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BY

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PREFACE

The purpose of this book is to present general as well as physical characteristics of a group of structural materials, most of which are of organic origin. Among the materials thus described are woods, paints and varnishes—with their associated oils, pigments, gums, and resins—glues, creosotes, and indiarubber. As stated, most of these materials are of organic origin. Those that are not, such as pigments and creosotes, have been added because of their close practical association with the others.

The book is designed for engineers, architects, students in schools of technology, teachers of manual training and others who use the materials described or who are interested in their properties.

A statement of the reasons for separating structural materials along the line of organic and inorganic origin, seems to be in order. First, this basis is convenient: in fact, so many of the important organic materials are used in connection with one another that most of the present book might easily appear under such a title as "Properties of Woods and Associated Materials of Construction"; and, in the same way, the principal inorganic materials, steel, stone and concrete, are commonly associated. Second, the basis suggested is logical: organic materials are fundamentally different from inorganic materials, for the former are results of physiological processes and have within them the influence of life; these materials may manifest variations and special traits which do not appear in the more homogeneous and constant materials of the inorganic group. Assuming that some form of classification is desirable, where subject matter is as extensive as that within the present field, the writer ventures to urge the merits of the one now employed. Also, a book devoted especially to the materials here considered seems warranted. It is true that the inorganic materials, metals, stones, and concrete, upon which principal attention is so often bestowed in text-books, do predominate in the larger engineering structures; but it is equally true that the organic material wood predominates in other structures, and that some of the materials now considered are used in practically all structures with which the engineer has to do.

The opportunity is taken to criticise the degree of emphasis often laid in text-books upon those properties of structural materials which relate to strength. That this phase of the subject should be given precedence is beyond all question, but that it should ever be emphasized so greatly as to diminish or more or less replace attention which might otherwise be given to other features, such as durability, is questioned. In other words, it is regarded as pedagogically unfortunate when the whole story cannot be at least outlined to the student, when one part is detailed to such an extent that the other parts cannot be detailed at all. The belief is expressed that many students in schools of technology do not realize as early as they should, how real, live, and practical the subject "Properties of Structural Materials" is, and how greatly knowledge of it will influence works which they may later design and construct, and that one cause for this, in the case of some students, is the slight or omission here referred to.

The printed sources of information employed are acknowledged in footnotes throughout the text, and in a bibliography arranged for those who wish further information on any of the parts in question. In addition to these printed sources of information, the writer is deeply indebted to some who have assisted him with special information and with criticisms and now acknowledges assistance thus received from Professors W. Kendrick Hatt, Hermann von Schrenk, C. Stuart Gager, Charles P. Sigerfoos, Edgar W. Olive, Alvah H. Sabin, the late Charles E. Bessey, and the late Mr. Octave Chanute, past president of the American Society of Civil Engineers. He also thanks, among others, Mr. C. D. Mell, Acting Dendrologist of the United States Forest Service, Mr. Charles A. Hexamer of the National Board of Fire Underwriters, Mr. Norman Taylor of the Brooklyn Botanic Garden, Mr. Edward A. Hewitt, late chemist of the Cooper Glue Company, Dr. Lothar E. Weber, of the Boston Indiarubber Laboratory, and several of his colleagues in New York University.

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INTRODUCTION

A knowledge of the properties of the substances used in construction gives confidence to those who employ them and permits smaller margins beyond calculated requirements than otherwise would be possible.

Wood is one of the primary materials of construction. The others are stone and iron. These fundamental materials possess distinguishing properties, and each as a class includes a series of individuals or varieties, which are again distinguishable from one another by certain minor or specific properties.

All structural materials may be divided as they are organic and inorganic. Wood and other organic structural materials are characterized by qualities due to life processes, age, and other physiological causes. Stone, iron, and other inorganic materials are not distinguished in this way; these materials are more simple, homogeneous, and constant.

What is now known as "conservation" has been defined[1] as "the greatest good to the greatest number—and that for the longest time." The idea of conservation includes the reduction of waste. The future as well as the present is regarded. The broader needs of the nation are placed before the immediate needs of the individual; and, whenever possible, resources are considered more as they produce yearly incomes and less as though they were fixed sums to be drawn upon directly and thus exhausted ultimately.

Woods and other organic materials respond more completely than metals and stones to the application of the principles of conservation because they can be reproduced. The development of a forest requires time, but such development is possible, and once established the forest can be maintained so as to yield for indefinite periods. On the other hand, inorganic materials exist in fixed and final quantities. The more the materials of the

[1] Van Hise in "The Conservation of Natural Resources in the United States." See also "The Fight for Conservation," Pinchot; "Conservation of Water by Storage," Swain (Yale University Press); etc., etc.

inorganic group are used, the more quickly they will become exhausted, and once exhausted these materials cannot be reproduced.

Wood is the principal organic structural material but it is not the only one. The oils that are used in paints, varnish-resins, glues, indiarubber and other materials are of this series.

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CHAPTER I

Woods Compared with Stones and Metals. Common and Botanical Names. Fundamental Classifications

Information relating to the general properties of wood compares in importance with information relating to the general properties of steel, stone, and cement. Engineers use more wood than any other set of men, yet general facts about wood, aside from those relating to its strength, are often relegated to the consideration of the botanist or the forester.

The consumption of wood has never decreased, although metals and stones have been substituted for it in many positions. In England, the consumption per capita more than doubled in the fifty years preceding 1895, in spite of the fact that nearly all of the wood used in that country had to be imported. In 1905, the total yearly mill value of wood products in the United States was over nine times as great as the combined product of gold and silver, and twice as great as the value of the wheat crops.[1]

The importance of wood as a material of construction is well expressed in the quotation that follows:[2]

"Wood is an indispensable part of the material structure upon which civilization rests; and it is to be remembered always that the immense increase of the use of iron and substitutes for wood in many structures,

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[1] A conservative estimate places the yearly mill value of wood products in the United States alone at $1,100,000.000. The spring and winter wheat crops of 1905 were together valued at $518,372,727. The production of gold and silver during the year 1904 was valued at $112,871,026. See also "Forest Resources of the World," Zon (United States Forest Service Bulletin, No. 83).

[2] Credited to the Honorable Theodore Roosevelt.

while it has meant a relative decrease in the amount of wood used, has been accompanied by an absolute increase in the amount of wood used. More wood is used than ever before in our history."

Wood is preferred because it is easily worked and light in weight. In many positions, it is as durable as iron. When dry it is a poor conductor of heat and electricity and is stronger than is commonly supposed. The tensile strength of a bar of hickory may exceed the tensile strength of a similar bar of wrought iron of the same length and weight.[1] However, wood is not homogeneous like metal and most of the stones that are used for building, but is so variable that several parts of the same tree often exhibit widely different qualities.

Most wood is used in construction; that is, in mines, railways, houses, and ships where size or quantity is required and where finish and appearance are less important. Much wood is used in cabinet work and in positions where appearance, appropriateness, and finish are important. Such woods are more in evidence, but the amounts used are actually very much smaller than the amounts used in construction. Some wood is required for turnery, carvings, and implements that demand exact qualities that can be secured in small pieces only. Some wood is used indirectly, and in the manufacture of paper-pulp, gunpowder, and chemicals. There are also by-products of trees, such as tanbark, turpentine, resin, and sugar.

Common and Botanical Names.—Woods appear to be more numerous than they actually are, because more than one name is so often applied to the same species. Supplies are often brought from far distant places when woods of the same kind are available nearby, but are not recognized because they are called by different names. One species, the Southern, Yellow, Georgia, or Longleaf Pine (Pinus palustris), has nearly thirty local names. Such confusion can be avoided only by regarding the recognized botanical nomenclature.

Not only is it true that several names are often applied to the same wood, but, strange as it may seem, a fairly constant single product is sometimes derived from several unrelated species. The single name cedar is thus applied to several species of durable characteristically scented woods, which have similar anatomical features and which are derived from species that are not closely related to one another.

[1] United States Department of Agriculture, Yearbook, 1896, p. 392, Roth.

The botanical name of a plant is made up of terms denoting genus and species. For example, Quercus is the generic name that includes all the species of oak, while alba and rubra are specific names that apply to two particular species of the genus Oak. Quercus alba and Quercus rubra are completed names. The names of species are not fixed, but differ with authorities so that it is often best to add the abbreviated name of the botanist responsible for the name employed. Illustrations would be Quercus alba Linn., Quercus rubra Linn., and Ulmus fulva Michx.

A genus may be defined as a collection of related species, and a species may be regarded as a collection of individuals that might easily have sprung from some single stem. Genera are grouped into families, and both genera and families differ with authorities. The term "variety" is applied to individuals that differ less from one another than do species. Quercus robur var. pedunculata indicates a variety (var. pedunculata) of a certain species (robur) of Oak (Quercus). It should be noted that the variety of one botanical authority is sometimes regarded as a distinct species by another botanical authority.

About five hundred species of trees grow in the United States[1] and many other species grow in other countries, yet, the great mass of wood that is used in construction comes from comparatively few of these species. Sudworth excludes all but one hundred sources in his "Trees of the United States Important to Forestry," while a United States Treasury Department Summary contains the statement that but sixteen (16) kinds of hardwood were quoted in the Chicago markets on the first day of September of the year 1900.[2]

The statement is also made in the source referred to, that the principal timbers of commerce in the United States are the genera known popularly as pine, fir, oak, hickory, hemlock, ash, poplar, maple, cypress, spruce, cedar and walnut.

Conditions are changing. The original forests are much smaller than in former years. Many woods that were once common are now scarce, while other woods that were once unfamiliar are now employed.

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[1] Fernow credits four hundred and ninety-five species to the United States (Introduction to United States Forestry Bulletin No. 17); Sargent, counting species only and excluding varieties, notes four hundred and twenty-two species (Silva of North America).

[2] 1900, p. 1081.

Botanical Classification of Trees and Their Woods.—Botanists group trees as they do other seed-bearing plants, mainly upon the characteristics of parts *other than the trunks.* In such groups, the flowers, fruit, and leaves are fundamentally important. A general classification is as follows:

I. GYMNOSPERMS.—The seeds are naked, that is, they are not enclosed in fruit. There are three natural groups or families as follows:

(*a*) *Cycadaceæ.*—Practically confined to tropical and sub-tropical regions. Practically valueless for wood. To be here disregarded.

(*b*) *Gnetaceæ.*—Consists of undershrubs, shrubs, and small trees, most of which grow in the tropics. Practically valueless for wood. To be here disregarded.

(*c*) *Coniferæ.*—This is by far the largest and most important of the three families, and the only one that yields merchantable lumber. The Pines, Spruces, Firs, and Cedars are among the members of this family. The seeds are borne on series of overlapping scales, arranged in what are known as cones. The leaves of ordinary species are narrow, rigid, needle-like, or scale-like. Resins are present. The trees are sometimes called Needle-leaf, Softwood, and Evergreen trees, as well as Coniferous and Cone-bearing trees.

II. ANGIOSPERMS.—The seeds are always enclosed in more or less obvious seed-vessels or fruit. These plants greatly exceed those in the preceding groups in the number of their species and in the variety of their habits. All ordinary flowering plants are Angiosperms. There are two classes, which, while they agree in having enclosed seeds, differ in other matters, and in none more than in the structure of their stems or trunks. The Angiosperms are sub-divided as follows:

(*a*) *Monocotyledons.*—These plants have one seed leaf or cotyledon, whence the name, *Mono*-cotyledon. The veins in the leaves are more or less parallel to one another. Some twenty-five thousand species are recognized, but very few of these species yield woods that are valued in construction. The few Monocotyledons that yield woods that are valued in construction are associated with the tropics. The Palms and Bamboos are Monocotyledons.

(*b*) *Dicotyledons.*—These plants have two seed-leaves or cotyledons, whence the name *Di*-cotyledon. The veins in the leaves of the Dicotyledons are netted. The stems of these plants increase by layers of new material that form, each one upon the outside of others that were formed before. Coniferous trees increase in practically the same manner. Several hundreds of the over one hundred thousand Dicotyledons are trees, and these Dicotyledonous trees yield the so-called Broadleaf woods, Deciduous woods, or Hardwoods of commerce. The Oaks, Maples, and Hickories are among the Dicotyledons.

The woods that are valued in construction are derived from the *Conifers*, the *Dicotyledons*, and the *Monocotyledons*, in the order named. The other divisions of plant life do not produce merchantable woods and may be disregarded in this connection.

Practical Classification of Trees and Their Woods.—Those who use woods are less concerned with the flowers, fruit, and leaves of the trees, than with the trunks, and the characteristics of the woods themselves. The present text has for its object a study of woods, as distinct from trees, and for this reason, the features of flowers, fruit, and leaves, which are so important to the botanist, will be regarded as secondary, and woods will be classified upon the basis of their own properties.

From this viewpoint all trees, trunks, and woods will be divided primarily according to the way in which new material is added to their sections. Two great divisions will be distinguished:

1. *Banded Trunks and Woods.*—In this case the wood is arranged in concentric bands or layers which, in cross-sections, appear as rings. The trees that yield banded woods are all

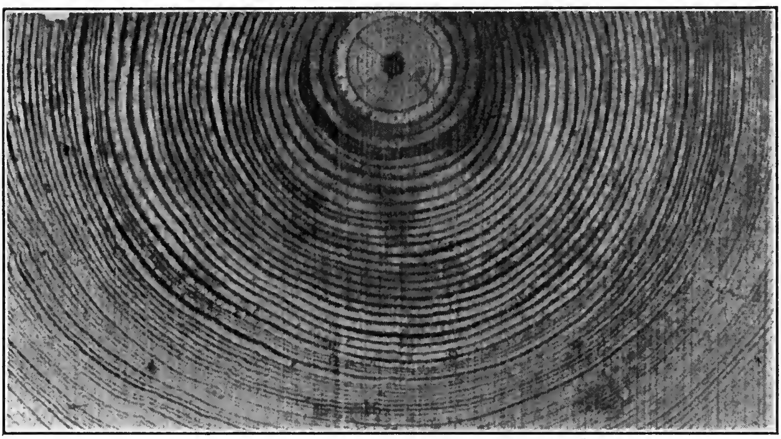

FIG. 1.—Section through a banded trunk (longleaf pine, *Pinus palustris*).

"outside-growers;" that is, new material is deposited in layers, each one of which is formed upon the outside of other layers that were formed before. Pines, oaks, and practically all other trees that yield woods that are valued in construction are included in this division. It is the group to which the name Exogen, or Outside-grower, has been applied by the engineer.

The names Exogen and Endogen are undesirable because engineers and botanists seldom employ them in the same way. Some botanists use the name Endogen in connection with Monocotyledonous trees and woods, but restrict the use of Exogen to Dicotyledonous trees and woods, while others do not employ these terms at all.

This group is divided into Conifers and Dicotyledons. The first sub-series includes the so-called Softwoods. Coniferous, Softwood, Needleleaf and Evergreen woods are the same. It should be noted that in spite of the use of the word Softwood some of the individuals of this sub-series are actually very hard. The Dicotyledons are often referred to as Hardwoods although some of them are really quite soft. Dicotyledonous, Hardwood, Non-coniferous, and Deciduous woods are the same.

2. *Non-banded Trunks and Woods.*—These woods are not arranged in concentric rings or layers. On the contrary, the

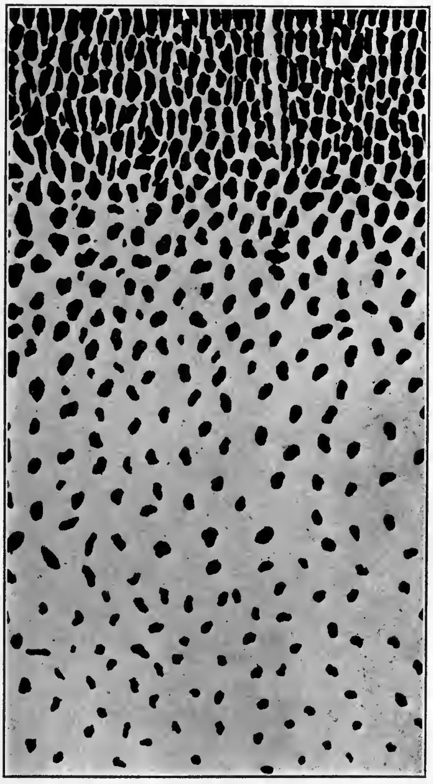

FIG. 2.—Section through a non-banded trunk (royal palm, *Oreodoxa regia*).

wood is scattered irregularly in small fibrous groups throughout the tree which is, therefore, known as an "inside-grower."

The Palms, Bamboos, and a few other plants of this group that yield useful woods are associated with the tropics. The woods are seldom used much in construction far from the places in which they grow. This group includes the Monocotyledons of the botanist and is the one to which the name Endogen, or Inside-grower, has been applied by engineers.[1]

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[1] See first paragraph page 6.

CHAPTER II

Trees. Physiology of Trees. Value of Forests. Forestry

A study of iron begins at the furnace; a knowledge of stone must include some facts with regard to the quarry from which the stone was taken; in the same way a study of wood must commence with a study of the tree within which the wood was formed.

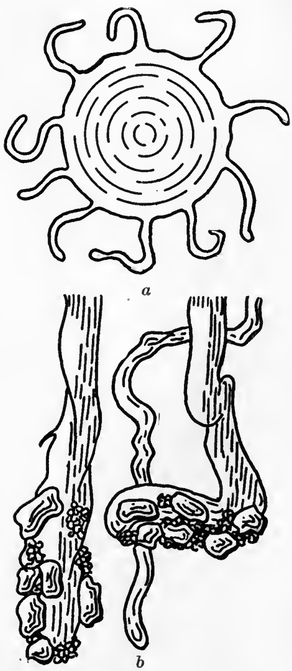


Fig. 3.—Roots. *a*, Cross-section through root; *b*, hairroots enlarged.

PHYSIOLOGY OF TREES.—A tree has been defined (Century Dictionary) as "a perennial plant which grows from the ground with a single, permanent, woody, self-supporting trunk or stem, ordinarily attaining a height of at least twenty or thirty feet." A tree has three principal parts or systems; they are the roots, the leaves or foliage, and the stem or trunk. The roots and the foliage are here regarded only as they are means by which the wood of the stem is manufactured.

The Roots.—This system of branches is as extensive as the one at the top of the tree. Roots serve in two ways: (1) they give stability and hold the tree firmly in its place; (2) they absorb moisture and various nutrient salts from the soil. With the exception of carbon and some oxygen used in respiration, all of the elements needed for the growth of trees are obtained from the soil through their roots.

References.—"Cyclopedia of American Horticulture," Bailey; "Forestry for Farmers," Fernow (United States Division of Forestry Bulletin No. 10); "First Book of Forestry," Roth; "Outlines of Botany," Leavitt (American Book Company); "Plant Anatomy," Stevens (Second Edition).

The Leaves.—Carbon, in the form of carbon dioxide, is obtained from the atmosphere by means of the green coloring matter which forms part of the leaf and which is known as chlorophyll. Leaves also serve as laboratories within which food materials are formed which may finally enter into the formation of wood.

By some peculiar property of the chlorophyll, the living tissue of the leaf is able, in the presence of sunlight, to split apart the CO_2 and to recombine the constituents with H_2O so as to form a carbohydrate, probably some form of sugar.[1] The chemical formulas of grape sugar ($C_6H_{12}O_6$) and cellulose ($C_6H_{10}O_5$) are essentially alike, so it is clear that, with the development of carbohydrate compounds in the leaves, a fundamental step has been taken toward the formation of wood.

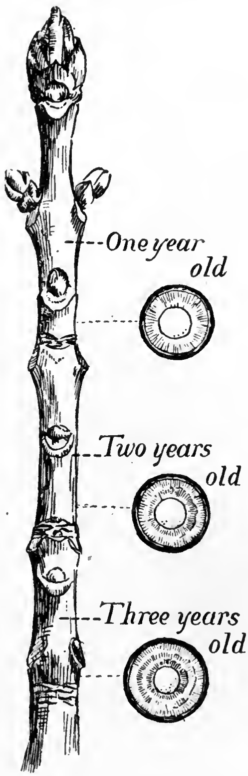


FIG. 4.—Elongation of white ash twig.

The Trunk.—The trunks of trees that yield banded woods must be distinguished from the trunks of trees that yield non-banded woods. In the first group, the wood-elements are arranged in concentric bands or layers, while in the second group they are distributed in separate bundles so that the cross sections, in this case, appear as though dotted (Figs. 1 and 2).

All trunks increase in two ways: in length and in thickness. Increase in length is quite distinct from increase in thickness. The terms length-growth and thickness-growth will be employed to indicate these two methods of increase.

Length-growth.—All trees lengthen by means of material that forms upon the ends of the main axis and of the twigs and branches. A point of embryonic cells exists at the end of each ultimate twig. These apical cells grow, divide, and in the course of the year leave behind them a whole new section of twig with its leaves. The twig then thickens by a centrifugal growth to be described, and eventually the twig becomes a part of the bough.

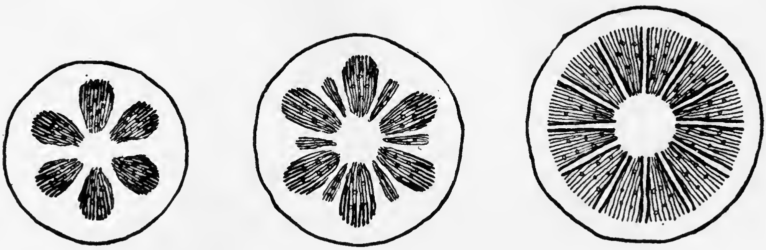
[1] "Light in Relation to Tree Growth," Zon and Graves (United States Forest Service, Bulletin No. 92.)

Length-growth precedes thickness-growth and is quite distinct from it. A nail driven into a tree at a certain distance up from the ground may be finally covered by new wood material, but it will not move up higher from the ground.

Thickness-growth.—With several exceptions, the few trees that yield *non-banded woods* do not increase in diameter by the formation of new layers deposited upon the outside of older growth. On the contrary these trees increase largely by the expansion of cells already formed. The trunks of these trees, few of which are of structural importance, do not continue to increase in diameter throughout their lives, but normally attain maximum diameters comparatively early in their growth.

The trees that yield *banded woods* thicken as follows:

During the first year, the wood material is in separate bundles arranged in a circle, but later these bundles are fused together so as to form a more or less compact cylinder. The



a *b* *c*

Fig. 5.—Cross-section of very young banded stem. *a*, Six fibro-vascular bundles are shown. *b*, The same stem later; the bundles are increased to twelve. *c*, At the end of the year the bundles are in the form of wedges separated by pith rays. Acknowledgments to "Outlines of Botany," Leavitt (American Book Company).

tissue known as *primary wood* is included in this early growth.[1] The several stages during the first year are sufficiently indicated in the pictures.

After the first year, the food materials, which are formed in the leaves, descend to the growing part where the new wood is formed. This part is known as the "cambium layer." Wood formed from the cambium layer is known as *secondary wood.* Practically all of the wood formed by the tree is of this kind. After the first year a new layer of secondary wood is formed every growing season, and these annual layers or bands are characteristic of all banded woods.

[1] Tissue at the growing end of the twig forms primary wood. The thin-walled cells of which it is composed are essentially similar to one another.

The Cambium Layer.—This part, which is of fundamental importance to the life of the tree, occupies the region between the sapwood and the bark, and may be described as a thin-walled formative tissue within which, by cell-division, growth, and modification, all wood-elements originate. The cambium layer consists of essentially the same kind of embryonic cells as those at the tips of the twigs.

The cambium layer, which suggests a thin layer of mucilage, is composed of very thin-walled cells, filled with protoplasm, and other organic and nutrient compounds. These cells multiply and develop. The inner cells eventually form a new layer of wood while those at the outside form bark. The wood cells, which are at first soft and delicate, become harder, as a material known as lignin begins to be deposited within their walls. The resulting change from the soft cell to the tough, woody cell is known as lignification.

The cambium, in its centrifugal advance, may leave one hundred or more thin layers of wood-elements behind every year and these very thin deposits together make up what is commonly known as the "annual band" already mentioned.

Sap Movement.—In the trees that yield banded woods, the "crude sap," containing mineral nutrients drawn from the soil, leaves the roots and passes upward through the outer sapwood to the foliage where the sap is by complex chemical changes "elaborated." The elaborated or completed sap, containing the more complex organic preparations needed for the life of the tree, then descends through the inner bark to the growing parts.

The fluids of a tree move continuously during the growing season. Up-currents and down-currents move simultaneously. In the main, fluids pass upward through the outer sapwood and downward through the inner bark, as has been noted. This continues through the larger part of the year and is not confined to the spring alone as some suppose.

The means by which sap ascends to the top of the tree are not fully understood, but evidence exists that the force is not capillary to the extent that was formerly supposed. The passage upward is doubtless encouraged by the evaporation of water from the leaves, but how far this acts in raising the water through distances as great as several hundred feet is not known.[1]

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[1] See "Tracheids."

Influence of Sunlight.—All trees require sunlight and are influenced by the way in which they receive it. A tree that stands by itself in the open will differ in form from a tree that stands with others in the forest. In the former environment, the growth of lower branches is encouraged, while in the latter environment, it may be discouraged. Sunlight does not have free access to the side branches of ordinary trees standing near together in a forest. The higher branches of such trees are therefore better nourished. These extend upward toward the sunlight, and consequently longer, cleaner trunks are formed.

FIG. 6.—Sugar maple tree grown in the open. (By courtesy of American Museum of Natural History.)

It is possible to modify the shapes of trees. Either full-branched trees, that are prized in landscape effects, or long, straight trunks that are valued by lumbermen can be obtained by proper exposure to sunlight. The lower branches of many forest trees are pruned away by nature, that is, these branches die naturally for want of sunlight. In other cases the same results are obtained by ordinary pruning. In any case where lower branches are removed, wood-making material which would otherwise pass into these branches is diverted to the trunk.

The value and influence of sunlight are described in the following quotation:[1]

[1] "Light in Relation to Tree Growth," Zon and Graves (United States Forest Service Bulletin No. 92).

"Light is indispensable for the life and growth of trees. In common with other green plants a tree, in order to live, must produce organic substance for the building of new tissues. Certain low forms of vegetable life, such as bacteria and fungi, do not require light. They exist by absorbing organic substance from other living bodies; but the higher forms of plants manufacture their own organic material by extracting carbon from the air. The leaves, through the agency of their chlorophyll, or green coloring-matter, absorb from the air carbon dioxide, and give off a nearly equal volume of oxygen. The carbon dioxide is then broken up into its elements and converted into organic substances which are used in building up new tissues.

"Light is not only indispensable for photosynthesis, but it is essential for the formation of chlorophyll. Only in exceptional cases, as in the embryo of fir, pine, and cedar seeds, does chlorophyll form in the dark, and, with the exception of some microbes, the green cell is the only place where organic material is built up from inorganic substances.

Fig. 7.—Tulip tree grown in the forest. (Courtesy of the American Museum of Natural History.)

"Light also influences transpiration, and consequently the metabolism of green plants. It influences largely the structure, the form, and the color of the leaf, and the form of the stem and the crown of the tree. In the forest it largely determines the height-growth of trees, the rate at which stands thin out with age, the progress of natural pruning, the character of the living ground cover, the vigor of young tree growth, the existence of several-storied forests, and many other phenomena upon which the management of forests depends. A thorough understanding, therefore, of the effect of light upon the life of individual trees, and especially on trees in the forest, and a knowledge of the methods by which the extent of this effect can be determined are essential for successful cultural operations in the forest."

VALUE OF FORESTS.—The top-soil of forests is porous and loose. The mixture of leaves and loose top-soil that forms under the trees is known as "humus." The humus receives and protects young seeds and is also valuable because it assists in equalizing the flow of streams.

Rain-water rolls quickly from sun-baked or otherwise compacted soil, but humus permits the raindrops to pass through into the more or less broken and comparatively loose and porous soil below and then obstructs the free evaporation of moisture from this soil. It is not known that forests influence rainfall, but their value in regulating stream-flow is beyond estimate.[1]

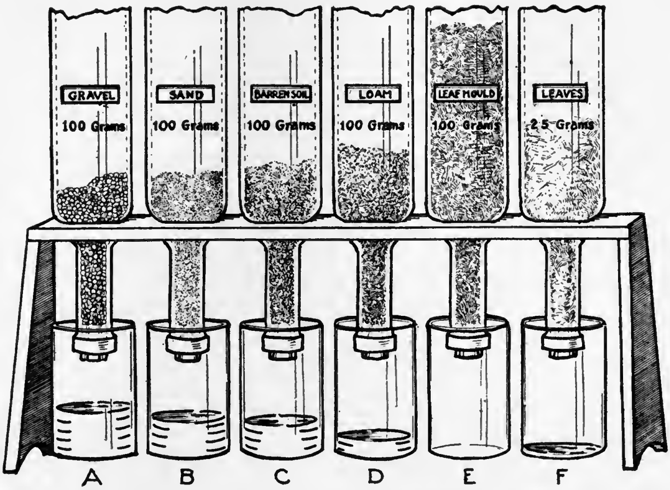

FIG. 8.—Ability of Surface Materials to hold Water. *A*, Most of the water in this bottle, which contains gravel, has passed through into the beaker. *B*, *C*, and *D*, These bottles contain sand, barren soil and loam. *E*, This contains leaf mould, which retains the most water. *F*, This contains leaves. (From "Trees and Forestry," Dickerson. By permission American Museum of Natural History.)

Forests Reduce or Prevent Erosion.—The humus protects the surface, and the roots contribute to the resistance offered by the soil below. Water flows with erosive force over unprotected and hardened surfaces. Quantities of soil are carried from higher elevations and deposited on lands below. Such results may be far reaching. Districts such as parts of India, China, Palestine, and Spain, that have supported considerable populations in the past, have been changed in this way and are now little else than deserts.

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[1] Leighton estimated that the flood damages to this country amounted to $237,800,000 in 1908; "Conservation of Natural Resources in the United States" (Van Hise, p. 182). See also Swain in "American Forestry," April, 1910, and Burr in "Engineering News," July 27, 1911, etc.

The possibilities in this direction are described further as follows (Van Hise[1]):

"Not only so, but after the rivers are partly filled with silt, at times of flood they overflow their banks and often cover with coarse débris large areas of arable land. When this process of erosion has continued for a sufficient length of time after the removal of the forests, the steep mountains are left with nearly bare rock and little soil. When this stage of the process has been reached the violence of the floods is then further greatly increased. The rain falling upon the bare rocks is carried down to the streams below as from the roof of a house, and unites in torrential floods. It is after this condition of affairs has come about as a result of a removal of the forests that the enormous flood losses occur to railroads, cities, and other structures of man."

FORESTRY.—Forestry is a phase of agriculture, rather than of lumbering. Under this system forests are not destroyed for immediate profit but are maintained so as to secure recurring crops of desirable, matured trees. Besides this, appropriate species are planted, top-soil or humus is preserved, fire risks are lowered, and young trees are introduced as older ones are cut down. Forestry yields smaller profits but these continue from year to year. The lumberman, who disregards the principles of forestry, receives larger profits once and for all.

The results that may be obtained by the practice of forestry are expressed in the quotations that follow:[2]

"Under right management our forests will yield over four times as much as now. We can reduce waste in the woods and in the mill at least one-third, with present as well as future profit. We can perpetuate the naval-stores industry. Preservative treatment will reduce by one-fifth the quantity of timber used in the water or in the ground. We can practically stop forest fires at a total yearly cost of one-fifth the value of the standing timber burned each year." . . . . "By reasonable thrift we can produce a constant timber supply beyond our present need and with it conserve the usefulness of our streams for irrigation, water-supply, navigation, and power."

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[1] "Conservation of Natural Resources in United States" (p. 246). See also "Washed Soils and How to Prevent Them" (United States Dept. Agriculture, Farmers' Bulletin No. 20); "Conservation of Water by Storage," Swain (Yale University Press, 1915).

[2] United States Forest Service Circular No. 171, Price, Kellogg and Cox.

The size and character of the trunk, and the range, locality, and distribution of the species, have much to do with the utility of the wood. Large and perfect timbers cannot be derived from species characterized by small or crooked trees. A given kind of wood is always used more if it is widely distributed and easily available.

CHAPTER III

WOOD. CHARACTER AND ARRANGEMENT OF WOOD-ELEMENTS. INFLUENCE OF CELLULAR STRUCTURE UPON CHEMICAL COMPOSITION AND PHYSICAL PROPERTIES OF WOODS. IDENTIFICATIONS. STATEMENTS OF WEIGHTS AND MODULI EMPLOYED IN TABULAR DESCRIPTIONS OF SPECIES

Wood is the solid part of trees—the part which, when otherwise suitable, is used in construction. It consists of a ground-work of starch-like substance known as cellulose, permeated by materials collectively known as lignin. There are also secretions, such as resin, coloring-matter, and water. The small proportion of mineral in wood is evident as ash.

Wood, timber, and lumber may not mean the same. Properly speaking, all woody tissue is wood; but roots and branches contain much wood that is not suitable for construction. Wood that is suitable, although not necessarily ready, for construction, is "timber;" and wood that is not only suitable, but also ready for construction, is "lumber." The word timber may thus include living trees in the forest, as well as logs and shaped pieces; whereas, lumber refers only to boards, planks, beams, and other sawn pieces of limited sizes, and then only in America. The term lumber, which is not sharply definable, is not used much outside of North America.

Wood is composed of innumerable minute structural units, known as wood-cells,[1] or wood-elements, which differ from one

[1] So named by Robert Hooke in 1667 because of resemblance to cells of honeycombs.

REFERENCES.—"Structure of Certain Timber Ties," Dudley (United States Forest Division, Bulletin No. 1, p. 31); "Timber," Roth (United States Forest Division, Bulletin No. 10); "The Decay of Timber," von Schrenk (United States Bureau of Plant Industry, Bulletin No. 14, p. 12); "Trans. American Railway Engineering Association," Tiemann (Bulletins No. 107 and No. 120); "Plant Anatomy," Stevens; "Identification of Economic Woods of United States," Record (John Wiley & Sons, 1912); "Wood," Boulger (London, Second Edition); "North American Gymnosperms," Penhallow; "Outlines of Botany," Leavitt; "Pithray Flecks in Wood," Brown (United States Forest Service Circular No. 215); etc.

another in shapes and sizes, in the thickness and surfaces of their walls, and in the ways in which they are arranged. There are also compounds associated with, although actually foreign to, the wood-elements. Of these associated materials, water is the most important.

The subject is fundamentally important. Physical properties, such as hardness, elasticity, and weight are influenced by (1) the

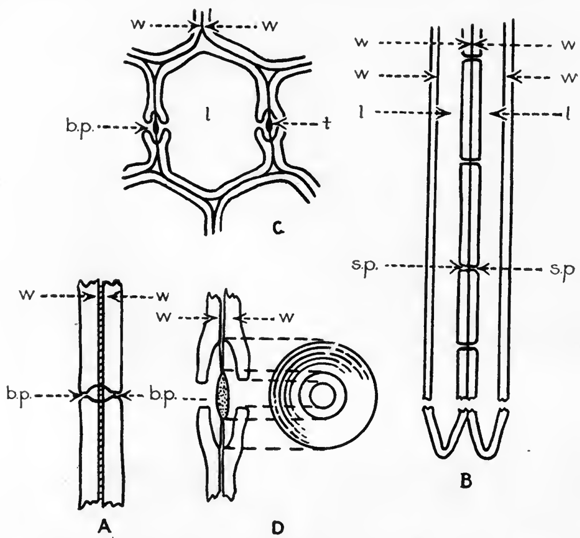
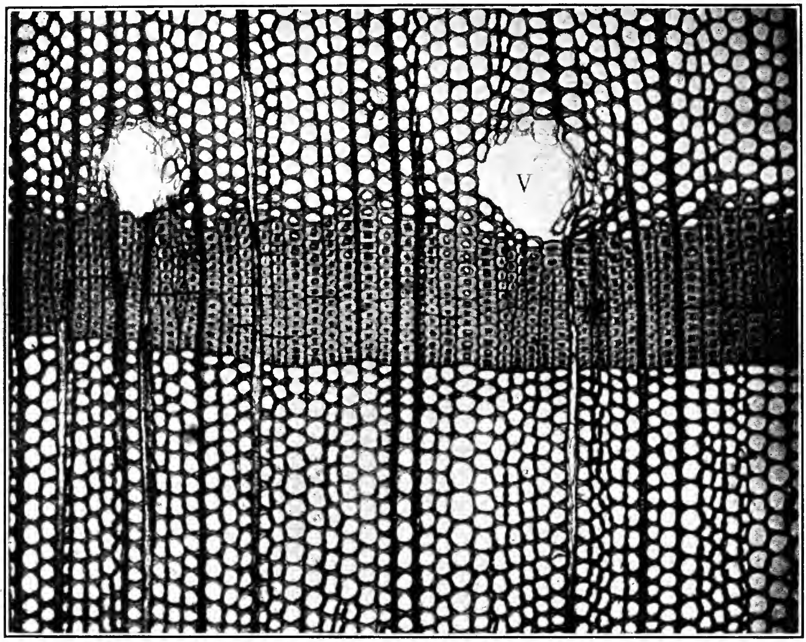


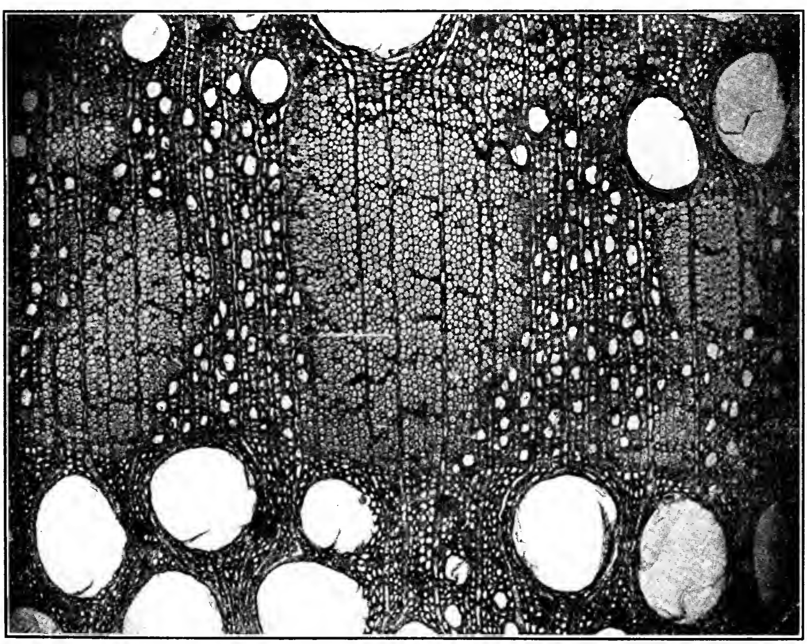
Fig. 9.—Pits. *A*, Longitudinal section through parts of two adjoining walls *w.w.* One pair of bordered pits *b.p.*, is shown. *B*, Longitudinal section through portions of two adjoining wood-fibers. Four pairs of simple pits in adjoining walls are shown; only one pair is marked *s.p.* The lumen of each fiber is marked *l.* The walls are marked *w.* *C*, Cross-section through entire wood-element, with parts of walls of adjoining wood-elements. Bordered pits are shown on the right, and on the left *b.p.* The torus *t* is the thick part of the common, separating, or primary portion of the wall also known as the "middle lamella." *D*, A larger and more detailed section through bordered pits shown in figure *C*. Two adjoining pits with torus and pit-canal are shown.

character of the wood-elements, (2) the arrangement of the wood-elements, and (3) by the characteristics and quantities of the compounds that are associated with the wood-elements.

Wood-Elements.—These vary in details, but are similar in this regard that all partake of the nature of minute tubes. The cavities within the tubes are the "lumina." A cell-cavity, or lumen, may be empty, or it may contain water or other compounds. Wood-elements are of several kinds, as wood-fibers,



(*a*) Cross-section of Longleaf Pine (*Pinus palustris*).



(*b*) Cross-section of White Oak (*Quercus alba*).

Acknowledgments to Bureau of Plant Industry, United States Department of Agriculture.

(*Facing page* 18.)

tracheids, vessels, wood-parenchyma fibers, and pith-ray cells. Each of these classes of wood-elements includes several varieties.

The walls of all wood-elements are thickened and appear under the microscope as double lines.

The young primary wall, is a very thin, practically imperforate and continuous membrane, which constitutes the first outline of the cell. This membrane originally surrounded the protoplasm and other materials that were contained within the living cell.

The secondary thickening is laid on later and gives strength to the wood-element. It is seldom, if ever, imperforate, but contains pits of characteristic shapes. The layer is sometimes disposed in ridges on the inside of the cell, much as a spiral staircase is placed within a tower. This structure is never present within wood-fibers, but is occasionally found within tracheids and vessels.

Holes or thin spots in the walls of wood-elements are known as "pits." Some pits are round, while others are elliptical or slit-shaped. They are further divided into what are known as "simple pits" and "bordered pits." Pits are "simple" when the walls that extend out from the middle lamella are nearly parallel, and they are "bordered" when the walls that extend out from the middle lamella diverge.

The bordered pits that are present in the walls of tracheids, vessels, and some wood-fibers, are invaria-

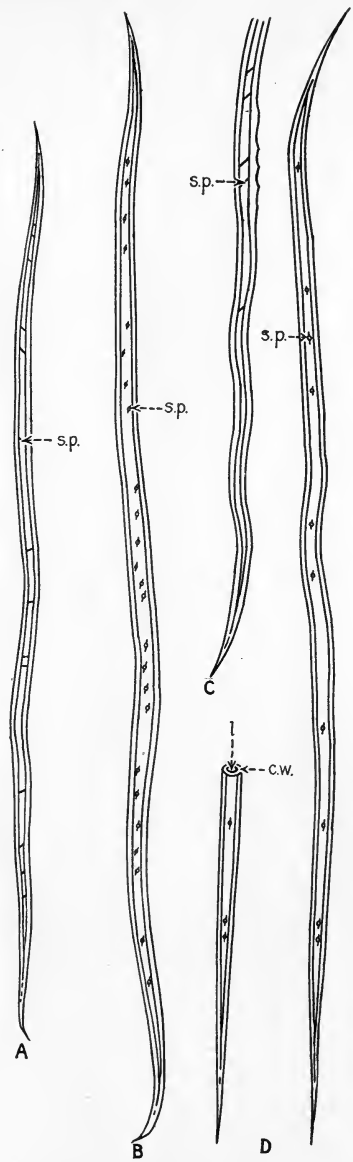
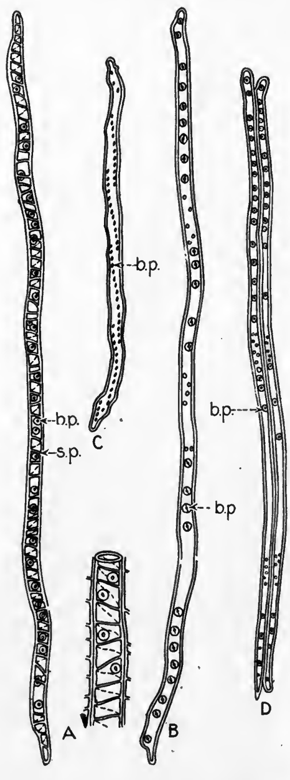


Fig. 10.—Wood-fibers. *A*, Wood-fiber of white oak (*Quercus alba.*) *B*, Wood-fiber of black gum (*Nyssa sylvatica*). *C*, Wood-fiber of beech (*Fagus americana*). *D*, Wood-fibers of black walnut (*Juglans nigra*). *c.w.* indicates cell-wall; *l* indicates lumen; *s.p.* indicates simple pit.

bly paired exactly in position with similar pits in the walls of adjoining elements. They do not open through, however, but are closed by partitions which exist in the primary walls or "middle lamellæ." There is usually a thickened disc in the middle of the partition that is known as the "torus."

Wood-Fibers.—Ordinary wood-fibers are long, slender, comparatively smooth-surfaced, and sharp-pointed wood-elements. The walls are thick and lignified, and the pits are usually simple; that is, they are without borders. Wood-fibers are not found in coniferous woods, but are nearly always present in, and are regarded as characteristic of the so-called broadleafed woods, to which they contribute much strength and hardness. The wood-fibers also give mechanical strength to the living tree and probably contribute in some way to the transportation of water through the tree, from the roots to the foliage.

FIG. 11.—Tracheids. *A*, Tracheid of yew (*Taxus bacata*). *B*, Tracheid of pinon pine (*Pinus edulis*). *C*, Tracheid of red oak (*Quercus rubra*). *D*, Tracheids of western yellow pine (*Pinus ponderosa*). *b.p.* indicates bordered pit; *s.p.* indicates spiral.



Tracheids (*Tra-ke-ids*).—Tracheids are elongated, taper-pointed cells, with peculiar markings, which appear, either in the form of bordered pits, located, for the most part, on the radial surfaces of the tracheids, or else in the form of ridges, variously disposed upon the inner walls. Tracheids are the wood-elements upon which coniferous woods largely depend for strength. They are characteristic of coniferous woods and although they do exist in many of the broadleafed woods are then invariably subordinate to wood-fibers and vessels.

Tracheids serve in the living tree because they contribute to its mechanical support, and also because the bordered pits are so designed as to assist very materially in the conduction of water through the stem from the roots to the leaves.

