THERMOPLASTIC ADHESIVE. An adhesive that will soften when reheated.

THERMOSETTING ADHESIVE. An adhesive that cures or hardens when heated and will not soften again if reheated.

TIE. See Cross Tie.

TIEHACK. One who fells and hews cross ties.

TIE PAD. A rectangular piece of wood or composition rubber placed under a tie plate to cushion the load and help prevent the plates from cutting the wood fibers.

TIE PLATES. Metal plates used between the rail and the tie to increase the bearing surface of the tie.

TIE SIDING. Lumber removed from a log in sawing it into a cross tie.

TIGHT COOPERAGE. Cooperage designed to hold liquids.

TIMBER, STANDING. Timber still on the stump.

TOXICITY. The inhibiting or lethal effect a material may have on a wood-destroying organism.

TRANSMISSION LINE. An arrangement of electric conductors for transmitting radio-frequency energy.

TRANSVERSE HEATING. See Perpendicular Heating.

TREATED TIE. A cross tie which has been treated with a preservative to protect it from decay by wood-rotting fungi.

TREATMENT, BUTT. Preservative treatment applied to the lower ground end of posts and poles; usually by the open-tank process or by brushing.

TUNING. The adjusting of circuit components in a radio-frequency generator to permit an optimum transfer of electric energy from the generator to a wood-glue combination to be cured.

TUNNEL KILN. A progressive-type dry kiln used to dry veneers or lumber.

TURPENTINE FACE. The surface area of a tree worked for naval stores.

TURPENTINE STILL. The processing establishment where the turpentine is distilled off from the gum resin. The molten rosin remains, and it is poured into barrels to harden.

TURPENTINING. The complete process of harvesting naval stores.

UNIT OF NAVAL STORES. See Naval-Stores Unit.

VENEER. Thin sheets of wood.

VENEER LATHE. A large lathe which holds a log or bolt between two chucks and turns the log against a knife in such a manner that a continuous sheet of veneer is produced.

VIRGIN CHIPPING. First year's work (in naval stores).

VOLTAGE GRADIENT. A measure of the electric field applied across a wood-glue combination in a radio-frequency wood-gluing setup.

WANE. Bark or lack of wood or bark, from any cause, on the edge or corner of a piece of wood, lumber, etc.

WARM BUSH. A sugar bush which is protected from cold winds and lies on a southerly exposure.

WASTE LIQUOR. The solution drawn off after the cooking or "digesting" is over (in pulp and paper manufacture).

WINDLASSING. The process of bending the staves together into the form of a barrel. This is done by passing a rope around the staves held together at the bottom by a circular form. The rope is then tightened by means of a windlass, and the upper ends of the staves are drawn together.

WING TIE. A heart and back tie.

WOOD DISTILLATION. The process of distilling off the volatile constituents of wood. The vapors are driven off by heat and condensed in a still. See Destructive Wood Distillation, also Steam and Solvent Distillation.

WOOD FLOUR. A flour made of wood by grinding sawdust or other wood particles.

WOOD NAVAL STORES. Naval stores produced from pine wood, by destructive distillation or steam and solvent distillation, or as a byproduct of the sulfate pulping of southern pine.

WOOD PULP. The fibers of wood separated from each other in such a manner that they can be used in papermaking.

WORKABILITY. The degree of ease and smoothness of cut obtainable with hand or machine tools.

WORKING LIFE. The period over which a liquid glue mixture remains spreadable. Synonyms: Bench life, pot life.

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APPENDIX

The U. S. Forest Service in Report 2 from a reappraisal of the forest situation entitled *Potential Requirements for Timber Products in the United States* indicated the potential annual requirements for timber products in the United States for 1950 to 1955. This was published in December 1946 and based on data up to 1944 or before.