The means by which water is thus raised has been credited to root pressure, transpiration, and osmotic pressure.[1]

Vessels.—These compound structures are formed by the breaking down of partitions that exist between the abutting ends of simpler or shorter structures, known as "vessel-segments." Tubes of very considerable length are formed in this manner and, as is the case with oak, are often so large in diameter that they can be seen with the unaided eye. These large cavities are commonly referred to as "pores," and the vessels themselves have been variously named by plant anatomists as pores, canals, ducts, tubes, vasa, tracheæ, tracheal-tubes, and fistulæ.

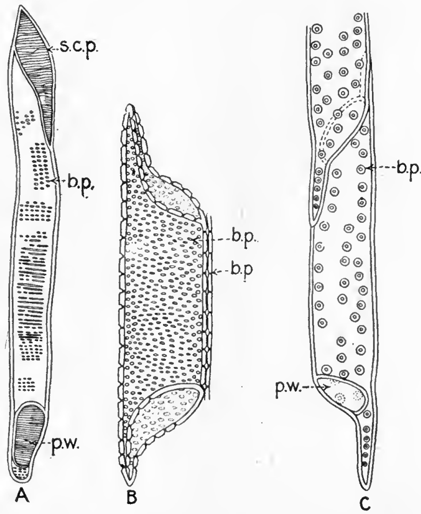


FIG. 12.—Vessel-segments. *A*, Vessel-segment of cotton gum (*Nyssa aquatica*). *B*, Vessel-segment of black walnut (*Juglans nigra*). *C*, Vessel-segment of oak (*Quercus*). *sc.p.* indicates scalariform (ladder-like) perforations; *b.p.* and *p.w.* indicate bordered pit and partition wall respectively.

Vessels Differ with Species.—The central cavities of lumina of the vessels of some species are open, while those of other species are obstructed by parenchymatous growths known as "tyloses." Air can readily be blown through several feet of red oak, even before it has been seasoned, because tyloses are absent in the vessels of this species. On the contrary, a pressure of one hundred pounds per square inch is sometimes insufficient to force air through a single inch of unseasoned white oak, because the vessels of that species contain quantities of tyloses.

A vessel increases in thickness by means of layers that are gradually deposited on its walls. Several layers of unequal thickness can often be distinguished with the aid of a powerful microscope. The thickened portions of the walls give strength, while the unthickened portions permit water and materials in solution to pass in and out. The differences in thickness are evidenced by markings such as are shown in the picture.

[1] "Plant Physiology," Jost (Gibson, Oxford, 1907, pp. 45–47.)

Wood-Parenchyma Fibers (Pa-ren-kih-ma). — These comparatively short, compound structures are made up of shorter, oblong, thin-walled cells, in groups, from a few in number to as many as eight or ten, of which the upper and lower cells are taper-pointed. Wood-parenchyma fibers resemble fibers and tracheids in general form, but differ from them in that, as groups of living cells, they contain, besides protoplasm, the various foods and products connected with the life-processes of the tree. They may contain crystals of calcium oxalate or crystals of calcium carbonate. The cells that contain these crystals are often cubical in outline and the cavities are sometimes completely filled with the crystalline mass. Such elements are known as "idioblasts."

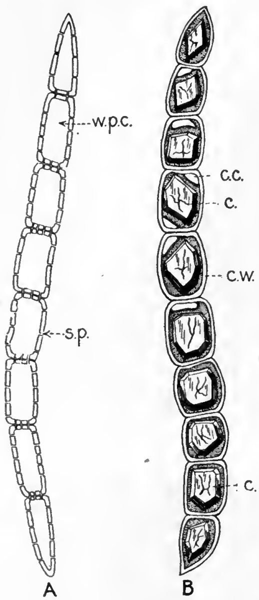
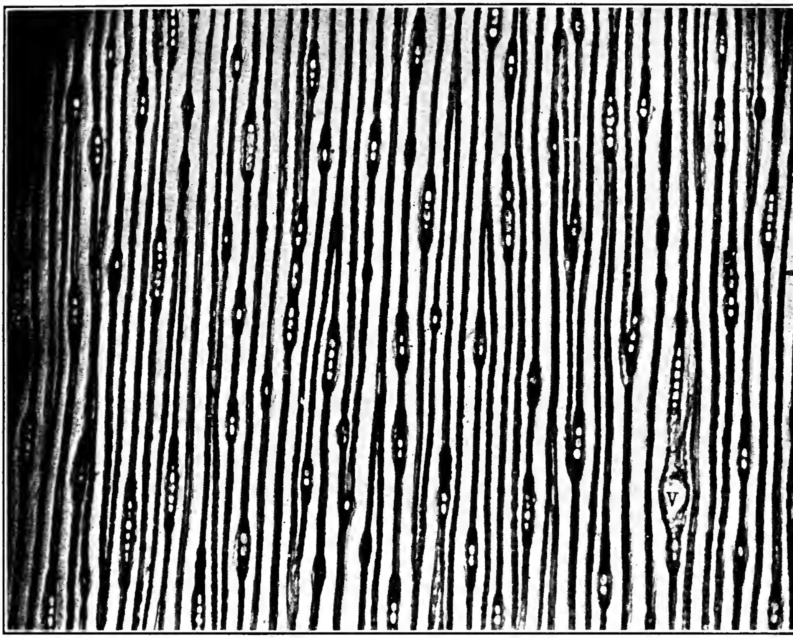


FIG. 13.—Wood-parenchyma fibers. *A*, Wood-parenchyma fiber of white oak (*Quercus alba*). *B*, Wood-parenchyma fiber of black walnut (*Juglans nigra*). *w.p.c.* indicates wood-parenchyma cell; *s.p.* indicates simple pit; *c.w.* indicates cell-wall; *c.c.* indicates cell-cavity; *c.* indicates crystal of calcium salts.

Wood-parenchyma fibers are usually, although not always, shorter than wood-fibers in the same species. They are peculiar, in that they retain their power of cell-division after they leave the cambium, and usually divide into a number of short parenchyma-cells, separated by horizontal or oblique partition-walls, as has been noted. There are simple pits that on the whole vary only slightly in different species of woods. Sanio, author of the term "wood-parenchyma fiber," describes them as tissues that originate through the division of cambium cells and that conduct and store up carbohydrates. He divides them into two classes, namely, septate and non-septate or intermediate wood-parenchyma fibers. The latter are sometimes difficult to distinguish from wood-fibers, but usually have thinner walls and larger cell-cavities. Solereder classifies wood-parenchyma fibers with wood-fibers, vessels, and tracheids, under the general term "wood-prosenchyma," and not with pith-ray elements.[1]

[1] See also "Wood," Boulger (Second Edition, pp. 28 and 29); "North American Gymnosperms," Penhallow (p. 109).

PLATE II. ARRANGEMENT OF WOOD ELEMENTS—TANGENTIAL SECTIONS



(*a*) Tangential Section of Longleaf Pine (*Pinus palustris*).

(*b*) Tangential Section of White Oak (*Quercus alba*) showing large Pith Ray.

Acknowledgments to Bureau of Plant Industry, United States Department of Agriculture.

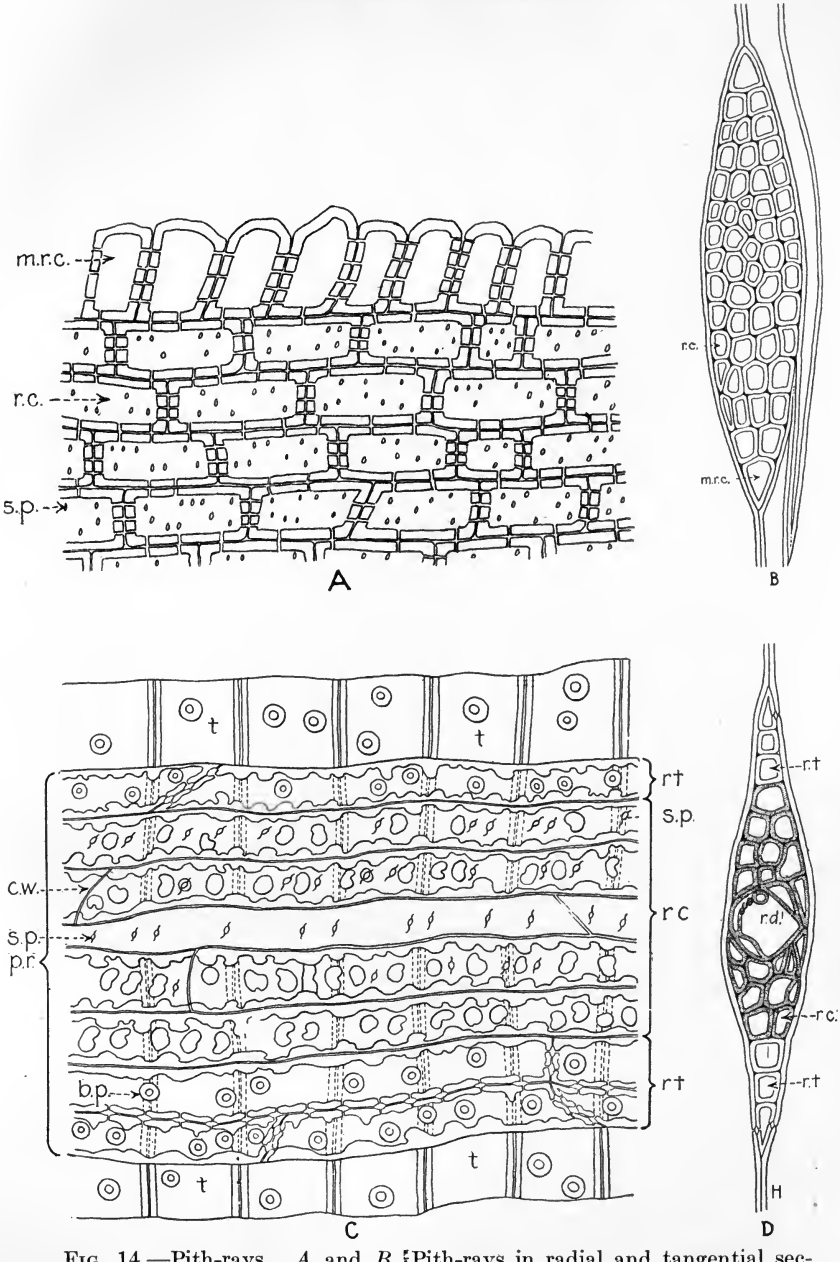


FIG. 14.—Pith-rays. *A* and *B*, Pith-rays in radial and tangential sections of black walnut (*Juglans nigra*). *C* and *D*, Pith-rays in radial and tangential sections of western yellow pine (*Pinus ponderosa*). *p.r.* indicates pith-ray; *t* indicates tracheid; *c.w.* indicates cell wall; *r.t.* indicates ray tracheid; *r.c.* indicates ray cells; *m.r.c.* indicates marginal ray cell; *s.p.* indicates simple pit; *r.d.* indicates resin-duct; *r.c.* indicates resin-cell.

Pith-rays.—These compound structures are made up of short, cubical or oblong cells, arranged in rows that pass radially from the center of a tree to its circumference. Pith-rays differ strikingly from other wood-elements in that *they are arranged horizontally.* They cross the tree, bind the vertical wood-elements together, and also serve as a vital link between the living elements of the tree. The cells of which pith-rays are composed resemble those making up wood-parenchyma fibers in form and structure, and because of the fact that they, too, contain various foods and products connected with the life-processes of the tree. The terms pith-ray, medullary ray, and ray mean the same.

Pith-rays are plainly visible in some woods, as oaks, but are not easily visible in other woods, as poplars, even when a hand magnifying glass is employed. Pith-rays contribute to the appearance of "quartered oak," which with other "quartered woods," are obtained by cutting logs radially (see Fig. 25). When cut in this way the pith-rays are split and their larger *surfaces* are exposed. Otherwise, in the tangential cut, the pith-rays are cut through vertically and appear as short *lines.* Pith-rays are not visible in some woods except when very thin pieces are placed under a compound microscope.

The small, cubical or oblong cells, of which pith-rays are composed, are indented with minute, simple pits. The pith-rays of some conifers also contain, in addition to the small parenchyma cells, one or more rows of peculiar flattened tracheids, known as "ray-tracheids." Resin-ducts are also present in some of the pith-rays that exist in the pines. Pith-rays may be divided into primary and secondary pith-rays. The first are those that extend completely through from the pith-cavity at the center of the tree to the bark, while the second are those that do not extend through thus completely.

The function of the pith-ray has been described as follows:[1]

"The medullary-rays have, for their primary function, the radial transmission and storage of food. Their intimate relation with the cells of the phloem at their outer and with the xylem parenchyma along the inner course, and the fact that we usually find them gorged with food, points to this conclusion. The short, vertical extent of the rays, and their isolation from each other renders them unsuited for the vertical or longitudinal transmission of foods. If they were of value in this respect girdling would not prevent the downward flow of foods."

[1] "Plant Anatomy" Stevens (p. 162).

Resin-canals.—Resin-canals are not wood-elements like tracheids and wood-fibers. On the contrary, they are intercellular passages which appear scattered irregularly here and there throughout the woods of some coniferous trees. They are not numerous and do not form conspicuous structural features in the cross-sections in which they occur. The continuity of the passages through some of these canals, as those in Douglas

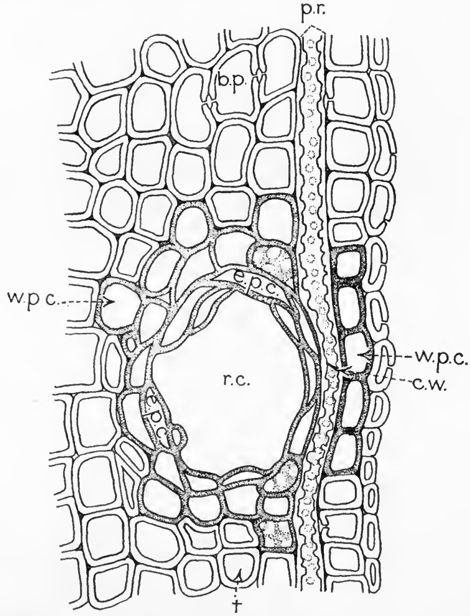


Fig. 15.—Resin-canal. Resin-canal in transverse section of western yellow pine (*Pinus ponderosa*). *r.c.* indicates resin-canal; *e.p.c.* epithelium cells; *w.p.c.* wood-parenchyma cells; *p.r.* pith-ray; *t.* tracheid; *b.p.* bordered pit; and *c.w.* cross-wall.

fir, is interrupted by constrictions. In some woods resin-canals are simple cavities known as "cysts." Resin-canals and resin-ducts are the same.

The resin-passages that exist in the trees that produce commercial resins have received most attention. Tschirch divides these passages, as they exist in the pines, into "primary resin-ducts" and "secondary resin-ducts." The former, scattered through the heartwood and the sapwood, produce comparatively small quantities of resins, while the latter, formed in the outer sapwood of trees that have been wounded, pour crude turpentine over the wounded surfaces in order to protect them. The turpentine of commerce is obtained from these "secondary resin-canals." It will be seen that the resins produced by the "primary canals" are physiological products, whereas those produced by the "secondary canals" are pathological products. Tschirch has demonstrated that the seat of resin-production is in a mucilaginous layer (epithelium cells, Fig. 15) that lines the inside of the resin canal.[1]

Arrangement of Wood-elements.—The character of wood depends not only upon its wood-elements but also upon the way in which these wood-elements are arranged. Most wood-elements are arranged up and down, a fact that explains the comparative ease with which most woods are split. But besides this, there is a horizontal arrangement. The pith-rays pass radially, that is horizontally, from the center of the tree to its circumference, and bind the vertical wood-elements together. The arrangement of wood-elements is much more regular in some woods, as pines, than in others, as eucalyptus and lignumvitæ; and woods are easy or difficult to work, in proportion as their elements are thus arranged in a simple or a complicated manner.

Associated Compounds.—Certain materials are associated with, although they do not form part of, the wood-elements, and such compounds are notable because they exert a material influence upon the character of the wood-elements, and, therefore, upon the character of the wood. Of these associated materials, the most important is water, which acts by distending the wood-elements and thus making them weaker and more pliable. The influence of moisture is so great as to require further notice (see "Moisture in Wood").[2]

Influence of Cellular Structure upon Chemical Composition and Physical Properties of Wood.—Chemical and physical properties of woods are influenced by the character and arrangement of the wood-elements, and by the qualities and quantities of the materials associated with these wood-elements. Chemical composition, strength, weight, appearance, and other properties regarded by those who use woods depend much upon these details.

[1] "Resin-Canals in White Fir," Mell (American Forestry, June, 1910); "Relation of Light Chipping to the Commercial Yield of Naval Stores," Herty (U. S. Forest Service, Bulletin No. 90).

[2] "Sap in Relation to the Properties of Wood," Record (Proc. American Wood Preservers Association, Baltimore, Md., 1913, pp. 160–166); "Effect of Moisture upon the Strength and Stiffness of Wood," Tiemann (United States Forest Service Bulletin No. 70 and United States Forest Service Circular No. 108).

Identification of Woods.—External appearances differ and are hard to describe. Colors vary, even in pieces cut from the same tree; moreover, colors are not permanent, but often change

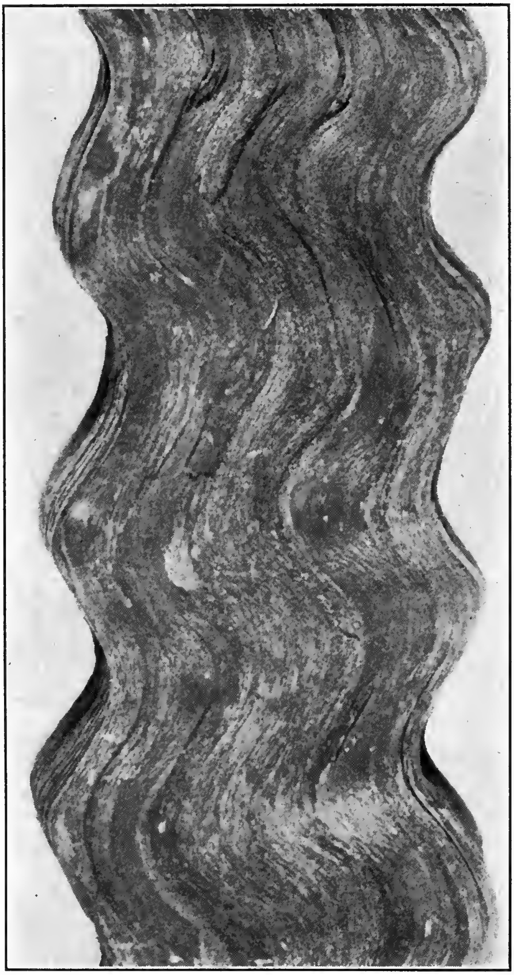


Fig. 16.—Dissection showing waving cell arrangement in a specimen of curly redwood.

with age and exposure. Artisans become familiar with the working qualities of a few woods, but are commonly uncertain with regard to the working qualities of other woods. On the whole, the character and arrangement of the wood-elements afford the only reliable basis upon which many woods can be finally identified. Some of the cellular characteristics of woods are evident to the naked eye, but, in most cases, the microscope is required.

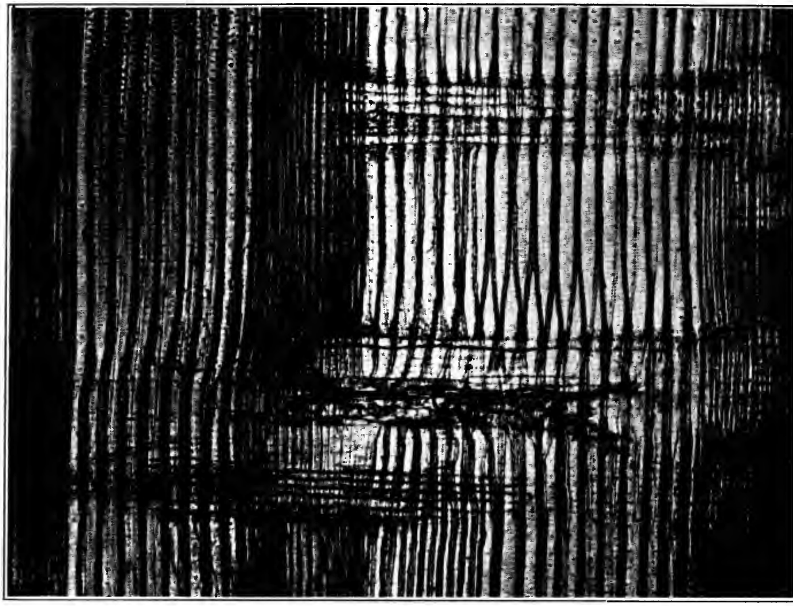
The cellular characteristics of woods are most evident in their cross-sections. The cross-sections of different species differ from one another, but each one exhibits certain traits that remain

FIG. 17.—Photomicrograph of spruce (cross-section). Thought to be about 500,000 years old.[1]

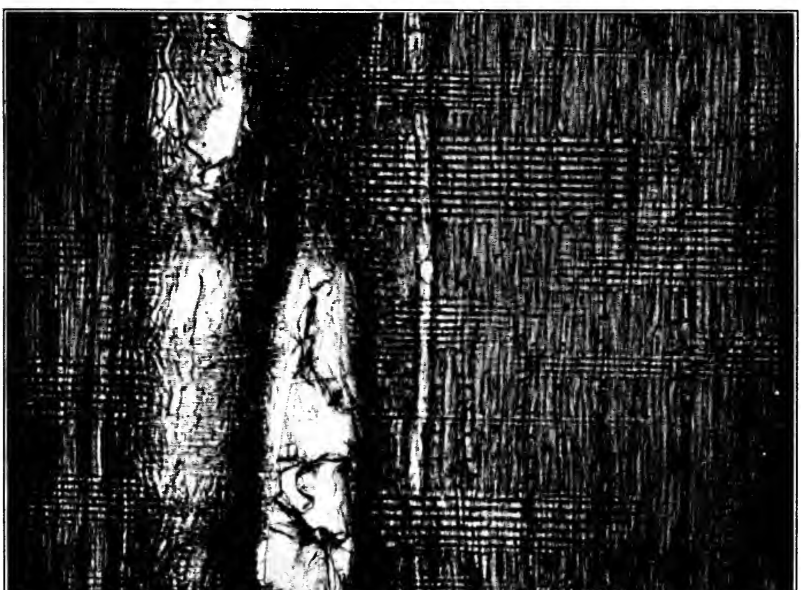
constant for that species, and in many cases these traits are sufficient to serve as a means of practical identification. For example, it will be noted that the section of white oak (Plate I) contains large vessels but is without resin-ducts, whereas the section of long-leafed pine (Plate I) contains resin-ducts but is without vessels.

[1] See footnote, p. 29.

PLATE III. ARRANGEMENT OF WOOD ELEMENTS—RADIAL SECTIONS



(*a*) Radial Section of Longleaf Pine (*Pinus palustris*).



(*b*) Radial Section of White Oak (*Quercus alba*).

Acknowledgments to Bureau of Plant Industry, United States Department of Agriculture.

(*Facing page* 28.)

The identification of a log removed from an ancient forest bed is described by Koehler.[1] The extent and character of the soil and other material deposited upon the log caused geologists to believe that it was 500,000 years old. The wood was brittle, and much distorted, most of the cell-elements being flattened. But when under a microscope the characteristic structure of the wood was revealed. The wood was reported as Spruce. (See Figures 17 and 18.)

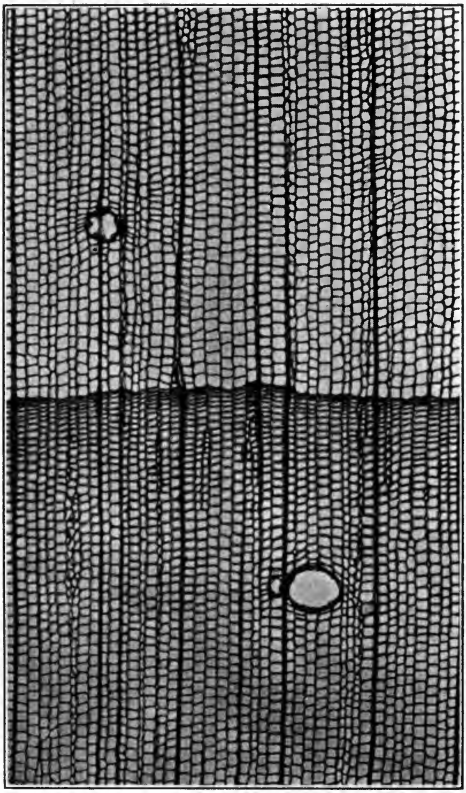


FIG. 18.—Photomicrograph of fresh spruce (cross-section).[1]

Banded woods may be easily distinguished from non-banded woods by the presence or absence of yearly bands, layers, or rings (Figs. 1 and 2); while the needleleaf and broadleaf woods, which together make up the banded woods, may be told from one another by noting the differences shown in the table that follows (Record[2]):

[1] From "Wood Older than the Hills," Koehler, by Courtesy of The American Forestry Magazine, Washington, D. C. (February, 1916).

[2] "Identification of Economic Woods of the United States," Record (p. 13).

BANDED WOODS

Needleleaf Woods, Softwoods (*Conifers*).	Broadleaf Woods, Hardwoods (*Dicotyledons*).
True vessels absent.	True vessels present.
Wood tracheids present and forming bulk of wood.	Tracheids present or absent; always subordinate.
Ray tracheids present or absent.	Ray tracheids absent.
Wood fibers absent.	Wood fibers present.
Wood parenchyma present (except in Taxaceæ), but usually subordinate.	Wood parenchyma present, and very often conspicuous.
Ray parenchyma present.	Ray parenchyma present.

The key prepared by Fernow and Roth[1] is based upon a division of banded woods into three classes, namely: non-porous woods, ring-porous woods, and diffuse-porous woods. The distinctions are as follows:

1. *Non-porous Woods.*—The pores (vessels) of these woods are not evident, even with magnifiers. The annual layers are distinguished by means of denser, dark-colored bands of summer-wood (see Fig. 19*A*). This group includes the pines and other so-called softwoods.

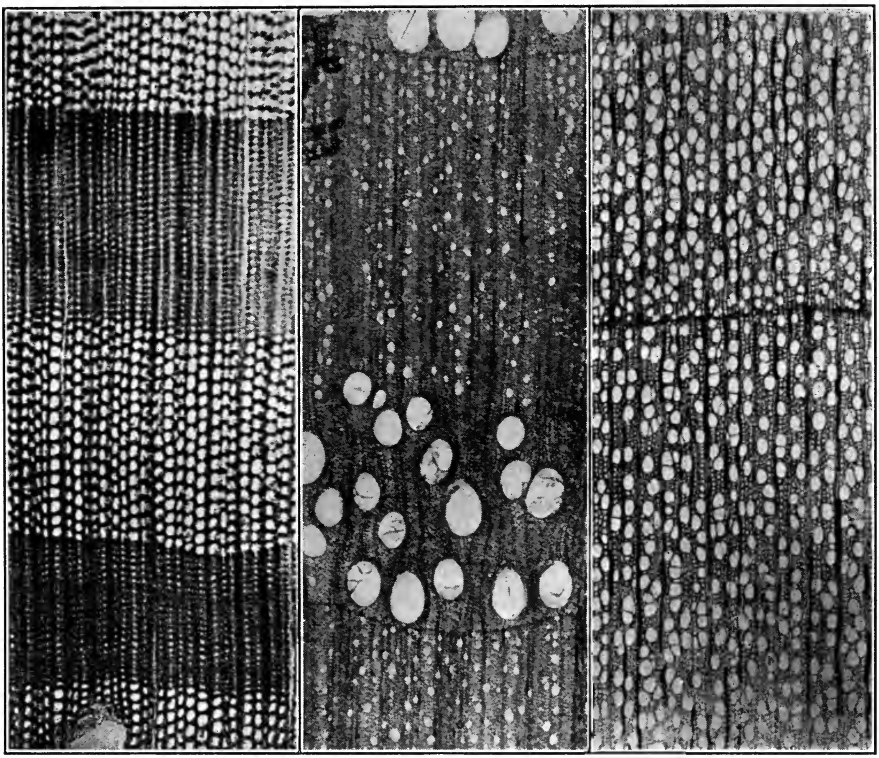
2. *Ring-porous Woods.*—The numerous pores (vessels) are usually visible even without magnifiers. The pores are collected in the spring deposits, which thus contrast with the denser summer-woods. This group includes oak, ash, catalpa, chestnut, black locust, hickory, persimmon, and others (see Fig. 19*B*).

3. *Diffuse-porous Woods.*—The numerous pores (vessels) are not collected in the spring-wood as in the case of the ring-porous woods, but are scattered throughout the entire annual layer. The pores are not usually visible without magnifiers. This group includes cherry, maple, beech, black walnut, holly, sycamore, cottonwood, and others. (See Fig. 19*C*.)

The value of cross-sections, which are more serviceable than radial or tangential sections in making microscopic examinations of woods, is influenced by the tools that are used to prepare these sections. Smooth surfaces are desired and, therefore, very sharp

[1] "Timber," Fernow and Roth (United States Forest Service Bulletin No. 10, pp. 59–83). See also "Identification of Economic Woods of the United States," Record (John Wiley & Sons); "Confusion of Technical Terms in Study of Wood Structure," Mell (Forest Quarterly, Vol. IX, 1911, No. 4, pp. 574–576); "Wood," Boulger (Second Edition, London); etc. The actual sections prepared by Hough are very helpful. "The Jesup Collection of Woods" at the American Museum of Natural History is available for those living near New York City.

tools should be employed. If the tools are not sharp, the surfaces will be rough and the characteristic features obscure. A shaving cut by a well-sharpened plane is sometimes sufficient, but, for more technical work, a microtome is necessary. Sections should be cut precisely at right angles to the vertical axis of the tree, since otherwise the rounded sections of the vessels appear as ovals.



A *B* *C*

Fig. 19.—Original photomicrographs. *A*, Cross-section of non-porous wood (longleaf pine). *B*, Cross-section of ring-porous wood (white oak). *C*, Cross-section of diffuse-porous wood (sweet gum).

For ordinary examinations, any microtomes, save those of the rotary type, are serviceable. The instrument shown in the picture gives excellent results. Compound microscopes manufactured by the Bausch & Lomb Optical Company of Rochester, and by the Spencer Lens Company of Buffalo, are very satisfactory.

Identification of Trees.—Trees are not always easily identified by laymen. Forms in the forest differ from those in the open. Bark varies with age, while leaves and fruit are often lacking in the winter. Most laymen find it easier to tell genus than species. They know that a tree is an oak, but do not know whether it is a red oak or a pin oak. Experience is required. Sargent's "Manual of the Trees of North America," and Hough's "Handbook of Trees of the Northern States and Canada"

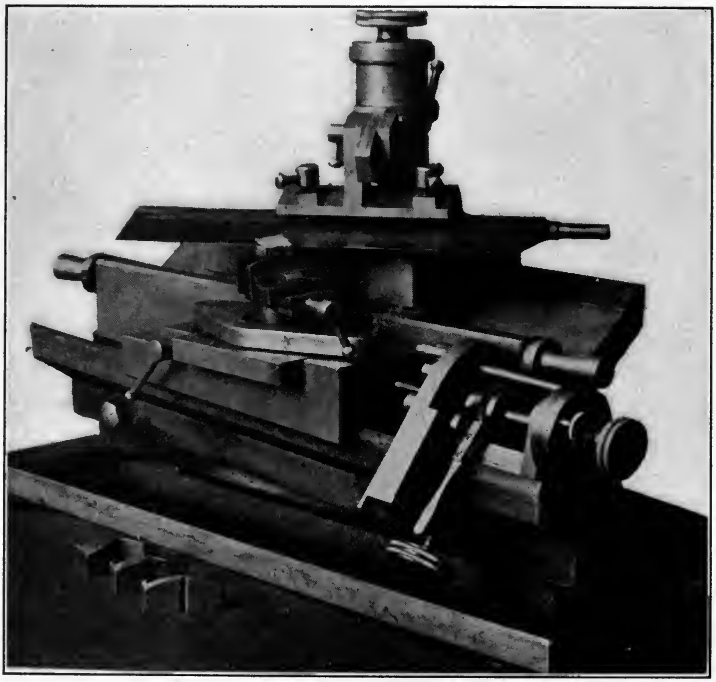


FIG. 20.—Modification of Jung-Thoma microtome for cutting wood, as described by Thomson, University of Toronto, in *Botanical Gazette,* August, 1910.

are convenient reference books, while Hough's "Leaf Key to Trees" and Ernest Thompson Seton's "Foresters' Manual" are serviceable in the field in identifying trees that are in summer condition.[1]

[1] See also Bibliography.

WEIGHTS AND MODULI.—It seems best thus early to introduce the two series of weights and moduli to be employed in the tabular descriptions of species that form part of succeeding chapters. Further descriptions and the reasons for preferring these particular series of figures will be given later. The figures referred to are as follows:

First.—Results of experiments conducted by the National Forest Service. These figures occupy the leading spaces in the descriptions of species (Chapters V, VI, VII, and VIII) under the titles of "Weight," "Modulus of Elasticity," and "Modulus of Rupture." Results have not yet been obtained for all of the species thus described so that some of the spaces set apart for the figures reported for the National Forest Service are vacant.

Second.—Results of experiments conducted by the Watertown Arsenal for the Tenth United States Census. These figures appear in the spaces immediately following those occupied by, or set apart for, the National Forest Service figures.

Weights are given in pounds, and coefficients in pounds per square inch. Fractions of pounds and lower figures in coefficients have been omitted as superfluous.[1]

[1] See also Chapter IX.

CHAPTER IV

Banded Trunks and Woods

(Conifers and Dicotyledons)

The trunks from which banded woods are obtained grow in thickness from the *outside*. The new layers of wood are deposited upon the outside of others that were formed before. Practically all of the woods that are used in construction are of this type. The forest sources are widely distributed, and the numerous species present an almost infinite range of possibilities.

PARTS OF A BANDED TRUNK.—A section through a banded trunk is made up as follows: A point or pith-cavity exists at the center of the section: This pith-cavity is surrounded by concentric rings made up of layers or bands of heartwood and sap-wood, which together constitute the wood, or xylem. The entire section is surrounded by bark, the succulent, fibrous inner part of which is the phloem. The line of separation between the bark and wood is the cambium. The wood-elements, the bands or layers in which they are arranged, and some characteristics of the bark, the sapwood, the heartwood, and the pith are important.

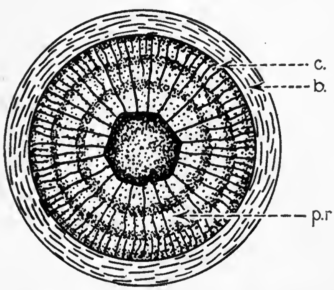


Fig. 21.—Section through young stem of box elder. Pith cavity surrounded by three annual deposits of wood. The whole enclosed by bark, *b*. The radiating lines *p.r.* are pith-rays. The cambium is at *c*.

Wood-elements.—The characteristics of fibers, tracheids, and other wood-elements have been described. So far as is known, there are no wood-elements that are particularly associated with the banded woods alone. Some wood-elements may be modified in certain cases, but the same kinds exist in both banded woods and non-banded woods.

Annual Bands, Rings, or Layers.—The wood-elements that stand vertically are arranged in concentric bands or layers one of which is formed every growing season between the bark and the wood that was formed during the preceding season. Each one of these bands or layers encloses all of the other bands or layers that were formed before, and each one will eventually be enclosed by others that are formed later. The bands cover the trunk and all of the living branches of the tree.

A band or layer is made up of two, more or less, well-defined parts as follows:

1. *Early Growth.*—This portion, sometimes referred to as "spring growth," is formed at a time of the year, when, because the leaves are unfolding, there is an increased demand for water.

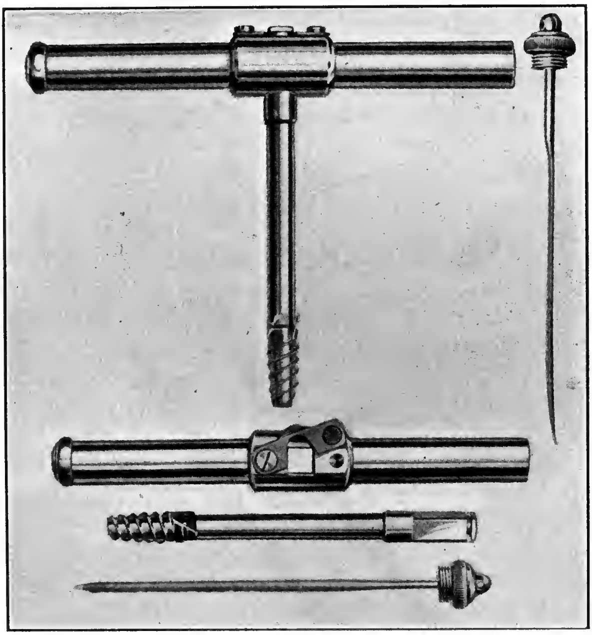


Fig. 22.—Instrument for removing cores to determine ages of trees.[1]

The more porous water conduction elements preponderate and as a result this part of the band is lighter, softer, and more porous than the other. (See Plate I, page 18).

2. *Late Growth.*—This portion, often referred to as "summer growth," is formed after the leaves have been fully expanded and when the cambium can devote itself more exclusively to the production of the wood-elements that contribute more to strength. It is, therefore, denser and heavier than the other.

[1] The instrument shown in the picture is manufactured by The Keuffe & Esser Company of New York.

The contrasts that exist between the porous early growth and the more compact later growth of the preceding year serve to define the limits of the yearly bands.

Bands exist in all needleleaf or softwood trees (conifers), and in all broadleaf or hardwood trees (dicotyledons), which grow where there are alternating seasons of wet and dry, or heat and cold. They also exist, but are often correspondingly less pronounced in localities where the differences in seasons are less marked. Bands are valuable as means by which the ages of trees can be determined, and, since they vary in thickness from year to year as the seasons are wet or dry, they also serve as history of the local conditions of growth.

The history of a Redwood tree, dating from two hundred and seventy-one years before the Christian Era, was reported by Professor Dudley to the United States Senate through the late Senator Platt of Connecticut, on February 11, 1904. The record obtained by counting the concentric layers of growth on the cross-section of the felled tree showed that forest fires had occurred during the years 245, 1441, 1580, and 1797 A.D. The last fire was locally severe, since it had charred a space thirty feet in height and eighteen feet in breadth. It is needless to state that this tree was exceptionally vigorous or it would not have recovered from such a wound. The new tissue, as deposited upon the outside of this wound, was full, even, and continuous.

The value of the band, layer, or ring as a means by which age can be determined is indicated in the quotation that follows (Fernow[1]):

"In a young, sound, and thrifty timber, the rings are laid on with the utmost regularity, and a cross-section of a stem furnishes, therefore, not only information as to the age of the given section, but is a fair indicator of the life-history of the tree, periods of suppression and thrift being indicated, respectively by zones of correspondingly narrow or broad rings. *In such timber*, the countings along different radii always give the same results.

"If, on the other hand, the rings are very old, especially if slow-grown stems are counted, it happens not infrequently that counting along one radius gives one to five rings more than the counting along some other radius. The reason for this is not always apparent; in some cases, such a difference in results is due merely to the inability of the eye to detect

[1] "Age of Trees and Time of Blazing Determined by Annual Rings," Fernow (United States Division of Forestry, Circular No. 16, pp. 2, 3, and 6).

an extremely narrow, but otherwise well-defined ring, and the error may be corrected by microscopical examination. In other cases, however, the difference is based on the actual absence of one or more rings of only a given radius, extremely unfavorable circumstances having led to failure of the regular continuous development of these rings."

Pith (Medulla).—Central pith areas, around which wood is deposited, are more or less evident in the sections of young trees, saplings, and young branches. They do not grow in size after the first year, and in mature trees are usually so compressed as to be quite obscure. Pith itself is made up of thin-walled parenchymatous cells within which food for the rapidly growing parts is stored, at least in the younger stems. The service which pith renders to the stem is apparently of a temporary nature.

Heartwood (Duramen).—Heartwood is modified sapwood. Heartwood gives stability to the tree but is not utilized in its physiological processes. A tree can survive, even although much of its heartwood has decayed or been otherwise removed. Heartwood is heavier, tougher, stronger, and darker than sapwood. Its cell-structures are older and its walls appear thicker through the accumulation of deposited materials. The protoplasm has disappeared and inert minerals, tannin, gums, and pigments have appeared. The change from sapwood to heartwood goes forward rapidly in the trees of some species, such as redwood and locust, and the sections of these trees appear to be almost wholly heartwood. In trees of other species, the changes take longer.

Von Schrenk believes that sapwood changes to heartwood suddenly; that the change does not take place in one ring every year, but that it frequently skips many years, so that eight, ten, or even more rings may change from sapwood to heartwood in one year. He also calls attention to the fact that one side of the tree may change before the other, and that part of a ring may be heartwood, while the rest remains sapwood.[1]

Sapwood (Alburnum).—This is the younger, lighter-colored, and more porous wood. It is the part that is directly beneath the bark, the part that later turns to heartwood. Sapwood is vitally essential to the life of the tree, but is less durable, and usually weaker, and less valued in construction than heartwood. The cell-elements are the same as those in heartwood, but the latter are usually modified, as was noted in the preceding paragraph. Sapwood is more pliable than heartwood, and the sap-

[1] United States Bureau Plant Industry, Bulletin No. 14, p. 15.

woods of several trees, such as hickory and ash, are preferred and much valued for this reason. The sap currents travel upward in the sapwood, hence the name.

The wood manufactured by a tree when it is old is usually softer and weaker than that made by the tree when it is younger. Because of the time in the life of the tree when it is grown, the sapwood of a large log may be inferior in strength to equally sound but older heartwood in the log. The United States Forest Service[1] reports upon the comparative strength of sapwood and heartwood as follows: "Sapwood, except that from old, overmature trees, is as strong as heartwood, other things being equal, and so far as the mechanical properties go should not be regarded as a defect."

Bark.—This husk or outer cover resembles the wood, although many of its properties are quite unlike those of wood. Bark is characteristic of exogenous trees and assists these trees in two ways: First, it is an agent in the physiological processes of the tree; and second, it affords protection.

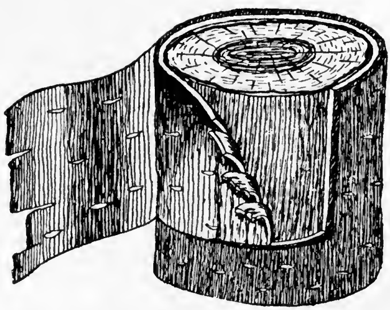


Fig. 23.—Compound structure of bark.

The bark is made up of several parts. They are as follows:

1. The phloem, inner, or fibrous bark, is composed partly of very long, thick-walled cell-structures, known as "bast fibers." These are the elements that give character to the stringy bark of the basswood and the grapevine, and that form the "fiber" of flax from which linen fabric is woven. These constitute the "hard bast." Associated with the cell-structures noted above are specialized elongated parenchyma-cells with their living contents. These constitute the "soft bast"; they are the sieve tubes and companion cells which serve as channels through which the elaborated sap passes in its journey from the leaves. These parts together are known as the "phloem."

2. The living or green part in the middle, called "green bark" or cortex, is largely composed of rounded parenchyma-cells, which contain the green substance, chlorophyll, that also exists in the leaves. The green part of the bark of a twig resembles the substance of a leaf, in that it also is a tissue which manufactures elaborated food. This layer

[1] "Tests of Structural Timber" (United States Forest Service, Bulletin No. 108, p. 35).

loses its green color in older stems because the surrounding "corky layer" is thick enough to cut out all the light. In the outer portion of this layer of green bark there are developed regions of "cork-cambium," which, by their repeated division, give rise to the outermost or corky layer.

3. The outermost corky layer is made up of dead and empty cells derived from the outermost cortex cells, constituting the "cork cambium." The walls of these cells are *suberized,* that is, they have been altered and rendered impermeable to water by the addition of a substance known as "suberin," or cork. This layer serves to prevent undue losses of fluids from the tree by evaporation. Moreover, it is a non-conductor and protects from the cold; it also protects against the entrance of disease. Composed as it is of dead cells, this cork layer cannot expand, but is, usually, gradually split by the expansion of the wood cylinder into ridges or scales, in characteristic fashion for each species, and is, usually, eventually worn away or otherwise lost, in large part, from the surface of the tree.

4. The epidermis consists of a single layer of close-fitting, tabular cells with thick, outer walls. It is impervious to water but lasts in most trees only during the first year or two, and is best seen on the surfaces of young stems or twigs. In smooth-barked trees, it may live many years.

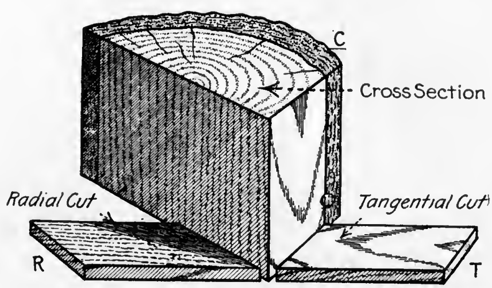


FIG. 24.—*C*, Cross surface. *R*, Radial surface. *T*, Tangential surface.

Three Surfaces of Wood.—The appearance or "grain" of wood is influenced by the way in which it is cut. There are three fundamental surfaces or exposures. They are as follows: (1) Cross surfaces in which the markings appear as circles. This is shown on the surface *C*. (2) Radial surfaces in which the yearly rings are cut directly across and appear as lines, as on the surface *R*. (3) Tangential surfaces in which the surface is cut parallel to the annual rings. Characteristic tangential figures are shown on the surface *T*.

Logs are sometimes quartered and then cut across the yearly rings. These "quarter-sawn" pieces are stronger and better than other pieces, but are more costly because of the extra labor and the waste. Edge-grained, vertical-grained, straight-grained, and rift-grained pieces are the same as quartered pieces when these names are applied to manufactured woods. The pith-rays of some woods are exposed by quartering; "quarter-sawn" oak is attractive for this reason.

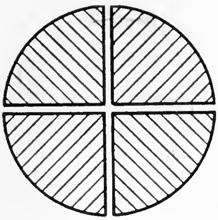


FIG. 25.—One method of quarter-sawing.

The best effects in grain or figure are sometimes obtained when pieces are developed by what is known as the "rotary cut." This is often the case with the wood of the birdseye maple. A revolving log of the wood that is to be cut is advanced against a tool that pares a broad, thin ribbon from its surface. The ribbons are later used as veneers.

It should be noted that grain and figure differ in different pieces of the same species. One Hard Maple tree (*Acer saccharum*) may yield characterless pieces that are suitable for little else than flooring, while another nearby tree of the same species may contain beautiful birdseye or curly maple, suitable for costly cabinet work.

Ordinary planks and boards are cut parallel to the diameters of the logs. Grain is not regarded in these pieces, which are used in ordinary constructions. Such pieces are known as bastard, slash-cut, or slice-cut boards or planks. The segments of bark and sapwood that are removed from the outside of a log are known as "slabs." The uneven appearance of the edges of boards that have been cut through from one side of the log to the other is referred to as "wain." "Edging" refers to the uneven pieces or edges that are removed when the boards are cut down to standard widths. Slabs and edging are worked into laths or are burned as fuel.

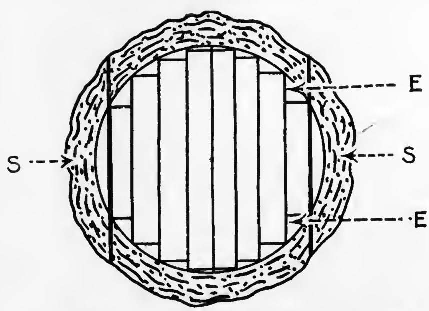


FIG. 26.—Ordinary method of sawing a log. *S* represents slabs; *E* represents edging.

DEFECTS.—Defects are of many kinds. The cracks or separations that radiate from the centers of trees are known as "heart-shakes" and "star-shakes." The separations between the yearly layers are known as "cup-shakes." It is assumed that "cup-shakes" are influenced by the winds, which roll the trees to and fro, and, for this reason, the pieces in which cup-shakes occur are referred to as "rolled lumber." Separations

Fig. 27.—Tree rolled by wind.

caused by wind or frost are "wind-shakes" or "frost-shakes" and the short but comparatively deep cracks that appear in planks as a result of rapid drying are known as "checks."

Knots are the Result of Branches.—Buds connected with the pith-cavity at the center appear upon the surface of the trunk. They extend and eventually develop into branches. The adjacent wood-elements between the pith-cavity and the surface of the trunk are disturbed and the result is a knot. Knots may be prevented by removing the buds while they are small.

Many Names Apply to Results of Diseases.—Wet-rot, dry-rot, soft-rot, disease, decay, bluing, rust, mildew, canker, bot, dote, and other terms are all thus employed. The results indicated by all of these names are usually due to the presence of bacteria or fungi. Wood that is lifeless and brittle as the result of disease is known as "brashwood," a name that is also applied to wood that has become lifeless and brittle as a result of age.

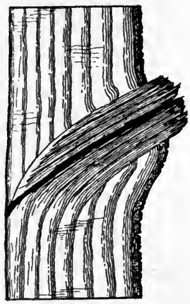


Fig. 28.—Distortion caused by branch.

Defects have been described and standardized by manufacturers and others, and lumber is now classified and sold upon the basis of accepted specifications. Such specifications have been prepared by the Hardwood Manufacturers' Association of the United States, the Pacific Coast Lumber Manufacturers' Association, the Yellow Pine Manufacturers' Association, and others. The principal series of specifications have been listed and published under one cover by the National Government.[1] Standards have also been prepared by the American Society for Testing Materials and by the American Railway Engineering Association.

A Committee appointed by the American Society for Testing Materials, has defined the several kinds of knots that appear in structural timber as follows (see Year Book, 1910):

1. *Sound Knot.*—A sound knot is one which is solid across its face and which is as hard as the wood surrounding it; it may be either red or black, and is so fixed by growth or position that it will retain its place in the piece.

2. *Loose Knot.*—A loose knot is one not firmly held in place by growth or position.

3. *Pith Knot.*—A pith knot is a sound knot with a pith hole not more than one-fourth inch in diameter in the center.

4. *Encased Knot.*—An encased knot is one which is surrounded wholly or in part by bark or pitch. Where the encasement is less than one-

[1] "Rules and Specifications for the Grading of Lumber Adopted by the Various Manufacturing Associations of the United States" (United States Forest Service Bulletin, No. 71).

PLATE IV. INFLUENCE OF WIND UPON TREES AT TIMBER LINE

(Facing page 42.)

eighth inch in width on both sides, not exceeding one-half the circumference of the knot, it shall be considered a sound knot.

5. *Rotten Knot.*—A rotten knot is one not as hard as the wood it is in.

6. *Pin Knot.*—A pin knot is a sound knot not over one-half inch in diameter.

7. *Standard Knot.*—A standard knot is a sound knot not over one and one-half inches in diameter.

8. *Large Knot.*—A large knot is a sound knot, more than one and one-half inches in diameter.

9. *Round Knot.*—A round knot is one which is oval or circular in form.

10. *Spike Knot.*—A spike knot is one sawn in a lengthwise direction; the mean or average width shall be considered in measuring spike knots.

All banded woods, and the trees that yield them are divided as follows:

1. **The Coniferous Series** (*Coniferæ*).—The terms softwoods, needleleaf and evergreen woods, which are so often used in connection with the woods of this series, are convenient but sometimes inaccurate. These names are unsatisfactory; first, because some of the woods are actually very hard; second, because the leaves of some are broader than the name "needleleaf" would indicate; and third, because the leaves of some drop away every year and are not evergreen as this term is understood. The name "conifer" which is best, includes, among others, the pines, spruces, firs, hemlocks and cedars.

2. **The Broadleaf Series** (*Dicotyledons*).— These woods are often incorrectly called hardwoods and deciduous woods. The first of these terms is incorrect, because some of the woods are very soft; the second fails because the leaves of some of the trees are persistent or evergreen, rather than deciduous. The leaves, with netted veins, are comparatively broad, and the name "broadleaf" is, on the whole, the best of the popular names. This series includes, among others, the oaks, elms, maples, hickorys and birches.

CHAPTER V

Banded Trunks and Woods (Continued)
Coniferous or Needleleaf Series

Conifers

Coniferous trees cover large areas in parts of Canada and the United States. The Pines, Spruces, Hemlocks, and other so-called softwoods are of this group.

Coniferous woods are comparatively light in weight and the arrangements of the wood-element is, on the whole, simpler than in the woods of the broadleaf series. The vertical fabric is made up almost entirely of tracheids. The preponderance of tracheids and the absence of true vessels are characteristic of these woods which, because of the simpler arrangement of the wood-elements, are comparatively easy to work. Coniferous woods are preferred where the demand is for bulk and strength rather than fine qualities, and the total requirement as to amount exceeds the requirement for woods of the broadleaf series. The trunks of many species yield very large, straight pieces.

The leaves of the coniferous trees are resinous and usually needlelike and evergreen. The seeds are exposed on the inner surfaces of woody scales arranged, overlapping one another, in what are known as cones. As already stated, the names "softwood" and "evergreen" do not always apply so that the name "conifer" should be preferred.

PINE

Pinus

These woods, which were formerly plentiful in the districts where the demands of construction were the greatest, have been more used in carpentry and construction than any others. They are to the coniferous woods what oaks are to the broadleaf woods; and, in this country, they yet stand to all woods somewhat as iron does to all metals. The pines are prized because of qualities, such as strength, elasticity, light weight and working qualities, that fit them for the constructions that require the largest quantities of wood.[1]

Pine trees have straight, solid trunks, which, when grown in forests, are usually free from branches for many feet up from the ground. They mature slowly and it is probable that, ultimately, some species will survive only as cultivated trees.

The needle-shaped, evergreen leaves, which are from one inch to fifteen or more inches in length, occur singly or in clusters of two, three, and five. Thirty-six of the known species grow naturally in the United States. The Dantzic or Northern Pine (*Pinus sylvestris*) is an important European species. Pines are often divided into "soft pines" and "hard pines."

Soft Pines.—The woods that form this group are soft, light, rather weak, clean, uniform, easily worked, and comparatively free from knots and resin. The yearly bands are less pronounced than in the hard pines. Many resin-ducts, that are often plainly visible without the microscope, are distributed over the sections. The Soft Pines may be divided according to their sources into White Pine (*Pinus strobus*) on the one hand, and Sugar Pine (*Pinus lambertiana*) with some minor species on the other hand.

White Pine (*Pinus strobus*). This tree, formerly the principal economic tree of North America, grows in the northern, central, and eastern portions of the United States. It formed the basis of the early forest resources of Maine and Michigan, and methods devised to cut and trans-

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[1] See also "Uses of Commercial Woods of United States: 2, Pines" (United States Forest Service, Bulletin No. 99, 1911).

fer the logs have influenced logging practices in all subsequently developed fields. White Pine was once the only soft wood seriously considered by lumbermen in the north, and, until as late as the beginning of the present century, it supplied about thirty per cent. of all the lumber that was used in this country.[1] No other wood known to man has been more valuable. There are no perfect substitutes, although sugar pine, spruce, fir, redwood, and even whitewood are used in its stead.

Sugar Pine (*Pinus lambertiana*). These trees grow at high elevations in parts of Oregon and California. The soft, coarse, clean wood can be used in place of true White Pine. Some of the trees are very large. Other minor American sources and localities are as follows: White Pine (*P. flexilis*), Rocky Mountain Region; White or Silver Pine (*P. monticola*), Pacific Coast Region; Whitebark Pine (*P. albicaulis*), Pacific Coast Region; Mexican White Pine (*P. strobiformis*), Arizona into Mexico; Parry's Pine (*P. quadrifolia*), Southern California; Nut Pine (*P. cembroides*), Arizona into Mexico.

Hard Pines.—These differ from soft pines in that they are harder, stronger, heavier, more resinous, of a deeper color, and more difficult to work. The yearly bands are pronounced. Large-sized pieces of Hard Pine can be obtained. The principal supplies are obtained from the Longleaf Pine (*Pinus palustris*), the Shortleaf Pine (*Pinus echinata*), the Cuban Pine (*Pinus heterophylla*), and the Loblolly Pine (*Pinus tœda*).

Longleaf Pine (*Pinus palustris*). This is the principal tree of the Hard Pine group. The wood, which is the strongest native construction wood obtainable in large-sized pieces in the United States, is used in docks, trestles, and other heavy constructions. The trees yield turpentine, tar, and resin. They are usually tapped a few times and are then felled and cut up into lumber.

The woods of the Cuban, Shortleaf, and Loblolly Pines are so nearly like that of the Longleaf Pine, that it is often hard to tell them from that wood or from one another. Either, or all of these woods may thus be delivered in response to a demand for Southern Hard Pine. It should be noted, however, that pieces of Southern Hard Pine may now be graded without difficulty by means of the so-called Density Rule[2]; and the results obtained by following this practical rule show that the strength of pieces of Longleaf, Shortleaf, Loblolly, and other kinds of Southern Hard Pine depend less upon distinctions due to species than upon relative densities of individual pieces.

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[1] Roth (United States Forestry Bulletin No. 22, p. 73); "White Pine Timber Supplies" (United States Senate Doc. 55–1, Vol. IV).

[2] See Index "Density Rules."

Much of the "*Hard Pine*" used on the Pacific Coast is derived from the Douglas Spruce or "Oregon Pine" (*Pseudotsuga taxifolia*). The species of pine may be distinguished from one another by differences that exist between their leaves and cones. These are as follows:[1]

Names	Leaves		Cones	
	Number in cluster	Length	Diameter (open)	Length
Longleaf pine (P. palustris)..	2 or 3	10 to 15 in.	4 to 5 in.	6 to 10 in.
Cuban Pine (P. heterophylla)	2 or 3	8 to 12 in.	3 to 5 in.	4 to 7 in.
Shortleaf Pine (P. echinata)..	2 or 3	2 to 5 in.	1 to 2 in.	2 in.
Loblolly Pine (P. tæda).....	3	5 to 10 in.	2 to 3 in.	3 to 4 in.

Tar, turpentine, and resin, which are included in what are known as "naval stores," are derived principally from the Longleaf and Cuban Pine trees. The quantities of naval stores that are contained in these trees vary with individuals. From five to twenty per cent. of the dry weight of the heartwood may be due to resin. There is less resin in sapwood. The resin in pine is known as *rosin*.

An exhaustive investigation[2] has proved that strength, weight, and shrinkage are not influenced by "bleeding," and that "bled" lumber is as good as lumber that has not been "bled." The Louisville & Nashville Railroad once specified "unbled" lumber. Some bled pieces were included by error. The mill offered to take them back again if they could be separated from the others. This proved to be impossible and the matter was dropped.

Confusion exists in regard to the names of the pines. All Southern Pines are known commercially as Yellow Pines. American White Pine is known as Yellow Pine in Europe, where all Hard Pines are often referred to as Pitch Pines. Spruce Pine, Bull Pine, and Bastard Pine are names frequently used to hide ignorance. The species *palustris* has thirty local names. Botanical names should be used to designate these as well as other trees.

[1] See also "Timber Pines of the Southern United States" (United States Forest Service, Bulletin No. 13, 1897); "Properties and Uses of the Southern Pines" (United States Forest Service, Circular No. 164, 1909); "Relation of Light Chipping to the Commercial Yield of Naval Stores," Herty (United States Forest Service, Bulletin No. 90, 1911); "The Naval Stores Industry," Schorger and Betts (United States Department of Agriculture, Bulletin No. 229); etc.

[2] United States Bureau of Forestry, Bulletins No. 8 and No. 10.

White Pine. *Pinus strobus Linn*

NOMENCLATURE (Sudworth).
White Pine (local and common name).
Weymouth Pine (Mass., S. C.).
Soft Pine (Pa.).
Northern Pine (N. C.).
Spruce Pine (Tenn.).
Pumpkin Pine.
Patternmaker's Pine.

LOCALITIES.
North-central and northeastern United States, northward into Canada; southward along the coast to New Jersey, and along the Alleghenies into Georgia; also Illinois.

FEATURES OF TREE.
Seventy-five to one hundred and fifty feet in height; three to six feet in diameter; sometimes larger; erect impressive form; tufts of five, slender, evergreen leaves in long sheaths; cones four to six inches long, one inch thick, slightly curved; the cone-scales are without prickles.

COLOR, APPEARANCE, OR GRAIN OF WOOD.
Heartwood cream white; sapwood nearly white; close, straight grain; compact structure; comparatively free from knots and resin.

STRUCTURAL QUALITIES OF WOOD.
Soft and uniform; seasons well, is easy to work, nails without splitting, and is quite durable in exposed positions; one of the lightest and weakest of eastern United States pines; shrinks, swells and warps less than other pines; receives paints well.

REPRESENTATIVE USES OF WOOD.
Carpentry, construction, matches, spars, boxes, and numerous other uses

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.
24 (United States Forestry Division).[1]
24.

MODULUS OF ELASTICITY.
1,390,000 (average of 130 tests by United States Forestry Division).[1]
1,210,000.

MODULUS OF RUPTURE.
7,900 (average of 120 tests by United States Forestry Division,)[1]
8,900.

REMARKS.
Formerly the chief lumber tree of the United States. The stand is rapidly diminishing. Besides its natural enemy the lumberman, the White Pine is seriously threatened by a disease known as the "White Pine Blister Rust."

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[1] See p. 33. See also "The White Pine," Spaulding (United States Forestry Bulletin No. 22); "White Pine—a Study," Pinchot (Century Company); "White Pine Timber Supplies" (United States Document No. 40, Senate, 551, Vol. IV); "White Pine," Pinchot (United States Forest Service, Circular No. 67, 1907), "The White Pine," Detwiler (American Forestry, July, 1916).

White Pine. *Pinus flexilis James*

NOMENCLATURE (Sudworth).

White Pine (Cal., Nev., Utah, Col., N. M.).
Pine (Utah, Mont.).
Limber Pine.
Rocky Mountain Pine.
Bull Pine (Col.).
Western and Rocky Mountain White Pine (Cal.).
Limber-twig Pine.
Arizona Flexilis Pine.

LOCALITIES.

Rocky Mountains, Alberta to Texas and southwestern California.

FEATURES OF TREE.

Forty to fifty feet in height; one to three feet in diameter; tufts of five rather short, rigid leaves in sheaths; the leaves are not more than two and one-half inches in length; the oval or cylindrical cones are about four inches in length.

COLOR, APPEARANCE, OR GRAIN OF WOOD.

Heartwood light, clear yellow, turning red upon exposure; sapwood nearly white; close-grained; compact structure; numerous and conspicuous medullary rays.

STRUCTURAL QUALITIES OF WOOD.

Light and soft; saws, planes, nails, and receives paints well; fairly durable; similar to White Pine (*Pinus strobus*).

REPRESENTATIVE USES OF WOOD.

Construction. Similar to White Pine (*Pinus strobus*).

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

27.

MODULUS OF ELASTICITY.

960,000.

MODULUS OF RUPTURE.

8,800.

REMARKS.

This tree forms mountain forests of considerable extent.

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[1] See also "Limber Pine, *Pinus flexilis*" James (United States Forest Service, Silvical Leaflet No. 46, 1909).

Sugar Pine. *Pinus lambertiana Dougl*

Nomenclature (Sudworth).

Sugar Pine (local and common name).
Big Pine, Shade Pine (Cal.).
Little or Great Sugar Pine.
Gigantic Pine.
White Pine.

Localities.

Oregon and California. Best at high altitudes (above four thousand feet).

Features of Tree.

One hundred to occasionally three hundred feet in height; fifteen to sometimes twenty feet in diameter; the finely toothed leaves, in tufts of five, are about four inches long; the cones are from ten to eighteen inches in length and contain edible seeds; there are sugar-like exudations; a great tree; the tallest and largest of all the pines.

Color, Appearance, or Grain of Wood.

Heartwood pinkish-brown; sapwood cream-white; coarse, straight-grained; compact structure; satiny, conspicuous resin-passages.[1]

Structural Qualities of Wood.

Light, soft and easily worked; resembles White Pine (*Pinus strobus*). In fact this is the "White Pine" of the Pacific Coast.

Representative Uses of Wood.

Carpentry, interior finish, doors, blinds, sashes, etc.

Weight of Seasoned Wood in Pounds per Cubic Foot.

22.

Modulus of Elasticity.

1,120,000.

Modulus of Rupture.

8,400.

Remarks.

This is the most impressive tree form of the genus. Some of the Sugar Pines may be grouped as to size with some Redwoods and other giant trees. The Sugar Pines grow at high elevations and form extensive forests. The sugar-like exudations contain a principle known in medicine as "pinite." The Sugar Pine, as well as the White Pine, is subject to the disease known as "Blister Rust," which bids fair to injure seriously the stands of these trees.

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[1] "Sugar Pine and Western Yellow Pine in California," Cooper (United States Forest Service, Bulletin No. 69, p. 25, 1906); "Sugar Pine," Larsen and Woodbury (United States Argricultural Bulletin, 426, 1916); "The Sugar Pine," Detwiler (American Forestry, May 1, 1917).

White Pine. *Pinus monticola Dougl*

NOMENCLATURE (Sudworth).

White Pine (Cal., Nev., Ore.).
Mountain Pine, Finger Cone Pine (Cal.).
Silver Pine.
Little Sugar Pine, Soft Pine (Cal.).
Western White Pine.
Mountain Weymouth Pine.

LOCALITIES.

Montana, Idaho, Pacific States, and British Columbia.

FEATURES OF TREE.

Eighty to one hundred and fifty feet in height; two to three feet in diameter; sometimes larger; foliage resembles, but is denser than that of White Pine (*Pinus strobus*); the stiff, bluish-green needles are about four inches long; long, smooth cones.

COLOR, APPEARANCE, OR GRAIN OF WOOD.

Heartwood light brown or red; sapwood nearly white; straight-grained; compact structure; suggests White Pine (*Pinus strobus*).

STRUCTURAL QUALITIES OF WOOD.

Light and soft; not strong.

REPRESENTATIVE USES OF WOOD.

Lumber.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

24.

MODULUS OF ELASTICITY.

1,350,000.

MODULUS OF RUPTURE.

8,600

REMARKS.

Found at elevations of seven thousand to ten thousand feet. Common and locally used in northern Idaho.

Georgia Pine, Hard Pine, Yellow Pine, Longleaf Pine. *Pinus palustris Mill*

NOMENCLATURE (Sudworth).

Turpentine Pine.
Rosemary Pine.
North Carolina Pitch Pine.
Southern Pine.
Longleaved Yellow Pine.
Longleaved Pitch Pine.
Long Straw Pine.
Pitch Pine.
Fat Pine.
Heart Pine.
Brown Pine.
Florida Yellow Pine.
Florida Pine.
Florida Longleaved Pine.
Southern Pitch Pine.
Southern Hard Pine.
Southern Heart Pine.
Southern Yellow Pine.
Georgia Pitch Pine.
Georgia Longleaved Pine.
Georgia Heart Pine.
Georgia Yellow Pine.
Texas Yellow Pine.
Texas Longleaved Pine.

LOCALITIES.

South Atlantic and Gulf States, Virginia to Florida, intermittently.

FEATURES OF TREE.

Fifty to one hundred and twenty feet in height; one to three feet in diameter; tufts of three leaves, ten to fifteen inches long, in long sheaths; the cones are usually at the ends of the small branches; the cone-scales have stout, recurved prickles.[1]

COLOR, APPEARANCE, OR GRAIN OF WOOD.

Heartwood orange; sapwood lighter; compact structure; conspicuous medullary rays; fine and even appearance in cross-section; quite uniform; narrow annual rings (twenty or twenty-five per inch); wide sapwood in young trees.[1]

STRUCTURAL QUALITIES OF WOOD.

Hard, heavy, tough, elastic, durable, and resinous; the strongest and stiffest of Pines.[1]

REPRESENTATIVE USES OF WOOD.

Heavy constructions, ship-building, cars, docks, beams, ties, flooring, house-trim, and many other uses.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

38 (United States Division of Forestry).[2]
43.

MODULUS OF ELASTICITY.

2,070,000 (average of 1,230 tests by United States Forestry Division).[2]
2,110,000.

MODULUS OF RUPTURE.

12,600 (average of 1,160 tests by United States Forestry Division).[2]
16,300.

REMARKS.

One of the best woods for car-building. One of the principal lumber trees of the Southeast.

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[1] American Forestry (September, 1915).

[2] See p. 33.

Cuban Pine. *Pinus caribæa Morelet; Pinus heterophylla (Ell.) Sudworth*

NOMENCLATURE (Sudworth).

Cuban Pine, Slash Pine (local and common names).
Pitch Pine, She Pine, She Pitch Pine (Ga., Fla.).
Swamp Pine (Fla., Miss.).
Bastard Pine, Meadow Pine, Spruce Pine.

LOCALITIES.

Coast region, North Carolina to Florida, westward to Louisiana; also Bahamas and Western Cuba.

FEATURES OF TREE.

Fifty to eighty feet in height; one to two feet in diameter; the leaves, which are ten to fifteen inches long, are gathered in tufts of two and three; the laterally attached cones are four or five inches long, and have short, recurved prickles.

COLOR, APPEARANCE, OR GRAIN OF WOOD.

Resembles Loblolly Pine wood; the color is dark straw, with tinge of flesh color; variable and coarse appearance in cross-section; annual rings are usually wide (ten or twenty per inch).

STRUCTURAL QUALITIES OF WOOD.

Similar to those of Longleaf Pine and of selected pieces of Loblolly Pine (*Pinus tæda*); sometimes more resinous than Longleaf Pine (*Pinus palustris*).

REPRESENTATIVE USES OF WOOD.

Similar to those of Longleaf Pine, from which it is seldom separated.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

39 (United States Forestry Division).[1]

MODULUS OF ELASTICITY.

2,370,000 (average of 410 tests of United States Division of Forestry).[1]

MODULUS OF RUPTURE.

13,600 (average of 410 tests by United States Division of Forestry).[1]

REMARKS.

This wood resembles and is marketed with Longleaf Pine (*Pinus palustris*), and also resembles Loblolly Pine (*Pinus tæda*). Cuban Pine trees reproduce rapidly and are often large enough to yield pitch and turpentine when they are forty years of age. This is important, since the species from which most "naval stores" are obtained are being destroyed so rapidly. The Cuban Pine grows in Honduras and Cuba, as well as in the sub-tropical regions of the United States. This explains why it is called the Cuban Pine.

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[1] See p. 33.

Shortleaf Pine, Yellow Pine. *Pinus echinata Mill; Pinus mitis Michx*

NOMENCLATURE (Sudworth).

Common Yellow Pine, Hard Pine.
Spruce Pine (Del., Miss., Ark.).
Bull Pine (Va.).
Shortshat Pine (Del.).
Pitch Pine (Mo.).
Poor Pine (Fla.).
Shortleaved Yellow Pine (N. C.).
Rosemary Pine (N. C.).
Virginia Yellow Pine.
North Carolina Yellow Pine.
North Carolina Pine.
Carolina Pine.
Slash Pine.
Old Field Pine.

LOCALITIES.

Staten Island to Florida; westward intermittently to Illinois, Kansas, and Texas.

FEATURE OF TREE.

Sixty to sometimes ninety feet in height; two to sometimes four feet in diameter; a large, erect tree; small, lateral cones have minute, weak prickles; the leaves are about four and one-half inches long; they are usually gathered in groups of two; the sheaths are long.

COLOR, APPEARANCE, OR GRAIN OF WOOD.

Resembles Longleaf and Loblolly Pines; variable appearance in cross-section; wide annual rings near heart.

STRUCTURAL QUALITIES OF WOOD.

Variable, usually hard, tough, strong, durable, and resinous; lighter than Longleaf and Loblolly Pines.

REPRESENTATIVE USES OF WOOD.

Lumber and construction; similar to Longleaf Pine (*Pinus palustris*).

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

32 (United States Forestry Division).[1]
30.

MODULUS OF ELASTICITY.

1,680,000 (average of 330 tests by United States Forestry Division).[1]
1,950,000.

MODULUS OF RUPTURE.

10,100 (average of 330 tests by United States Forestry Division).[1]
14,700.

REMARKS.

The Shortleaf Pine yields considerable pitch and turpentine, and is the principal species of northern Arkansas, Kansas, and Missouri.[2]

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[1] See p. 33.

[2] "Southern Pine," Mohr (United States Forestry Circular No. 12); "Timber Pines of Southern States," Mohr (United States Forestry Bulletin No. 13); "Shortleaf Pine," Mattoon (United States Department Agriculture Bulletin, 308, 1915); "The Shortleaf Pine," Detwiler (American Forestry, September, 1916).

Loblolly Pine. *Pinus tæda Linn*

NOMENCLATURE (Sudworth).

Old Field Pine.
Torch Pine.
Rosemary Pine.
Slash Pine.
Longschat Pine.
Longshucks.
Black Slash Pine.
Frankincense Pine.
Shortleaf Pine.
Bull Pine.
Virginia Pine.
Sap Pine.
Meadow Pine.
Cornstalk Pine (Va.).
Black Pine.
Foxtail Pine.
Indian Pine.
Spruce Pine.
Bastard Pine.
Yellow Pine.
Swamp Pine.
Longstraw Pine.
North Carolina Pine.

LOCALITIES.

Southern New Jersey to Florida; westward intermittently to Texas.

FEATURES OF TREE.

Fifty to one hundred or more feet in height; two to sometimes four feet in thickness; leaves in groups of threes are about six inches long; scales of lateral cones have short, straight spines; a large tree.

COLOR, APPEARANCE, OR GRAIN OF WOOD.

Resembles Longleaf Pine (*Pinus palustris*), but is variable; coarse cross-sections; very wide annual rings (three to twelve per inch).

STRUCTURAL QUALITIES OF WOOD.

Resembles Shortleaf Pine (*Pinus echinata*); selected pieces rank with Longleaf Pine (*Pinus palustris*).[1]

REPRESENTATIVE USES OF WOOD.

Used with other Southern pines; inferior in uniformity, strength, and durability.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

33 (United States Forestry Division).[2]
33.

MODULUS OF ELASTICITY.

2,050,000 (average of 660 tests by United States Forestry Division).[2]
1,600,000.

MODULUS OF RUPTURE.

11,300 (average of 650 tests by United States Forestry Division).[2]
12,500.

REMARKS.

These trees grow naturally on deforested land, whence the name of Old Field Pine. A source of abundant and cheap material. A vigorous, prolific grower, probably one of the pines of the future.

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[1] "Loblolly Pine in eastern Texas," Zon (United States Forest Service, Bulletin No. 64, 1905).

[2] See p. 33.

Bull Pine, Yellow Pine, Western Yellow Pine. *Pinus ponderosa Laws*

NOMENCLATURE (Sudworth).

Big Pine.
Longleaved Pine.
Red Pine.
Pitch Pine.
Southern Yellow Pine.
Heavy-wooded Pine.
Western Pitch Pine.
Heavy Pine (Cal.).
Foothills Yellow Pine.
Montana Black Pine.

LOCALITIES

Rocky Mountains; westward intermittently to Pacific Ocean; always at elevations of eighteen hundred or more feet.

FEATURES OF TREE.

One hundred to sometimes three hundred feet in height; six to sometimes twelve feet in diameter; thick, deeply furrowed bark; the leaves, which are in tufts of twos and threes, are from five to nine inches long; the conical cones are at the ends of small branches; the scales are tipped with prickles.[1]

COLOR, APPEARANCE, OR GRAIN OF WOOD.

The thin heartwood is light red; sapwood nearly white; rather coarse grain; compact structure.

STRUCTURAL QUALITIES OF WOOD.

Variable, heavy, hard, strong, and brittle; not durable.

REPRESENTATIVE USES OF WOOD.

Lumber, railway ties, mine-timbers, fuel, etc.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

29.

MODULUS OF ELASTICITY.

1,260,000.

MODULUS OF RUPTURE.

10,200.

REMARKS.

These trees are often killed by tree-boring beetles (*Dendroctonus ponderosa*), and the wood of trees thus attacked eventually assumes a bright blue color (see also von Schrenk, United States Bureau of Plant Industry, Bulletin No. 36). The specific name *ponderosa* was given because of the great size of the trees.

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[1] "Western Yellow Pine in Arizona and New Mexico," Woolsey (United States Forest Service, Bulletin No. 101, 1911). "Western Yellow Pine in Oregon," Munger (United States Department of Agriculture, Bulletin No. 418, 1917).

Norway Pine, Red Pine. *Pinus resinosa Ait*

NOMENCLATURE (Sudworth).
Norway Pine, Red Pine (local and common names).
Hard Pine (Wis.).
Canadian Red Pine (Eng.).

LOCALITIES.
Southern Canada, northern United States from Maine to Minnesota; Pennsylvania.

FEATURES OF TREE.
Sixty to ninety feet in height; one to three feet in diameter; reddish bark on branchlets; leaves are in twos from long sheaths; the cones are at the ends of the branches; the scales are not prickle-tipped; a tall, straight tree.

COLOR, APPEARANCE, OR GRAIN OF WOOD.
The thin heartwood is light red; sapwood yellow to white; numerous pronounced medullary rays.

STRUCTURAL QUALITIES OF WOOD.
Light, hard, elastic, not durable, and resinous.

REPRESENTATIVE USES OF WOOD.
Piles, telegraph poles, masts, flooring, and wainscoting.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.
31 (United States Forestry Division).[1]
30.

MODULUS OF ELASTICITY.
1,620,000 (average of 100 tests by United States Forestry Division).[1]
1,600,000

MODULUS OF RUPTURE.
9,100 (average of 95 tests by United States Forestry Division).[1]
12,500.

REMARKS.
In spite of the specific name *resinosa,* which signifies resinous, these trees yield unimportant quantities of turpentine and resin.[2]

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[1] See p. 33.

[2] "Red or Norway Pine, Pinus resinosa Ait," (United States Forest Service, Silvical Leaflet No. 43, 1909); "Norway Pine in the Lake States," Woolsey (United States Department of Agriculture, Bulletin No. 139, 1914).

Pitch Pine. *Pinus rigida Mill*

NOMENCLATURE (Sudworth).

PitchPine (local and common name)
Longleaved Pine, Longschat Pine (Del.).
Hard Pine (Mass.).
Yellow Pine (Pa.).
Black Pine (N. C.).
Black Norway Pine.
Rigid Pine, Sap Pine.

LOCALITIES.

New Brunswick to Ontario and Ohio, southward to northern Georgia and Alabama; the predominant tree of the New Jersey "pine-barrens."

FEATURES OF TREE.

Forty to sometimes eighty feet in height; one to sometimes three feet in diameter; the rigid, flattened leaves, which are three and one-half to five inches long, are in groups of threes; the sheaths are short; the cones are compact; the reddish scales have stout, recurved prickles.

COLOR, APPEARANCE, OR GRAIN OF WOOD.

Heartwood light brown or red; thick sapwood yellow to nearly white; coarse, conspicuous grain; compact structure; very resinous.

STRUCTURAL QUALITIES OF WOOD.

Light, soft, not strong, and brittle.

REPRESENTATIVE USES OF WOOD.

Coarse lumber, fuel, and charcoal.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

32.

MODULUS OF ELASTICITY.

820,000.

MODULUS OF RUPTURE.

10,500.

REMARKS.

In North America the name, "Pitch Pine" is sometimes misleadingly used to include all Hard Pines; abroad, it is sometimes made to include White Pine. So much resin is present that Pitch Pine is not greatly valued in construction. In spite of this fact, the trees are not relied upon for naval stores. The trees are hardy. They sometimes grow on rocks or on sand near the ocean where they survive in spite of occasional inundations.

Northern Pine, Scotch Pine, Dantzic Pine. *Pinus sylvestris Linn*

NOMENCLATURE.

Dantzic Fir (from place of shipment).
Rigi Fir (from place of shipment).
Memel Fir (from place of shipment).
Stettin Fir (from place of shipment).
Swedish Fir.
Scots or Scottish Fir.
Northern Fir.
Redwood, Yellow-wood.
Deal (local).

LOCALITIES.

Widespread in Europe, as Scotland, Germany, and Russia; also Asia. Cultivated in the United States.

FEATURES OF TREE.

Fifty to one hundred feet in height; two to five feet in diameter; sometimes larger; the leaves, which are about four inches in length, are slightly twisted, and are gathered in tufts of twos and threes; the cones are at the ends of the small branches; the scales are not prickle-tipped.

COLOR, APPEARANCE, OR GRAIN OF WOOD.

Heartwood reddish white to yellowish white; sapwood similar; even, straight grain (varies with locality).

STRUCTURAL QUALITIES OF WOOD.

Moderately light, hard, tough, and elastic; easily worked (varies with locality).

REPRESENTATIVE USES OF WOOD.

Carpentry, construction, planks, beams, masts, and heavy timber.[1]

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

34 (Laslett) (varies with locality).

MODULUS OF ELASTICITY.

1,680,000 (Laslett) (varies with locality).
1,800,000 (Thurston).

MODULUS OF RUPTURE.

7,000 (Thurston) (varies with locality).

REMARKS.

This is the principal softwood produced by the forests of Europe. The trees are widely distributed. The Dantzic and Rigi forests produce the best wood. Wood "equal to Dantzic Fir" is sometimes specified. The wood suggests *true White Pine* (*Pinus strobus*).

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[1] "Scotch Pine" (*Pinus sylvestris*), Pinchot (United States Forest Service, Circular No. 68, 1907).

The **Stone Pine** (*Pinus cembra,*) which is said to be best developed in Switzerland, yields a smooth, fine-grained wood which suggests true White Pine. This wood is often seen in carvings.

The **Bhotan Pine** (*Pinus excelsa*) of the Himalayas closely resembles the White Pine tree in size and habit, and yields a wood which is very similar to White Pine.

The **Lodgepole Pine** (*Pinus murrayana*) also called the Tamarack, Tamarack Pine, Murray Pine, Prickly Spruce, Black Spruce, and White Spruce, grows from Alaska to California and New Mexico. Trees often grow at altitudes of six to eleven thousand feet. The remarkably tall, slender trunks can be made into ties, posts, and poles. The light, straight-grained woods are hard to season, but easy to work. Trees are sensitive to fires, but these fires do not normally kill the seeds (see also Erickson, "Forestry and Irrigation," p. 503, 1904; "The Lodgepole Pine," Ziegler, U. S. Forest Service Circular No. 126; "Utilization and Management of Lodgepole Pine in the Rocky Mountains," Mason, United States Department of Agriculture, Bulletin No. 234, 1915; etc.).

The **Spruce Pine** (*Pinus glabra*) is the least common of the lower southern states pines. It seldom forms pure forests and is of relatively small commercial importance. The wood resembles that of the Loblolly Pine. The name Spruce Pine is popularly applied to trees of ten other American species (Sudworth). Two of these are not pines.

The **Pond Pine** (*Pinus serotina*).—This is the Marsh Pine of the woodsman. The wood is seldom distinguished at the mills where it furnishes much of the lumber known as North Carolina Pine. Pond pine trees grow along the Atlantic coast from Albermarle Sound south to Florida. The six-inch or eight-inch leaves are in tufts of three. The cones sometimes remain on the trees for several years. The trees are now bled for turpentine. The Pond Pine is also known as the Meadow, Loblolly, Spruce, Bastard and Bull Pine (see also Roth, U. S. Forestry Bulletin No. 13).

The **Monterey Pine** (*Pinus radiata*).—This tree grows best near Monterey, California. It is often one hundred feet high and is symmetrical or distorted, according to its exposure. Monterey pine trees are widely transplanted for landscape effects, and the trunks are occasionally cut into lumber.

The **Digger, Grayleaf, Gray or Sabine Pine** (*Pinus sabiniana*) of western California affords a poor and seldom-used wood. The nuts were prized by Digger Indians, whence the name. The tree forms are unusual. The trunks are divided and the sparse, grayish foliage is more or less concentrated near the ends of the branches. The Digger Pine yields a turpentine (abietene) that is used in medicine.

The **Scrub Pine or Jack Pine** (*Pinus divaricata*) of the north-central and Atlantic states, yields a wood that is sometimes classed among the lighter Hard Pines and that is used for ties and fuel. The species is hardy in some semi-arid regions where other pines will not grow.

The **Scrub Pine or Jersey Pine** (*Pinus virginiana*) grows from Staten Island, southward and westward into Alabama and Tennessee. The inferior wood is used for fuel, water-pipes, and coarse lumber.[1]

[1] See also "Scrub Pine" (*Pinus virginiana*), (United States Forest Service, Bulletin No. 94, 1911).

KAURI PINE

Dammara

The Kauri Pine grows in New Zealand and yields a strong light, durable, and elastic wood. The tough, leather-like leaves suggest those of the Box.

The reputation of the species depends principally upon a resin which is much used in the manufacture of high-grade varnishes. This resin unites with linseed oil more perfectly and at lower temperatures, than most other varnish resins, and has sold for more than one thousand dollars a ton. The best Kauri, known as "fossil resin," is obtained by digging over areas from which the trees have disappeared. These deposits exist a few feet below the surface and yield pieces that commonly vary in size from small pebbles to lumps as large as eggs. One exceptional mass, weighing two hundred and twenty pounds, has been reported.[1] There are also "semi-fossil" and "fresh-product" resins. The fresh exudations from Kauri Pine trees resemble the product known as Venice turpentine.

Varnish resins may be roughly divided according to the manner in which they unite with oil and with spirit. In the first case, oil becomes part of the whole, whereas, in the second case, spirits simply dissolve the ingredients and then evaporate from them. As noted, Kauri resin is one of the best of the oil-varnish resins, and, in a similar way, shellac is among the valuable spirit-varnish resins.

Gums and resins should be distinguished from one another. A true gum usually dissolves in water, while a true resin usually yields to oil or spirit. A solution of gum and water forms a mucilage. The name gum is often applied for convenience to substances that are actually resins.

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[1] "Notes on Fossil Resins," R. Ingham Clark (published by C. Letts & Company, London).

Kauri Pine. *Dammara australis Lambert*
Agathis australis Salisbury

OMENCLATURE.
Kauri Pine (local and general).
Cowdie Pine (New Zealand and many localities).

LOCALITIES.
New Zealand.

FEATURES OF TREE.
Ninety to one hundred feet in height; three to four feet in diameter; occasional specimens much larger; a tall, handsome tree; the willow-like leaves are from two to three and one-half inches long, and from one-half to three-fourths of an inch in breadth; the cones are about two and one-half inches in diameter; the resin is characteristic.

COLOR, APPEARANCE, OR GRAIN OF WOOD.
Heartwood straw-colored; fine, straight grain, with silky luster suggesting Satinwood; "mottled Kauri" is separated and used for cabinet work.

STRUCTURAL QUALITIES OF WOOD.
Moderately hard, light, elastic, and strong; it seasons well, works readily, and receives a high polish; it is quite free from knots; it stands well, wears evenly, and has an agreeable odor.

REPRESENTATIVE USES OF WOOD.
Carpentry and masts.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.
33 (Laslett) varies with locality.

MODULUS OF ELASTICITY.
1,810,000 (Laslett).

MODULUS OF RUPTURE.

REMARKS.
The species is widely known by its resin. The most valuable forest tree of New Zealand.

SPRUCE

Picea

Spruce trees form forests in North America and in Europe. The Norway Spruce, or "White Fir" (*Picea excelsa*), is the principal species in Europe, while the Black Spruce (*Picea nigra*), the White Spruce (*Picea alba*), and the Red Spruce (*Picea rubens*) are notable in some parts of the East in the United States. The White Spruce (*Picea engelmanni*) is an important species in the West. In North America spruce trees prefer northern localities where there are short summers and long winters.

The eastern American species yield soft, clean, light, close-grained woods that are much valued in constructions. The Western Spruce yields a valuable wood, but this is less familiar because of its remoteness from the eastern markets. Spruce resembles and forms one of the best eastern substitutes for White Pine. It is also valued for paper pulp.

The eastern product is divided according to appearance, and irrespective of species, into "White Spruce" and "Black Spruce." The pieces that have wide annual layers are usually classed as White Spruce, while those that have narrow layers are classed as Black Spruce. Spruce woods and Fir woods are often confused with one another, and there are so-called spruce trees, as "Douglas Spruce" and "Kauri Spruce," that are not true spruces. European Spruce is sometimes known locally as "White Deal."

The insect and fungus enemies of spruce trees have received much attention.[1] The largest and best trees seem most liable to attack. Hopkins states that the spruce-destroying beetle (*Dendroctonus piceaperda*) is accountable for much of the damage done in the eastern states. This beetle gains entrance to the tree through crevices in the bark, and then cuts grooves on the surface of the sensitive outer sapwood. The resins that collect in these grooves or tunnels are ejected and form what are known as "pitch tubes." The presence of pitch tubes and particles of wood on the ground at the base of a tree is evidence that the tree has been attacked. An intimate connection exists between the attacks of these and other insects, and those of fungi. The latter may lodge in and infect wounds caused by the former. It should be noted that wood may remain sound for sometime after the physical death of the tree, and that such wood can be used for lumber and for paper pulp.

"Windfalls" may result from insects, fungi, age, fire, and tornadoes, or from a combination of these agencies. In windfalls, trees are piled promiscuously upon one another like giant jackstraws. Trunks and limbs intermingle and later the mass is often penetrated by wiry, second-growth saplings. Passage through such a district is made by cautiously walking backward and forward, up and down over trunks and limbs. It is sometimes impossible to proceed for more than two or three miles daily in a straight line through a windfall. The term "blowdown" is also sometimes used.[2]

Spruce trees have single, short, sharp-pointed leaves which are keeled above and below and which therefore appear four-sided. Spruce cones hang downward. Spruce trees may be distinguished from Pines, Firs, and Hemlocks, by remembering that pine leaves are longer and grow in clusters, that hemlock leaves are flat, blunt, and two-ranked, and that the cones of the Fir tree point upward.

Names	Arrangement of leaves	Shape of leaves	Cones
Pine (Pinus)...	In tufts or clusters.	Comparatively long.	
Spruce (Picea).	Single, scattered, point in all directions.	Short, sharp ends, keeled above and below. Somewhat four-sided.	Hang down, 1 to 6 inches long.
Fir (Abies)....	Single, scattered, appear somewhat as in two ranks.	Short, blunt ends, flat.	Stand erect, 2 to 4 inches long.
Hemlock (Tsuga).	Single, scattered, appear as in two ranks.	Short, blunt ends, flat.	Hang down, ¾ to 1 inch long.