Product	*Potential Requirements* Unit of Measure	Quantity, million	*Estimated Drain of Domestic Timber,* million cu. ft.*	*Estimated Drain from Trees of Saw-Timber Size ** %	Million bf
Lumber (total)	Board feet	42,500 †	8,670	98.9	44,345
For construction (total)	Board feet	31,500	......	.....	......
New residential (nonfarm)	Board feet	11,000	......	.....	......
All other new (nonfarm)	Board feet	8,500	......	.....	......
Farm, including maintenance and repair	Board feet	6,500	......	.....	......
Railroad construction ‡	Board feet	2,300	......	.....	......
Lumber for use in mines	Board feet	500	......	.....	......
All other maintenance and repair	Board feet	2,700	......	.....	......
For use in manufactures	Board feet	5,000	......	.....	......
For use in shipping	Board feet	6,000	......	.....	......
Railroad ties, hewed	Ties	22	238	98.5	1,084
Fuel wood	Cords	63	1,836 §	37.6	3,066
Pulpwood	Cords	29	1,660 ‖	70.2	5,784
Poles	Poles	5.7	91	90.0	318
Piling	Linear feet	38	29	100.0	114
Fence posts	Posts	600 ¶	480	25.7	492
Veneer logs and bolts	Board feet	2,400 **	566	98.5	2,837
Cooperage stock	Board feet	775 **	183	98.8	919
Mine timbers, not sawed	Cubic feet	220	220	35.6	312
Wood for hardwood distillation	Cords	0.5	34	35.0	53
Logs and bolts for all other uses	Board feet	1,000 *	236	100.0	1,200
Cordwood for all other uses	Cords	5	350	35.0	529
Total all products		......	14,593	82.7	61,053

* For converting factors see following table.

† Lumber tally.

‡ Includes sawed ties, car lumber, maintenance, and repair.

§ It is estimated that 27 million cords (43%) might be cut from sound, living trees.

‖ It is estimated that the equivalent of 9 million cords may be imported in paper, wood, pulp, and pulpwood. Domestic pulpwood requirement is estimated at 20 million cords.

¶ It is estimated that 20% might be cut from cull and dead trees, 480 million posts from sound, living trees.

** Log scale.

Timber Product Converting Factors *

Commodity	*Unit of Measure*	*Equivalent Volume of Timber Drain* Cu. ft.	Bd. ft.	*Estimated Proportion Cut from Trees of Saw-Timber Size, %*
Lumber	1 M b.f., lumber tally	204	1055.0	98.9
Fuel wood	1 cord	68.0	302.0	37.6
Pulpwood	1 cord	83.0	412.0 †	70.2
Railroad ties, hewed	1 tie	10.8	50.0	98.5
Veneer logs and bolts	1 M b.f., log scale	236	1200.0	98.5
Poles	1 pole	16.0	62.0	90.0
Piling	1 lin. ft.	0.75	3.0	100.0
Fence posts	1 fence post	1.0	4.0	25.7
Mine timbers, not sawed	1 cu. ft.	1.0	4.0	35.6
Cooperage stock	1 M b.f., log scale	236	1200.0	98.8
Wood for hardwood distillation	1 cord	68.0	302.0	35.0
Logs and bolts for all other uses	1 M b.f., log scale	236	1200.0	100.0
Cordwood for all other uses	1 cord	70.0	302.0	35.0

* These factors are rough average for the country as a whole. They are not generally applicable in any subnational area.

† For the long-term estimate 380 is used.

Source: Technical committee of U. S. Forest Service Staff.

The following table shows the estimated output and the value of non-manufactured forest products in the United States for the year 1947. It gives the output in various units and also an estimated total value f.o.b. mill or local point of delivery for the sale of these primary products of the forest. This table is from *Trees—the Yearbook of Agriculture*, U. S. Department of Agriculture, Washington, D.C., 1949.

ESTIMATED OUTPUT AND VALUE OF NONMANUFACTURED FOREST PRODUCTS IN THE UNITED STATES, 1947

Product		*Output, Units Cut, No.*	*Total Value at Mill or Local Point of Delivery, million dollars*
Sawlogs	Billion board feet *	35.5	1233
Veneer logs and bolts	Billion board feet *	2.3	122
Cooperage logs and bolts	Million standard cords	1.4	31
Pulpwood logs	Billion board feet *	1.8	54
Pulpwood bolts	Million standard cords	14.4	202
Other logs	Billion board feet *	.4	14
Other bolts	Million standard cords	1.1	24
Fuel wood from live timber	Million standard cords	27.8	309
Other fuel wood	Million standard cords	27.9	193
Chemical wood used for distillation (hardwood)	Million standard cords	.4	4
Piling	Million linear feet	34.4	15
Poles	Million pieces	7.5	32
Mine timbers (not sawed)	Million pieces	68.9	29
Hewn ties	Million pieces	23.6	27
Posts	Million pieces	234.7	61
Crude gum for naval stores		.....	33
Pine distillation wood (naval stores)	Million tons	2.3	14
Christmas trees	Million trees	21.4	6 †
Maple sirup and sugar		.....	11 ‡
Miscellaneous		.....	5
Total		.....	2419

* International ¼-in. rule.
† 1946 data.
‡ Bureau of Agricultural Economics data.

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