[1] "Insect Enemies of Spruce in the Northeast" and "Insect Enemies of the Forest of the Northwest," Hopkins (United States Division Entomology, Bulletins No. 28 and No. 21); also "Diseases New England Conifers," von Schrenk (United States Division Vegetable Physiology and Pathology, Bulletin No. 25.

[2] See "Transactions American Institute Mining Engineers," 1899; see also "Third Annual Report Pennsylvania Department Agriculture."

Black Spruce. *Picea nigra Link*
Picea mariana Mill

NOMENCLATURE (Sudworth).
Spruce (Vt.), Yew Pine, Spruce Pine (W. Va.).
Double Spruce (Me., Vt., Minn.).
Blue Spruce (Wis.).
White Spruce (W. Va.).
He Balsam (Del., N. C.).
Water Spruce (Me.).

LOCALITIES.
Labrador and Alaska, southward to New York, Pennsylvania, Wisconsin, and Saskatchewan.

FEATURES OF TREE.
Forty to eighty feet in height; one to two feet in diameter; conical shape, with straight trunk; four-sided leaves are somewhat narrowed toward the tips; the leaves are from three-eighths of an inch to five-eighths of an inch in length; they are lighter on the upper surfaces than on the lower; cones remain for several years, being thus distinct from those of the White Spruce (*Picea alba*).

COLOR, APPEARANCE, OR GRAIN OF WOOD.
Heartwood reddish, nearly white; sapwood lighter; straight grain; compact structure.

STRUCTURAL QUALITIES OF WOOD.
Light, soft, not strong, elastic, and resonant; not durable when exposed.

REPRESENTATIVE USES OF WOOD.
Lumber, flooring, carpentry, ship-building, piles, posts, railway ties, paddles, oars, "sounding-boards," and paper-pulp.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

28.

MODULUS OF ELASTICITY.

1,560,000.

MODULUS OF RUPTURE.

10,600.

REMARKS.
A substitute for Soft Pine. See also "Black Spruce, *Picea mariana* (Mill.)" (United States Forest Service, Silvical Leaflet No. 28, 1908).

The Red Spruce (*Picea rubens*) is one of the principal lumber trees of northern New England. This tree, which is much like the Black Spruce, is from fifty to eighty feet in height, and from two to three feet in diameter. Large quantities of its light, close-grained, reddish, satiny wood are cut into lumber or used in the manufacture of paper-pulp.

White Spruce. *Picea alba Link*
Picea canadensis Mill

NOMENCLATURE (Sudworth).
Single Spruce (Me., Vt., Minn.).
Bog Spruce, Cat Spruce (New Eng.).
Skunk Spruce (Wis., New Eng.).
Spruce, Double Spruce (Vt.).
Pine (Hudson Bay).

LOCALITIES.
Northern United States, Canada to Labrador and Alaska.

FEATURES OF TREE.
Fifty to one hundred feet in height; one to two feet in diameter; occasionally larger; compact, symmetrical, conical shape; foliage lighter than Black Spruce; cones fall sooner than those of Black Spruce; whitish resin.

COLOR, APPEARANCE, OR GRAIN OF WOOD.
Heartwood light yellow; sapwood similar; straight-grained; numerous prominent medullary rays; compact structure.

STRUCTURAL QUALITIES OF WOOD.
Light and soft; not strong (similar to those of Black Spruce (*Picea nigra*).

REPRESENTATIVE USES OF WOOD.
Lumber, flooring, carpentry, etc. (similar to those of Black Spruce (*Picea nigra*).

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

25.

MODULUS OF ELASTICITY.

1,450,000.

MODULUS OF RUPTURE.

10,600.

REMARKS.
Notable as resident of high latitudes. One of the chief trees of the Arctic forests. The wood, used similarly to Black Spruce, is substituted for White Pine.

It is often difficult to distinguish between Black Spruce trees and those of the White Spruce. On the whole, the foliage of the former is darker; there are also differences in the shapes and in the persistence of the cones. The names "Double Spruce" and "Single Spruce" are without botanical foundation. Woods obtained from these two trees exhibit similar qualities and are not separated by lumbermen.

White Spruce. *Picea engelmanni Engelm*

Nomenclature (Sudworth).

White Spruce (Ore., Col., Utah, Idaho).
Balsam, Engelmann's Spruce (Utah).
White Pine (Idaho), Mountain Spruce (Mont.).

Localities.

British Columbia to Oregon, eastward to Alberta, and south through the Rocky Mountain region to northern New Mexico and Arizona.

Features of Tree.

Frequently seventy-five to one hundred feet in height; sometimes one hundred and fifty feet in height; two to three feet in diameter; sometimes a low shrub; the straight, slender leaves are from three-fourths of an inch to one and one-fourth inches in length; they are flexible, with sharp, thick tips, and they spread in all directions; the elliptical cones are from one and one-half inches to two and one-half inches long; the scales are toothed at the apex.[1]

Color, Appearance, or Grain of Wood.

Heartwood pale reddish yellow; sapwood similar; close, straight grain; compact structure; conspicuous medullary rays.

Structural Qualities of Wood.

Light and soft; not strong.

Representative Uses of Wood.

Lumber, charcoal and fuel; bark rich in tannin is sometimes used for tanning.

Weight of Seasoned Wood in Pounds per Cubic Foot.

21.

Modulus of Elasticity.

1,140,000.

Modulus of Rupture.

8,100.

Remarks.

Notable as a resident of high altitudes, extensive forests occurring at eight to ten thousand feet above sea-level. A valuable tree of the central and southern Rocky Mountain regions.

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[1] "Engelmann Spruce in the Rocky Mountain," Hodson and Foster (United States Forest Service, Circular No. 170); "Engelmanns Spruce" Pinchot (United States Forest Service, Silvical Leaflet No. 3, 1907).

Sitka Spruce. *Picea sitchensis Trautv. and Mayer*

NOMENCLATURE (Sudworth).

Sitka Spruce (local and common name).
Tideland Spruce (Cal., Oreg., Wash.).
Menzies Spruce.
Western Spruce.
Great Tideland Spruce.

LOCALITIES.

Pacific Coast region, Alaska to central California; extends inland about fifty miles; prefers low elevations.

FEATURES OF TREE.

One hundred and fifty or more feet in height; three feet or more in diameter; the stiff, straight, flat leaves, which are from five-eighths of an inch to three-fourths of an inch in length, radiate in all directions; the oval or cylindrical cones are from three to four inches in length; the bark is scaly and of a reddish-brown color.[1]

COLOR, APPEARANCE, OR GRAIN OF WOOD.

Heartwood light reddish brown; sapwood nearly white; coarse-grained; satiny.

STRUCTURAL QUALITIES OF WOOD.

Light and soft; not strong.

REPRESENTATIVE USES OF WOOD.

Construction, interior finish, fencing, boat-building, and cooperage.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

2,626.

MODULUS OF ELASTICITY.

MODULUS OF RUPTURE.

10,400.

REMARKS.

A giant among the spruces. Forms an extensive coast-belt forest.

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[1] "Sitka Spruce," Pinchot (United States Forest Service, Silvical Leaflet No. 6, 1907).

DOUGLAS SPRUCE, DOUGLAS FIR, OREGON PINE

Pseudotsuga.

These trees form almost pure forests in Washington and Oregon. They grow sparingly in Mexico, Texas, and at high altitudes in Colorado. Transplanted specimens have survived in New York. It should be noted that the Douglas Spruce is neither Spruce, Fir, or Pine. The generic name is from *pseudo* or "false," and *tsuga* or "Hemlock," and the tree may be regarded as in the nature of a bastard Hemlock. The species has also been classed as *Pinus taxifolia* and *Abies taxifolia.*[1]

The durable, strong, light red, or yellow wood, which resembles larch or true hard pine is used in place of hard pine on the Pacific Coast. It is one of the general utility woods of that coast. The trees are among the greatest known to man. Individuals have reached heights of three hundred and fifty feet,[2] and diameters of twelve and even fifteen feet. Logs that yield timbers two feet square and one hundred feet long are not uncommon. Single trees have been cut that scaled sixty thousand feet board measure. The Douglas Spruce grows rapidly. It is hardy, and, like the redwoods, is likely to resist commercial extinction.

Red and Yellow varieties of Douglas Spruce wood are recognized by lumbermen. The former woods come from younger trees, and are coarser and less valuable than the latter kinds which come from the older trees. The wood is also marketed under the commercial names of Oregon Pine, Hard Pine, Pacific Pine, Red Spruce, Red Fir, Yellow Fir, etc. The genus includes one other species, the much less important Big Cone Spruce (*Pseudotsuga macrocarpa*) of California, which yields an inferior wood.

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[1] Some difficulties associated with the classification of this tree are enumerated on pages 23 and 24 of Sudworth's Check List.

[2] The tallest specimen recorded was three hundred and eighty feet high.

See also "Growth and Management of Douglas Fir in Pacific Northwest," Munger (United States Forest Service Circular No. 175, p. 23); "Properties and Uses of Douglas Fir," Cline and Knap (United States Forest Service Bulletin No. 88); "Douglas Fir," Frothingham (United States Forest Service, Circular No. 150, 1909); "Douglas Fir," Detwiler (American Forestry, February, 1916).

Douglas Spruce, Douglas Fir. *Pseudotsuga mucronata Sudw.* *Pseudotsuga taxifolia Lam* *Pseudotsuga Douglasii Carr*

Nomenclature (Sudworth).

Oregon Pine (Cal., Wash., Ore.)
Red Fir, Yellow Fir (Ore., Wash., Idaho, Utah, Mont., Col.).
Red Pine (Utah, Idaho, Col.).
Douglas-tree, Cork-barked Douglas Spruce. (Occasional)
Spruce, Fir (Mont.)
Puget Sound Pine (Wash.).

Localities.

Pacific Coast region, Mexico to British Columbia; best in Western Oregon and Washington.

Features of Tree.

One hundred and seventy-five to sometimes three hundred feet in height; three to five and sometimes ten feet in diameter; older bark rough-gray, often looking as though braided. One of the world's greatest trees.

Color, Appearance, or Grain of Wood.

Heartwood light red to yellow; scant sapwood nearly white; comparatively free from resins; pronounced variable rings (four to forty per inch).

Structural Qualities of Wood.

Variable, usually hard, and strong; rather difficult to work, durable, splits easily, can be obtained in large pieces. [1]

Representative Uses of Wood.

Heavy constructions, dimension-timbers, lumber, railway ties, paving blocks, wood-stave pipes, posts, poles, piles, masts, and fuel. The wood is used much as hard pine is used.

Weight of Seasoned Wood in Pounds per Cubic Foot.

32 (United States Forestry Division).[2]
36 (Average of 20 tests by Soulé).[3]
32.

Modulus of Elasticity.

1,680,000 (average of 41 tests by United States Forestry Division).[2]
1,862,000 (average of 21 tests by Soulé).[3]
1,824,000.

Modulus of Rupture.

7,900 (average of 41 tests by United States Forestry Division).[2]
9,334 (average of 21 tests by Soulé).[3]
12,500.

Remarks.

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[1] See also "Properties and Uses of Douglas Fir: Pt. 1, Mechanical Properties; Pt. 2, Commercial Uses" (United States Forest Service, Bulletin No. 88, 1911).

[2] See p. 33.

[3] Professor Frank Soulé, University of California, Trans. Am. Inst. M. E., Vol. XXIX, p. 552.

FIR

Abies

The Silver Fir (*Abies grandis*), the Red Fir (*Abies magnifica*), and the Noble Fir (*Abies nobilis*), are valued west of the Rocky Mountains, while the Balsam Fir (*Abies balsamea*) is of some commercial importance in the East.

Some of the Fir trees in the Western States are so large as to call for the special methods that are used to fell the giant specimens of other species. In such cases platforms are erected, far enough up from the ground, so that axemen, standing upon them, can cut through above the hollow or decayed parts that are common near the surface of the ground. It is also arranged so that the trees, as they fall, shall strike the ground more or less uniformly along their sides and thus diminish the danger from splintering or breaking, which is associated with the impact of such large trunks.[1]

Fir and Spruce resemble one another in appearance and structural qualities and are often used in place of one another in the United States. Fir, Spruce, and Pine are often confused with one another in Europe.

Fir trees have flat, scattered, evergreen leaves and erect cones. The Balsam Fir may be distinguished by blisters, abundantly supplied in the bark of all but the oldest trunks, which contain a clear, liquid resin known as Canada Balsam.

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[1] Descriptions of special methods employed in harvesting Douglas Spruce, Redwoods, Giant Cedars, and other Western species are as follows: Engineering Magazine, Bishop (Vol. XIII, p. 70); National Geographic Magazine, Gannett (Vol. X, No. 5, May, 1899).

Balsam Fir, Common Balsam Fir. *Abies balsamea (L.) Mill.*

NOMENCLATURE (Sudworth).

Balsam (Vt., N. H., N. Y.).
Fir Tree (Vt.).
Balm of Gilead (Del.).
Canada Balsam (N. C.).
Balm of Gilead Fir (N. Y., Pa.).
Blister pine, Fir Pine (W. Va.).
Single Spruce, Silver Pine (Hudson Bay).

LOCALITIES.

Labrador, southward through the mountains, and westward to Minnesota.

FEATURES OF TREE.

Fifty to seventy feet in height; one to two feet in diameter; sometimes a low shrub; blisters in smooth bark contain thick balsam; erect cones.

COLOR, APPEARANCE, OR GRAIN OF WOOD.

Heartwood white to brownish; sapwood lighter; coarse-grained; compact structure; satiny.

STRUCTURAL QUALITIES OF WOOD.

Soft, light, not durable or strong, resinous, and easily split.

REPRESENTATIVE USES OF WOOD.

Occasionally used as inferior lumber.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

23.

MODULUS OF ELASTICITY.

1,160,000.

MODULUS OF RUPTURE.

7,300.

REMARKS.

These trees grow naturally over Northern pine lands, and yield wood which is commonly sold with Spruce and Pine. Of all the native conifers this is one of the most difficult trees to cultivate. The thick fluid-resin, or balsam, known as Canada Balsam, is used in medicine. It should be noted that the Poplar (*Populus balsamifera*) is also called Balm of Gilead. See also "Balsam Fir," Zon (United States Department of Agriculture Bulletin No. 55).

Great Silver Fir, White Fir. *Abies grandis Lindl.*

NOMENCLATURE (Sudworth).
Silver Fir (Mont., Idaho).
Oregon White Fir, Western White Fir (Cal.).
Yellow Fir (Mont., Idaho).
Lowland Fir.

LOCALITIES.
Vancouver region, northwestern United States; best in western Washington and Oregon.

FEATURES OF TREE.
Two hundred to sometimes three hundred feet in height; two to five feet in diameter; leaves deep green above, silvery below, usually curved; a handsome tree.

COLOR, APPEARANCE, OR GRAIN OF WOOD.
Heartwood light brown; sapwood lighter; coarse-grained; compact structure.

STRUCTURAL QUALITIES OF WOOD.
Light and soft; not strong.

REPRESENTATIVE USES OF WOOD.
Lumber, interior finish, packing-cases, and cooperage.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.
22.

MODULUS OF ELASTICITY.
1,360,000.

MODULUS OF RUPTURE.
7,000.

REMARKS.
These trees form an important part of local mountain forests and furnish much lumber locally. They grow best on rich bottom lands, but are also found at altitudes of five thousand and even six thousand feet. The balsam contained in blisters in the young bark is used in medicine. The specific name *grandis* was given because of the great size to which some trees of this species grow. See also "Lowland Fir," Pinchot (United States Forest Service, Silvical Leaflet No. 5, 1907).

Red Fir. *Abies magnifica Murr*

NOMENCLATURE (Sudworth).
California Red Fir, California Magnificent Fir, Golden Fir (Cal.). Red-bark Fir (Cal.).

LOCALITIES.
Mountains of northern California, Oregon, and Nevada.

FEATURES OF TREE.
One hundred to two hundred and fifty feet in height; six to ten feet in diameter; large, erect cones; beautiful form.

COLOR, APPEARANCE, OR GRAIN OF WOOD.
Heartwood reddish; sapwood distinguishable; rather close-grained; compact structure.

STRUCTURAL QUALITIES OF WOOD.
Light and soft; not strong, durable when exposed, liable to injury in seasoning.

REPRESENTATIVE USES OF WOOD.
Construction, sills, lumber, and fuel.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

29.

MODULUS OF ELASTICITY.

940,000.

MODULUS OF RUPTURE.

9,900.

REMARKS.
The specific name refers to the appearance and size of the tree.

White Fir, Balsam Fir. *Abies concolor Lindl. and Gord.*

NOMENCLATURE (Sudworth).
Silver Fir, Balsam (Cal.).
California White Fir (Cal.).
Black Gum, Bastard Pine (Utah).
White Balsam (Utah).
Balsam-tree (Idaho).
Colorado White Fir, Concolor White Fir.

LOCALITIES.
Rocky Mountains and coast ranges; high elevations.

FEATURES OF TREE.
Seventy to one hundred and fifty feet in height; three to five feet in diameter; the blisters in the bark are filled with clear pitch.[1]

COLOR, APPEARANCE, OR GRAIN OF WOOD.
Heartwood light brown to nearly white; sapwood same or darker; coarse-grained; compact structure.

STRUCTURAL QUALITIES OF WOOD.
Light and soft; not strong; without odor.

REPRESENTATIVE USES OF WOOD.
Butter-tubs, packing-boxes, and lumber.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

22.

MODULUS OF ELASTICITY.

1,290,000.

MODULUS OF RUPTURE.

9,900.

REMARKS.
Not always distinguished from the species *Abies lowiana.*

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[1] "White Fir," Pinchot (United States Forest Service, Silvical Leaflet No. 4, 1907).

Red Fir, Noble Fir. *Abies nobilis Lindl.*

NOMENCLATURE (Sudworth).

Noble Silver Fir, Noble Red Fir. Larch (Oreg.). Bigtree, Feather-cone, Red Fir (Cal.).

LOCALITIES.

Northwestern United States; cultivated in the East.

FEATURES OF TREE.

One to two hundred feet in height; six to nine feet in diameter; the leaves are curved; a large, beautiful tree.[1]

COLOR, APPEARANCE, OR GRAIN OF WOOD.

Heartwood reddish-brown; sapwood darker; rather close-grained; compact structure.

STRUCTURAL QUALITIES OF WOOD.

Light, hard, strong, and elastic.

REPRESENTATIVE USES OF WOOD.

Fitted for house-trimmings.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

28.

MODULUS OF ELASTICITY.

1,800,000.

MODULUS OF RUPTURE.

22,200.

REMARKS.

Red Fir trees grow at elevations of three thousand and four thousand feet. With other fir trees, they form extensive forests. The wood is often sold as Larch.

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[1] Peters (Forestry and Irrigation, Vol. VIII, No. 9, Sept., 1902, pp. 362, 366); "Noble Fir," Pinchot (United States Forest Service, Silvical Leaflet No. 7, 1907).

HEMLOCK

Tsuga

Hemlock trees grow in some of the central and northern states east of the Rocky Mountains, and also on the Pacific Coast as far north as Alaska. They sometimes mingle with other trees, and sometimes form pure forests by themselves.

The wood of the Eastern Hemlock (*Tsuga canadensis*) is coarse, brittle, often cross-grained, usually hard to work, liable to warp and splinter, and perishable when exposed. It cannot be relied upon to sustain shocks. It holds nails firmly and is used for coarse lumber, dimension pieces, paper pulp, and cheap finish. Some of the prejudice that exists against hemlock is due to the fact that it was formerly compared with white pine, spruce and fir. The supplies of these better woods have since diminished and the value of hemlock has increased correspondingly.

The wood of the Western Hemlock (*Tsuga heterophylla*), which is much better and stronger than Eastern Hemlock, has suffered because of the reputation of the Eastern Hemlock. Western Hemlock has a pronounced odor which makes it disliked by insects and rodents. For this reason it is sometimes used to line grain-bins. The wood is also used for flooring, mill frames, boxes, and paper pulp. It is seldom sold under its true name, but names such as Alaska Pine and Red Fir are preferred. Black streaks sometimes exist with the grain. These are more or less evident and the pieces in which the streaks exist are often sold as Black Hemlock. The True Black or Alpine Hemlock (*Tsuga mertensiana*) often grows at high altitudes or in the far North and is not yet widely available.[1]

Hemlock trees have flat, blunt, evergreen leaves, the undersides of which appear to be whitened. The leaves are arranged in two ranks. The inner bark is red.

The Western Hemlock (*Tsuga heterophylla*) grows from Alaska to California and attains a height of one hundred and eighty feet and a diameter of nine feet. It is said to afford heavier and better wood than that obtained from the common Hemlock. The Western Hemlock is known by the following names (Sudworth): Western Hemlock, Hemlock Spruce (Cal.); Hemlock (Oreg., Idaho, Wash.); Alaska Pine (Northwestern Lumberman); Prince Albert's Fir, Western Hemlock Fir, California Hemlock Spruce (England).[2]

[1] "Black Hemlock (*Tsuga mertensiana*) (United States Forest Service, Silvical Leaflet No. 31, 1908).

[2] "The Western Hemlock," Allen (United States Forestry Bureau, Bulletin No. 33); "Mechanical Properties of Western Hemlock," Goss (United States Forest Service, Bulletin No. 115).

Hemlock. *Tsuga canadensis (L.) Carr*

NOMENCLATURE (Sudworth).
Hemlock (local and common name).
Spruce (Pa., W. Va.).
Spruce Pine (Pa., Del., Va., N. C., Ga.).
Hemlock Spruce (Vt., R. I., N. Y., Pa., N. J., W. Va., N. C., S.C.)

LOCALITIES.
Eastern and central Canada, southward to North Carolina and Tennessee.

FEATURES OF TREE.
Sixty to eighty or more feet in height; two or three feet in diameter; short leaves, green above and white beneath; straight trunk, beautiful appearance.

COLOR, APPEARANCE, OR GRAIN OF WOOD.
Heartwood reddish brown; sapwood distinguishable; coarse, pronounced, usually crooked grain.

STRUCTURAL QUALITIES OF WOOD.
Light, soft, not strong or durable, brittle, difficult to work; the wood splinters easily; it retains nails firmly.

REPRESENTATIVE USES OF WOOD.
Coarse lumber, joists, rafters, laths, plank walks, and railway ties.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

26.

MODULUS OF ELASTICITY.

1,270,000.

MODULUS OF RUPTURE.

10,400.

REMARKS.
The specific name *canadensis* refers to Canada, the locality where these trees excel. See also "The Eastern Hemlock," Frothingham (United States Department of Agriculture, Bulletin No. 152, 1915). The Southern or Carolina Hemlock (*Tsuga caroliniana*) yields wood that resembles that of Hemlock.

LARCH OR TAMARACK

Larix

The Eastern Larch (*Larix americana*) grows in low, wet areas known as tamarack swamps. The Western species (*Larix occidentalis*) grows where it is dry and the European Larch (*Larix europæa*) also thrives upon dry soil.

Many interesting records exist with regard to the wood, which was apparently known and prized centuries ago. It was mentioned by Pliny, and Vitruvius wrote of a bridge, which having burned, was replaced by one of Larch, because it was thought that that wood would not burn as readily. Some of the piles upon which the city of Venice is founded are said to be of larch.[1] While seemingly authoritative, such statements should be received with caution, since the names of woods mentioned by ancient writers are not always those employed at the present time.

Larch wood is hard and very durable. In structure it resembles spruce, and in weight and appearance it resembles hard pine. The tall, straight trunks are so slender that they are seldom cut up into lumber. The trunks are usually used for poles, posts, and railway ties. Although the Eastern species is usually found in deep swamps, it often grows better on drier ground. A swamp specimen required forty-eight years to reach a diameter of two inches, while another specimen, located where there was less water, was eleven inches thick at the end of thirty-eight years. The European Larch is often employed in American landscape effects.

The foliage of the Larch is shed every autumn, and, for this reason, Larch trees are not truly "evergreen." The tufts of small needle-like leaves are of a fresh pea-green color when they first appear in the spring, and the trees are then very beautiful. The trees present a somewhat gloomy appearance in the winter. Larch trees are very hardy, and the species deserves more attention than it receives.

The European Larch (*Larix europœa*) is a native of central Europe. The trees thrive upon dry soil and are used in American landscape work. They are good coniferous trees to plant near houses, because they lose their leaves during the winter. The wood is similar to that obtained from American species. The European Larch yields the Venice turpentine of commerce. This substance, once collected through Venetian markets, is now largely drawn from America. See also "European Larch," Pinchot (United States Forest Service, Circular No. 70).

[1] Pliny, XVI, 43–49 and XVI, 30; also Vitruvius II, 9; also Encyclopædia Britannica, Vol. XIV, p. 310; and "Forestry in Minnesota," Green.

Tamarack, Larch. { *Larix americana Michx.* / *Larix laricina (Du Roi) Koch*

Nomenclature (Sudworth).
Tamarack, Larch, American Larch (local and common names).
Hackmatack (Me., N. H., Mass., R. I., Del., Ill., Mich.)
Black Larch, Red Larch (Minn., Mich.).
Juniper (Me., Canada).

Localities.
From Newfoundland, Labrador, and Alaska, southward to New York, Pennsylvania, and Minnesota

Features of Tree.
Seventy to ninety feet high; one to three feet in diameter; short, pea-green, deciduous leaves in tufts; a slender tree, winter aspect gloomy.

Color, Appearance, or Grain of Wood.
Heartwood light brown; sapwood nearly white; coarse, conspicuous grain; compact structure; annual layers pronounced.

Structural Qualities of Wood.
Heavy, hard, very strong, and durable; resembles spruce.

Representative Uses of Wood.
Railway ties, fence-posts, sills, ship-timbers, telegraph poles, flagstaffs, etc.

Weight of Seasoned Wood in Pounds per Cubic Foot.

38.

Modulus of Elasticity.

1,790,000

Modulus of Rupture.

12,800.

Remarks.

Almost all of the comparatively slender logs are used for poles, masts, posts, and railway ties. Very few of them are cut up into lumber. Lumbermen sometimes divide tamarack logs as they are "Red" or "White." Red Tamarack is thought to be better and more durable than White Tamarack. This distinction is probably due to differences in the ages of the trees. Tamarack trees grow in swamps, known as Tamarack Swamps, which are often very extensive. See also "Transactions American Institute of Mining Engineers" (Vol. XXIX, p. 157).

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[1] See also "Tamarack, *Larix laricina* (Du Roi)," Koch (United States Forest Service, Silvical Leaflet No. 32, 1908).

Tamarack, Larch. *Larix occidentalis Nutt.*

NOMENCLATURE (Sudworth).
Tamarack, Larch (local and common names).
Hackmatack (Idaho, Wash.).
Western Larch, Great Western Larch, Red American Larch.
Western Tamarack (Cal.).

LOCALITIES.
Washington and Oregon, intermittently to Montana.

FEATURES OF TREE.
Ninety to one hundred and twenty-five feet high; two and one-half to four feet in diameter; a large tree.

COLOR, APPEARANCE, OR GRAIN OF WOOD.
Heartwood light red; thin sapwood lighter; coarse-grained; compact structure; annual rings pronounced.

STRUCTURAL QUALITIES OF WOOD.
Hard, heavy, strong, and durable.

REPRESENTATIVE USES OF WOOD.
Posts, railway ties, and fuel; limited quantity of lumber; similar to Larch (*Larix americana*).

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

46.

MODULUS OF ELASTICITY.

2,300,000.

MODULUS OF RUPTURE.

17,400.

REMARKS.
These trees are much larger than those of the species *Larix americana.* They also differ, in that they grow on dry ground, often at comparatively high elevations.[1]

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[1] See also "Mechanical Properties of Western Larch," Goss (United States Forest Service, Bulletin No. 122); "Western Larch," Pinchot (United States Forest Service Silvical Leaflet No. 14).

CEDAR

Cedrus, Thuya, Chamæcyparis, Libocedrus, Juniperus

The name Cedar was first applied to the true, foreign, or Lebanon Cedars (Cedrus), but was later applied to certain Arborvitæs (*Thuya*), Junipers (*Juniperus*), Cypresses (*Chamæcyparis*), and other trees[1] that yield the durable, fine-grained characteristically scented woods that are commonly known as cedar woods. It is recorded that cedar was employed in such early constructions as the Temple of Solomon and the Temple of Diana at Ephesus,[2] and it is possible that the product referred to was the same as that to which this name applies at the present time.

Cedar is divided as it is Red Cedar and White Cedar.

Red Cedar.—A large part of the supply is derived from the Eastern, Western, and Southern species (*Juniperus virginiana*), (*Juniperus scopulorum*), and (*Juniperus barbadensis*). The woods are soft, light, durable, fine-grained, fragrant, and of a reddish-brown color. They are sometimes used in construction, but are more often employed in lead-pencils, chests, and closets. The demand for wood to be used in lead-pencils alone is very great.[3] Cedar chips and shavings are often used in place of camphor to protect woolens. The total demand is greater than the supply. Trees grow easily on almost any soil. They are normally hardy, but are sometimes subject to disease.[4] Some of these diseases cease after the trees have been felled and the wood cut from the diseased trees is as durable as wood cut from trees that are not diseased.

The Western Red Cedar (*Juniperus scopulorum*) and the Southern Red Cedar (*Juniperus barbadensis*) yield woods that resemble those from the Cedar (*Juniperus virginiana*).

White Cedar.—Most "White Cedar" is obtained from several Arborvitæs and Cypresses. The woods are soft, light, durable, fine-grained, and very inflammable. They are used for fence posts and shingles. Practically all cedar that is not red cedar, is white cedar. White cedar railway ties are defective because they crush and cut under the rails and because they do not hold spikes. The trees often grow in swamps.[5]

Some important Red and White Cedars are as follows:

Red Cedar	*White Cedar*
Red Cedar (*Juniperus virginiana*).	Arborvitæ (*Thuya occidentalis*).
Red Cedar (*Juniperus scopulorum*).	Canoe Cedar (*Thuya gigantea*).
Red Cedar (*Juniperus barbadensis*).	White Cedar (*Chamæcyparis thyoides*).
	Port Orford Cedar (*Chamæcyparis lawsoniana*).
	Yellow Cedar (*Chamæcyparis nutkatensis*).
	Incense Cedar (*Libocedrus decurrens*).

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[1] See "Spanish Cedar" (*Cedrela odorata*).

[2] Pliny, 16, 213, and 16, 216.

[3] "Notes on Red Cedar," Mohr (United States Division of Forestry, Bulletin No. 31). See also "Uses of Commercial Woods of United States: 1, Cedars, Cypresses, and Sequoias" (United States Forest Service, Bulletin No. 95, 1911).

[4] Two diseases are recognized. They are white rot, caused by Polyporus juniperus, and red rot, caused by Polyporus carneus, von Schrenk (United States Division Vegetable Physiology and Pathology, Bulletin No. 21); also von Schrenk, Shaw School of Botany, Contribution No. 14 (St. Louis, Mo.).

[5] Timbered swamps are very formidable. For example, the "White Cedar swamp," of the Lake Superior region, is covered close down to the ground, by the vigorous branches of the trees. These branches meet and cross one another, and passage through such a district resembles passage through a cultivated hedge. The roots lie partly out of the water, and, while apparently sound, are slippery and sometimes decayed, so that the pedestrian, stepping or springing from one root to another, encumbered by burdens, and obstructed by the wiry branches, is liable to slip and fall. The constant use of arms and legs, with the shock caused by packs shifting upon the shoulders when the pedestrian falls, and the annoying insects, require much strength and patience. Such Northern swamps can best be penetrated during the winter season, when the ground is frozen. The "Tamarack swamp" of the North differs from the "White Cedar swamp," in that the lower branches of the Tamarack are higher from the ground. The "Cypress" is the characteristic swamp tree of the South.

Red Cedar. *Juniperus virginiana Linn.*

Nomenclature (Sudworth).
Red Cedar (local and common name).
Cedar (Conn., Pa., N. J., S. C., Ky., Ill., Ia., Ohio).
Pencil Cedar, Cendre (La.).
Savin (Mass., R. I., N. Y., Pa., Minn.).
Juniper, Red Juniper, Juniper Bush (local).

Localities.
Atlantic Coast, Canada to Florida, westward intermittently to the Mississippi River in the North and the Colorado River in the South.

Features of Tree.
Fifty to eighty feet in height; two to three feet in diameter; dark-green, scale-like foliage; loose, ragged, outer bark.

Color, Appearance, or Grain of Wood.
Heartwood dull-red; thin sapwood nearly white; close, even grain; compact structure; annual layers easily distinguishable.

Structural Qualities of Wood.
Light, soft, weak, and brittle; easily worked; durable; fragrant; the fragrance is such that the wood is used as an insecticide.

Representative Uses of Wood.
Ties, sills, posts, interior finish, pencil-cases, chests, and cigar-boxes.

Weight of Seasoned Wood in Pounds per Cubic Foot.

30.

Modulus of Elasticity.

950,000.

Modulus of Rupture.

10,500.

Remarks.
The trunks of these trees are sometimes attacked by fungi similar to those that attack Cypress and Incense Cedar trees. The disease stops when the trees are felled, and boards cut from such trees have been known to last for over fifty years. See also Contribution No. 44, Shaw School of Botany, von Schrenk; "Two Diseases of Red Cedar" (United States Division of Vegetable Physiology and Pathology, Bulletin No. 21); Mohr (United States Forestry Bulletin No. 31); "Red Cedar," Pinchot (United States Forest Service, Circular No. 73).

Juniper. *Juniperus occidentalis Hook*

NOMENCLATURE (Sudworth).
Juniper (Oreg., Cal., Col., Utah, Nev., Mont., Idaho, N. M.).
Cedar, Yellow Cedar, Western Cedar (Idaho, Col., Mont.).
Western Red Cedar, Western Juniper (local).

LOCALITIES.
California, Washington, Oregon, and Idaho.

FEATURES OF TREE.
Twenty-five to fifty feet in height; two to four feet in diameter; often smaller.

COLOR, APPEARANCE, OR GRAIN OF WOOD.
Heartwood reddish-brown; sapwood nearly white; very close-grained; compact structure.

STRUCTURAL QUALITIES OF WOOD.
Light, soft, and durable; receives a high polish.

REPRESENTATIVE USES OF WOOD.
Fencing, railway ties, posts, and fuel.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

35.

MODULUS OF ELASTICITY.

MODULUS OF RUPTURE.

REMARKS.
Rarely found below an altitude of six thousand feet. Fruit said to be eaten by Indians.

The California Juniper (*Juniperus californica*) grows intermittently in some districts in California, near the coast line. The trees are sometimes as much as thirty or forty feet in height, and one or two feet in diameter, but are often much smaller. The shaggy bark is of a grayish color. The soft, close-grained, fragrant, durable wood has been used to meet minor needs.

White Cedar, Arborvitæ. *Thuya occidentalis Linn.*

NOMENCLATURE (Sudworth).
White Cedar, Arborvitæ (local and common names).
Cedar (Me., Vt., N. Y.).
Atlantic Red Cedar (Cal.).
Vitæ (Del.).

LOCALITIES.
Northern States, eastward from Manitoba and Michigan; northward, also occasionally southward, as in the mountain region of North Carolina and eastern Tennessee.

FEATURES OF TREE.
Thirty to sixty feet high; one to three or more feet in diameter; often smaller; bruised leaves emit a characteristic pungent odor; the trunks taper rapidly.

COLOR, APPEARANCE, OR GRAIN OF WOOD.
Heartwood light brown, darkening with exposure; the thin sapwood is nearly white; even, rather fine grain; compact structure.

STRUCTURAL QUALITIES OF WOOD.
Soft, light, weak, brittle, durable, and inflammable; does not hold spikes firmly.

REPRESENTATIVE USES OF WOOD.
Railway ties, telegraph poles, posts, fencing, shingles, and boats.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

19.

MODULUS OF ELASTICITY.

750,000.

MODULUS OF RUPTURE.

7,200.

REMARKS.
The comparatively slender trunks are seldom cut up into lumber, but are used for poles; or else, the thin, upper ends are used for posts, and the lower parts are flattened and used for ties. The wood is remarkably durable. Hough describes a prostrate cedar tree over the trunk of which a hemlock, which later exhibited one hundred and thirty yearly bands, had taken root. The cedar tree had evidently been in contact with the ground for at least one hundred and thirty years, yet much of its wood was sound enough to be cut up into shingles.

most commonly known as Western Red Cedar

Canoe Cedar, Arborvitæ, Giant Arborvitæ. *Thuya plicata Don.* *Thuya gigantea Nutt.*

Nomenclature (Sudworth).
Canoe Cedar, Giant Arborvitæ (local and common names).
Red Cedar, Giant Red Cedar, Pacific Red Cedar (Wash., Oreg., Cal., Idaho).
Cedar, Giant Cedar, Western Cedar (Oreg., Cal.).
Shinglewood (Idaho).

Localities.
Coast region, California to Alaska, Idaho to Montana.

Features of Tree.
One hundred to two hundred feet in height; two to eleven feet in diameter; the trunks are often buttressed at the surface of the ground; the tiny, bright green leaves are scale-like.

Color, Appearance, or Grain of Wood.
Heartwood dull reddish brown; the thin sapwood is nearly white; coarse-grained; compact structure; annual layers distinct.

Structural Qualities of Wood.
Soft, weak, light, brittle, easily worked, and very durable.

Representative Uses of Wood.
Shingles, fencing, cooperage, interior finish and canoes.

Weight of Seasoned Wood in Pounds per Cubic Foot.
23.

Modulus of Elasticity.
1,460,000.

Modulus of Rupture.
10,600.

Remarks.
The large parts at the bottoms of the trees are usually hollow.

See also "Giant Arborvitæ *Thuya plicata Don*," (United States Forest Service Silvical Leaflet No. 11, 1907); "Western Red Cedar," Detwiler (American Forestry, March, 1916).

White Cedar. *Chamæcyparis thyoides L.*

NOMENCLATURE (Sudworth).
White Cedar (local and common name).
Post Cedar, Swamp Cedar (Del.).
Juniper (Ala., N. C., Va.).

LOCALITIES.
Maine to Florida, Gulf Coast to Mississippi; best in Virginia and North Carolina.

FEATURES OF TREE.
Sixty to eighty feet in height; three to four feet in diameter; shaggy, rugged bark; a graceful tree.

COLOR, APPEARANCE, OR GRAIN OF WOOD.
Heartwood pinkish brown to darker brown; sapwood lighter; close-grained; compact structure; conspicuous layers.

STRUCTURAL QUALITIES OF WOOD.
Very light and soft; not strong; extremely durable in exposed positions; fragrant; easily worked; White Cedar posts last for many years.

REPRESENTATIVE USES OF WOOD.
Boats, railway ties, fencing, poles, posts, and shingles.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.
23 (United States Forestry Division).[1]
20.

MODULUS OF ELASTICITY.
910,000 (average of 87 tests by United States Forestry Division).[1]
570,000.

MODULUS OF RUPTURE.
6,310 (average of 87 tests by United States Forestry Division).[1]
6,400.

REMARKS.
These trees often grow in swamps, as see footnote, page 86.

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[1] See p. 33.

Port Orford Cedar, Lawson Cypress. *Chamæcyparis lawsoniana Murr.*

NOMENCLATURE (Sudworth).

White Cedar, Oregon Cedar, (Oreg., Cal.). Ginger Pine (Cal.).

LOCALITIES.

Pacific Coast, California and Oregon.

FEATURES OF TREE.

One hundred to sometimes two hundred feet in height; four to ten feet in diameter; the leaves overlap in sprays; the very small cones are one-fourth of an inch in diameter.[1]

COLOR, APPEARANCE, OR GRAIN OF WOOD.

Heartwood yellowish-white; sapwood similar; very close-grained.

STRUCTURAL QUALITIES OF WOOD.

Light and hard; strong, durable, and easily worked; fragrant; resinous.

REPRESENTATIVE USES OF WOOD.

Lumber, flooring, interior finish, ties, posts, matches, and shipbuilding.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

28.

MODULUS OF ELASTICITY.

1,730,000.

MODULUS OF RUPTURE.

12,600.

REMARKS.

The resin is employed as an insecticide.

[1] See also "Port Orford Cedar," Pinchot (United States Silvical Leaflet No. 2).

The Yew (*Taxus*) yields a close-grained wood that suggests Cedar, save that it is tough like Hickory. The early Celtic races associated Yew trees with funerals. The wood was one of the "fighting woods" of the Greeks. The best Yew bow-staves came from Italy, Turkey and Spain, and were distributed through the Venetian markets. Spanish staves were once so important that they were controlled by the Spanish Government. More recently, European bows were backed with other and more plentiful woods. Yew is now occasionally employed for chairs, canes, and whips.

Pacific Coast Indians prized the Western, Oregon, or California Yew (*Taxus brevifolia*) for bows, paddles, and fish hooks. The Florida Yew (*Taxus floridana*) is another United States species. Ernest Thompson Seton classes American woods suitable for bows in order of excellence as follows: "Oregon Yew, Osage Orange, White Hickory, Elm, Cedar, Apple, etc."

Yellow Cedar, Yellow Cypress, Sitka Cypress.

{ *Chamæcyparis nootkatensis (Lamb) Spach*
  Chamæcyparis nutkaënsis Spach

NOMENCLATURE (Sudworth).
Nootka Cypress, Nootka Sound Cypress (local).
Alaska Cypress, Alaska Ground Cypress (local).

LOCALITIES.
Oregon to Alaska.

FEATURES OF TREE.
One hundred or more feet in height; three to five or more feet in diameter; sharp-pointed, overlapping leaves; small, globular cones.

COLOR, APPEARANCE, OR GRAIN OF WOOD.
Heartwood clear light yellow; thin sapwood nearly white; close-grained; compact structure.

STRUCTURAL QUALITIES OF WOOD.
Light, not strong, brittle, and hard; durable in contact with soil; easily worked; receives a high polish; fragrant.

REPRESENTATIVE USES OF WOOD.
Ship-building, furniture, and interior finish.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

29.

MODULUS OF ELASTICITY.

1,460,000.

MODULUS OF RUPTURE.

11,000.

REMARKS.
A valuable lumber tree.

Incense Cedar, White Cedar. { *Libocedrus decurrens Torr.* / *Heyderia decurrens.* }

NOMENCLATURE (Sudworth).

Post Cedar, California Post Cedar (local).

California White Cedar (local).

Juniper (Nevada).

Bastard Cedar, Red Cedar.

LOCALITIES.

California, Lower California, Oregon, and Nevada.

FEATURES OF TREE.

Ninety to one hundred and twenty-five feet in height, occasionally higher; three to six feet in diameter.

COLOR, APPEARANCE, OR GRAIN OF WOOD.

Heartwood brownish; sapwood lighter; close-grained; compact structure; heartwood often pitted; fragrant.

STRUCTURAL QUALITIES OF WOOD.

Light, brittle, soft, and durable.

REPRESENTATIVE USES OF WOOD.

Posts, Flumes, shingles, and interior finish. Pencils greatest use.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

25.

MODULUS OF ELASTICITY.

1,200,000.

MODULUS OF RUPTURE.

960,000.

REMARKS.

The heartwood of these trees is often attacked by fungi that create large, oval pits. The wood between the decayed spaces is apparently sound, even in living trees. The disease stops when the trees are felled, and the wood that remains is so durable that it can be used for posts or for other purposes where appearance is not important. Some dealers charge as much for wood with pits as for that without pits. This disease is similar to the diseases that attack Cypress and Red Cedar. It is said that about one-half of the standing supply of Incense Cedar has been affected by this disease, which is popularly known as "pin rot" (see also von Schrenk, Contribution No. 14, Shaw School of Botany).

CYPRESS

Cupressus and Taxodium

The name Cypress has been applied to trees of the genera *Chamœcyparis, Cupressus,* and *Taxodium.* Most of the species of the genus *Chamœcyparis* are now classed as Cedars. The genus Cupressus includes true Cypresses, and is important in Europe, but the trees themselves, rather than their woods, are valued in the United States. The single species of the genus Taxodium is not a Cypress, but the trees of this species supply the "cypress wood" of American commerce. The name Cypress will be applied only to the true Cypresses (*Cupressus*), and to the commercial Cypress (*Taxodium*).

True cypress wood is mentioned by Herodotus and other ancient authors, and is construed by some to have been the "Gopher wood" of which the Ark was built.[1] Pliny mentions cypress doors that were good after four hundred years, and a cypress statue that was preserved for six hundred years. It is said that the cypress gates of the early Saint Peter's, removed after one thousand years of service, were found to be in excellent condition.[2] Cypress wood has been prized for mummy cases, and cypress trees are yet planted as funeral emblems over graves in Turkey and in Italy.[3] The common or evergreen Cypress is the principal species in Europe. The eight or nine American species (*Cupressus*) do not produce valuable woods, but the trees are sometimes used for ornamentation, as in hedges.

The Monterey Cypress (*Cupressus macrocarpa*) is evidenced by a group of trees that includes the only original specimens of this species that survive in the United States. The famous "seventeen mile drive" near Monterey, California, passes through the district in which these trees are located. Their weird forms, with gnarled, wind-beaten branches, are very unusual. The fact that transplanted specimens of the Monterey Cypress grow so readily in many places on the Pacific Coast is hard to reconcile with the further fact that so few of the original trees remain at the present time.

American Cypress wood is obtained from the Bald Cypress (*Taxodium distichum*) which grows on submerged lands and in deep swamps, making unusual logging methods necessary. The trees are subject to a peculiar fungus disease that causes cavities such as would be made by driving pegs into the wood and then withdrawing them, and wood thus affected is known as "peggy cypress." The disease ceases as soon as trees are felled, and wood then cut from them is as durable as wood cut from perfectly healthy trees. About one-third of the standing supply is affected. American Cypress wood has many names. Pieces that float and pieces that sink in water have been classed as White Cypress and Black Cypress respectively. All dark pieces are now classed as Black Cypress, while the tinted woods are sometimes sold under the names of Red Cypress and Yellow Cypress.[4]

The Bald Cypress bears needle-like leaves, which are about three-fourths of an inch in length, and separated from one another. They are not arranged in tufts as in the case of the larch, yet the foliage resembles that of the larch, in that it is shed at the end of the season. The name Bald Cypress is due to the appearance of the trees after the leaves have fallen. The roots that appear above the surface of the surrounding soil or water are known as "cypress knees."

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[1] Pliny, 16, 214 and 16, 215; Herodotus, 4, 16; Virgil, Georgics, 2, 443. Funk & Wagnalls' Standard Dictionary, quoting Horace Smith, "Gayeties and Gravities," Chapter VII, p. 57.

[2] Encyclopædia Britannica, B. 6, p. 745.

[3] Brockhaus, Konversations-Lexikon, B. 4, p. 654.

[4] See also von Schrenk, (Contribution No. 14, Shaw School of Botany); "Uses of Commercial Woods of the United States," Hall and Maxwell (United States Forest Service, Bulletin No. 95, 1911); "The Cypress and Juniper Trees of the Rocky Mountain Region," Sudworth (United States Department of Agriculture, Bulletin No. 207); "The Southern Cypress," Matoon (United States Department of Agriculture, Bulletin No. 272, 1915); "The Bald Cypress," Detwiler (American Forestry, October, 1916).

Cypress, Bald Cypress. *Taxodium distichum Rich.*

NOMENCLATURE (Sudworth).

White Cypress (N. C., S. C., Fla., Miss.).
Black Cypress (N. C., S. C., Ala., Tex.).
Red Cypress (Ga., Miss., La., Tex.).
Swamp Cypress (La.).
Deciduous Cypress (Del., Ill., Tex.).
Southern Cypress (Ala.).

LOCALITIES.

South Atlantic and Gulf States, Maryland, through Florida to Texas, Mississippi Valley from southern Illinois to the Gulf. Forms forests in swamps and barrens.[1]

FEATURES OF TREE.

Seventy to one hundred and fifty feet in height; four to ten feet in diameter; the knees on the roots often become hollow with old age; the leaves are flat and deciduous.

COLOR, APPEARANCE, OR GRAIN OF WOOD.

Heartwood brownish; sapwood nearly white; close, straight grain; the trunks are frequently pitted by disease.

STRUCTURAL QUALITIES OF WOOD.

Light and soft; not strong; durable; green wood is often very heavy.

REPRESENTATIVE USES OF WOOD.

Carpentry, construction, cooperage, and railway ties.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

29 (United States Forestry Division).[1]
28.

MODULUS OF ELASTICITY.

1,290,000 (average of 655 tests by United States Forestry Division).[2]
1,460,000.

MODULUS OF RUPTURE.

7,900 (average of 655 tests by United States Forestry Division).[2]
9,600.

REMARKS.

Cypress is often divided into "White Cypress" and "Black Cypress," the difference being probably due to differences in the ages and environment of the trees from which these two grades were cut. Cypress trees are often attacked by fungi that create pits in the wood. The disease stops when the trees are felled, and the wood that remains is very durable. This disease is similar to others that attack Incense Cedar trees and Red Cedar trees.

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[1] See "Transactions American Institute of Mining Engineers" (Vol. XXIX, p. 157).

[2] See p. 33.

REDWOOD

Sequoia

These trees grow in California. There are two species as follows:

The Common Redwood (*Sequoia sempervirens*) grows near the coast line where it is said to "follow the fogs." The trees are large and very perfect. The soft, light, clean, reddish-brown wood works easily and can be obtained in large-sized pieces.

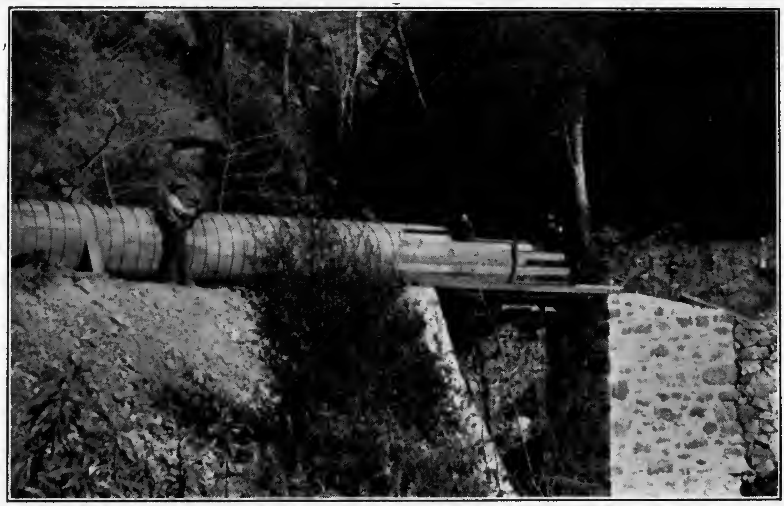

FIG. 29.—Assembling parts of redwood stave pipe.

The wood resists fire more than many others and is extremely durable in exposed places. It repels some forms of terrestrial wood-borers, but has given way before the attacks of shipworms. It is used for fence posts, railway ties, water-pipes, house-trim, flumes, coffins, and shingles. Average pieces are often used in cheaper forms of indoor finish, while unusual and attractive pieces, in which grain is distorted, are classed as Curly Redwood and preferred in a better grade of work.

Some of the trees of this species are so large that they have been confused with the exceptional or "giant" specimens of the Mammoth Redwood. The fire-resisting qualities of the wood were shown in the buildings that existed in San Francisco before the earthquake. Redwood was largely employed in these buildings, yet comparatively few fires took place until the conflagration caused by the earthquake. Durability is shown by trunks that fell in the forests one hundred or more years ago. Some of these trunks not only have not rotted, but contain good wood that can be used in construction. Resistance to attacks by land wood-borers is shown by the stave-pipes used in irrigation work in the West. These pipes usually remain safe from attack as long as the wood remains wet and in use. It should be noted, however, that they are sometimes attacked by termites while dry.

Fig. 30.—Completed redwood stave pipe with gate.

The Mammoth Redwood (*Sequoia washingtoniana*) is found inland where there is less moisture. Some of the trees are the most massive, although not the tallest, trees known to man. Individuals three hundred and twenty feet high and thirty-five feet in diameter have been measured. It is estimated that some specimens twenty-five feet in diameter were thirty-six hundred years old, and it is thought probable that under favorable conditions such trees could have survived for a total of five thousand years. The almost non-inflammable bark is sometimes nearly two feet in thickness. Even the oldest trees are sound throughout. The wood is brittle, but otherwise resembles and is seldom distinguished commercially from the wood of the Common Redwood. Many of the smaller trees of this species are cut down every year, but the largest trees are now protected or used for exhibition purposes. Most of these exceptional trees have names such as the "Pride of the Forest," the "Grizzly Giant," and the "U. S. Grant." These exceptional specimens, which do not exceed several hundred in number, are grouped in the Mariposa, Calavaras, and other groves.

The genus is notable, first, because of the present value of the wood, and second, because the quick-growing, healthy trees are likely to resist commercial extinction. The name Sequoia is that of an Indian Chief. Redwood trees may be known by their size and locality, and also by their fine, dull, evergreen leaves.[1]

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[1] See also "The Big Trees of California" (United States Forestry Division Bulletin No. 28); "The Bigtree," Sudworth (United States Forest Service Silvical Leaflet No. 19); "Redwood" (United States Forest Service Bulletin No. 38); "Mechanical Properties of Redwood," Heim (United States Forest Service, Circular No. 193, 1912); "The Secret of the Big Trees," Huntington (United States Department of Interior, Document); "Uses of Commercial Woods of the United States," Hall and Maxwell (United States Forest Service, Bulletin No. 95, 1911).

Redwood. *Sequoia sempervirens (Lamb.) Endl.*

NOMENCLATURE (Sudworth).

Redwood (local and common name).

Sequoia, California Redwood, Coast Redwood (local).

LOCALITIES.

Central and North Pacific Coast region.

FEATURES OF TREE.

Two hundred to three hundred feet in height, sometimes higher; six to eight and sometimes twenty feet in diameter; straight, symmetrical trunk; low branches are rare.

COLOR, APPEARANCE, OR GRAIN OF WOOD.

Thick heartwood red, changing to reddish brown when seasoned; thin sapwood nearly white; coarse, normally straight grain; compact structure; very thick bark.

STRUCTURAL QUALITIES OF WOOD.

Light and soft; not strong; very durable; easily worked, and receives a high polish; not resinous, and does not burn easily.

REPRESENTATIVE USES OF WOOD.

Timber, shingles, flumes, fence-posts, coffins, railway ties, water-pipes, and interior decoration; the bark is made into souvenirs.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

26 (Census figure, see p. 33).

MODULUS OF ELASTICITY.

790,000 (average of 8 Humboldt specimens).[1]
1,140,000 (average of 7 Humboldt specimens).[1]
960,000 (Census figure, see p. 33).

MODULUS OF RUPTURE.

4,920 (average of 9 Humboldt specimens).[1]
7,138 (average of 7 Mendocino specimens).[1]
8,400 (Census figure, see p. 33).

REMARKS.

Redwood is the principal construction wood of California. Occasional pieces with curled or distorted grain are valued for minor cabinet work.

The Bigtree, Mammoth Tree, or Giant Redwood (*Sequoia washingtoniana*) is the largest tree known to man. The wood, which resembles that of the Common Redwood, is used locally. See also "Bigtree, *Sequoia washingtoniana* (*Winsl.*) *Sudw.*" (United States Forest Service, Silvical Leaflet No. 19, 1908); etc., etc.

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[1] Soulé, Transactions American Institute of Mining Engineers (California Meeting, 1899).

CHAPTER VI

Banded Trunks and Woods (Continue.)
Broadleaf Series. Part One

Dicotyledons

The trees of the Broadleaf Series grow in natural forests and under cultivation in many parts of the world. The Oaks, Elms, Maples, and other so-called hardwood trees are of this group.

Broadleaf woods are comparatively heavy in weight and, in most cases, the arrangement of the wood-elements is more complicated than in the woods of the Coniferous series. Broadleaf woods are difficult to work in proportion as they are complicated in cellular structure. Tiemann has compared the cellular structure of broadleaf woods with the cellular structure of coniferous woods as follows:[1]

> "The wood of the angiosperms (broadleaf woods), on the other hand, is much more complex, as the vertical cells are exceedingly variable both in size and character. The vertical cells, consisting of wood-fibers, vessels, tracheids, and others, in some species of the angiosperms, are often of four or five distinct kinds, and vary in size and shape from the finest hair of a few millimeters in length, to the long vessels as large as the lead in a lead-pencil. There are also short, thin-walled cells interspersed. The Oak is one of the most complex woods in this respect, while the Red Gum and the Tulip are comparatively simple.
>
> In the Conifers, it is the tracheids which give the strength to the wood, but in the angiosperms it is the long, narrow, hair-shaped cells or wood-fibers which are the chief parts of the structure producing the strength. The latter are usually grouped in bunches and form the principal structural feature in the angiosperms. In the late wood of the annual rings, their walls, compared to their diameters, become exceedingly thick. These also have pits, but of a simpler kind, which are slit-like and known as "simple pits."

Broadleaf woods are used in construction, although the greater need as to quantity in this field is met by the woods of the other series. Woods for cabinet purposes and implements are drawn from the present group which, with a few exceptions, cannot be depended upon for the large, straight pieces so often obtained from coniferous trees.

The comparatively broad leaves of the trees of this series are usually distinguished from the more or less needlelike, resinous leaves of the conifers. Most, but not all, broadleaf trees are deciduous, and many, but not all, of the woods are comparatively hard. The names "deciduous" and "hardwood" are less satisfactory than the name "Broadleaf," which should be preferred.

[1] "Wood Preservation" (American Railway Engineering and Maintenance of Way Association, Bulletin No. 120, p. 361).

OAK

Quercus

The Oaks grow in many parts of the northern hemisphere, and at high altitudes just south of the equator. The historical importance of the wood was founded upon the reputation of the English Oaks (*Quercus robur var. pedunculata* and *Quercus robur var. sessiliflora*),[1] which once formed large forests over parts of northern and central Europe.

The woods were formerly relied upon to meet many needs in ships and houses, and did not give way to iron for vessels, and to the so-called softwoods for houses, until comparatively recent periods. Practically all ships were built of wood until the battle of the Merrimac and the Monitor; and oaken timbers were used in many English houses, even of the cottage type, until the supplies of softwoods from the Baltic forests and from those of North America became easily available. Oak is yet used for railway ties and high-grade construction timbers, but to a more limited extent than formerly; while the demands for oak to be used in cabinet work are constantly increasing.

Oak wood is tough and durable in contact with the ground. It receives a high polish and is more or less easily obtained. On the other hand, it is liable to warp and check in seasoning, and hard to nail without splitting. It contains gallic acid, which attacks iron fastenings. Experiments indicate that the iron is eventually protected by the formation of a scale, and that the wood, although darkened, remains practically uninjured. Oak bark is so charged with gallic acid that it is used in the tanning of leather.

An experiment made to determine the effect of gallic acid upon iron[2] was as follows: Five grams of clean iron wire were immersed in a 5 per cent. solution of gallic acid. In nine days the weight was 4.720 grams and the solution intensely black. Thirteen days later the same specimen weighed 4.7453 grams. The fact that the iron increased in weight during the last thirteen days, was thought to indicate the formation of a crust, which probably protected it to some extent.

Oak trees commonly require many years to reach maturity but are then usually long lived. The leaves of some species are deciduous, while those of others are evergreen. Oak trees bear oblong thin-shelled kernels which protrude from hard scaly cups and are known as acorns. In the United States the woods are grouped under three heads as follows:

The White Oaks.—These woods, which are more or less easily obtained, are preferred for most purposes. The principal sources are White Oak (*Quercus alba*), Cow Oak (*Quercus michauxii*), Chestnut Oak (*Quercus prinus*), Post Oak (*Quercus minor*), Bur Oak (*Quercus macrocarpa*), Pacific Post Oak (*Quercus garryana*).

The Red or Black Oaks.—These woods are inferior to the others, but are yet very valuable. The principal sources are Red Oak (*Quercus rubra*), Pin Oak (*Quercus palustris*), Spanish Oak (*Quercus digitata*), Yellow or Black Oak (*Quercus velutina*).

The Live Oaks.—The Live Oaks, which are among the hardest and most durable of all construction woods, were formerly valued for ship building. The supply is now limited. The name is due to the "live" or evergreen leaves. The principal sources are Live Oak (*Quercus virginiana*), California Live Oak (*Quercus agrifolia*), Live Oak (*Quercus chrysolepis*).

[1] Usually taken as sub-species or varieties of the species *Quercus robur*, but thought by some botanists to be distinct species, namely, *Quercus pedunculata* and *Quercus sessiliflora*.

[2] Havemeyer Chemical Laboratory of New York University.

White Oak. *Quercus alba Linn.*

NOMENCLATURE.
White Oak (general). Stave Oak (Ark.).

LOCALITIES.
Widespread throughout north-central and eastern United States.

FEATURES OF TREE.
Seventy-five to one hundred and fifty feet in height; three to six feet in diameter; fine shape and appearance; grayish-white bark; comparatively sweet, ovoid, oblong acorns in rough, shallow cups; the leaves are blunt, they are not bristle-tipped.

COLOR, GRAIN, OR APPEARANCE OF WOOD.
Heartwood brown with sapwood lighter; annual layers are well marked; medullary rays are broad and prominent.

STRUCTURAL QUALITIES OF WOOD.
Tough, strong, heavy and hard; liable to check unless seasoned with care; durable in contact with the soil; receives a high polish.

REPRESENTATIVE USES OF WOOD.
Ship-building, construction, cooperage, cabinet-making, railway ties, fuel, etc. The bark is rich in tannin.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.
50 (United States Forestry Division).[1]
46.

MODULUS OF ELASTICITY.
2,090,000 (average of 218 tests by United States Forestry Division).[1]
1,380,000.

MODULUS OF RUPTURE.
13,100 (average of 218 tests by United States Forestry Division).[1]
12,800.

REMARKS.
The best known of the American oaks. A tree of the first economic importance. The cellular arrangement of the wood is complicated, and, for this reason, the wood is hard to season. It stands well, however, after it has once been seasoned.[2]

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[1] See p. 33.

[2] See also "White Oak," Pinchot (United States Forest Service, Circular No. 106, 1907); "The American White Oak," Detwiler (American Forestry, January, 1916); etc.

Cow Oak. *Quercus michauxii Nutt.*

NOMENCLATURE (Sudworth).

Cow Oak (local and common name).
Basket Oak (Ala., Miss., La., Tex., Ark.).
Swamp White Oak (Del., Ala.).
Swamp Chestnut Oak (Fla.).

LOCALITIES.

Southeastern United States, Delaware, and Florida, westward along the Gulf to Texas; also southern Indiana and Illinois to the Gulf; best on rich bottoms in Arkansas and Louisiana.

FEATURES OF TREE.

Seventy-five to one hundred feet in height; three to six feet in diameter; rough, light-gray bark with loose, scaly ridges; the leaves are only shallowly toothed; the blunt teeth are not bristle-tipped.

COLOR, APPEARANCE, OR GRAIN OF WOOD.

Heartwood light-brown; sapwood light-buff; conspicuous medullary rays; close-grained.

STRUCTURAL QUALITIES OF WOOD.

Hard, heavy, very strong, tough, durable, and easily split.

REPRESENTATIVE USES OF WOOD.

Construction, agricultural implements, and wheel-stock.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

46 (United States Forestry Division).[1]
50.

MODULUS OF ELASTICITY.

1,610,000 (average of 256 tests by United States Forestry Division.)[1]
1,370,000.

MODULUS OF RUPTURE.

11,500 (average of 256 tests by United States Forestry Division).[1]
15,800.

REMARKS.

The principal white oak of the Southern States; the acorns are devoured by cattle, whence its name.

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[1] See p. 33.

Chestnut Oak. *Quercus prinus Linn.*

NOMENCLATURE (Sudworth).

Chestnut Oak (local and common name).
Rock Oak (N. Y., Del., Pa.).
Rock Chestnut Oak (Mass., R. I., Pa., Del., Ala.).
Tanbark Oak (N. C.).
Swamp Chestnut Oak (N. C.).
Mountain Oak (Ala.).

LOCALITIES.

Maine to Georgia, westward intermittently to Kentucky, Tennessee, and Alabama; best development in southern Alleghany Mountain region.

FEATURES OF TREE.

Seventy-five to eighty feet in height; three to four feet in diameter; the leaves resemble those of the Chestnut (*Castanea dentata*); the shallow teeth are not bristle-tipped.

COLOR, APPEARANCE, OR GRAIN OF WOOD.

Heartwood dark-brown; sapwood lighter; close-grained; conspicuous medullary rays.

STRUCTURAL QUALITIES OF WOOD.

Heavy, tough, hard, strong, and durable in contact with the soil.

REPRESENTATIVE USES OF WOOD.

Largely used for railway ties. The bark is rich in tannin.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

46.

MODULUS OF ELASTICITY.

1,780,000.

MODULUS OF RUPTURE.

14,600.

REMARKS.[1]

[1] See also "Chestnut Oak, *Quercus prinus Linn.*" (United States Forest Service, Silvical Leaflet, No. 41, 1908).

Post Oak. { *Quercus minor Sargent* / *Quercus obtusiloba Michx.* / *Quercus stellata Wang* }

NOMENCLATURE (Sudworth).

Post Oak (local and common name).
Iron Oak (Del., Miss., Neb.).
Box White Oak (R. I.).
Chêne étoilé (Quebec).
Overcup Oak (Fla.).
White Oak (Ky., Ind.).
Box Oak (Md.)
Brash Oak (Md.).

LOCALITIES.

East of Rocky Mountains—Nebraska and the Gulf States, eastward intermittently to Massachusetts and northern Florida.

FEATURES OF TREE.

Fifty to seventy feet in height; two to three feet in diameter; a low shrub in Florida; there are blunt lobes or projections to the leaves; the deeply-cut lobes are not bristle-tipped; the leaves are clustered at the ends of the branches; a fine tree with a rounded top.

COLOR, APPEARANCE, OR GRAIN OF WOOD.

Heartwood light or dark brown with lighter sapwood; close-grained; annual rings well marked; numerous and conspicuous medullary rays.

STRUCTURAL QUALITIES OF WOOD.

Heavy, hard, and strong; checks badly in drying; durable in contact with the soil.

REPRESENTATIVE USES OF WOOD.

Largely used, particularly in the Southwest, for fencing, railway ties, and fuel; also for cooperage, construction, etc.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

50 (United States Forestry Division).[1]
52.

MODULUS OF ELASTICITY.

2,030,000 (average of 49 tests by United States Forestry Division).[1]
1,180,000.

MODULUS OF RUPTURE.

12,300 (average of 49 tests by United States Forestry Division).[1]
12,900.

REMARKS.

A common tree in the Gulf States west of the Mississippi River. The wood of this species is seldom distinguished commercially from that of white oak.

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[1] See p. 33.

Bur Oak. *Quercus macrocarpa Michx.*

NOMENCLATURE (Sudworth).

Bur Oak (local and common name).
Overcup Oak (R. I., Del., Pa., Miss., La., Ill., Minn.).
Mossycup White Oak (Minn.).
Mossycup Oak (Mass., Pa., Del., Miss., La., Tex., Ark., Ill., Iowa, Neb., Kan.).
Scrub Oak (Neb., Minn.).
Overcup White Oak (Vt.).

LOCALITIES.

Nova Scotia to Manitoba, Wyoming, Georgia, and Texas.

FEATURES OF TREE.

Seventy to one hundred and thirty feet in height; five to seven feet in diameter; deep, opposite depressions in leaves; the deeply-cleft lobes are not bristle-tipped; this is the only Oak yielding structural woods which bears acorns with mossy, fringed borders around their cups; there are corky ridges on the twigs and young branches.

COLOR, APPEARANCE, OR GRAIN OF WOOD.

Heartwood rich brown; sapwood lighter; close-grained; broad, conspicuous medullary rays.

STRUCTURAL QUALITIES OF WOOD.

Heavy, hard, strong, tough, and very durable in contact with the ground.

REPRESENTATIVE USES OF WOOD.

Similar to those of the White Oak (*Quercus alba*).

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

46.

MODULUS OF ELASTICITY.

1,320,000.

MODULUS OF RUPTURE.

13,900.

REMARKS.

The range extends farther into the West and Northwest than that of other Eastern oaks. The Bur Oak has been recommended for planting on the prairies.[1]

[1] See also "Bur Oak," Pinchot (United States Forest Service, Circular No. 56, 1907).

White Oak. *Quercus garryana Douglas*

NOMENCLATURE (Sudworth).

White Oak (Cal., Oreg.).
Pacific Post Oak (Oreg.).
Western White Oak (Oreg.).
Oregon White Oak (Cal.).
California Post Oak.

LOCALITIES.

Pacific Coast, British Columbia into California.

FEATURES OF TREE.

Sixty to ninety feet high; one and one-half to two and one-half feet in diameter; a small shrub at high elevations; the rounded lobes of the leaves are not bristle-tipped.

COLOR, APPEARANCE, OR GRAIN OF WOOD.

Heartwood light-brown or yellow; sapwood lighter, often nearly white; compact structure; distinctly-marked annual rings; medullary rays often conspicuous.

STRUCTURAL QUALITIES OF WOOD.

Heavy, strong, hard, and tough.

REPRESENTATIVE USES OF WOOD.

Ship-building, carriages, furniture, indoor decoration, and fuel.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

46.

MODULUS OF ELASTICITY.

1,150,000.

MODULUS OF RUPTURE.

12,400.

REMARKS.

Locally, this tree is important. The best substitute for Eastern White Oak produced on the Pacific Coast.[1]

The Weeping, Valley, Swamp, White, or California White Oak (*Quercus lobata*), a native of central-western California, is one of the largest and most symmetrical of all oaks. It adds to landscapes where it grows as the elms add to landscapes in the East. The brittle wood is seldom used in construction, but is an important local fuel.

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[1] See also "Oregon Oak," Graves (United States Forest Service, Silvical Leaflet No. 52, 1912).

Red Oak. *Quercus rubra Linn.*

NOMENCLATURE (Sudworth).

Red Oak (local and common name). Spanish Oak (Pa., N. C.).
Black Oak (Vt., Conn., N. Y., Wis., Ia., Neb., So. Dak., Ont.).

LOCALITIES.

East of the Rocky Mountains, Nova Scotia to Florida, westward intermittently to Nebraska and Kansas; best in Massachusetts.

FEATURES OF TREE.

Ninety to one hundred feet in height; three to six feet and over in diameter; the brownish-gray bark is smooth on the branches; the leaves have sharp-pointed, bristle-tipped lobes; there are relatively small acorns in flat, shallow cups; a fine, complete tree.

COLOR, APPEARANCE, OR GRAIN OF WOOD.

Heartwood light-brown or red; sapwood lighter; coarse-grained; well-marked annual rings; medullary rays few, but broad.

STRUCTURAL QUALITIES OF WOOD.

Heavy, hard, and strong; inclined to check in drying; acid; red oak is inferior to white oak.

REPRESENTATIVE USES OF WOOD.

Works of secondary importance, clapboards, cooperage, and fuel.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

45 (United States Forestry Division).[1]
40.

MODULUS OF ELASTICITY.

1,970,000 (average of 57 tests by United States Forestry Division).[1]
1,600,000.

MODULUS OF RUPTURE.

11,400 (average of 57 tests by United States Forestry Division).[1]
14,000.

REMARKS.

The Red Oak grows more rapidly than other oaks. The bark is used in tanning.

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[1] See p. 33.

Pin Oak. *Quercus palustris*

NOMNECLATURE (Sudworth).
Pin Oak (local and common name).
Swamp Spanish Oak (Ark., Kan.).
Water Oak (R. I., Ill.).
Swamp Oak (Pa., Ohio, Kans.).
Water Spanish Oak (Ark.).

LOCALITIES.
Massachusetts, Michigan, and Missouri, southward to Virginia, Tennessee, and Oklahoma.

FEATURES OF TREE.
Fifty to eighty feet in height; two to four feet in diameter; a full-rounded or pyramidal top; the bark is thin and smooth; there are numerous small, pin-like branches; the leaves are deeply-cleft; their lobes are bristle-tipped.

COLOR, APPEARANCE, OR GRAIN OF WOOD.
Heartwood variegated light-brown; sapwood nearly white; coarse-grained; medullary rays numerous and conspicuous.

STRUCTURAL QUALITIES OF WOOD.
Heavy, hard, and strong; checks badly in seasoning.

REPRESENTATIVE USES OF WOOD.
Shingles, clapboards, construction, interior finish, and cooperage.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

43.

MODULUS OF ELASTICITY.

1,500,000.

MODULUS OF RUPTURE.

15,400.

REMARKS.
The numerous slender, secondary branches suggest pins and cause the tree to be easily recognized, even in winter.

Spanish Oak. { *Quercus digitata Sudworth*
Quercus falcata Michx.
Quercus triloba }

NOMENCLATURE (Sudworth).
Spanish Oak (local and common name).
Red Oak (N. C., Va., Ga., Fla., Ala., Miss., La., Ind.).

LOCALITIES.
New Jersey and Florida, westward intermittently to Illinois and Texas; most abundant in the Gulf States.

FEATURES OF TREE.
Thirty to seventy feet in height; two and one-half to four feet in diameter; variable foliage; the deeply-cleft, sharp-pointed leaves are bristle-tipped; the acorns are globular to oblong.

COLOR, APPEARANCE, OR GRAIN OF WOOD.
Heartwood light-red; sapwood lighter; coarse-grained; the annual layers are strongly marked; the medullary rays are few, but conspicuous.

STRUCTURAL QUALITIES OF WOOD.
Hard, heavy, and strong; not durable; checks badly in drying.

REPRESENTATIVE USES OF WOOD.
Somewhat used for cooperage, construction, etc. The bark is very rich in tannin.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

43.

MODULUS OF ELASTICITY.

1,900,000.

MODULUS OF RUPTURE.

16,900.

REMARKS.
Grows rapidly, often on dry, barren soil.

Black Oak, Yellow Oak. { *Quercus velutina Lam.* / *Quercus tinctoria Michaux* }

Nomenclature (Sudworth).
Black Oak, Yellow Oak (local and common names).
Yellow Bark, Yellow-bark Oak (R.I., Minn.).
Dyer's Oak (Tex.).
Tanbark Oak (Ill.).
Spotted Oak (Mo.).
Quercitron Oak (Del., S. C., La., Kans., Minn.).

Localities.
East of longitude 96 degrees; Maine and Florida, westward intermittently to Minnesota and Texas; best in North-Atlantic States.

Features of Tree.
Ninety to one hundred and thirty feet in height; three to five feet in diameter; dark-gray to black bark; yellow inner bark; the acorns have bitter, yellow kernels; the foliage turns handsomely in the autumn; the sharply-cleft leaves are bristle-tipped.

Color, Appearance, or Grain of Wood.
Heartwood light reddish-brown; sapwood lighter; coarse-grained; the annual layers are strongly marked; the medullary rays are thin.

Structural Qualities of Wood.
Heavy, hard, and strong; liable to check in drying; not tough.

Representative Uses of Wood.
Cooperage, construction, furniture, and decoration.

Weight of Seasoned Wood in Pounds per Cubic Foot.
45 (United States Forestry Division).[1]
44.

Modulus of Elasticity.
1,740,000(average of 40 tests by United States Forestry Division).[1]
1,470,000.

Modulus of Rupture.
10,800 (average of 40 tests by United States Forestry Division).[1]
14,800.

Remarks.
The yellow inner bark affords a yellow dye

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[1] See p. 33.

Live Oak. { *Quercus virginiana Mill.* / *Quercus virens Ait.* }

NOMENCLATURE (Sudworth).

Live Oak (Va., N. C., S. C., Ga., Fla., Miss., Ala., Tex., La., Cal.). Chêne Vert (La.).

LOCALITIES.

Atlantic Coast from Virginia to Florida, westward to Texas and Lower California; southern Mexico, Central America, and Cuba; a Southern species; grows best in South-Atlantic States.

FEATURES OF TREE.

Fifty to sixty feet in height; three to six feet in diameter; general resemblance to the Apple-tree; evergreen foliage; the oblong, blunt leaves are not bristle-tipped.

COLOR, APPEARANCE, OR GRAIN OF WOOD.

Heartwood light-brown or yellow; sapwood nearly white; close-grained; compact structure; the medullary rays are pronounced; the annual layers are often hardly distinguishable.

STRUCTURAL QUALITIES OF WOOD.

Heavy, strong, tough, and hard; difficult to work; splits easily; receives a high polish; very durable.

REPRESENTATIVE USES OF WOOD.

Ship-building.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

59.

MODULUS OF ELASTICITY.

1,600,000.

MODULUS OF RUPTURE.

14,000.

REMARKS.

The trunks and branches furnish small, straight pieces, but the principal yield is in knees and crooked or compass timbers. The wood splits so easily that it is often fastened with bolts or trenails, rather than with spikes. The trees, which are now scarce, grow rapidly.

California Live Oak. *Quercus agrifolia Nee*

Nomenclature (Sudworth).

Coast Live Oak (Cal.).
California Live Oak (Cal.).
Encena (Cal.).
Evergreen Oak (Cal.).

Localities.

California and Lower California.

Features of Tree.

Forty to seventy-five and occasionally more feet in height; three to six feet in diameter; evergreen foliage; the leaves are spiked like those of the Holly; the shape resembles that of the Apple-tree.

Color, Appearance, or Grain of Wood.

Heartwood creamy-white, darkens on exposure; compact structure; the annual layers are hardly distinguishable.

Structural Qualities of Wood.

Heavy and hard, but brittle.

Representative Uses of Wood.

Fuel.

Weight of Seasoned Wood in Pounds per Cubic Foot.

51.

Modulus of Elasticity.

1,350,000.

Modulus of Rupture.

13,200.

Remarks.

Live Oak. *Quercus chrysolepis Liebm.*

NOMENCLATURE (Sudworth).
Live Oak (Cal., Oreg.).
Canyon Live Oak, Black Live Oak, Golden-cup Oak (Cal.).
Canyon Oak, Iron Oak, Maul Oak, Valparaiso Oak (Cal.).

LOCALITIES.
West of the Rocky Mountains, in canyons and at high elevations.

FEATURES OF TREE.
Fifty to eighty feet in height; three to six feet in diameter; often a low shrub; impressive appearance; evergreen foliage; some leaves have smooth, thickened margins, but occasionally leaves have spiny-toothed margins.

COLOR, APPEARANCE, OR GRAIN OF WOOD.
Heartwood light-brown; sapwood lighter; there are small pores in the wide bands that are parallel to the conspicuous medullary rays; close-grained.

STRUCTURAL QUALITIES OF WOOD.
Hard, heavy, strong, tough, and difficult to work.

REPRESENTATIVE USES OF WOOD.
Implements, wagons, and tool-handles.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

52.

MODULUS OF ELASTICITY.

1,700,000.

MODULUS OF RUPTURE.

18,000.

REMARKS.
Said to be the most valuable of the California oaks. Grows at elevations of two thousand to five thousand feet. The Highland Live Oak (*Quercus wislizeni*) is an evergreen tree which also grows on the Pacific Coast. The Highland Live Oak differs from the Live Oak (*Quercus chrysolepis*) in the fact that the leaves of the former are *always* spiny-toothed.

English Oak. *Quercus robur var. pedunculata*

NOMENCLATURE.
English Oak. Common Oak.
British Oak.

LOCALITIES.
Widespread throughout northern and central Europe.

FEATURES OF TREE.
Seventy to one hundred feet in height; three to five feet in diameter; the branches are crooked, the leaves stalkless, and the acorns long-stalked.

COLOR, APPEARANCE, OR GRAIN OF WOOD.
Heartwood light-brown, darker spots frequent; sapwood lighter; compact structure.

STRUCTURAL QUALITIES OF WOOD.
Hard, tough, strong, and durable; difficult to work; liable to warp in seasoning.

REPRESENTATIVE USES OF WOOD.
Ship-building, beams, and cabinet-work; used formerly in carpentry.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.
51 (Laslett).

MODULUS OF ELASTICITY.
1,170,000 (Thurston).

MODULUS OF RUPTURE.
10,000 (Thurston).

REMARKS.
The English, Chestnut, Durmast, or Red Oak (*Quercus robur var. sessiliflora*), which is distinguished from the English Oak (*Quercus robur var. pedunculata*)[1] by its long leafstalks and its short acorn stalks, yields a similar but lower-rated wood. These two trees supply the "British Oak" of commerce. Dantzic, Rigi, and some other European oaks are in all probability really English Oaks, which are named from the ports from which they are shipped. Durmast Oak (*Quercus pubescens* or *Quercus robur intermedia*) is not as common as the English Oak (*Quercus robur var. pedunculata*) with which it is often confused. Laslett states that it is often hard to distinguish one of these woods from another without tracing the logs back to their original sources. Early authorities advised that these woods, which contain much gallic acid, should not be fastened with iron; but the woods are now better seasoned, and, as stated before, oak woods are now safely fastened with iron, at least in the United States.

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[1] As stated, these two trees are usually assumed to be sub-species or varieties of the species *Quercus robur*. But by some they are believed to be distinct species, that is, *Quercus pedunculata* and *Quercus sessiliflora*.

ASH

Fraxinus

These trees grow in many places in the temperate regions of the northern hemisphere.

The wood resembles oak in many particulars, but is coarser, lighter, easier to work, tougher, more elastic, and less attractive than oak. Ash seasons well, but does not last well when exposed to the weather. It is used for stairs, furniture, and some of the cheaper forms of cabinet work. Second-growth ash is tougher and more pliable than first-growth ash.[1]

Ash woods are often grouped under two heads: White Ash includes the lighter colored and more desirable pieces, while Black Ash includes the darker and inferior woods. This practical division agrees with the botanical division in the North, since in the North the only notable species are White Ash (*Fraxinus americana*) and Black Ash (*Fraxinus nigra*). The wood of the Green Ash (*Fraxinus lanceolata*) of the south is usually classed as White Ash. One-half of the thirty-nine known species of the genus Fraxinus are natives of North America.[2]

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[1] Trees that grow up after virgin forests are cut away afford what are known as "second-growth woods." Ordinarily, second-growth woods are inferior to first-growth woods, because second-growth woods, being younger, have more sapwood. In this case it is the sapwood that is often preferred.

[2] See also "The Ashes: Their Characteristics and Management," Sterrett (United States Department of Agriculture, Bulletin No. 299).

White Ash. *Fraxinus americana Linn.*

NOMENCLATURE (Sudworth).

White Ash (local and common name).
Ash (Ark., Ia., Wis., Ill., Mo., Minn.).
Cane Ash (Ala., Miss., La.).
American Ash (Ia.).

LOCALITIES.

Nova Scotia to Florida, westward intermittently to Minnesota and Texas; greatest development in the Ohio River basin.

FEATURES OF TREE.

Forty-five to ninety feet in height, occasionally higher; three to four feet in diameter; the dark-brown or gray-tinged bark is deeply divided by narrow fissures into broad, flattened ridges; the seeds have long wings.

COLOR, APPEARANCE, OR GRAIN OF WOOD.

Heartwood reddish-brown, usually mottled; sapwood much lighter, sometimes nearly white; coarse-grained; compact structure; the layers are clearly marked by large, open ducts; the medullary rays are often obscure.

STRUCTURAL QUALITIES OF WOOD.

Heavy, hard, strong, and elastic, becoming brittle with age; not durable in contact with the soil.

REPRESENTATIVE USES OF WOOD.

Agricultural implements, carriages, handles, oars, interior and cheap cabinet-work.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

39 (United States Forestry Division).[1]
40.

MODULUS OF ELASTICITY.

1,640,000 (average of 87 tests by United States Forestry Division).[1]
1,440,000.

MODULUS OF RUPTURE.

10,800 (average of 87 tests by United States Forestry Division).[1]
12,200.

REMARKS.

These valuable trees grow rapidly, particularly when on low, rather moist soil. They are not apt to form forests, but are usually found in clumps or mingled with trees of other species. Large trees sometimes have large heart-cracks. The trees are also subject to a fungus disease which reduces the wood to a useless, soft, pulpy, yellowish mass. This disease, which is known as white rot, progresses until the tree becomes so weak that it is blown over by the winds. The disease does not attack dead or seasoned woods. See also von Schrenk (United States Bureau of Plant Industry, Bulletin No. 32.)

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[1] See p. 33.

Red Ash. { *Fraxinus pennsylvanica Marsh* / *Fraxinus pubescens Lam.* }

NOMENCLATURE (Sudworth).

Red Ash (local and common name).
River Ash (R. I., Ont.).
Brown Ash (Mo.).
Black Ash (N. J.).
Ash (Neb.).

LOCALITIES.

New Brunswick to Florida, westward intermittently to the Dakotas and Alabama; best developed in the North-Atlantic States.

FEATURES OF TREE.

Rarely much over forty-five feet in height and about one foot in diameter.

COLOR, APPEARANCE, OR GRAIN OF WOOD.

Heartwood rich brown; sapwood light brown, streaked with yellow; coarse-grained; compact structure.

STRUCTURAL QUALITIES OF WOOD.

Heavy and hard; strong, but brittle.

REPRESENTATIVE USES OF WOOD.

Agricultural implements, handles, boats, oars, and paper-pulp.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

38.

MODULUS OF ELASTICITY.

1,154,000.

MODULUS OF RUPTURE.

12,300.

REMARKS.

Grows on borders of streams and swamps, in low, rich soil.

Blue Ash. *Fraxinus quadrangulata Michx.*

NOMENCLATURE (Sudworth).
Blue Ash (Mich., Ill., Ky., Mo., Ala.).

LOCALITIES.
Ontario and Minnesota, southward to Tennessee, Alabama, and Arkansas.

FEATURES OF TREE.
Fifty to seventy-five feet in height, occasionally higher; one to two feet in diameter; a slender tree; blue properties in inner bark; smooth, square twigs; leaves composed of seven to eleven pointed, rough-margined leaflets.

COLOR, APPEARANCE, OR GRAIN OF WOOD.
Heartwood light yellow, streaked with brown; sapwood lighter; close-grained; compact structure; satin-like appearance.

STRUCTURAL QUALITIES OF WOOD.
Hard and heavy, but brittle; not strong; the most durable of the Ash woods.

REPRESENTATIVE USES OF WOOD.
Largely used in flooring, carriage-building, pitchfork and other tool-handles.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

44.

MODULUS OF ELASTICITY.

1,100,000.

MODULUS OF RUPTURE.

11,500.

REMARKS.
Blue Ash trees grow best on limestone formations. The inner bark contains properties which give water a bluish tint. Blue Ash has no superior among the Ash woods. Blue Ash pitchfork-handles are highly prized.

Black Ash. { *Fraxinus nigra Marsh* / *Fraxinus sambucifolia Lam.* }

NOMENCLATURE (Sudworth).

Black Ash (local and common name).
Water Ash (W. Va., Tenn., Ind.).
Swamp Ash (Vt., R. I., N. Y.).
Brown Ash (N. H., Tenn.).
Hoop Ash (Vt., N. Y., Del., Ohio, Ill., Ind.).

LOCALITIES.

Newfoundland, through Canada to Manitoba, southward to Illinois, Missouri, and Arkansas.

FEATURES OF TREE.

Seventy to eighty feet in height; one to one and one-half feet in diameter; a thin tree; excrescences or knobs are frequent on trunks; dark, almost black, winter buds.

COLOR, APPEARANCE, OR GRAIN OF WOOD.

Heartwood dark brown; sapwood light brown, often nearly white; coarse-grained; compact structure; the medullary rays are numerous and thin.

STRUCTURAL QUALITIES OF WOOD.

Separates easily in layers; rather soft and heavy, tough, and elastic; not strong or durable when exposed.

REPRESENTATIVE USES OF WOOD.

Largely used for interior finish, fencing, barrel-hoops, cabinet-making, splint baskets, and chair-bottoms.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

39.

MODULUS OF ELASTICITY.

1,230,000.

MODULUS OF RUPTURE.

11,400.

REMARKS.

The Black Ash is found farther north than other Ash trees. It is one of the most slender of trees. The distorted grain in the excrescences, knobs, or burls, causes the wood from such burls to be prized for veneers.

Green Ash. { *Fraxinus lanceolata Borkh.* / *Fraxinus viridis Michx. f.* / *Fraxinus pennsylvanica var. lanceolata Sarg.* }

NOMENCLATURE (Sudworth).

Green Ash (local and common name).
Blue Ash (Ark., Iowa).
White Ash (Kans., Neb.).
Ash (Ark., Iowa).
Swamp Ash (Fla., Ala., Tex.).
Water Ash (Iowa).

LOCALITIES.

East of the Rocky Mountains—Vermont and northern Florida, intermittently to Utah and Arizona.

FEATURES OF TREE.

Forty to fifty feet in height; one to two feet in diameter; the upper and lower surfaces of the smooth leaves are bright green.

COLOR, APPEARANCE, OR GRAIN OF WOOD.

Heartwood brownish, sapwood lighter; rather coarse-grained; compact structure.

STRUCTURAL QUALITIES OF WOOD.

Hard, heavy, and strong, but brittle.

REPRESENTATIVE USES OF WOOD.

Similar to those of White Ash (*Fraxinus americana*).

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

39 (United States Forestry Division).[1]
44.

MODULUS OF ELASTICITY.

2,050,000 (average of 10 tests by United States Forestry Division).[1]
1,280,000.

MODULUS OF RUPTURE.

11,600 (average of 10 tests by United States Forestry Division.)[1]
12,700.

REMARKS.

Sometimes considered a variety of Red Ash (*Fraxinus pennsylvanica*).

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[1] See p. 33.

Oregon Ash. *Fraxinus oregona Nutt.*

NOMENCLATURE.
Oregon Ash (Cal., Wash., Oregon).

LOCALITIES.
Pacific Coast, British Columbia to southern California.

FEATURES OF TREE.
Fifty to occasionally seventy-five feet in height; one to one and one-half feet in diameter; the dark grayish-brown bark exfoliates in thin scales.

COLOR, APPEARANCE, OR GRAIN OF WOOD.
Heartwood brown; sapwood lighter; coarse-grained; compact structure; there are numerous thin medullary rays.

STRUCTURAL QUALITIES OF WOOD.
Rather light and hard, but not strong.

REPRESENTATIVE USES OF WOOD.
Furniture, carriage-frames, cooperage, and fuel.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

35.

MODULUS OF ELASTICITY.

1,200,000.

MODULUS OF RUPTURE.

9,400.

REMARKS.
One of the valuable deciduous trees of the Pacific Coast. Thrives only on moist soils and in moist climates.

The Toothache Trees (*Xanthoxylum americana* and *Xanthoxylum clava-herculis*) are known as Ash and Prickly Ash. The Gopher Wood (*Cladrastis tinctoria*) is Yellow Ash. These woods are not important.

The name "Mountain Ash" is applied to several species (*Sorbus americana* and *Sorbus sambucifolia*) that yield bright red berries and soft, light, close-grained, practically valueless woods. The trees are related to the apple.

Most trees that yield edible fruits are valued for the fruits, and are not normally cut in large quantities for wood.

The Apple (*Pyrus malus*). These trees originated in Europe, but are now common in all temperate climates. They are seldom much over thirty feet in height, and normally afford hard, heavy, close-grained, brittle woods, that are liable to warp during seasoning. The woods are suitable for implements and tool handles. Many varieties of Apple have been perfected by cultivation.[1]

The Sweet or American Crab Apple Trees (*Pyrus coronaria*) grow in many places from Massachusetts and Nebraska southward to Georgia and Texas. The trees are seldom more than twenty-five feet in height and one foot in diameter. The hard, close-grained wood is occasionally used in turnery. The trees are prized in landscape effects because of their sweet-scented blossoms.

The Oregon Crab Apple (*Pyrus rivularis*) grows on the Pacific Coast from California to Alaska and sometimes attains a height of forty feet. The fine, hard, heavy, close-grained woods are used for mallets and tool handles. The Narrowleaf Crab Apple (*Pyrus augustifolia*) yields a similar wood.

The Pear (*Pyrus communis*) is widely cultivated in many regions with temperate climates. The wood, which is rather hard and heavy, is so firm, fine, tough, and close-grained that it has been used for type, drawing squares, and triangles. It is used in turnery and occasionally in furniture. Many varieties have been obtained by cultivation.

The Orange (several species, as *Citrus aurantium* and *Citrus trifoliata*) was introduced into the West Indies, Florida, Louisiana, and California from Asia and the shores of the Mediterranean. The small trees bear oily, partially evergreen leaves, fragrant flowers, and edible fruit, which with oils and essences are highly prized. The strong, hard, heavy, close-grained, lemon-colored wood is cut into souvenirs and other small objects. A piece of American Orange wood, exhibited at the St. Louis Exposition, was ten inches wide. Many varieties of Orange trees have been obtained by cultivation.

The Olive (*Olea europæa*).—Olive trees were introduced into southern California from Asia and the shores of the Mediterranean by the early Spanish missionaries. The irregularly formed trees, from thirty to forty feet in height, bear evergreen leaves and valuable oily fruit. The mottled, rich orange-brown, hard, heavy, close-grained heartwood of foreign trees is prized for inlaid work, small objects, and souvenirs. The heartwood of the older trees is the best. American Olive wood is not particularly attractive because the heartwood has not yet had time to mature sufficiently. Many varieties of Olive trees have been obtained by cultivation.

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[1] "The Apples of New York," Beach, Booth and Taylor (New York State Department of Agriculture).

ELM

Ulmus

The several species of Elm are distributed over the eastern and central portions of the United States. Elm trees are prized for their fine form and appearance. Because they have no lower branches, they are particularly good for planting along streets and near houses. Elm trees attain a high degree of perfection in some parts of New England.

Elm wood is tough, fibrous, durable, strong, hard, heavy, and difficult to split and work. It stands well against shocks, and, for this reason, piles of Elm are useful in ferry slips. The grain arrangement is often attractive, and the wood is sometimes used in less important kinds of cabinet work. It is characteristically employed in piles, flumes, wagons, cars, agricultural implements, and machinery. The tall, straight trunks yield pieces of considerable size. The wood is used in naval construction from parts of the largest ships to canoes where it enters the lattice upon which occupants sit or place their feet. Elm is also used for carriages upon which heavy cannon are mounted. It is used in cooperage, floors, pump handles, and trunks. The bark of the elm tree was used by the Indians in canoes and for rope.

The tree is easily recognized by its form. Fifteen or sixteen species are known to exist.[1]

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[1] See also "The American Elm," Detwiler (American Forestry, May, 1916).

White Elm. *Ulmus americana Linn.*

NOMENCLATURE (Sudworth).
White Elm (local and common name).
Water Elm (Miss., Tex., Ark., Mo., Ill., Ia., Mich., Minn., Neb.).
Elm (Mass., R. I., Conn., N. J., Pa., N. C., S. C., Ia., Wis.).
American Elm (Vt., Mass., R. I., N. Y., Del., Pa., N. C., Miss., Tex., Ill., Ohio, Kans., Neb., Mich., Minn.).

LOCALITIES.
East of the Rocky Mountains, Newfoundland to Florida, westward intermittently to the Dakotas, Nebraska, and Texas.

FEATURES OF TREE.
Ninety to one hundred feet in height; three to seven feet in diameter; a characteristic and beautiful form; smooth buds; the leaves, which are smaller than those of the Slippery Elm (*Ulmus pubescens*), are rough only when rubbed one way.

COLOR, APPEARANCE, OR GRAIN OF WOOD.
Heartwood light brown; sapwood yellowish white; rather coarse-grained; annual rings clearly marked.

STRUCTURAL QUALITIES OF WOOD.
Strong, tough, fibrous, and difficult to split.

REPRESENTATIVE USES OF WOOD.
Flooring, wheel-stock, barrel staves, ship-building, flumes, and piles.[1]

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.
34 (United States Forestry Division).[2]
40.

MODULUS OF ELASTICITY.
1,540,000 (average of 18 tests by United States Forestry Division).[2]
1,060,000.

MODULUS OF RUPTURE.
10,300 (average of 18 tests by United States Forestry Division).[2]
12,100.

REMARKS.
The concentration of the foliage at the top, together with their pleasing form, renders these trees valuable in landscape effects. Elm trees do not cause dense shade. Elm trees and Silver Maple trees are among the first to show life in the spring. At that time, discarded brownish scales cover the ground in the vicinity of the trees.

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[1] See also "White Elm," Pinchot (United States Forest Service, Circular No. 66, 1907); "The American Elm," Detwiler (American Forestry, May, 1916).

[2] See page 33.

Cork Elm. { *Ulmus racemosa Thomas* / *Ulmus thomasi Sarg.* }

NOMENCLATURE (Sudworth).

Cork Elm (local and common name).
Hickory Elm (Mo., Ill., Ind., Ia.).
Rock Elm (R. I., W. Va., Ky., Mo. Ill., Wis., Ia., Mich., Neb.).
White Elm (Ont.).
Cliff Elm (Wis.).

LOCALITIES.

Quebec, Ontario, Michigan, and Wisconsin, southward to Connecticut, northern New Jersey, Ohio, Missouri, and eastern Nebraska.

FEATURES OF TREE.

Seventy to ninety feet in height; two to three feet in diameter; thick, corky, irregular projections give the bark a characteristic, shaggy appearance.

COLOR, APPEARANCE, OR GRAIN OF WOOD.

Heartwood light brown, often tinged with red; sapwood yellowish or greenish white; compact structure; the fibers interlace.

STRUCTURAL QUALITIES OF WOOD.

Heavy, hard, very strong, tough, elastic, and difficult to split; receives a beautiful polish.

REPRESENTATIVE USES OF WOOD.

Heavy agricultural implements, wheel-stock, barrel staves, railway ties, sills, bridge-timbers, axe-helves, etc.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

45.

MODULUS OF ELASTICITY.

2,550,000.

MODULUS OF RUPTURE.

15,100.

REMARKS.

This is the best of the Elm woods.

Slippery Elm, Red Elm. { *Ulmus pubescens Walt.* / *Ulmus fulva Michx.* }

NOMENCLATURE (Sudworth).
Slippery Elm, Red Elm (local and common names).
Rock Elm (Tenn.).
Redwooded Elm (Tenn.).
Moose Elm (occasional).

LOCALITIES.
Ontario and Florida, westward intermittently to Nebraska and Texas; best developed in the Western States.

FEATURES OF TREE.
Forty-five to sixty feet in height; one to two feet in diameter; characteristic form; mucilaginous inner bark; the buds are hairy; the leaves are rough when rubbed either way.

COLOR, APPEARANCE, OR GRAIN OF WOOD.
Heartwood dark brown or red; sapwood lighter; compact structure; the annual layers are marked by rows of large, open ducts; heartwood greatly preponderates.

STRUCTURAL QUALITIES OF WOOD.
Heavy, hard, strong, and durable in contact with the soil.

REPRESENTATIVE USES OF WOOD.
Largely used for fence-posts, rails, barrel staves, railway ties, sills, sleigh-runners, and wheel-stock; the mucilaginous bark is employed in medicine.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

43.

MODULUS OF ELASTICITY.

1,300,000.

MODULUS OF RUPTURE.

12,300.

REMARKS.

Wing Elm, Winged Elm. *Ulmus alata Michx.*

NOMENCLATURE.
Wing Elm, Winged Elm (local and common names).
Wahoo, Whahoo (W. Va., N. C., S. C., La., Tex., Ky., Mo.).
Cork Elm, Corky Elm (Fla., S. C., Tex.).
Mountain Elm, Red Elm (Fla., Ark.).
Elm, Witch Elm (W. Va.).
Water Elm (Ala.).
Small-leaved Elm (N. C.).
Wahoo Elm (Mo.).

LOCALITIES.
Southern United States, Virginia, and Florida, westward intermittently to southern Illinois and Texas.

FEATURES OF TREE.
Forty feet or more in height; one to two feet in diameter; there are corky "wings" on the branches; the smooth leaves are smaller than those of the White Elm (*Ulmus americana*).

COLOR, APPEARANCE, OR GRAIN OF WOOD.
Heartwood brownish; sapwood lighter; close-grained; compact structure.

STRUCTURAL QUALITIES OF WOOD.
Hard, heavy, tough, and fibrous.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

46.

MODULUS OF ELASTICITY.

740,000.

MODULUS OF RUPTURE.

10,200.

REMARKS.
Not a very common tree.

MAPLE

Acer

Maple trees grow on all the northern continents. Nearly one-half of the known species are native to Asia. The principal European species (*Acer pseudo-platanus*) is known in Europe as a Sycamore. The Hard or Sugar Maple (*Acer saccharum*) is one of the principal deciduous trees of North America.[1]

Maple wood is noted for its attractive appearance and its fine, compact structure. Its appearance is so attractive that selected pieces are classed with the most beautiful of the cabinet woods, and its structure is so fine and compact that it is sometimes used for carvings and even for type. Birdseye Maple and Curly Maple are not separate species, but are results of cellular distortions that may occur, in some form, on other trees as well as Maples. Birdseye and blister effects are most often seen in the wood of the Hard Maple (*Acer saccharum*), while curly effects are most often seen in the Soft Maples. It is usually impossible to tell definitely how the woods are figured until the bark is removed or the trees are cut. Maple wood is tough and strong. It shrinks moderately and stands well in protected places, but is not durable when exposed. It is used for flooring, panelling, furniture, school supplies, implements, machinery, and shoe-lasts. Sugar is separated from the sap of the Sugar Maple.

The Boxelder (*Acer negundo*) is a true Maple. The trees are very beautiful, and, like other Maple trees, are valued for ornamental purposes. The soft, light wood is occasionally used for woodenware, interior finish, and paper pulp. Small quantities of sugar are present in the sap of this tree.

Maple trees bear two-seeded fruit or "keys;" the parts of these keys spread differently in different species. The leaves of some species change from green to red and other brilliant colors in the autumn. Sixty to seventy species have been distinguished. Nine of these are native to North America.

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[1] See also "Beech, Birches and Maples," Maxwell (United States Department of Agriculture Bulletin No. 12, 1913.)

Sugar Maple, Hard Maple. { *Acer saccharum Marsh* / *Acer saccharinum Wang*

NOMENCLATURE (Sudworth).

Sugar Maple, Hard Maple (local and common names).
Black Maple (Fla., Ky., N. C.).
Sugar Tree (frequent).
Rock Maple (Me., Vt., N. H., Conn., Mass., R. I., N. Y., Tenn., Ill., Mich., Ia., Kan., Wis., Minn.).

LOCALITIES.

Best development Newfoundland to Manitoba. Range extends southward to Florida and Texas.

FEATURES OF TREE.

Seventy to one hundred or more feet in height; one and one-half to four feet in diameter; the flowers appear with the leaves in the spring; the fruit or "maple-keys," with wings less than at right angles, ripen in the early autumn; one seed-cavity in each is usually empty; the leaves exhibit brilliant reds and other colors in the autumn; a large, impressive tree.

COLOR, APPEARANCE, OR GRAIN OF WOOD.

Heartwood brownish; sapwood lighter; close-grained; compact structure; occasional curly, blister, or birdseye effects.

STRUCTURAL QUALITIES OF WOOD.

Tough, heavy, hard, strong, and receives a good polish; wears evenly; not durable when exposed.

REPRESENTATIVE USES OF WOOD.

Furniture, shoe-lasts, piano-actions, wooden type for showbills, pegs interior finish, flooring, ship-keels, vehicles, fuel, veneers, rails, etc.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

43.

MODULUS OF ELASTICITY.

2,070,000.

MODULUS OF RUPTURE.

16,300.

REMARKS.[1]

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[1] See also "Sugar Maple, *Acer saccharum Marsh*" (United States Forest Service, Silvical Leaflet No. 42, 1908). "The Sugar Maple," Detwiler (American Forestry, November, 1915).

Silver Maple, Soft Maple. { *Acer saccharinum Linn.* / *Acer dasycarpum Ehr.* }

Nomenclature (Sudworth).
Silver Maple, Soft Maple (local common names).
Swamp Maple (W. Va., Md.).
Water Maple (Pa., W. Va.).
River Maple (Me., N. H., R. I., W. Va., Minn.).
White Maple (Me., Vt., R. I., N. Y., N. J., Pa., W. Va., N. C., S. C., Ga., Fla., Ala., Miss., La., Ky., Mo., Ill., Ind., Kans., Neb., Minn.).

Localities.
New Brunswick to Florida, westward intermittently to the Dakotas and Oklahama; best development in lower Ohio River basin.

Features of Tree.
Forty to ninety feet in height, occasionally higher; three to five feet in diameter; fine form, sometimes suggesting that of the Elm; the maple-keys, with long, stiff, more than right-angled wings, ripen in the early summer; the flowers appear before the leaves in the spring; the leaves exhibit yellows, but seldom reds, in the autumn.

Color, Appearance, or Grain of Wood.
Heartwood reddish brown; sapwood ivory white; fine-grained; compact structure; the fibers are sometimes twisted, waved, or "curly."

Structural Qualities of Wood.
Light, brittle, easily worked, and moderately strong; receives a high polish; not durable when exposed to the weather.

Representative Uses of Wood.
Woodenware, turned work, interior decoration, flooring, and fuel.

Weight of Seasoned Wood in Pounds per Cubic Foot.

32.

Modulus of Elasticity.

1,570,000.

Modulus of Rupture.

14,400.

Remarks.
Waving, spiral, or curly figures are pronounced in the woods of this species. Resemblances to light and shadows are particularly real on planed surfaces.

Red Maple, Swamp Maple. *Acer rubrum Linn.*

NOMENCLATURE (Sudworth).

Red Maple, Swamp Maple (local and common names).

Soft Maple (Vt., Mass., N. Y., Va., Miss., Mo., Kans., Neb., Minn.).

Water Maple (Miss., La., Tex., Ky., Mo.).

White Maple (Me., N. H.).

Red Flower (N. Y.).

LOCALITIES.

New Brunswick and Florida, westward intermittently to the Dakotas and Texas. Wide range.

FEATURES OF TREE.

Sixty to eighty feet and more in height; two and one-half to four feet in diameter; red twigs and flowers appear before the leaves in the early spring.

COLOR, APPEARANCE, OR GRAIN OF WOOD.

Heartwood brown, tinged with red; sapwood lighter; close-grained; compact structure.

STRUCTURAL QUALITIES OF WOOD.

Heavy, hard, and elastic, but not strong; easily worked.

REPRESENTATIVE USES OF WOOD.

Largely used in cabinet-making, turnery, woodenware, and gun-stocks.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

38.

MODULUS OF ELASTICITY.

1,340,000.

MODULUS OF RUPTURE.

15,000.

REMARKS.

The wood occasionally shows a "curly figure."

Oregon Maple. *Acer macrophyllum Pursh.*

NOMENCLATURE (Sudworth).
Oregon Maple (Oreg., Wash.).
White Maple (Oreg., Wash.).
Maple (Cal.).
Broad-leaved Maple (Central Cal., Willamette Valley, Ore.).

LOCALITIES.
Alaska to California; best in rich bottom lands of southern Oregon.

FEATURES OF TREE.
Seventy to one hundred feet in height; three to five feet in diameter; beautiful appearance; pendant clusters of flowers appear after the leaves in the spring.

COLOR, APPEARANCE, OR GRAIN OF WOOD.
Heartwood reddish brown; sapwood whitish; close-grained; compact structure; occasionally figured.

STRUCTURAL QUALITIES.
Light, hard, and strong; receives a high polish.

REPRESENTATIVE USES OF WOOD.
Locally used for tool-handles. turned work, and furniture.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

30.

MODULUS OF ELASTICITY.

1,100,000.

MODULUS OF RUPTURE.

9,720.

REMARKS.
This ornamental tree has been introduced into Europe.[1]

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[1] See also "Manual Trees of North America," Sargent, p. 628.

Boxelder, Ash-leaved Maple. { *Acer negundo Linn.* *Negundo aceroides Moench.* }

NOMENCLATURE (Sudworth).

Boxelder, Ash-leaved Maple (local and common names).
Red River Maple, Water Ash (Dak.).
Cut-leaved Maple (Colo.).
Stinking Ash (S. C.).
Negundo Maple (Ill.).
Three-leaved Maple (Fla.).
Black Ash (Tenn.).
Sugar Ash (Fla.).

LOCALITIES.

Atlantic Ocean, westward intermittently to Rocky Mountains and Mexico.

FEATURES OF TREE.

Forty to seventy feet in height; one and one-half to three feet in diameter; the wings to the keys are straight or incurved; the leaves exhibit yellows, but seldom reds, in the autumn; the flowers appear with or before the leaves in the spring.

COLOR, APPEARANCE, OR GRAIN OF WOOD.

Thin heartwood, cream white; sapwood similar; close-grained; compact structure.

STRUCTURAL QUALITIES OF WOOD.

Light and soft; not strong.

REPRESENTATIVE USES OF WOOD.

Woodenware, cooperage, paper-pulp, and occasionally interior finish.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

26.

MODULUS OF ELASTICITY.

82,000.

MODULUS OF RUPTURE.

7,500.

REMARKS.

The Boxelders withstand severe climatic changes, grow rapidly and are good trees to plant in many otherwise treeless sections. Sugar is sometimes obtained from the sap of this species. See also "Boxelder" (United States Forest Service Circular No. 86).

WALNUT

Juglans

The English or Royal Walnut (*Juglans regia*) is the principal species in Europe, while the Black Walnut (*Juglans nigra*), and the Butternut or White Walnut (*Juglans cinerea*) grow in the United States. Botanically, Circassian Walnut is the same as English, Royal, or European Walnut. English Walnut is the name used almost exclusively by those who grow the tree for its nuts, while Circassian Walnut is the name usually applied to the wood.[1]

The English Walnut was introduced from Asia into Greece and Italy, and, through these countries, into others. It is cultivated in the United States, but principally for its nuts. The appearance and desirability of the wood differ with localities. Pieces cut from English trees are said to be paler and coarser than those cut from Italian and French trees. Ordinary pieces exhibit large open figures, with waves and streaks of gray and yellowish-white, while exceptional excrescences known as burrs, which are sometimes two or three feet across, yield figured woods of great beauty. Circassian Walnut is very valuable, and is now used almost exclusively in costly decorations, piano cases, and high-grade furniture. No other wood is better for gun-stocks, and, until the battle of Waterlo, othe demand in Europe for this purpose was so great that as much as six hundred pounds sterling is said to have been paid for a single tree.

At the present time (1917) the supply of Black Walnut for making stocks for military rifles is ample. A manufacturer writes as follows: "At the beginning of the great war (1914) we were under the impression that we might experience some difficulty in securing sufficient of this wood; but we have had no such trouble, in fact, we have had much more of it offered to us than we require."

American or Black Walnut was once very popular, in the United States, as a cabinet wood. The trees are now scarce; lighter colored woods are preferred, and, at present, walnut is seldom seen save in gun-stocks and old furniture. The figures that characterize pieces of Circassian Walnut are absent in the darker, more uniformly tinted American woods. Black Walnut trees seldom form forests by themselves, but are usually found mixed with those of other species. They grow rapidly, but the valuable heartwood does not mature until a number of years after the trees have been planted.

Small pieces of dark, rich brown wood are obtained from the Mexican or Arizona Walnut (*Juglans rupestris*), which grows in some of the sparsely settled regions of the Southwest, where it is also known as the Western, Dwarf, Little, and California Walnut. The true California Walnut (*Juglan californica*) is found on the Pacific Coast from the Sacramento River to the San Bernardino Mountains, and sometimes attains diameters of fifteen inches. The blue-brown woods can be, but seldom are, used in cabinet making. The White Walnut or Butternut (*Juglans cinerea*) yields a rather soft, light, grayish-brown heartwood that is sometimes used in cabinet making.

Walnut trees may be known by their nuts. The husks or pods are not quartered as in the case of the hickories.

[1] "Circassian Walnut," Sudworth and Mell (United States Forest Service, Circular No. 212).

Circassian Walnut, European Walnut. *Juglans regia*

NOMENCLATURE (Sudworth and Mell).

- Circassian Walnut, European Walnut, English Walnut, Royal Walnut (local and common names).
- Persian Walnut.
- French Walnut.
- Italian Walnut.
- Austrian Walnut.
- Russian Walnut.
- Turkish Walnut.
- Nogal (Spain, Cuba, and South America).
- Ancona Auvergne (Italy).
- Noyer (France).

LOCALITIES.

Widely planted on all of the continents.

FEATURES OF TREE.

About 40 feet in height; attractive in appearance.

COLOR, APPEARANCE, OR GRAIN OF WOOD.

Heartwood dark chocolate brown, tints sometimes extending from light brown to black; sapwood lighter; beautiful veins and figures, particularly in the wood of older trees; fine, close grain.

STRUCTURAL QUALITIES OF WOOD.

Moderately hard, moderately heavy; splits but little in seasoning; the sapwood is liable to become worm-eaten.

REPRESENTATIVE USES OF WOOD.

Circassian Walnut was formerly used in turnery, toys, carved work, carpentry, wooden shoes, and gun-stocks. The wood is now scarce and is only employed in the most costly furniture and cabinet work.

WEIGHTS OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

MODULUS OF ELASTICITY.

MODULUS OF RUPTURE.

REMARKS.

For many years the demands for this wood have been greater than the supply. Among the related woods which have been used as substitutes are the Caucasian Walnut (*Pterocarya caucasica*)[1], the West Indian Walnut (*Juglans insularis*), the Nogal (*Juglans australis*), and the Butternut (*Juglans cinerea*). The Red Gum (*Liquidambar styraciflua*), which is sometimes called the Satin Walnut, is often handsomely veined, and is then very similar to true Circassian Walnut.

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[1] The similarity of names is such that Caucasian Walnut and Circassian Walnut are sometimes confused with one another. The wood of the former lacks the veining which characterizes the latter.

Black Walnut. *Juglans nigra Linn.*

NOMENCLATURE (Sudworth).

Black Walnut (local and common name). Walnut (N. Y., Del., W. Va., Fla., Ky., Mo., Ohio, Ind., Ia.).

LOCALITIES.

Ontario and Florida, westward intermittently to Nebraska and Texas.

FEATURES OF TREE.

Ninety to one hundred and twenty-five feet in height; three to eight feet in diameter; a tall, handsome tree with rough, brownish, almost black, bark; the compound leaves are composed of from thirteen to twenty-three leaflets; the nuts are large and rough-shelled.

COLOR, APPEARANCE, OR GRAIN OF WOOD.

Heartwood rich, dark, chocolate brown; the thin sapwood is much lighter in color; rather coarse-grained.

STRUCTURAL QUALITIES OF WOOD.

Heavy, hard, strong, easily worked, and durable; receives a high polish.

REPRESENTATIVE USES OF WOOD.

Cabinet-making and gun-stocks; also formerly furniture and decoration.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

38.

MODULUS OF ELASTICITY.

1,550,000.

MODULUS OF RUPTURE.

12,100.

REMARKS.

This tree is now somewhat rare in the Eastern parts of the United States.[1]

[1] See also "Handbook Trees of Northern States and Canada," Hough.

Butternut, White Walnut. *Juglans cinerea Linn.*

NOMENCLATURE.

Butternut, White Walnut (local and common names).
Oil Nut (Me., N. H., S. C.).
Walnut (Minn.).
White Mahogany.

LOCALITIES.

New Brunswick to Georgia, westward to Dakota and Arkansas; best in Ohio River basin.

FEATURES OF TREE.

Medium size, sometimes seventy-five feet or over in height; two to four feet in diameter; the branches are widespread; the compound leaves are composed of from eleven to seventeen leaflets; there are large-sized, oblong, edible nuts.

COLOR, APPEARANCE, OR GRAIN OF WOOD.

Heartwood light gray-brown, darkening with exposure; sapwood nearly white; coarse-grained; compact structure; an attractive wood.

STRUCTURAL QUALITIES OF WOOD.

Light, soft, and easily worked, but not strong; receives a high polish.

REPRESENTATIVE USES OF WOOD.

Interior finish and cabinet-work. The inner bark furnishes a yellow dye.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

25.

MODULUS OF ELASTICITY.

1,150,000.

MODULUS OF RUPTURE.

8,400.

REMARKS.[1]

[1] See also "Handbook Trees of Northern States and Canada," Hough.

HICKORY

Hicoria

The Hickories grow in the temperate regions of eastern North America, and eastern Asia.

The woods, which are noted for strength, toughness, flexibility, and resilience, are used for handles, implements, machinery and carriage parts. Axe handles and hammer handles of this wood have no superiors. The reputation of American axes and hammers owes much to the qualities of these handles. The properties that render Hickory valuable are most pronounced in the sapwood, which, in this species, is more desirable than the heartwood. Second growth Hickory is prized, since, being younger, it contains more of the pliable sapwood. Hickory does not last well in exposed positions.

The genus includes about a dozen species. The Hickories may be distinguished from the Walnuts by the nuts. In most cases, the nuts of the Hickories are covered with husks that divide into four parts, while those of the Walnuts remain unbroken.[1]

[1] See also "The Commercial Hickories," Boisen and Newlin (United States Forest Service, Bulletin No. 80, 1910); "Manufacture and Utilization of Hickory," Hatch (United States Forest Service, Circular No. 187, 1911).

Shagbark Hickory, Shellbark Hickory, Shagbark. { *Hicoria ovata Mill.* / *Carya alba Nutt.* }

NOMENCLATURE (Sudworth).

Shagbark or Shellbark Hickory (local and common names).	Hickory (Vt., Ohio).
Scalybark Hickory (W. Va., S. C., Ala.).	Upland Hickory (Ill.).
Shellbark (R. I., N. Y., Pa., N. C.).	White Hickory (Ia., Ark.).
Shagbark (R. I., Ohio).	Walnut (Vt., N. Y.).
	Sweet Walnut (Vt.).
	Shagbark Walnut (Vt.).

LOCALITIES.

Quebec to Florida, westward intermittently to Minnesota and Texas. Wide range, best in Ohio Valley.

FEATURES OF TREE.

Seventy-five to ninety feet in height, occasionally higher; two and one-half to three feet in diameter; shaggy bark; the compound leaves are composed of five and, rarely, seven leaflets; there are thin-shelled, edible nuts.

COLOR, APPEARANCE, OR GRAIN OF WOOD.

Heartwood light brown; sapwood ivory white or cream colored; close-grained; compact structure; the annual rings are clearly marked; the medullary rays are numerous but thin.

STRUCTURAL QUALITIES OF WOOD.

Very heavy, very hard, strong, exceptionally tough and flexible; not durable when exposed.

REPRESENTATIVE USES OF WOOD.

Largely used for agricultural implements, wheels, runners, axe handles, baskets, and fuel.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

51 (United States Forestry Division).[1]
52.

MODULUS OF ELASTICITY.

2,390,000 (average of 137 tests by United States Forestry Division).[1]
1,900,000.

MODULUS OF RUPTURE.

16,000 (average of 137 tests by United States Forestry Division).[1]
17,000.

REMARKS.

The nuts form an important article of commerce. "Shagbark" refers to the shaggy appearance of the bark.[2]

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[1] See p. 33.

[2] See also "Shagbark Hickory" (United States Forest Service, Circular No. 62, 1907).

Pignut. *Hicoria glabra Mill.*
Carya porcina Nutt.

NOMENCLATURE (Sudworth).

Pignut (local and common name).
Black Hickory (Miss., La., Ark., Mo., Ind., Ia.).
Brown Hickory (Del., Miss., Tex., Tenn., Minn.).
Bitternut (Ark., Ill., Ia., Wis.).
White Hickory (N. H., Ia.).
Broom Hickory (Mo.).
Hardshell (W. Va.).
Red Hickory (Del.).
Switchbud Hickory (Ala.).

LOCALITIES.

Maine to Florida, westward intermittently to southern Nebraska and eastern Texas.

FEATURES OF TREE.

Seventy-five to one hundred feet in height, occasionally higher; two to four feet in diameter; rather smooth bark; the compound leaves are composed of from three to seven leaflets; the large, thick-shelled nuts contain kernels that are often astringent or bitter.

COLOR, APPEARANCE, OR GRAIN OF WOOD.

Heartwood light and dark brown; the thick sapwood is lighter; close-grained.

STRUCTURAL QUALITIES OF WOOD.

Heavy, hard, flexible, tough, and strong.

REPRESENTATIVE USES OF WOOD.

Similar to those of Shagbark Hickory (*Hicoria ovata*).

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

56 (United States Forestry Division).[1]
51.

MODULUS OF ELASTICITY.

2,730,000 (average of 30 tests by United States Forestry Division.)[1]
1,460,000.

MODULUS OF RUPTURE.

18,700 (average of 30 tests by United States Forestry Division.)[1]
14,800.

REMARKS.[2]

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[1] See p. 33.

[2] See also "Pignut Hickory, *Hicoria glabra* (Mill.)" Britton (United States Forest Service, Silvical Leaflet No. 48, 1909).

Mocker Nut. { *Hicoria alba Linn.* / *Carya tomentosa Nutt.* }

NOMENCLATURE (Sudworth).

Mocker Nut, Whiteheart Hickory (local and common names).
Bullnut (N. Y., Fla., Miss., Tex., Mo., Ohio, Ill., Minn.).
Black Hickory (Tex., Miss., La., Mo.).
Hickory (Ala., Tex., Pa., S. C., Neb.).
Big-bud, Red Hickory (Fla.).
Common Hickory (N. C.).
White Hickory (Pa., S. C.).
Hickory Nut (Ky., W. Va.).
Hog Nut (Del.).
Hard bark Hickory (Ill.).

LOCALITIES.

Ontario to Florida, westward intermittently to Missouri and Texas. Wide range.

FEATURES OF TREE.

Seventy-five to one hundred feet in height; two and one-half to three and one-half feet in diameter; a tall, slender tree with rough, but not shaggy, bark; the compound leaves are composed of from five to nine leaflets; there are thick-shelled, edible nuts.

COLOR, APPEARANCE, OR GRAIN OF WOOD.

Heartwood rich, dark brown; the thick sapwood is nearly white; close-grained.

STRUCTURAL QUALITIES OF WOOD.

Very heavy, hard, tough, strong, and flexible.

REPRESENTATIVE USES OF WOOD.

Similar to those of Shagbark Hickory (*Hicoria ovata*).

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

53 (United States Forestry Division).[1]
51.

MODULUS OF ELASTICITY.

2,320,000 (average of 75 tests by United States Forestry Division).[1]
1,630,000.

MODULUS OF RUPTURE.

15,200 (average of 75 tests by United States Forestry Division).[1]
16,000.

REMARKS.

The most generally distributed species of the genus in the South

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[1] See p. 33.

Pecan. { *Hicoria pecan Marsh* / *Carya olivæformis Nutt.* }

NOMENCLATURE (Sudworth).
Pecan (local and common name).
Pecan Nut, Pecan-tree, Pecanier (La.).

LOCALITIES.
Valley of Mississippi, southward to Louisiana and Texas.

FEATURES OF TREE.
Ninety to one hundred feet in height, sometimes higher; two and one-half to five feet in diameter; a tall tree; the compound leaves are composed of from nine to fifteen leaflets; there are smooth-shelled, oblong, edible nuts.

COLOR, APPEARANCE, OR GRAIN OF WOOD.
Heartwood light-brown, tinged with red; sapwood lighter brown; close-grained and compact; the medullary rays are numerous, but thin.

STRUCTURAL QUALITIES OF WOOD.
Heavy and hard, but not strong and brittle.

REPRESENTATIVE USES OF WOOD.
Fuel; seldom used in construction.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.
49 (United States Forestry Division).[1]
44.

MODULUS OF ELASTICITY.
2,530,000 (average of 37 tests by United States Forestry Division).[1]
940,000.

MODULUS OF RUPTURE.
15,300 (average of 37 tests by United States Forestry Division).[1]
8,200.

REMARKS.
Grows on borders of streams in low, rich soil. It is the largest and most important tree of Western Texas. The sweet, edible nuts form an important article of commerce.

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[1] See p. 33.

CHESTNUT, CHINQUAPIN

Castanea

These trees grow in many parts of eastern North America, southern Europe, northern Africa, western Asia, and parts of China and Japan.

European Chestnut wood was once held in high regard. It should be noted, however, that some of the constructions, in which this wood was thought to exist, were actually built of oak. The wood of the North American Chestnut (*Castanea vulgaris*), which is weak, brittle, easily worked, and very durable, is one of the best of those used for fence posts, and mud sills, where durability rather than great strength is required. Hough mentions a Chestnut fence-rail that was good after having been exposed for about one hundred years.

The chestnut bark disease now tentatively named *Diaporthe parasitica Murrill*[1] was first detected in New York City parks in 1904. Seventeen thousand trees soon succumbed in one park alone (Forest Park, Brooklyn). The disease, which was probably introduced from Japan, is conveyed by winds and insects, and no tree once attacked ever recovers. The value of the trees thus far destroyed is very great and the prospective losses are enormous.[2]

The name Chinquapin applies to two North American species: the Common Chinquapin (*Castanea pumila*) grows in the Central and Southeastern States; while the Western, Goldenleaf, or California Chinquapin, or "Evergreen Chestnut," (*Castanopsis chrysophylla*) grows on the Pacific Coast. Both of these species afford woods that resemble ordinary chestnut.

The American Chestnut (*Castanea vulgaris*) is known by its large, prickly burrs that contain from one to three thin-shelled, triangular, wedge-shaped, edible nuts. The Chinquapins bear prickly burrs that hold one, or occasionally two, sweet edible nuts.

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[1] Some botanists believe that this blight is *Endothia gyrosa*, while others characterize it as *Endothia gyrosa var. parasitica*.

[2] See also Journal of New York Botanical Garden (Vol. II, p. 143); also, Marlatt (National Geographic Magazine, April, 1911); "Report of Chestnut Tree Blight," Mickleborough (Pennsylvania State Department of Forestry); etc.

Chestnut. *Castanea dentata (Marsh) Borkh.* / *Castanea vesca var. americana Michx.* / *Castanea vulgaris var. americana A. de C.*

NOMENCLATURE.
Chestnut (local and common name).

LOCALITIES.
New England, Ontario, and New York to Georgia, Alabama, and Mississippi; also Kentucky, Missouri, and Michigan; best on the Western slope of the Alleghany Mountains.

FEATURES OF TREE.
Seventy-five to one hundred feet in height; five to twelve feet in diameter; a fine, characteristic shape, not easily distinguished from that of the Red Oak (*Quercus rubra*) in winter; the trees blossom in midsummer; the prickly burrs contain three, exceptionally five, thin-shelled nuts.[1]

COLOR, APPEARANCE OR GRAIN OF WOOD.
Heartwood brown; sapwood lighter; coarse-grained.

STRUCTURAL QUALITIES OF WOOD.
Light and soft; not strong; liable to check and warp in drying; easily split; very durable in exposed positions.

REPRESENTATIVE USES OF WOOD.
Cabinet-making, railway ties, posts, fencing, and sills.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

28.

MODULUS OF ELASTICITY.

1,200,000.

MODULUS OF RUPTURE.

9,800.

REMARKS.
In the eastern part of the United States, chestnut trees have been attacked by a fungus (tentatively named *Diaporthe parasitica*),[2] which (1913) is apparently destroying all of the chestnut forests.

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[1] See also "Chestnut," Pinchot (United States Forest Service, Circular No. 71, 1907); "The American Chestnut Tree," Detwiler (American Forestry, October, 1915); etc.

[2] As stated elsewhere, some botanists believe that this blight should be characterized as *Endothia gyrosa* or *Endothia gyrosa var. parasitica.*

Chinquapin. *Castanea pumila (Linn.) Mill.*

NOMENCLATURE (Sudworth).

Chinquapin (Del., N. J., Pa., Va., W. Va., N. C., S. C., Ga., Ala., Fla., Miss., La., Tex., Ark., Ohio, Ky., Mo., Mich.).

LOCALITIES.

Pennsylvania and New Jersey to Florida, Mississippi, Louisiana, Texas, Arkansas, Ohio, Kentucky, Missouri, and Michigan.

FEATURES OF TREE.

A small tree, sometimes forty-five feet in height; one to two feet or over in diameter; sometimes a low shrub; can be distinguished from the Chestnut (*Castanea dentata*) by the fact that the leaves are smooth on both sides; the small, prickly burrs contain single, small chestnut-colored nuts.

COLOR, APPEARANCE, OR GRAIN OF WOOD.

Heartwood dark brown; sapwood hardly distinguishable; coarse-grained; the annual layers are marked by rows of open ducts.

STRUCTURAL QUALITIES OF WOOD.

Rather heavy, hard, and strong; durable in exposed positions; liable to check in drying.

REPRESENTATIVE USES OF WOOD.

Posts, rails, railway ties, etc.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

36.

MODULUS OF ELASTICITY.

1,620,000.

MODULUS OF RUPTURE.

14,000.

REMARKS.

This tree is more suitable for planting in parks than as a source of lumber.

The Chinquapin (*Castanopsis chrysophylla*) is a tree with characteristics which are between those of the Oak and Chestnut. Its wood, which is nearly similar to that of the Chinquapin (*Castanea pumila*), is sometimes used for implements. It is native in Oregon and California.

BEECH

Fagus

The Beeches are represented in the temperate regions of the northern hemisphere by a single species (*Fagus americana*). The European Beech (*Fagus sylvatica*) is an important tree abroad.[1]

Beech wood is hard, heavy, strong, fine-grained, not durable when exposed, and somewhat subject to attack by insects. European Beech is employed to a considerable extent in construction and turnery, and is used more than almost any other local wood for fuel. Beech possesses almost all of the properties that are valued in construction, save durability in exposed positions; in Europe, this deficiency is corrected by artificial means. Beech responds more completely than Oak to treatment with antiseptics, and the French secure longer service from many treated Beech ties, than Americans secure from many treated Oak ties.

Beech trees are covered with smooth, light-colored bark. They produce small prickly burrs, each of which contains two triangular, sharp-edged nuts, which are sometimes referred to as beech-mast, and which yield an oil that is occasionally used in place of olive oil. The nuts are not gathered to any extent in the United States.

The Coffee, Coffeenut, Coffeebean, Coffeebean-tree, or Mahogany (*Gymnocladus dioicus*).—These trees grow best between the Alleghany Mountains and the Mississippi River. They are valued in landscape effects, and, in many places, are cultivated. The strong, durable, reddish-brown wood works easily, polishes well, and can be used in cabinet work.

The Hackberry, Sugarberry, One-berry, Nettle-tree, or False Elm (*Celtis occidentalis*).—This tree is occasionally found between Canada and Florida and between the Atlantic Coast and the Rocky Mountains. Isolated specimens are sometimes locally famed as "Unknown Trees." The rather hard, strong wood is occasionally used in fencing and in cheap furniture.[2]

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[1] See also "Beech, Birches and Maples," Maxwell (United States Department of Agriculture, Bulletin No. 12, 1913).

[2] See also "Hackberry," Pinchot (United States Forest Service, Circular No. 75, 1907).

Beech.
Fagus americana Sweet
Fagus grandifolia
Fagus atropunicea (Marsh) Sudworth
Fagus ferruginea Ait.

NOMENCLATURE (Sudworth).
Beech (local and common name).
Red Beech (Me., Vt., Ky., Ohio).
White Beech (Me., Ohio, Mich.).
Ridge Beech (Ark.).

LOCALITIES.
Nova Scotia to Florida, westward intermittently to Wisconsin and Texas.

FEATURES OF TREE.
Sixty to eighty feet in height, occasionally higher; two to four feet in diameter; the small, rough burrs contain two thin-shelled nuts.

COLOR, APPEARANCE, OR GRAIN OF WOOD.
Heartwood reddish, variable shades; sapwood white; rather close-grained; conspicuous medullary rays.

STRUCTURAL QUALITIES OF WOOD.
Hard, strong, and tough; not durable when exposed; liable to check during seasoning; takes a fine polish.

REPRESENTATIVE USES OF WOOD.
Shoe-lasts, plane-stocks, ship-building, handles, and fuel; carpentry (abroad), wagon-making, etc.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

42.

MODULUS OF ELASTICITY.

1,720,000.

MODULUS OF RUPTURE.

16,300.

REMARKS.
There is but one species of Beech in North America. The wood is occasionally divided into "Red Beech" and "White Beech," according to its color. This division has no botanical basis, since both of these woods come from the same tree.

Ironwood, Blue Beech. *Carpinus caroliniana Walt.*

Nomenclature (Sudworth).

Ironwood, Blue Beech (local and common names).

Water Beech (R. I., N. Y., Pa., Del., W. Va., Ohio, Ill., Ind., Mich., Minn., Neb., Kans.).

Hornbeam (Me., N. H., Mass., R. I., Conn., N. Y., N. J., Pa., Del., N. C., S. C., Ala., Tex., Ky., Ill., Kans., Minn.).

Localities.

Quebec to Florida, westward intermittently to Nebraska and Texas.

Features of Tree.

Thirty to fifty feet in height; six inches to occasionally two feet in diameter; a small tree.

Color, Appearance, or Grain of Wood.

Heartwood light brown; thick sapwood nearly white; close-grained.

Structural Qualities of Wood.

Very hard, tough, strong, and heavy; very stiff; inclined to check during seasoning; not durable when exposed.

Representative Uses of Wood.

Levers, tool-handles, etc.

Weight of Seasoned Wood in Pounds per Cubic Foot.

45.

Modulus of Elasticity.

1,630,000.

Modulus of Rupture.

16,300.

Remarks.

The name Ironwood is also applied to the Hornbeam (*Ostrya virginiana*), and to some other North American species that afford unusually hard, heavy woods suitable for handles and implements. The trunks of the species known as Ironwoods are generally small.

Ironwood, Hop Hornbeam. *Ostrya virginiana Willd.*

NOMENCLATURE (Sudworth).

Ironwood, Hop Hornbeam (local and common names).
Leverwood (Vt., Mass., R. I., N. Y., Pa., Kans.).
Hornbeam (R. I., N. Y., Fla., S. C., La.).
Hardhack (Vt.).

LOCALITIES.

Nova Scotia to Florida, westward intermittently to North Dakota, South Dakota, and Texas.

FEATURES OF TREE.

Thirty to forty feet in height; one foot or less in diameter; the bark exhibits long, vertical rows of small squares; small fruit suggest hops in appearance; the leaves resemble those of the Birch.

COLOR, APPEARANCE, OR GRAIN OF WOOD.

Heartwood reddish brown, sometimes white; sapwood lighter or white; close-grained; compact structure.

STRUCTURAL QUALITIES OF WOOD.

Very strong, hard, heavy, and tough; durable when exposed.

REPRESENTATIVE USES OF WOOD.

Posts, levers, tool-handles, axe-helves, mill-cogs, and wedges.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

51.

MODULUS OF ELASTICITY.

1,950,000.

MODULUS OF RUPTURE.

16,000.

REMARKS.

Trees over twelve inches in diameter are often hollow.

SYCAMORE

Platanus

The name Sycamore applies to a Maple (*Acer pseudo-platanus*) in Europe, to a Fig tree (*Ficus sycomorus*) in the Orient, and to the Buttonball or Plane trees (*Platanus*) in North America. Of the Sycamore or Plane trees, the Common or Oriental Plane (*Platanus orientalis*) is a native of Europe; the Plane, Buttonball, or Sycamore tree (*Platanus occidentalis*) is a native and common tree of eastern North America; and the California Sycamore (*Platanus racemosa*) is a native of western North America.[1]

American sycamore wood is tough, strong, and difficult to split. The cellular structure is complicated, and a typical use of the wood is for butcher's blocks. Because of its beauty, quartered sycamore is used in cabinet work and indoor finish.

American Plane, Buttonball, or Sycamore trees are distinguished by rough heads or balls, which remain hanging on long stems throughout the winter. The bark is also characteristic. Large flakes of the outer bark drop away and expose inner surfaces, so smooth and white that they appear to be painted. Six or seven species are included in this genus. Three of the species occur in North America.

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[1] The sycamore possesses an emblematic interest because of its biblical association with Zaccheus. Many European sycamores were planted by religious persons during the Middle Ages because of the belief that they were the trees referred to in the Bible.

Sycamore, Buttonwood, Buttonball-tree. *Platanus occidentalis Linn.*

NOMENCLATURE (Sudworth).

Sycamore, Buttonwood, Buttonball-tree (local and common names).

Buttonball (R. I., N. Y., Pa., Fla.).

Plane Tree (R. I., Del., S. C., Kans., Neb., Ia.).

Water Beech (Del.).

Platane, cotonier, Bois puant (La.).

LOCALITIES.

Maine and Ontario to Florida, westward intermittently to Nebraska and Texas; best in the bottom lands of the Ohio and Mississippi River basins.

FEATURES OF TREE.

Ninety to over one hundred feet in height; six to sometimes twelve feet in diameter; the inner bark is exposed in white patches; the rough balls or heads are about one inch in diameter.

COLOR, APPEARANCE, OR GRAIN OF WOOD.

Heartwood reddish-brown; sapwood lighter; close-grained; compact structure; satiny; conspicuous medullary rays; the wood is attractive when quartered.

STRUCTURAL QUALITIES OF WOOD.

Heavy, hard, and difficult to work; not strong; stands well when not exposed.

REPRESENTATIVE USES OF WOOD.

Tobacco-boxes, ox-yokes, butcher-blocks, and cabinet-work.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

35.

MODULUS OF ELASTICITY.

1,220,000.

MODULUS OF RUPTURE.

9,000.

REMARKS.

Some specimens are among the largest of American deciduous trees, but the bottoms of such exceptionally large trees are usually hollow. The bark is thin and soft when the tree is young but becomes thicker and harder as the tree grows older, until a point is reached when it can no longer stretch to accommodate the growth of the tree. Large areas of the bark are then thrown off by the tree and the inner surfaces which are exposed appear so smooth and white as to suggest the possibility that they have been painted.

California Sycamore. *Platanus racemosa Nutt.*

NOMENCLATURE.

Sycamore, Buttonwood, Buttonball Tree, Buttonball (California).

LOCALITIES.

California and Lower California.

FEATURES OF TREE.

Seventy-five to one hundred feet in height, occasionally higher; three to four feet in diameter; differs from the Sycamore (*Platanus occidentalis*) in that the balls or heads are in clusters and not solitary; the bark exfoliates in irregular patches.

COLOR, APPEARANCE, OR GRAIN OF WOOD.

Heartwood light reddish brown; sapwood lighter; close-grained; compact structure; the medullary rays are numerous and conspicuous; the wood is quite attractive when quartered.

STRUCTURAL QUALITIES OF WOOD.

Brittle, very difficult to split and season; the qualities are similar to those of the Sycamore (*Platanus occidentalis*).

REPRESENTATIVE USES OF WOOD.

Decoration and furniture; used as the wood of the Sycamore (*Platanus occidentalis*) is used.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

30.

MODULUS OF ELASTICITY.

800,000.

MODULUS OF RUPTURE.

7,900

REMARKS.

BIRCH

Betula

Birch trees grow in many places in North America, Europe, and Asia. The ranges of some species extend far into the North. Birch trees are noted for their bark, quite as much as for their wood.[1]

The Paper Birch (*Betula papyrifera*) is the species that is most noted for its bark, which is smooth, pliable, inflammable, water-tight, of a cream or ivory-white color, and marked with long, horizontal, raised dashes or lenticels. The bark contains resinous oils and is so durable that it often remains intact on fallen trees, long after the wood inside has rotted and disappeared. The layers, of which it is composed, separate easily from one another and can be obtained in large-sized pieces. The North American Indians employed it for canoes, tents, troughs, and buckets. It has also been used to write upon and to cover houses.

The Yellow Birch (*Betula lutea*) and the Sweet Birch (*Betula lenta*) are prized for their hard, heavy, strong, fine-grained, and attractive woods, which, however, are not durable in exposed positions. These woods are used in spools, woodenware, interior finish, and furniture. They are often stained so as to imitate cherry and mahogany. One of the best of the "imitation mahoganies" is obtained by staining Birch. The European Birch (*Betula alba*) yields the cheapest native hardwood obtainable in many parts of Europe. This wood, which is moderately hard and strong, but not durable, is used for furniture, plates, spoons, sabots, and similar objects. The Russians glue rotary-cut veneers of birch across one another and form thin, rigid planks that are used for tea-chests and chair-bottoms. Occasional burrs yield figured woods that are turned into cups, bowls and mallets.

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[1] See also "Beech, Birches and Maples," Maxwell (United States Department of Agriculture Bulletin No. 12, 1913); "The Birches," Detwiler (American Forestry, April, 1916).

White Birch. *Betula populifolia Marsh*

NOMENCLATURE (Sudworth).
White Birch (local and common name).
Gray Birch (Me., R. I., Mass.).
Oldfield Birch, Poverty Birch (Me.).
Poplar-leaved Birch, Small White Birch (Vt.).

LOCALITIES.
Atlantic Coast, Canada to Delaware and Kentucky.

FEATURES OF TREE.
Twenty to forty feet in height; rarely one foot in diameter; durable, laminated, smooth white bark on the large branches and on the trunk, save near the ground; the bark is not very easily detached from the tree.

COLOR, GRAIN, OR APPEARANCE OF WOOD.
Heartwood light brown; sapwood lighter; close-grained.

STRUCTURAL QUALITIES OF WOOD.
Soft and light; not strong or durable.

REPRESENTATIVE USES OF WOOD.
Clothes-pins, shoe-pegs, toothpicks, and paper-pulp.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

35.

MODULUS OF ELASTICITY.

1,036,000.

MODULUS OF RUPTURE.

11,000.

REMARKS.
The white bark is distinct from that of the Paper Birch (*Betula papyrifera*) in that it does not cover the whole trunk. The layers split less easily from one another.

Paper Birch, White Birch. *Betula papyrifera Marsh*

NOMENCLATURE (Sudworth).

Paper Birch, White Birch (local and common names).
Silver Birch (Minn.).
Large White Birch (Vt.).
Boleau (Quebec).
Canoe Birch (Me., Vt., N. H., R. I., Mass., N. Y., Pa., Wis., Mich., Minn.).

LOCALITIES.

Northern United States, northward into Canada and to the valley of the Yukon in Alaska.

FEATURES OF TREE.

Fifty to seventy feet in height; one and one-half to two and one-half feet in diameter; smooth white exterior bark on large limbs and on trunks at a distance from the ground; brown or orange-colored inner surfaces of bark; the bark splits freely into thin, paper-like layers.

COLOR, GRAIN, OR APPEARANCE OF WOOD.

Heartwood brown, tinged with red; sapwood nearly white; very close-grained; compact structure.

STRUCTURAL QUALITIES OF WOOD.

Strong, hard, and tough; is not durable when exposed to the weather; the bark takes fire easily, even when it is wet.

REPRESENTATIVE USES OF WOOD.

Spools, shoe-lasts, pegs, pill-boxes, paper-pulp, and fuel; the bark was used in canoes.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

37.

MODULUS OF ELASTICITY.

1,850,000.

MODULUS OF RUPTURE.

15,000.

REMARKS.

These trees grow at higher latitudes than most other American deciduous trees. They form forests.[1]

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[1] See also "Paper Birch, *Betula papyrifera Marsh*" (United States Forest Service, Silvical Leaflet No. 38, 1908).

Red Birch. *Betula nigra Linn.*

NOMENCLATURE (Sudworth).

Red Birch (local and common name).
Black Birch (Fla., Tenn., Tex.).
Birch (N. C., S. C., Miss., La.).
River Birch (Mass. R. I., N. J., Del., Pa., W. Va., Ala., Miss., Tex., Mo., Ill., Wis., Ohio).
Water Birch (W. Va., Kans.).
Blue Birch (Ark.).

LOCALITIES.

Massachusetts to Florida, westward intermittently to Nebraska and Texas; best development in South Atlantic and lower Mississippi valley regions.

FEATURES OF TREE.

Thirty to eighty feet in height; one to three feet in diameter, sometimes larger; dark red-brown scaly bark on trunk; red to silver-white bark on branches; the bark separates into thin, paper-like scales, which curl outward.

COLOR, APPEARANCE, OR GRAIN OF WOOD.

Heartwood light brown; sapwood yellowish white; close-grained, compact structure.

STRUCTURAL QUALITIES OF WOOD.

Light, rather hard, and strong.

REPRESENTATIVE USES OF WOOD.

Furniture, woodenware, shoe-lasts, and ox-yokes; inferior cask-hoops are made from the branches; also used as a base upon which enamelled paints are applied.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

35.

MODULUS OF ELASTICITY.

1,580,000.

MODULUS OF RUPTURE.

13,100.

REMARKS.

Dark-brown bark, whence the name Red Birch. Prefers moist bottoms, whence the name River Birch.

Yellow Birch. *Betula lutea Michx. f.*

NOMENCLATURE (Sudworth).

Yellow Birch (local and common name).
Gray Birch (Vt., R. I., Pa., Mich., Minn.).
American Mahogany.
Swamp Birch (Minn.).
Silver Birch (N. H.).
Merisier, Merisier Rouge (Quebec).

LOCALITIES.

Newfoundland to North Carolina, westward intermittently to Manitoba and Texas; best developed north of the Great Lakes.

FEATURES OF TREE.

Sixty to eighty or more feet in height; two to four feet in diameter; a medium-sized tree; the bark on the trunk is silver-gray to silver-yellow, while the bark on the branches varies between green and lustrous or dull-brown; the bark exfoliates, causing a rough, ragged appearance.

COLOR, APPEARANCE, OR GRAIN OF WOOD.

Heartwood light reddish brown; sapwood nearly white; close-grained; compact structure; satin-like appearance.

STRUCTURAL QUALITIES OF WOOD.

Heavy, strong, hard, and tough; is susceptible to a high polish; the qualities suggest those of Maple; is not durable when exposed to the weather.

REPRESENTATIVE USES OF WOOD.

Furniture, buttons, tassel-moulds, pill-boxes, spools, wheel-hubs, and chair seats; occasional burls are valued for making mallets; the wood is also used as a base upon which enamelled paints are applied.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

40.

MODULUS OF ELASTICITY.

2,290,000.

MODULUS OF RUPTURE.

17,700.

REMARKS.

The thin outer bark is sometimes ruptured in such a way as to show the almost metallic yellow of the inner bark. The name is due to the yellow appearance of the inner bark, which is also characterized by the fact that it possesses a pungent, pleasant flavor.

Sweet Birch, Cherry Birch. *Betula lenta Linn.*

Nomenclature (Sudworth).
Sweet Birch, Cherry Birch. (many localities).
Mahogany Birch (N. C., S. C.).
River Birch (Minn.).
Black Birch (N. H., Vt., Mass., R. I., Conn., N. Y., N. J., Pa., W. Va., Ga., Ill., Ind., Mich., Ohio).
Mountain Mahogany (S. C.).

Localities.
Newfoundland, intermittently to Illinois, southward intermittently along the Alleghanies to Kentucky, Tennessee, and Florida.

Features of Tree.
Fifty to eighty feet in height; three to four feet in diameter; the dark reddish-brown bark resembles that of the Cherry; it does not separate into layers as in the case of the Paper Birch (*Betula papyrifera*); the leaves, bark, and twigs are sweet, spicy, and aromatic.

Color, Appearance, or Grain of Wood.
Heartwood dark brown, tinged with red; sapwood light brown or yellow; close-grained; compact structure.

Structural Qualities of Wood.
Heavy, very strong, and hard; the wood is often stained so as to resemble cherry and mahogany; it is also used as a base upon which enamelled paints are applied.

Representative Uses of Wood.
Woodenware, furniture, ship-building (Canada), and fuel.

Weight of Seasoned Wood in Pounds per Cubic Foot.

47.

Modulus of Elasticity.

2,010,000.

Modulus of Rupture.

17,000.

Remarks.
A common tree in some of the Northern States. The name Cherry Birch is due to the bark, the appearance of which suggests that of the Cherry tree. The name Sweet Birch is due to the sweet, spicy essences in the bark.

LOCUST, MESQUITE

Robinia, Gleditsia, Prosopis

The name Locust applies to species of three distinct genera of the family Leguminosæ. The Black Locust (*Robinia pseud-acacia*), the Honey Locust (*Gleditsia triacanthos*), and the Mesquite or Honey Locust (*Prosopis juliflora*) grow in the United States.[1]

The wood of the Black Locust is noted for toughness, durability, and great torsional strength. Black Locust trenails and wheel-spokes have few, if any, superiors. Black Locust trees may be known by their clusters of large peablossom-shaped flowers and by their bean-shaped pods, which are from three to six inches in length. The large thorns on the trunks are also characteristic. There are several species and varieties of the genus Robinia in the United States.

The wood of the Honey Locust resembles that of the Black Locust, but is seldom used, save in rough constructions, as fence rails. The Honey Locust bears blossoms that are smaller than those of the Black Locust, but the pods of the Honey Locust are from ten to eighteen inches long. There are several species and varieties.

The wood of the Mesquite is hard, heavy, and practically indestructible when exposed. Mesquite beams exist in some native houses in the Southwest, and Mesquite railway ties and fence posts are also occasionally seen. Mesquite trees are found where those of other species cannot grow. They can survive when almost entirely covered with sand. To the localities in which they grow, they are much as Bamboos are to China and Japan. The woods themselves are valued; the rich, pulpy pods are used as food; a mucilage is made from the gum; and a dye is made from the sap. One other species, the Screwpod Mesquite (*Prosopis odorata*) is found in the United States.

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[1] See also "An Economic Study of Acacias," Shinn (United States Department of Agriculture, Bulletin No. 9, 1913). "The Locusts," Detwiler (American Forestry, February, 1917).

Locust, Black Locust, Yellow Locust. *Robinia pseudacacia Linn.*

NOMENCLATURE (Sudworth).
Locust, Black Locust, Yellow Locust (local and common names).
False Acacia (S. C., Ala., Tex., Minn.
Pea-flower Locust, Post Locust (Md.).
Red Locust, Green Locust (Tenn.).
Honey Locust (Minn.).
White Locust (R. I., N. Y., Tenn.).
Acacia (La.).

LOCALITIES.
Mountains, Pennsylvania to Georgia, westward to Iowa and Kansas; widely naturalized in the northeastern part of the United States.

FEATURES OF TREE.
Fifty to seventy feet in height; two to three feet or over in diameter; the seven to seventeen leaflets curl up or close at night; there are long spines on young branches.

COLOR, APPEARANCE, OR GRAIN OF WOOD.
Heartwood brownish; the thin sapwood is of a light greenish-yellow color; close-grained and compact; the annual layers are clearly marked.

STRUCTURAL QUALITIES OF WOOD.
Heavy, hard, and strong; durable when exposed to the weather.

REPRESENTATIVE USES OF WOOD.
Long wooden bolts or pins called trenails; posts, ties, construction, turnery, ship-ribs, ornamentation, and fuel.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

45.

MODULUS OF ELASTICITY.

1,830,000.

MODULUS OF RUPTURE.

18,100.

REMARKS.
Extensively planted, particularly in the West. Subject to attacks by insect-borers. One of the most valuable timber trees in the United States. Heartwood forms very early in the life of this tree.

Honey Locust. *Gleditsia triacanthos Linn.*

Nomenclature (Sudworth).
- Honey Locust (local and common name).
- Thorn or Thorny Locust Tree or Acacia (N. Y., N. J., Ind., Tenn., La.).
- Three-thorned Acacia (Mass., R. I., La., Tex., Neb., Mich.).
- Black Locust (Miss., Tex., Ark., Kan., Neb.).
- Honey or Honeyshucks (R. I., N. J., Va., Fla., La.).
- Honeyshucks Locust (Ky.).
- Sweet Locust (S. C., La., Kan., Neb.).
- Piquant Amourette (La.).
- Confederate Pintree (Fla.).
- Locust (Neb.).

Localities.
Ontario and Pennsylvania to Florida, westward intermittently to Nebraska and Texas; best in lower Ohio River basin.

Features of Tree.
Seventy to ninety feet or more in height; two to four feet in diameter; long spines are plentiful on some individuals, but are absent on others; the brown fruit pods, which are from ten to eighteen inches long, contain sweetish, succulent pulp.

Color, Appearance, or Grain of Wood.
Heartwood bright brown or red; sapwood yellowish; annual layers strongly marked; coarse-grained; the medullary rays are conspicuous.

Structural Qualities of Wood.
Heavy, hard, and strong; very durable in contact with the soil.

Representative Uses of Wood.
Fence-posts, rails, wagon-hubs, rough construction work, etc.[1]

Weight of Seasoned Wood in Pounds per Cubic Foot.

42.

Modulus of Elasticity.

1,540,000.

Modulus of Rupture.

13,100.

Remarks.
These trees are widely cultivated for landscape effects. They are also used in hedges.

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[1] See also "Honey Locust," Pinchot (United States Forest Service, Circular No. 74, 1907).

Mesquite. *Prosopis juliflora de C.*

NOMENCLATURE (Sudworth)
Mesquite (Tex., N. M., Ariz., Cal.).
Algaroba (Tex., N. M., Ariz., Cal.).
Honey Pod or Honey Locust (Tex., N. M.).
Ironwood (Tex.).

LOCALITIES.
Texas, west to the San Bernardino Mountains in California. Also Colorado, Utah, Nevada, and northern Mexico. Mesquite trees are cultivated in Hawaii.

FEATURES OF TREE.
Forty to fifty feet in heigth; one to two feet in diameter; sometimes a low shrub; the roots are often very large; the pods contain a sweet pulp; there are gums which resemble gum arabic.

COLOR, APPEARANCE, OR GRAIN OF WOOD.
Heartwood rich dark brown, often red; sapwood clear yellow; close-grained; compact structure; distinct medullary rays.

STRUCTURAL QUALITIES OF WOOD.
Weak, difficult to work, heavy, hard, and very durable receives a high polish.

REPRESENTATIVE USES OF WOOD.
Posts, fencing, ties, house-beams, fuel, and charcoal.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.
47.

MODULUS OF ELASTICITY.
820,000.

MODULUS OF RUPTURE.
6,800.

REMARKS.
The Mesquite tree can survive when almost entirely covered with sand. The roots develop greatly in their search for water, and are often dug up and used for fuel in localities where there is nothing better. The tree is important locally.

CHAPTER VII

Banded Trunks and Woods (Continued)
Broadleaf Series, Part Two

Dicotyledons

WHITEWOOD OR TULIP-TREE WOOD. POPLAR OR COTTONWOOD. CUCUMBER-TREE WOOD. BASSWOOD.

Liriodendron. Populus. Magnolia. Tilia.

These unrelated trees are grouped together because they yield similar, soft, clean, fine-grained woods that are all valued for indoor work. The woods all last well when protected from the weather, but no one of them is durable when exposed.

The Whitewood or Tulip-tree (*Liriodendron tulipifera*) is a native of North America. The wood, which is the best of its kind, is soft, rigid, fine-grained, clean, free from knots, straight-grained, capable of being nailed without splitting, and obtainable in large-sized pieces. It is used for boxes, shelves, the bottoms of drawers, and house-trim. In spite of its name, it is of a greenish-yellow color. The trees are often very large. Matthews[1] mentions a specimen that was thirty-nine feet in circumference. Whitewood trees may be known by their large tulip-shaped flowers.

Poplar Trees Grow on Both Hemispheres.—The tough, light woods will indent without breaking, and were formerly used for shields. The woods are now used much as whitewood is used, for trunks, boxes, woodenware, and indoor finish, but they are not as good as whitewood. The trees are sometimes called Cottonwoods because their seeds are covered with a cotton-like down. The foliage of some species, as the Aspen (*Populus tremuloides*), is agitated by the slightest wind. This is due to the shape of the long leaf-stems[2].

The Balsam Poplar or Balm of Gilead (*Populus balsamifera*), which thrives far into the North, must not be confused with the true Balsam or Balm of Gilead (*Abies balsamea*). Sudworth credits twelve species of the genus Populus to the United States.

The Cucumber-tree (*Magnolia acuminata*) is a member of the Magnolia family, and yields a wood that is seldom distinguished commercially from Whitewood.

Basswood Trees are Known by Many Names.—Limes, Limetrees, Lind, Linden, Tiel, Tieltrees, Beetrees, Bass, and Basswood trees are the same. The woods are prized for their working qualities which resemble, but are inferior to those of whitewood; and the trees are prized for their dense shade and fine appearance. The Basswood (*Tilia americana*) is the principal species in the United States. Basswood trees bear small, fragrant, cream-colored flowers that are often surrounded by bees.

[1] "Familiar Trees," F. Schuyler Matthews (p. 39, Appleton, 1901).

[2] See also "The Aspens," Weigle and Frothingham (United States Forest Service, Bulletin No. 93, 1911); "Cottonwood in the Mississippi Valley," Williamson (United States Department of Agriculture, Bulletin No. 24, 1913.)

Tulip Tree, Whitewood, Yellow Poplar. *Liriodendron tulipifera Linn.*

NOMENCLATURE (Sudworth).

Tulip Tree, Whitewood, Yellow Poplar (local and common names).
Poplar (R. I., Del., N. C., S. C., Fla., Ohio).
Tulip Poplar (Del., Pa., S. C., Ill.).
Hickory Poplar (Va., W. Va., N. C.).
Blue Poplar (Del., W. Va.).
Popple (R. I.).
Cucumber Tree (N. Y.).
Canoewood (Tenn.).

LOCALITIES.

New England to Florida, westward intermittently to Michigan and Arkansas.

FEATURES OF TREE.

Ninety to one hundred and fifty feet in height; six to twelve feet in diameter; tulip-shaped flowers appear in the spring; the greenish cone-like fruit dries and remains after the leaves have fallen.

COLOR, APPEARANCE, OR GRAIN OF WOOD.

Heartwood light yellow or greenish brown; the thin sapwood is nearly white; close and straight-grained; compact structure; free from knots.

STRUCTURAL QUALITIES OF WOOD.

Light, soft, moderately strong, but brittle; easily worked; not durable in contact with the ground; hard to split; shrinks little; resembles White Pine (*Pinus strobus*); stands well in protected places.

REPRESENTATIVE USES OF WOOD.

Lumber, interior finish, woodenware, shelves, and bottoms of drawers; used as a base upon which enamelled paints are applied.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

26.

MODULUS OF ELASTICITY.

1,300,000.

MODULUS OF RUPTURE.

9,300.

REMARKS.

Very large trees were formerly common. Whitewood is sometimes divided by lumbermen into "White Poplar" and "Yellow Poplar." One of the largest and most useful of American deciduous trees.

Poplar, Largetooth Aspen. *Populus grandidentata Michx.*

NOMENCLATURE (Sudworth).

Poplar, Largetooth Aspen (local and common names).
Largetooth Poplar (N. C.).
Large Poplar (Tenn.).
White Poplar (Mass.).
Popple (Me.).
Large American Aspen (Ala.).

LOCALITIES.

Nova Scotia and Delaware, westward intermittently to Minnesota. Alleghany Mountains, to Kentucky, and Tennessee.

FEATURES OF TREE.

Sixty to eighty feet in height; two feet or more in diameter; there are irregular points or teeth on the margins of the leaves; the flowers appear before the leaves in the spring; the gray bark is smooth.

COLOR, APPEARANCE, OR GRAIN OF WOOD.

Heartwood brownish; sapwood nearly white; close-grained; compact structure.

STRUCTURAL QUALITIES OF WOOD.

Soft, light, and weak.

REPRESENTATIVE USES OF WOOD.

Paper-pulp and occasionally woodenware.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

28.

MODULUS OF ELASTICITY.

1,360,000.

MODULUS OF RUPTURE.

10,200.

REMARKS.

The Quaking Aspen (*Populus tremuloides*) has long leafstalks, flattened vertically to the leaf-surfaces, which cause the leaves to tremble in slight winds. This characteristic is more or less pronounced with other species of the genus Populus.

Ailanthus (*Ailanthus glandulosa*). This sturdy, beautiful, very quick-growing, but short-lived tree was once popular in the United States, particularly in city landscapes, but it was discarded because of the disagreeable, far-reaching odor of its flowers. The tree has many merits. In Europe, the wood is used for woodenware and charcoal; in China, certain silkworms feed upon the leaves of the trees. The Chinese call the Ailanthus the "Tree of Heaven." American specimens have grown in excess of ten feet in length during the first year.

Cottonwood. {*Populus deltoides Marsh* / *Populus monilifera Ait.*}

Nomenclature (Sudworth).

Cottonwood (local and common name).
Carolina Poplar (Pa., Miss., La., N. M., Ind., Ohio).
Yellow Cottonwood (Ark., Ia., Neb.).
Big Cottonwood (Miss., Neb.).
Whitewood (Ia.).
Cotton Tree (N. Y.).
Necklace Poplar (Tex., Colo.).
Broadleaved Cottonwood (Colo.).

Localities.

Canada to Florida, westward intermittently to Rocky Mountains.

Features of Tree.

Seventy-five to one hundred feet in height; four to five feet in diameter; occasionally much larger; long catkins distribute cotton-like fibers.

Color, Appearance, or Grain of Wood.

Thin heartwood dark brown; sapwood nearly white; close-grained; compact structure.

Structural Qualities of Wood.

Light, soft, weak, liable to warp, and difficult to season.

Representative Uses of Wood.

Greatly valued in the manufacture of paper-pulp; also used for packing-boxes, fence-boards, and fuel.

Weight of Seasoned Wood in Pounds per Cubic Foot.

24.

Modulus of Elasticity.

1,400,000.

Modulus of Rupture.

10,900.

Remarks.—

See also "Cottonwood" (United States Forest Service, Circular No. 77).

Black Cottonwood. *Populus trichocarpa Torr. and Gr.*

NOMENCLATURE (Sudworth).
Black Cottonwood (Oreg., Cal.).
Balsam Cottonwood, Balm (Oreg.).
Cottonwood (Oreg., Cal.).
Balm Cottonwood (Cal.).

LOCALITIES.
Pacific Coast region, Alaska to California.

FEATURES OF TREE.
A large tree, sometimes one hundred and fifty feet in height and four to six feet in diameter; the broadly ovate leaves have blunt, marginal teeth.

COLOR, APPEARANCE, OR GRAIN OF WOOD.
Heartwood light dull brown; sapwood nearly white; compact structure.

STRUCTURAL QUALITIES OF WOOD.
Light, soft, and weak.

REPRESENTATIVE USES OF WOOD.
Staves, and sometimes woodenware.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

23.

MODULUS OF ELASTICITY.

1,580,000.

MODULUS OF RUPTURE.

8,400.

REMARKS.
The largest deciduous tree of the Puget Sound district.

The Cottonwood, Tacmahac, Balsam, Balsampoplar, or Balm of Gilead (*Populus balsamifera*) which grows from Hudson Bay and Alaska, southward to Oregon and New England is a distinctly northern species. The large upright trunk yields a light, soft, light-colored wood which has been used in making paper. The exudations are sometimes used in medicine.

Cucumber-tree. *Magnolia acuminata Linn.*

Nomenclature (Sudworth).
Cucumber-tree (R. I., Mass., N. Y., Pa., N. C., S. C., Ala., Miss., La., Ark., Ky., W. Va., Ohio, Ind., Ill.).
Mountain Magnolia (Miss., Ky.).
Black Lin, Cucumber (W. Va.).
Magnolia (Ark.).

Localities.
New York to Illinois, southward intermittently through Kentucky and Tennessee to the Gulf.

Features of Tree.
Fifty to occasionally one hundred feet in height; two to four feet in diameter; a large, handsome, symmetrical tree, with fruit suggesting cucumbers; large greenish-yellow or cream-colored flowers.

Color, Appearance or Grain of Wood.
Heartwood brownish yellow; sapwood nearly white; close-grained; compact structure; thin medullary rays.

Structural Qualities of Wood.
Light, soft, not strong, but durable.

Representative Uses of Wood.
Cabinet-making, cheap furniture, flooring, pump-logs, troughs, crates, and packing-boxes.

Weight of Seasoned Wood in Pounds per Cubic Foot.

29.

Modulus of Elasticity.

1,310,000.

Modulus of Rupture.

9,500.

Remarks.
The wood resembles and is often sold for that obtained from the Tulip Tree (*Liriodendron tulipifera*).

Basswood, Linn, Linden. *Tilia americana Linn.*

Nomenclature (Sudworth).
- Basswood, Linn, Linden, American Linden (local and common names).
- Limetree (R. I., N. C., S. C., Ala., Minn., La., Ill.).
- Black or Smooth-leaved Limetree (Tenn.).
- Whitewood (Vt., W. Va., Ark., Minn.).
- Yellow Basswood, Lein (Ind.).
- Beetree (Vt., W. Va., Wis.).
- White Lind (W. Va.).
- Wickup (Mass.).

Localities.
New Brunswick to Georgia, westward intermittently to Manitoba and Texas. A wide range.

Features of Tree.
Sixty to ninety feet in height; two to four feet in diameter; occasionally larger; large smooth leaves; fragrant flowers, borne on slender, leaf-like structures.

Color, Appearance, or Grain of Wood.
Heartwood light or reddish brown; thick sapwood nearly similar; very straight and close-grained; compact structure.

Structural Qualities of Wood.
Light, soft, easily worked, and tough; not strong or durable.

Representative Uses of Wood.
Sides and backs of drawers, bodies of carriages, woodenware, and paper-pulp.[1]

Weight of Seasoned Wood in Pounds per Cubic Foot.

28.

Modulus of Elasticity.

1,190,000.

Modulus of Rupture.

8,300.

Remarks.
Parts of the inner bark have occasionally been utilized for cordage. The fragrant flowers attract bees. The wood of the White Basswood (*Tilia heterophylla*) is not distinguished from that of the Common Basswood by dealers.

[1] See also "Basswood," Pinchot (United States Forest Service, Circular No. 63, 1907).

WILLOW

Salix

The willows grow in many places on both hemispheres. North Americans value the fast-growing, characteristically shaped trees; while Europeans value the woods. The principal experience with the wood of the Willow has been gained in Europe. The wood is light, tough, easily worked, and elastic. It resists splintering, stands well against abrasion, and in Europe is used for friction-brake linings, lapboards, cricket bats, keels and paddles. Willow charcoal ignites readily and for this reason is used in gunpowder. Willow rods are used in basket-making.[1]

In the United States Willow trees are used to protect and sometimes, by creating eddies, to recover land from water encroachment. Saplings up to three or four inches in diameter are used in river improvements. These saplings are made into mattresses which are placed along the banks of streams to prevent scour. Some of the mattresses thus constructed for Mississippi River improvement work are three hundred feet wide and one thousand feet long.[2] Saplings are known as "Osiers" and are regularly cultivated in Europe.

The term Osier Willow is sometimes applied to trees that yield strong, slender shoots. The true Osier, Sandbar, or Longleaf Willow (*Salix fluviatilis*) grows in many places from the Arctic Ocean southward to Mexico. The White, Crack, Bedford, and Goat Willows (*Salix alba, Salix fragilis, Salix russeliana,* and *Salix caprea*) are said to afford good woods.

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[1] See also "The Basket Willow" (United States Forest Service, Bulletin No. 46); "Production and Consumption of Basket Willows in the United States, etc.," Mell (United States Forest Service, Circular No. 155, 1909); "Basket Willow Culture," Lamb (United States Department of Agriculture, Farmers" Bulletin No. 622, 1914); "Willows: Their Growth, Use, and Importance," Lamb (United States Forest Service, Bulletin No. 316, 1915). "The Willows: Identification and Characteristics," Detwiler, (American Forestry, January, 1917).

[2] "Bank Revetment on the Lower Mississippi," Coppee (Transactions American Society of Civil Engineers, Vol. 35, p. 198); "Erosion of River Banks on the Mississippi and Missouri Rivers," Ockerson (Transactions American Society of Civil Engineers, Vol. 38, p. 396).

Black Willow. *Salix nigra Marsh*

NOMENCLATURE (Sudworth).
Black Willow (local and common name).
Swamp Willow (N. C., S. C.).
Willow (N. Y., Pa., N. C., S. C., Miss., Tex., Cal., Ky., Mo., Neb.).

LOCALITIES.
New Brunswick to Florida, westward intermittently to the Dakotas, Arizona, California, and Mexico; grows best on bottom lands and along the borders of rivers.

FEATURES OF TREE.
Forty to fifty feet in height; two to four feet in diameter; long, narrow leaves; a characteristic appearance.

COLOR, APPEARANCE, OR GRAIN OF WOOD.
Heartwood brown; sapwood nearly white; close-grained.

STRUCTURAL QUALITIES OF WOOD.
Soft, light, and weak; checks badly in drying; readily worked; dents without splitting.

REPRESENTATIVE USES OF WOOD.
Lap-boards, basket-making, fuel, and charcoal.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

27.

MODULUS OF ELASTICITY.

550,000.

MODULUS OF RUPTURE.

6,000.

REMARKS.
Many species and varieties of Willow trees grow in the United States, but none of them yield wood that is used to any extent in construction. Willow rods, either whole or split, are used by basket makers. It is said that sap-peeled rods retain their light color, and that steamed rods turn yellow. The European uses of Willow wood have been referred to.

The White Willow (*Salix alba*), which has been naturalized in North America, is hardy, even when located in dry places. On the prairies, this tree is sometimes used as a wind-break. Trees planted several feet apart serve as fence-posts to support barbed wire.

CATALPA

Catalpa

Catalpa trees grow in the eastern part of the United States, in the West Indies, and in some parts of China. The Common Catalpa (*Catalpa catalpa*) and the Hardy Catalpa (*Catalpa speciosa*) are natives of North America. The name of the genus is that which was given to one of these species by the Cherokee Indians.

Until recently the Catalpas have attracted but little attention. But they are now regarded with interest, because, when the right conditions prevail, the trees grow rapidly and yield woods that can be used in construction. Catalpa trees have reached a thickness of as much as sixteen inches in seventeen years. The wood is soft, weak, brittle, clean, smooth-grained, and very durable. Von Schrenk believes that the final disintegration of this wood will not be due to attacks from fungi, since no fungus has yet been found that will grow in dead Catalpa lumber. The wood is attractive in appearance and is suitable for some forms of interior finish as well as for carpentry. Catalpa posts and poles are highly valued, but railway ties of this wood do not stand well under heavy traffic. The supply of Catalpa wood thus far is limited.

Catalpa trees may be known by their flowers and by their long beans, which are sometimes known as smoking-beans.[1]

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[1] The Forester, October, 1900, and November, 1902. Forestry Quarterly, vol. iii, N. Y. "An Experiment in Western Catalpa." (Report of the Pennsylvania Dept. of Forestry for 1910–11.) "Hardy Catalpa," Hall and von Schrenk (United States Forestry Bureau, Bulletin No. 37).

Catalpa, Hardy Catalpa. *Catalpa speciosa Warder*

NOMENCLATURE (Sudworth).

Catalpa (R. I., N. Y., La., Ill., Ind., Mo., Wis., Ia., Neb., Minn.).
Hardy Catalpa (Ill., Ia., Kan., Mich.).
Western Catalpa (Pa., Ohio, Ia., Neb., Ill.).
Cigar Tree (Mo., Ia.).
Indian Bean, Shawneewood (Ind.).
Bois Puant (La.).

LOCALITIES.

Central Mississippi Valley, naturalized in many localities.

FEATURES OF TREE.

Forty to sixty feet or more in height; three to six feet in diameter; well-formed trunk; large, white, faintly mottled flowers; long pods or beans.

COLOR, APPEARANCE, OR GRAIN OF WOOD.

Thick heartwood brown; thin sapwood lighter, nearly white; coarse-grained; compact structure; annual layers clearly marked; an attractive wood.

STRUCTURAL QUALITIES OF WOOD.

Light, soft, not strong, but durable in contact with the soil.

REPRESENTATIVE USES OF WOOD.

Railway ties, fence-posts, and rails; can be used in cabinet-work and interior finish.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

25.

MODULUS OF ELASTICITY.

1,160,000.

MODULUS OF RUPTURE.

9,000.

REMARKS.

Catalpa trees are not seriously injured by occasional inundations, and, for this reason, are sometimes planted along streams. Under the right conditions, they grow rapidly, and are sometimes used in landscape effects. As a rule, the trunks of the Hardy Catalpa are better formed than those of the Catalpa.

Paulownia (*Paulownia tomentosa*). This tree is a native of Asia, but is now cultivated in some of the Central-Atlantic and Southern States. It has catalpa-like leaves, which are preceded by large pale blue or violet flowers and followed by woody, capsule-like fruit that in form suggests hickory nuts. The species, which is of small importance, is not related to the Catalpa, but is sometimes confused with it.

Catalpa. { *Catalpa catalpa (Linn.) Karst*
Catalpa bignonioides Walt. }

Nomenclature (Sudworth).

Catalpa (local and common name).
Indian Cigar Tree (Pa.).
Smoking Bean (R. I.).
Cigar Tree (R. I., N. J., Pa., W. Va. Mo., Ill., Wis., Ia.).
Indian Bean (Mass., R. I., N. Y., N. J., Pa., N. C., Ill.).
Catawba, Catawba Tree (Del., W. Va., Ala., Fla., Kan.).
Beantree (N. J., Del., Pa., Va., La., Neb.).

Localities.

Native only in the Gulf States, but naturalized in many localities east of the Rocky Mountains.

Features of Tree.

Thirty to fifty feet in height; one to two or more feet in diameter; often the trunks are not well formed; low, wide trees, with large heart-shaped leaves and characteristic flowers; long slender pods or beans; distinguished from the Hardy Catalpa by the fact that the flowers are smaller and in denser clusters.

Color, Appearance, or Grain of Wood.

Thick heartwood is light pink brown; the thin sapwood is nearly white; coarse-grained; compact structure.

Structural Qualities of Wood.

Light, soft, not strong, but durable in contact with the soil.

Representative Uses of Wood.

Fence-posts, railway ties, etc.

Weight of Seasoned Wood in Pounds per Cubic Foot.

27.

Modulus of Elasticity.

960,000.

Modulus of Rupture.

8,300.

Remarks.

These trees grow rapidly, but the wood is less desirable than that obtained from the Hardy Catalpa (*Catalpa speciosa*). The long pods which remain on the trees after the leaves have disappeared, are sometimes used locally as cigars.

MULBERRY

Morus

Two species of Mulberry grow in North America, and a few others grow abroad. Of these, the most valuable is the White Mulberry (*Morus alba*), a native of northern China and Japan, which is now also cultivated in many other countries for its leaves which form the best food for silkworms. The Red Mulberry (*Morus rubra*) and the Mexican Mulberry (*Morus celtidifolia*) are the species that are native to the United States.

The American species yield fairly hard, rather heavy, and quite durable woods that are sometimes used in cooperage, flumes, boats, and fences.

White, Red, and Black Mulberry trees may be distinguished from one another by the color of their sweet berries.

Red Mulberry, Mulberry. *Morus rubra Linn.*

Nomenclature (Sudworth).

Red Mulberry, Mulberry (local and common names).
Black Mulberry (N. J., Pa., W. Va.).
Virginia Mulberry Tree (Tenn.).
Murier Sauvage (La.).

Localities.

Massachusetts to Florida, westward intermittently to Nebraska and Texas; best in lower Ohio and Mississippi River basins.

Features of Tree.

Fifty to sixty feet in height; two and one-half to three feet in diameter; sweet, edible fruit; the leaves are very variable, sometimes entire, but often three-lobed; dark brown broken bark; smooth gray branches.

Color, Appearance, or Grain of Wood.

Thick heartwood, light orange yellow; thin sapwood whitish; coarse-grained; compact structure; the annual layers are clearly marked.

Structural Qualities of Wood.

Light, soft, not strong, but very durable in contact with the soil; it receives a good polish.

Representative Uses of Wood.

Fencing, cooperage, etc.

Weight of Seasoned Woods in Pounds per Cubic Foot.

36.

Modulus of Elasticity.	Modulus of Rupture.
11,700,000.	11,000.

Remarks.

An ornamental tree.

HORSE CHESTNUT. BUCKEYE

Aesculus

Horse Chestnut trees (*Aesculus hippocastanum*), supposed to be natives of Asia, have long been among the most popular shade trees of Europe and North America. The Buckeyes (*Aesculus glabra, Aesculus octandra,* and *Aesculus californica*) grow from Ohio and southern Iowa, southward to northern Georgia and northern Louisiana, and in California. The name "Horse Chestnut" is probably due to an ironical reference to the coarse nuts, while the name "Buckeye" refers to the appearance of the nut of that tree which, under certain conditions, suggests the eye of the deer.

Horse Chestnut and Buckeye woods resemble one another, in that both are soft, straight-grained, and easily worked. They decay rapidly when exposed to the weather. The woods are sometimes employed in artificial limbs, splints, woodenware, and paper pulp.

Both trees may be known by their nuts, which are enclosed in prickly husks.[1]

[1] See also "Trees of Northern States and Canada," Hough, page 338.

Ohio Buckeye, Fetid Buckeye. *Aesculus glabra Willd.*

NOMENCLATURE (Sudworth).

Buckeye, Ohio Buckeye (local and common names).
Fetid Buckeye (W. Va.).
Stinking Buckeye (Ala., Ark.).
American Horse Chestnut (Pa.).

LOCALITIES.

Ohio River basin to Alabama, portions of Iowa, Kansas, and Oklahoma.

FEATURES OF TREE.

Twenty-five to forty-five feet in height; one to one and one-half feet in diameter; the yellowish-white flowers are succeeded by round prickly pods which contain nuts.

COLOR, APPEARANCE, OR GRAIN OF WOOD.

Heartwood white; sapwood a little darker; close-grained; frequent dark lines of decay.

STRUCTURAL QUALITIES OF WOOD.

Weak, light, and soft, but hard to split.

REPRESENTATIVE USES OF WOOD.

Artificial limbs, woodenware, and paper-pulp; rarely lumber.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

28.

MODULUS OF ELASTICITY.

910,000.

MODULUS OF RUPTURE.

7,000.

REMARKS.

The nearly similar Horse Chestnut (*Aesculus hippocastanum*) is not native, but is largely planted in North America. It is from forty to fifty or more feet in height, and is from two to sometimes four feet in diameter. The Horse Chestnut tree is one of the most popular of all shade trees. The light, weak wood is seldom used.

Buckeye, Sweet Buckeye. *Aesculus octandra Marsh*; *Aesculus flava Ait.*

NOMENCLATURE (Sudworth).
Buckeye (N. C., S. C., Ala., Miss., La., Tex., Ky.).
Sweet Buckeye (W. Va., Miss., Tex., Mo., Ind.).
Yellow Buckeye (S. C., Ala.).
Large Buckeye, Big Buckeye (Tex. Tenn.).

LOCALITIES.
Alleghany Mountains, Pennsylvania to Georgia, westward intermittently to Iowa and Texas.

FEATURES OF TREE.
Forty to seventy feet in height; one to three feet in diameter; sometimes a low shrub; the pods are distinguished from those of the Ohio Buckeye (*Aesculus glabra*) by the fact that they are smooth.

COLOR, APPEARANCE, OR GRAIN OF WOOD.
Heartwood creamy white; sapwood similar; compact structure; close-grained; difficult to split.

REPRESENTATIVE USES OF WOOD.
Similar to those of the Ohio Buckeye (*Aesculus glabra*).

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

26.64.

MODULUS OF ELASTICITY.

MODULUS OF RUPTURE.

REMARKS.
The California Buckeye or California Horse Chestnut (*Aesculus californica*), grows along the Pacific Coast from Mount Shasta, southward to Los Angeles. It is often quite small, but in some localities is from thirty to forty feet in height. The soft, light, compact, close-grained, ivory-white wood could probably be employed in turnery.

GUM

Liquidambar, Nyssa

This name applies to a number of trees that lie within at least two genera. One genus (*Liquidambar*) contributes about four species, which grow in many places in the eastern part of the United States and parts of Mexico, Central America, and Asia; while the other genus (*Nyssa*) includes five species which grow only in the eastern part of the United States and in the southern part of Asia.[1]

The wood of the Red or Sweet Gum (*Liquidambar styraciflua*) is about as strong and stiff as that of the chestnut. It is brittle, straight-grained, rather fine and dense, absorbent, liable to warp and twist in seasoning, fairly heavy, and moderately soft. Its natural color is attractive, but this is often changed by staining, so as to resemble the colors of other woods. Some pieces of Red Gum resemble walnut and these are usually cut into veneers which are sometimes misleadingly sold under such names as "California Red Gum," "Hazel," "Satin Walnut," and even "Circassian Walnut." Ordinary pieces are sparingly used for many purposes, as railway ties, carpentry, flooring, furniture, paving blocks, packing boxes, barrel staves, pulley-facing, coffin boards, and woodenware. The trees, which are very attractive and which are prized in landscape effects, bear rough fruiting heads or balls about as large as the fruiting heads of the sycamore. Their pointed, star-shaped leaves exhibit bright scarlet and purple tints during the autumn.

The wood of the Water Gum or Tupelo Gum (*Nyssa aquatica*) is often marketed with that of the Red Gum. This wood is light, strong, tough, fine-grained, easily glued, and comparatively cheap. Its cellular arrangement is complicated and the wood is correspondingly hard to split and work. The heartwood varies in color from dull gray to dull brown, while the color of the sapwood resembles that of ordinary poplar. After seasoning, it is often hard to distinguish between the sapwood of the better grades of Tupelo Gum and ordinary poplar. This wood is also sold under other names, as "Bay Poplar," and "Circassian Walnut," and is used for packing boxes, furniture, the backs of drawers, and house-trim. The trees, which often grow in deep swamps and along the margins of water courses, bear leaves which exhibit beautiful purple and reddish tints in the autumn. The Sour Gum or Black Gum (*Nyssa sylvatica*) yields a rather soft, light, tough, fine, but irregularly grained wood, which is hard to split and work, and which is used for wheel-hubs, rollers, woodenware, thin lumber, and fruit crates. The Sour Gum tree grows in swamps and hardwood bottoms. Its range is greater than that of the others, but the Sour Gum forms a much less important part of the forest.

[1] See also "The Red Gum" Chittenden and Hatt (United States Forest Service, Bulletin No. 58, 1906), "The Utilization of Tupelo," Holroyd (United States Forest Service, Circular No. 40, 1906), "Distinguishing Characteristics of North American Gumwoods," Sudworth and Mell (United States Forest Service, Bulletin No. 103, 1911), "The Red Gum" Detwiler (American Forestry, November, 1916).

Gum, Sweet Gum, Red Gum. *Liquidambar styraciflua Linn.*

NOMENCLATURE (Sudworth).

Gum, Sweet Gum, Red Gum (local and common names).
Liquidambar (R. I., N. Y., Del., N. J., Pa., La., Tex., Ohio, Ill.).
Gum Tree (Va., S. C., La.).
Alligatorwood, Blisted, (N. J.).

LOCALITIES.

Connecticut to Florida, westward intermittently to Illinois, Texas, and Mexico; best development in basin of Mississippi River.

FEATURES OF TREE.

Eighty to one hundred or more feet in height; three to five feet in diameter; a tall, straight trunk; corky ridges are frequent on the branches; the star-shaped leaves turn to brilliant scarlet in the autumn; there are round balls on long stems.

COLOR, APPEARANCE, OR GRAIN OF WOOD.

Heartwood rich brown, suggests Black Walnut; sapwood nearly white; close-grained; compact structure.

STRUCTURAL QUALITIES OF WOOD.

About as strong and stiff as Chestnut;[1] heartwood is durable when exposed; wood shrinks and warps badly if seasoned by ordinary methods, but responds to special methods; glues and paints well; holds spikes well; receives a high polish; tasteless.

REPRESENTATIVE USES OF WOOD.

Veneers, cabinet-work, packing boxes, carpentry, shingles, clapboards, paving-blocks, wooden plates, and barrel staves.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

37 (United States Forestry Division).
36.

MODULUS OF ELASTICITY.

1,700,000 (average of 118 tests by United States Forestry Division).[2]
1,220,000.

MODULUS OF RUPTURE.

9,500 (average of 118 tests by United States Forestry Division).[2]
9,200.

REMARKS.

The wood has other commercial names as "Hazel," "Satin Walnut," "Star-leaved Gum." Clear wood can be obtained in boards of large size. The larger trees often have hollow butts.

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[1] Woodward, reported Gum ties as good after five years of service on the Texas & Pacific Railroad.

[2] See p. 33.

Tupelo Gum, Cotton Gum, Large Tupelo. *Nyssa aquatica Linn.*

Nomenclature (Sudworth).

Tupelo Gum, Cotton Gum, Large Tupelo (local and common names).
Sour Gum (Ark., Mo.).
Tupelo, Swamp Tupelo (N. C. S. C., La.).
Olivetree, Wild Olivetree (Miss. La.).

Localities.

Virginia and Kentucky, southward and westward to Missouri and Texas.

Features of Tree.

Sixty to eighty feet in height; two to three feet in diameter.

Color, Appearance, or Grain of Wood.

Heartwood light brown, often nearly white; sapwood nearly the same.

Structural Qualities of Wood.

Soft, light, not strong; close, compact grain; difficult to work.

Representative Uses of Wood.

Turnery, woodenware, boxes, and fruit-crates; pieces of the root are sometimes used to float nets.

Weight of Seasoned Wood in Pounds per Cubic Foot.

32.

Modulus of Elasticity.

730,000.

Modulus of Rupture.

9,300.

Remarks.

These trees grow on rich bottom lands and in deep swamps. They are often associated with cypress trees. The specific name is due to the fact that the trees tolerate quantities of water. The butts of large trees are usually hollow, while the parts above are usually sound.

The Sour Gum (*Nyssa ogeche*) grows along the Atlantic Coast from South Carolina to Northern and Western Florida. The trees, which are usually found on wet lands, attain heights of from thirty to fifty feet. The soft, compact, weak, brownish heartwood is hardly distinguishable from the brownish sapwood. The tree is also known as Ogeechee Lime, Wild Limetree, Limetree, Tupelo, Sour Tupelo, and Gopher Plum.

Sour Gum, Black Gum, Tupelo.

Nyssa sylvatica Marsh.
Nyssa multiflora Wang.

NOMENCLATURE (Sudworth).

Sour Gum, Black Gum, Tupelo (local and common names).
Pepperidge (Vt., Mass., R. I., N. Y., N. J., S. C., Tenn., Mich., Ohio, Ontario).
Wild Pear Tree, Yellow Gum Tree (Tenn.).
Gum (Md.).
Stinkwood (W. Va.).
Tupelo Gum (Fla.).

LOCALITIES.

Ontario and Maine to Florida, westward intermittently to Michigan and Texas.

FEATURES OF TREE.

Forty-five to one hundred feet in height; several inches to occasionally four feet in diameter; ovoid, bluish black, sour fruit, with ribbed seed; horizontal branches; short, spur-like lateral branchlets.

COLOR, APPEARANCE, OR GRAIN OF WOOD.

Heartwood light brown or yellow, often nearly white; the sapwood is hardly distinguishable; fine-grained; interwoyen cell-structures.

STRUCTURAL QUALITIES OF WOOD.

Strong, tough, not hard; the cell-structures are interlaced, and for this reason the wood checks unless it is carefully seasoned; it is hard to work.

REPRESENTATIVE USES OF WOOD.

Wagon-hubs, rollers, and ox-yokes; woodenware, such as bowls and shoes; thin lumber is used for boxes and crates; selected pieces used in cabinet work.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

39.

MODULUS OF ELASTICITY.

1,160,000.

MODULUS OF RUPTURE.

11,800.

REMARKS.

These trees grow on hillsides and along the borders of swamps and waterways. Large trees are often hollow near the ground. The wood has a limited field of usefulness because it is so hard to work.

HOLLY	BOXWOOD	LIGNUMVITÆ
Ilex	*Buxus, Cornus, etc.*	*Guajacum*

These trees yield small but very perfect pieces of wood that fill needs for which no other woods seem equally fitted.

Holly trees (*Ilex opaca*) grow along the coast in the United States from Quincy, Massachusetts, to Louisiana, and in the interior, in parts of Missouri, Illinois, Kentucky, Tennessee, and Arkansas. The wood, which is noted for its fine even grain and its smooth, ivory-white color, is used for carvings, decorations, and inlaid work, where fine qualities and white effects are required. The European source is the Holly (*Ilex aquifolium*). Holly trees are noted for their brilliant evergreen foliage and bright red berries, that have long been associated with the Christmas season.

The true Boxwood (*Buxus sempervirens*) becomes a tree in some parts of Europe, Asia, and northern Africa, but, in the United States, is generally a small shrub that is useless, save in landscape effects. The wood is noted for its fine, firm, even texture and is used for carvings and mathematical instruments. No other wood is better for wood engravings. Boxwood is often hard to season. It is said that French engravers place pieces designed for their finest work in dark cellars as soon as they are cut, and that they keep them in such surroundings for several years before they are used. American Boxwood is derived from the Flowering Dogwood (*Cornus florida*) and from several other species.

The Lignumvitæs (*Guajacum sanctum and Guajacum officinale*) grow in Florida, the West Indies, Colombia, and Venezuela, and yield wood that is noted for great weight, strength, complicated cellular structure, and durability. Under the axe, it may be said to crumble rather than to split. It contains a resin (Guajac) that is sometimes used in medicine and as a lubricant. The wood is used for rollers, pulley sheaves, tool handles, and sometimes in place of bearing metals in parts of marine engines. Some lignumvitæ ties, removed from the Panama Railway after more than thirty years of service, because they were too small to afford proper bearings for the rails, were still in good condition.

Holly, American Holly. *Ilex opaca Ait.*

NOMENCLATURE (Sudworth).

Holly, American Holly (local and common names). White Holly (Va.).

LOCALITIES.

Maine to Florida, westward intermittently to Indiana and Texas.

FEATURES OF TREE.

Occasionally fifty feet in height and three feet in diameter, but frequently much smaller, particularly in the North; the spiny-margined evergreen leaves are of a bright green color; the bright red berries remain until the spring.

COLOR, APPEARANCE, OR GRAIN OF WOOD.

Heartwood cream white, darkening or spotting on exposure; sapwood similar or lighter; very close-grained; compact structure.

STRUCTURAL QUALITIES OF WOOD.

Tough, moderately hard and heavy, easily worked.

REPRESENTATIVE USES OF WOOD.

Inlaid work, carvings, scrollwork, and turnery; moderately used for furniture and decoration.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

36.

MODULUS OF ELASTICITY.

910,000.

MODULUS OF RUPTURE.

9,700.

REMARKS.

The wood suggests ivory, and is characteristically employed for the white of inlaid work. The more elaborate specimens of inlaid work are manufactured in Italy, but are not always durable when brought into highly heated houses in the United States. Inlaid work manufactured in the United States may be less elaborate than the foreign product, but it is often more durable.

Dogwood, Flowering Dogwood. *Cornus florida Linn.* / *Cynoxylon floridum.*

Nomenclature (Sudworth).
Dogwood, Flowering Dogwood (local and common names).
Boxwood (Conn., R. I., N. Y., Mich., Ky., Ind., Ont.).
False Box-dogwood (Ky.).
New England Boxwood (Tenn.).
Cornel, Flowering Cornel (Tex., R. I.).

Localities.
Ontario and New England to Florida, westward intermittently to Minnesota and Texas; also found in the Sierra Madre Mountains and in Mexico.

Features of Tree.
Twenty-five to thirty-five feet in height; one foot or more in diameter; often a low shrub; large, white flower-like bracts precede the development of the true, but less conspicuous, greenish flowers which precede the leaves; in the fall, red berries are exhibited; the bark is rough and dark.

Color, Appearance, or Grain of Wood.
Heartwood rich brown, changing to green and red; sapwood lighter; close-grained; compact structure.

Structural Qualities of Wood.
Heavy, strong, tough, and hard; it receives a high polish.

Representative Uses of Wood.
Wood-carving, wood-engraving, bearings of machinery, and turnery.

Weight of Seasoned Wood in Pounds per Cubic Foot.

50.

Modulus of Elasticity.

1,160,000.

Modulus of Rupture.

12,800.

Remarks.
The Mexican or Black Persimmon, and the Great Laurel (*Rhododendron maximum*) yield woods that are used in place of Dogwood. The Yellow-wood (*Schœfferia frutescens*), which is found in Florida, also yields wood that is known as Boxwood. The names Dogwood and Poison Dogwood are sometimes applied to the Sumach.

Lignumvitæ. *Guajacum sanctum*

NOMENCLATURE (Sudworth).
Lignumvitæ (Fla.). Ironwood (Fla.).

LOCALITIES.
Semitropical Florida, the Bahamas, San Domingo, Cuba, Puerto Rico, Jamaica and Yucatan.

FEATURES OF TREE.
Twenty-five feet in height; one foot in diameter; a low, gnarled tree.

COLOR, APPEARANCE, OR GRAIN OF WOOD..
Heartwood rich yellow brown in younger specimens and almost black in older ones; sapwood light yellow; close-grained; compact structure.

STRUCTURAL QUALITIES OF WOOD.
Very heavy and exceedingly hard; strong, hard to work, and brittle; very durable; the wood contains a resin which acts as a lubricant when in water.

REPRESENTATIVE USES OF WOOD.
Rollers, pulley-sheaves, and tool-handles; bearings for parts under water.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

71.

MODULUS OF ELASTICITY.

1,220,000.

MODULUS OF RUPTURE.

11,100.

REMARKS.
Two other species (*Guajacum officinale* and *Guajacum arboreum*) afford similar woods which are not distinguished commercially from the above.

LAUREL

Magnolia, Rhododendron, Arbutus, etc.

The name Laurel applies locally or botanically to a number of American plants, several of which attain to the dignity of trees.

The Big Laurel or Magnolia (*Magnolia fœtida*) grows naturally along the Atlantic Coast from North Carolina to Florida, and thence through the Gulf region westward to Texas. The tree, which is also cultivated in other localities with temperate climates, is very beautiful and valued in landscape effects, while the hard, heavy, whitish wood is occasionally used in cabinet work. The California Laurel (*Umbellularia californica*) and the Laurel or Madroña (*Arbutus menziesii*) are Pacific Coast species, which yield strong, hard, heavy, and attractive woods that are sometimes used in furniture. Sargent[1] regards the wood of the former species as the most valuable of those produced in the forests of the Pacific region for interior finish and furniture. The wood of the Great Laurel or Rose Bay (*Rhododendron maximum*) is hard, rather brittle, close-grained, and heavy, and is sometimes used as a substitute for Boxwood in wood engraving. The gnarled roots of the Mountain Laurel or Calico Bush (*Kalmia latifolia*) are occasionally used for rustic hanging-baskets, rustic seats, and the like.

[1] "Manual of the Trees of North America," Sargent (Houghton, Mifflin & Company, 1905, p. 335).

California Laurel, Mountain Laurel. *Umbellularia californica Nutt*

NOMENCLATURE (Sudworth).
California Laurel, Mountain Laurel (Cal., Nev.).
California Bay-tree, Spice-tree (Cal., Nev., Oreg.).
Laurel, Bay-tree, Oreodaphne (Cal.).
Myrtle-tree, Cajeput, California Olive (Oreg.).
Californian Sassafras.

LOCALITIES.
California and Oregon.

FEATURES OF TREE.
Seventy-five to one hundred feet in height; three to five feet in diameter; evergreen foliage; beautiful appearance.

COLOR, APPEARANCE, OR GRAIN OF WOOD.
Heartwood light rich brown; sapwood lighter brown; close-grained; compact structure.

STRUCTURAL QUALITIES OF WOOD.
Heavy, hard, and strong; receives a beautiful polish.

REPRESENTATIVE USES OF WOOD.
Ship-building, cabinet-work, cleats, and crosstrees.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

40.

MODULUS OF ELASTICITY.

1,510,000.

MODULUS OF RUPTURE.

11,400.

REMARKS.
A valuable local cabinet wood.

Madroña, Madroña Laurel. *Arbutus menziesii Pursh.*

NOMENCLATURE (Sudworth).

Madroña, Madroña Laurel (Cal., Oreg.).
Laurel, Laurelwood, Madrone.
Madrone-tree, Manzanita (Oreg., Cal.).
Madrove (Cal.).

LOCALITIES.

Pacific Coast from British Columbia to southern California.

FEATURES OF TREE.

Fifty to seventy-five feet in height, occasionally higher; two to four feet in diameter; a straight, well-formed trunk; evergreen foliage; a shrub in the South.

COLOR, APPEARANCE, OR GRAIN OF WOOD.

Thick heartwood reddish; thin sapwood slightly pink; close-grained; numerous and conspicuous medullary rays.

STRUCTURAL QUALITIES OF WOOD.

Heavy, hard, and strong; checks badly in seasoning.

REPRESENTATIVE USES OF WOOD.

The charcoal is used in gunpowder; the wood is sometimes used for furniture.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

43.

MODULUS OF ELASTICITY.

1,190,000.

MODULUS OF RUPTURE.

12,000.

REMARKS.

A beautiful ornamental tree yielding attractive wood which is seldom used save locally. The Madroña tree has been confused with the Laurel, Madroña, or Mexican Madroña (*Arbutus xalapensis* or *Arbutus texana*), also called the Manzanita, and with the California species of the genus *Arctostaphylos* from which Manzanita wood is derived.

The name Manzanita is somewhat loosely used to designate hard, heavy, close-grained, rich, reddish-brown woods, that in California are sometimes used for trinkets, such as cuff buttons, checkers, and rulers. Large-sized pieces of Manzanita wood are rare, and long pieces are practically unknown. Probably most of this wood is derived from the Manzanitas (*Arctostaphylos pungens, Arctostaphylos tomentosa,* and *Arctostaphylos glauca*).

SASSAFRAS — CAMPHOR TREE

Sassafras — *Cinnamomum*

The Sassafras grows in many parts of the eastern half of the United States. It was one of the first of the North American trees to be described in Europe, where at that early date, many fictitious properties were credited to the aromatic essences by which it is characterized. The soft, light, brittle, slightly aromatic, and rather durable wood is occasionally used for buckets and fences. The trees may be known by their fragrant, mucilaginous leaves, some of which are without lobes, while others have lobes on one side, and still others have lobes on both sides. The characteristic sassafras odor and flavor are more or less evident in the wood, twigs, and leaves, but are much more pronounced in the bark of the roots.

The Camphor tree (*Cinnamomum camphora*), which is related to the Sassafras, has been acclimated in California, and, on the Atlantic Coast, from Charleston to Florida. The trees, with their shining, evergreen leaves, are very attractive, and, in the United States, are valued in landscape work. The close-grained, aromatic, yellowish woods are sparingly used in cabinet work and insect-proof chests. In Asia, where this tree is native, it is the chief source of commercial camphor; but, in this country, the trees, although thrifty, do not appear to secrete the same quantities of this resin. Camphor is found also in the roots of the Cinnamon tree (*Cinnamomum zeylanicum*) of India and Ceylon. The Cassia Bark (*Cinnamomum cassia*), of Burmah and China, yields cassia but no camphor. Transplanted specimens of the two last-named trees have been made to grow in some parts of California and Florida.[1]

[1] See also Dewey (United States Division of Botany, Circular No. 12, Revised).

Sassafras. { *Sassafras officinale Nees and Eberm.* / *Sassafras sassafras (Linn.) Karst.* }

Nomenclature (Sudworth).

Sassafras (local and common name).
Saxifrax, Sasifrax Tree (Fla., Tenn.).
Sassafac, Sassafrac (W. Va., Del.).
Gumbo file (La., negro).

Localities.

Vermont to Florida, westward intermittently to Michigan and Texas.

Features of Tree.

Thirty to fifty feet in height; one to three feet in diameter, sometimes larger; often a low shrub; characteristic odor; the greenish-yellow flowers precede the leaves in early spring.

Color, Appearance, or Grain of Wood.

Thick heartwood delicate brown; thin sapwood yellowish-white; coarse-grained; the annual rings are clearly marked.

Structural Qualities of Wood.

Light, soft, not strong, and brittle; checks in drying; very durable in contact with the soil; the wood is slightly aromatic.

Representative Uses of Wood.

Pails, buckets, ox-yokes, fence-posts, and rails.

Weight of Seasoned Wood in Pounds per Cubic Foot.

31.

Modulus of Elasticity.

730,000.

Modulus of Rupture.

8,500.

Remarks.

The leaves and young shoots are mucilaginous. The bark, leaves, and wood emit a characteristic odor. The bark of the root is particularly aromatic. Small Sassafras bushes often form thickets.

GREENHEART

Nectandra

The Greenheart tree (*Nectandra rodioei*), which is a member of the Laurel family, grows in British Guiana and some adjacent parts of South America, as well as in the West Indies.

The wood is hard, strong, tough, and very heavy. The colors of the heartwood vary from dark green to chestnut brown, selected pieces presenting an exceptionally rich appearance when finished. The quality of durability, which is partly due to the presence of an alkaloid, known as "biberine," is so remarkable that the wood has earned a world-wide reputation. Greenheart is one of the best of all construction timbers and, although seldom seen in the United States, is used abroad for docks, bridges, keels, rollers, flooring, wagons, carriage-shafts, furniture, and belaying-pins. All of the gates, piers, and jetties of the Liverpool Docks, and the lock gates of the Bridgewater and Manchester Canals, were built of this wood. Pieces used in the construction of the Canada Dock, which was built in 1856, were used again in the reconstruction of that work in 1894. Greenheart was specified for the sills and fenders of the lock gates of the Panama Canal. The Antarctic ship, *Discovery*, and Nansen's ship, *The Fram*, were built of it.[1]

[1] See also "Greenheart," Mell and Brush (United States Forest Service, Circular, No. 211); "Greenheart Used in Panama Canal, etc." Armstrong (Engineering Record, Vol. 73, Nos. 5 and 6, pp. 149 and 180); "The Greenheart of Commerce," Mell (American Forestry, May, 1916).

Greenheart. *Nectandra rodioei*

NOMENCLATURE (Mell and Brush).[1]

Greenheart (local and common name).
Sipiri, Bebeeru, Bibiru, Supeira (native Indian names).
Torchwood.

LOCALITIES.

British, Dutch, and French Guiana, some adjacent parts of South America, and the West Indies. It is seldom found more than fifty miles, and never found more than one hundred miles, from the coast.

FEATURES OF TREE.

Twenty-five to sometimes seventy feet in height; two to four feet in diameter.

COLOR, APPEARANCE, OR GRAIN OF WOOD.

Heartwood dark green to chestnut brown, sometimes nearly black; clean; straight-grained; free from knots; some pieces possess great beauty.

STRUCTURAL QUALITIES OF WOOD.

Hard, heavy, tough, elastic, strong, and durable; repels termites and teredoes; liable to split and splinter, and so requires care in seasoning and working; receives a high polish; withstands wear.

REPRESENTATIVE USES OF WOOD.

Abroad, the wood is used in docks, ships, machine parts, piles, trestles, bridges, floors, wagons, carriage-shafts, furniture, and belaying-pins. In the United States, it is occasionally used in veneers, automobile spokes, turnery, and in the tips of fishing rods.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

72 (Laslett).

MODULUS OF ELASTICITY.

1,090,000 (Laslett).

MODULUS OF RUPTURE.

10,000 (Thurston).

REMARKS.

The Yellow, Gray, and Black varieties recognized by dealers come from the same species, the distinctions being due to differences in the ages and environment of the trees from which the several kinds were cut. Black Greenheart resembles Lignumvitæ and is valued more highly than the others.[1]

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[1] See also "Greenheart," Mell and Brush (United States Forest Service, Circular No. 211).

PERSIMMON EBONY OSAGE ORANGE CHERRY
Diospyros *Toxylon* *Prunus*

The Persimmon (*Diospyros virginiana*) grows in the eastern and southern parts of the United States and is a member of the Ebony family (*Ebenaceæ*). The trees may be known by their fruit, which is remarkably astringent when green, but sweet and palatable when ripe. The wood is tough and hard. The sapwood, which resembles fine-grained hickory, is of a light brown color, while the thin heartwood is almost black. Persimmon wood is sometimes used for plane-stocks, shuttles, and shoe-lasts.

The true Ebony (*Diospyros ebenum*) grows in Ceylon, India, and Siam. The Mexican Ebony (*Diospyros ebenaster*), which is a native of India, has been cultivated in the tropics of the western hemisphere, and in the Philippine Islands. The Madagascar Ebony (*Diospyros mespiliformis*) is a native of tropical Africa, and the Green Ebony (*Diospyros chloroxylon*) is a native of southern India. There are other sources in this and other genera. The Ebony of commerce, which is fine-grained, very hard and heavy, more or less durable, and of a deep black color, is used for veneers, cabinet work, and piano keys.

The Osage Orange or Bois d'Arc (*Toxylon pomiferum*) grows naturally in parts of Oklahoma, Arkansas, Texas, and Louisiana, while transplanted trees have succeeded as far north as New England. The more or less slender trees yield useless fruit which, in size and general appearance, suggests the common orange. The thin sapwood is of a light yellow color, while the thick heartwood is bright orange. The wood is very hard and strong. It takes a beautiful polish and is worthy of much more attention than it receives. The aborigines made bows and arrows of it, whence the name Bois d'Arc.

The Wild Black Cherry (*Prunus serotina*) grows in many localities in the eastern half of the United States, and bears small, purplish-black cherries, that are sweetly bitter when ripe. The Cherry wood of commerce is obtained from this species. The strong, clean, straight-grained, hard, durable, fine, reddish colored wood is easily worked; it receives a high polish, and is used in cabinet wood and indoor finish. It is often stained so as to imitate mahogany, while it itself is often imitated by staining the wood of the Sweet Birch (*Betula lenta*). Wild Cherry bark contains a bitter principal that is used in medicine.

Persimmon. *Diospyros virginiana Linn.*

Nomenclature (Sudworth).

Persimmon (local and common name).
Date Plum (N. J., Tenn.).
Simmon, Possumwood (Fla.).
Plaqueminier (La.).

Localities.

Rhode Island to Florida, westward intermittently to Missouri and Texas.

Features of Tree.

Occasionally seventy feet in height; one to two feet in diameter; the soft, plum-like fruit is astringent when green and sweet when ripe.

Color, Appearance, or Grain of Wood.

Heartwood dark brown or black; sapwood light brown, often with darker spots; very thin heartwood; very close-grained; compact structure; the medullary rays are conspicuous; resembles Hickory.

Structural Qualities of Wood.

Hard, heavy, and strong.

Representative Uses of Wood.

Plane-stocks, shoe-lasts, etc.; prized for shuttles.

Weight of Seasoned Wood in Pounds per Cubic Foot

49.

Modulus of Elasticity.

1,110,000.

Modulus of Rupture.

12,400.

Remarks.

The astringent properties of the unripe fruit are due to tannic acid. The dark heartwood is not greatly developed in trees that are under one hundred years old.

Osage Orange. *Maclura aurantiaca Nutt* / *Toxylon pomiferum Raf.*

Nomenclature (Sudworth).

Osage Orange (local and common name).
Bois D' Arc (La., Tex., Mo.).
Bodark, Bodock (Kans.).
Yellow-wood, Osage Apple Tree (Tenn.).
Hedge, Hedge-plant, Osage (Ill. Ia., Neb.).
Mock Orange (La.).
Bow-wood (Ala.).

Localities.

Southern Arkansas, Oklahoma, and Texas; cultivated elsewhere, as in Massachusetts, Pennsylvania, and Michigan.

Features of Tree.

Twenty to fifty feet in height; rarely beyond one and one-half feet in diameter; the form of the useless fruit suggests that of the orange. The trees survive when planted close together and the living trunks of trees thus planted are often used as fence posts.

Color, Appearance, or Grain of Wood.

Heartwood bright orange, which turns brown on exposure; the sapwood is light yellow; close-grained; the annual rings are clearly marked.

Structural Qualities of Wood.

Hard, heavy, very strong, flexible, and durable in contact with the soil; receives a beautiful polish; shrinks in seasoning.

Representative Uses of Wood.

Fence-posts, piles, telegraph poles, railway ties, paving-blocks, occasionally indoor decoration, wagon felloes, and machinery.

Weight of Seasoned Wood in Pounds per Cubic Foot.

48.

Modulus of Elasticity.

1,300,000.

Modulus of Rupture.

16,000.

Remarks.

The Indians used this wood for bows. The early name, Bois D'Arc, has been corrupted to Bow Dark or Bodark. Bodark wagon felloes are much prized in arid regions where the rains are confined to a short season of the year, and where the balance of the year is hot and dry. Under such circumstances, wheels made of some other woods shed their tires and are otherwise less satisfactory.

Wild Black Cherry, Wild Cherry. { *Prunus serotina Ehrh.* / *Padus serotina* }

NOMENCLATURE (Sudworth).
Wild Black Cherry, Wild Cherry (local and common names).
Black Cherry (Me., N. H., Vt., R. I., N. Y., Miss., Ky., Mich., Wis., Ind., Neb.).
Rum Cherry (N. H., Mass., R. I., Miss., Neb.).
Whiskey Cherry (Minn.).
Choke Cherry (Mo., Wis., Ia.).

LOCALITIES.
Eastern to central United States.

FEATURES OF TREE.
Forty to eighty feet in height; two to three or more feet in diameter; the bark and pea-sized fruit contain a bitter principal.

COLOR, APPEARANCE, OR GRAIN OF WOOD.
Heartwood reddish brown; sapwood yellow; fine, straight grain; compact structure.

STRUCTURAL QUALITIES OF WOOD.
Light, hard, strong, and easily worked.

REPRESENTATIVE USES OF WOOD.
Cabinet work and interior finish; preferred beyond many other woods as a base upon which enamelled paints are to be applied.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

36.

MODULUS OF ELASTICITY

1,200,000.

MODULUS OF RUPTURE.

11,700.

REMARKS.

MAHOGANY

Swietenia, Khaya, Soymida, Cedréla, etc.

The many botanical sources of the woods known as Mahogany, may be grouped upon a geographical basis as they grow in Central America, the East Indies and Africa.

Central American Mahogany was originally obtained from the Mahogany (*Swietenia mahagoni*), but is now derived from other trees as well, such as some of those of the genus Cedrela. Central American Mahogany was once divided as it came from the then Spanish American possessions and from Honduras. The first was called "Spanish Mahogany" and the last "Honduras Mahogany." Most of the wood that comes from Mexico is named from the ports from which it is shipped. There are thus, Frontera, and other kinds of Mahogany. East Indian Mahogany is obtained, largely, from the Mahogany (*Sóymida febrifúga*). The African sources are very numerous, a fact that explains the differences that exist in the qualities of these woods. The most important source is the Mahogany (*Khaya senegalensis*), while other sources are the species *Khaya grandifolia* and *Entandrophrágma candóllei*. Some Mahogany is brought from the Philippine Islands.

Mahogany has been used to a limited extent in construction, but is now so greatly valued as a decorative wood that it is used for little else, save, occasionally, the hulls of small pleasure craft. The decorative value of this wood is due to a combination of appearance, working qualities, and durability. The appearance of mahogany is influenced by its cellular structure and its warm reddish color. The latter is often comparatively light at first; but, usually, darkens eventually to characteristic tints, which, however, are usually induced at once by means of stains. The cellular structure of mahogany is not only beautiful of itself, but is such as to respond to the stains and finishing processes commonly applied. Mahogany works and glues well. It is very durable; few woods shrink or distort less than Mahogany after it is in place. It should be noted that woods produced in different localities differ in grain and color from one another, and that pieces cut from different trees in the same locality often differ also. Beautiful grain effects are often seen where trunks and branches join, and such pieces, known as "crotches," usually bring very high prices.

The Spanish Cedar (*Cedrêla odorata*) is not a true Cedar. In spite of its name it is not even remotely related to the trees from which the Cedar woods of commerce are ordinarily obtained. The true Cedars are all Conifers, whereas this tree is a Dicotyledon, and belongs to the family which includes the mahoganies.[2] Aside from this the wood suggests fine Cedar in appearance, and possesses the odor that is associated with that wood. It is used for cigar boxes and cabinet work.

The Prima vera or White Mahogany (*Tabebuia donnell-smithii*) is related to the Catalpas, and grows in Mexico and Central America, where it is often associated with the true Mahogany (*Swietenia mahagoni*). The wood resembles true Mahogany, save in color, which is a light yellow that darkens with age. The characteristic color of the finished wood is golden-yellow. It is hard to find large pieces of Prima vera free from worm holes. The wood is used in car finish, cabinet work, and fine furniture, where ordinary Mahogany might be used, save for its darker color.

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[1] The name Mountain Mahogany is applied to several trees that grow in the Rocky Mountain region and yield woods that are sometimes employed for fuel. Some of these species are Mountain Mahogany (*Cercocarpus ledifolius*), Mountain Mahogany; Valley Mahogany (*Cercocarpus parvifolius*), Mountain Mahogany; Birchleaf Mahogany (*Cercocarpus parvifolius betuloides*).

[2] Meliaceæ has been divided into *Swieteniæ*, which includes some of the true Mahoganies, and *Cedrêlæ*, which includes about nine genera and twenty-five species, distributed over tropical Asia and America. See also "True Mahogany," Mell (United States Department of Agriculture Bulletin No. 474, 1917).

Mahogany. *Swietenia mahagoni Jacq.*

NOMENCLATURE.

Mahogany (local and common name).
Spanish Mahogany (Cuba, San Domingo, West Indies).
Mexican Mahogany (Frontera, and other Mexican ports).
Honduras Mahogany (Honduras).
Baywood, Madeira, Redwood.

LOCALITIES.

Florida Keys, the Bahamas, the West Indies, Mexico, Central America, and Peru.

FEATURES OF TREE.

Florida specimens are forty-five feet in height and two or more feet in diameter; foreign trees are larger.

COLOR, APPEARANCE, OR GRAIN OF WOOD.

Heartwood light, rich reddish brown; the thin sapwood is yellow; smooth, fine, uniform texture; inconspicuous rings; the conspicuous pores are sometimes filled with white substance.

STRUCTURAL QUALITIES OF WOOD.

Strong and durable, but brittle; it holds glue, takes stains, and receives a high polish; it changes but little in seasoning and stands well.

REPRESENTATIVE USES OF WOOD.

Veneers and cabinet-work; was formerly used in ship-building.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

45.

MODULUS OF ELASTICITY.

1,510,000.

MODULUS OF RUPTURE.

14,000.

REMARKS.

The desirability of Mahogany from this and other species varies with locality. Mahogany is usually stained,

Spanish Cedar, Mexican Cedar. *Cedrêla odorata Linn.*

NOMENCLATURE.
Spanish Cedar, Mexican Cedar, Cuban Cedar (local and common names).

LOCALITIES.
Mexico, Cuba, and the West Indies.

FEATURES OF TREE.
Fifty to eighty feet in height; two to five feet in diameter; pale yellow flowers; there are pods that suggest pecan nuts as to form; the form of the tree suggests that of the English Walnut (*Juglans regia*).

COLOR, APPEARANCE, OR GRAIN OF WOOD.
Heartwood brownish red; straight, even, compact grain.

STRUCTURAL QUALITIES OF WOOD.
Soft, fragrant, porous, and durable; resembles Cedar woods which are derived from coniferous trees, and also resembles Mahogany.

REPRESENTATIVE USES OF WOOD.
Cigar-boxes, boats, and sometimes cabinet-work; may be used in place of Mahogany.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

MODULUS OF ELASTICITY.

MODULUS OF RUPTURE.

REMARKS.
The trees grow rapidly. The related Australian Red Cedar (*Cedrêla australis*) is locally used for furniture, joinery, carriages, ceilings, and door frames. These woods must not be confused with true cedars, which are derived from non-related trees of the coniferous series.

The Toon Cedar (*Cedrêla toona Roxburgh*) of the Orient is the same as the Red Cedar (*Cedrêla australis F. v. M.*). of Australia. The Cedar (*Cedrêla odorata Blanco*) is thought to be a distinct Philippine species.

White Mahogany. *Tabebuia donnell-smithii Rose*
Prima vera.

NOMENCLATURE.
White Mahogany, Prima vera (local and common names) — Jenicero, Genesero, Roble.

LOCALITIES.
Southern States of Mexico to Peru.

FEATURES OF TREE.
Fifty to ninety feet in height; two to four feet in diameter; trunks are often clear for thirty or forty feet from the ground; numerous golden-yellow flowers precede the leaves; a beautiful tree.

COLOR, APPEARANCE, OR GRAIN OF WOOD.
The heartwood is of a cream white color which often darkens with exposure; the thin sapwood is almost white; beautiful mottled or clouded effects usually seen best when pieces are quarter sawn; fine grained; the wood resembles mahogany save in color.

STRUCTURAL QUALITIES OF WOOD.
Moderately heavy, tough, rather soft and not strong; dries without checking, works well and stands well; receives stains and retains high polish; durable in contact with the soil.

RFPRESENTATIVE USES OF WOOD.
Local constructions and railway ties; widely used for cabinet-work and fine furniture; veneers.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

28. (reported).

MODULUS OF ELASTICITY.

MODULUS OF RUPTURE.

REMARKS.
The wood can be used where fine, light colored, cheerful effects are required; or it can be stained so as to imitate ordinary mahogany. The wood of the butternut or white walnut is sometimes sold as white mahogany but is seldom if ever seriously confused with the true wood.[1]

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[1] See also Botanical Gazette (Vol. XVII, 1892, p. 418); Contribution, United States National Herbarium (Vol. I, No. 9, p. 346).

TEAK

Tectona, Oldfieldia

The Indian Teak (*Tectona grandis*) grows in India, Burmah, the Malay Peninsula, Sumatra, Java, and Ceylon, and is a very important tree that is sometimes referred to as the "Oak of the East Indian forests." The less plentiful African Teak (*Oldfieldia africana*) is a native of western tropical Africa. These two trees are not related to one another, yet they yield woods that possess the same anatomical characteristics.

Teak wood is fairly hard and heavy. The colors of freshly cut pieces vary from light yellow to brownish red. Older pieces are much darker. Teak contains a peculiar resin which probably contributes to durability for which this wood is noted. This resin also serves because it is obnoxious to insects and because it preserves iron fastenings. Teak was long regarded as one of the best of all woods for ship-building. It is now used in many local constructions, such as railway ties, bridge-timbers, and artillery wagons. It is extensively exported to Great Britain. The grain is such that the wood is often carved, and Teak wood is now known in North America chiefly through such carvings.[1]

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[1] See also "Wood," Boulger (London, 2d Ed., p. 285.)

Teak. *Tectona grandis*

NOMENCLATURE.

Teak. Teek.
Indian Oak. Sagwan.

LOCALITIES.

India, Burma, Siam, and Ceylon.

FEATURES OF TREE.

Eighty to one hundred feet in height; three to four feet in diameter; sometimes larger; a straight trunk; large, drooping, deciduous leaves.

COLOR, APPEARANCE, OR GRAIN OF WOOD.

Heartwood is of a variable, brownish-yellow color; a straight, even-grained wood.

STRUCTURAL QUALITIES OF WOOD.

Moderately hard, strong, and easily worked; stands well; oily, fragrant, resists termites, and preserves iron.

REPRESENTATIVE USES OF WOOD.

Furniture, ship-building, timbers, and backing for armor-plates.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

50 (Laslett).

MODULUS OF ELASTICITY.

1,338,000 (Laslett).
2,100,000 (Thurston).

MODULUS OF RUPTURE.

15,000 (Thurston).

REMARKS.

It is thought that the properties by which iron fastenings are preserved, and by which termites are repelled, are due to oil contained in the wood. Burma Teak, Malabar Teak, and other kinds take their names from the districts in which they were produced, or from which they were shipped. Transplanted specimens have not succeeded well in California. The distinct African Teak (*Oldfieldia africana*) yields a wood that is sometimes marketed as African Mahogany and African Oak.

Some other tropical species that yield widely known woods, or other products, or that are valued in landscape work, are as follows:

Sabicu (*Lysiloma sabicu*).—This West Indian wood is hard, heavy, strong, and durable. It seasons and works well and has been used for ships and furniture. The wood is of a dark chestnut-brown color. Some pieces are highly figured. The appearance and the working qualities of the wood are such that it may be used in place of rosewood.

Sissoo (*Dalbergia sissoo*).—These trees grow in northern India. Some transplanted specimens have succeeded in other places as California. The wood, which is highly valued in India, is hard, heavy, strong, and elastic. The sapwood rots quickly, but the heartwood remains sound and hardens as the wood grows older. Sissoo seasons well and stands well. It is used in wheels, boat-building, agricultural implements, and furniture. Gun-carriage wheels made of Sissoo wood are highly prized. Some pieces of Sissoo are almost as beautiful as pieces of rosewood. An important source of commercial rosewood is related to the Sissoo.

The Rubber Tree.—The substance known as India rubber is like sugar in that its constituents exist in a number of unrelated plants. These constituents form part of a milky juice which is secreted by most of the plants in question, and which is known as latex. Latex, which is quite distinct from sap, is a thin, watery emulsion made up of cream-like globules suspended in a thinner liquid of different composition; the appearance of latex is similar to that of cows' milk. The latex of the common milkweed is a familiar example. An exception to the rule that rubber is obtained from latex is furnished by the Guayule plant. The rubber obtained from this plant is distinct from most others in that it is not obtained from latex but exists *as such* in the cells of the plants.

The trees, vines, and shrubs from which India rubber may be obtained are numbered by the hundred, but the sources from which it is actually obtained in commercial quantities are comparatively few. The principal trees from which it is obtained are the Para or Hevea Rubber Tree (*Hevea braziliensis*) the Central American Rubber Trees (*Castilla elastica* and others) and the Assam Rubber Tree (*Ficus elastica*). The wood of the rubber tree is seldom employed save locally. It should be noted that the latex from which India rubber is obtained is secreted only under favorable conditions. (See also Chapter XVII).

The Pepper, California Pepper or Peruvian Mastic (*Schinus molle*) was introduced into California from Peru by the early Spanish missionaries, and is now one of the most popular shade trees on the Pacific Coast, south of San Francisco. The Pepper tree grows to heights of thirty to fifty feet. The outline suggests that of the Apple tree, while the drooping foliage suggests the foliage of the Willow. There are long sprays of rose-tinted berries, masses of slender, drooping branchlets, and delicate, bright evergreen leaves that emit a pleasant, pungent odor. The berries are the size of currants or pepper corns, whence the name Pepper tree. The soft, smooth, whitish-colored woods are seldom employed, save for fuel. The California Pepper tree is the host of the "black scale," and is now being replaced by the better, faster-growing, Longleaved Pepper tree (*Schinus terebinthifolius*) from Brazil.

The Tung Oil Tree.—The Tung Oil tree (*Aleurites fordii*), also known as the Chinese Wood Oil tree, belongs to the family Euphorbiaceæ. It is associated with China, but is grown in other parts of the world, and has succeeded, in the United States, in southern California, and in the region that extends southward from Cairo, Georgia. It grows to a height of thirty or more feet and has an ornamental value about equal to that of the Catalpa. The flowers precede the leaves and cause the tree to be very beautiful when in bloom. The soft wood is not valuable; but the fruit, which suggests an apple two or three inches in diameter, contains from two to eight large seeds from which the Tung oil of commerce is obtained. The tree begins to bear fruit when four or five years old. It is said that, in China, a tree yields from thirty to seventy-five pounds of seed every year.[1]

The Balsa (*Ochroma lagopus*).—This native of Central America and the West Indies attains a diameter of about one foot. The large, broad leaves resemble those of the Catalpa. The weak, uniform, spongy, parenchymatous wood is free from knots and checks and is so soft that it can be indented with the finger nail. It is one of the lightest of all woods, its weight of seven pounds per cubic foot being half that of ordinary cork. It does not last well; and it absorbs water so readily that it soon becomes water logged unless impregnated with paraffin or some similar compound. It is extremely porous, and for this reason is an excellent insulator against heat and cold. Balsa wood is used in refrigerator linings, and, after treatment with paraffin, is used in life preservers in place of cork. It is used locally for canoes.[2]

The China or China-berry (*Melia azedarach*) is a native of India, China, and some other parts of the eastern hemisphere, but is now grown successfully in many parts of the world, including districts in the southern part of the United States. The China tree is also referred to as the Pride of India, the Bead tree, and the Umbrella tree. The short, straight trunk merges abruptly into numerous branches that radiate outward like the ribs of an umbrella. The peculiar form, rapid development, and thick, handsome foliage cause the true to be valued in landscape effects, wherever it will grow. The wood, which is sometimes improperly referred to as "White Cedar" and "Bastard Cedar," is occasionally made into furniture. The berries contain pits that are sometimes used as beads.

The Rosewood.—There are many "Rosewood trees." The African Rosewood (*Pterocarpus erinaceus*) grows in tropical western Africa. The Brazilian Rosewood (probably *Dalbergia nigra*) is a native of Brazil. The Canary Rosewood (*Convolvulus scoparius*) grows in the Canary

Islands. In California, rosewood is derived from the stems of very large rose bushes. Commercial rosewood is hard, tough, fine grained, and compact. The colors vary from rich reds to chestnut browns; there are often black streaks and sometimes purplish effects. The name Rosewood is due to the more or less pronounced scent of roses which the woods emit. The wood is also known by other names, as Blackwood and Bloodwood. Rosewood is sometimes used in local constructions, but is normally seen in costly furniture, piano cases, burial caskets, and panel work. It is sometimes associated with Circassian Walnut and Satinwood in the decorative work in compartment cars. An oil, distilled from one of the species from which commercial rosewood is obtained, has been used to adulterate attar of roses.

The Sandalwood.—The Sandalwood of commerce is obtained from many botanical sources. The genus *Santalum* alone includes about twenty species. Until the eighteenth century, Sandalwood was obtained from China. The discovery of sources on the Islands of the Pacific led to lawless traffic and much bloodshed. The adventures associated with the collection of this wood were equal to those encountered in whaling and the search for ivory. The Sandalwood tree (*Santalum album*) yields a reddish-brown, close-grained, very fragrant wood that weighs about fifty-five pounds a cubic foot. Red Sandalwood or Sanderswood (*Pterocarpus santalinus*) yields a red dye that is known as "santalin." Sandalwood was prized by the French nobility for medallions that were mounted on otherwise decorated surfaces. It was also sometimes made into rich furniture, and is now occasionally seen in finely carved small objects, as jewel boxes and fan handles. The powdered wood is burned as incense. A fragrant oil is separated by distillation.

Satinwood.—The East Indian Satinwood (*Chloroxylon swietenia*), grows in India and Ceylon, while the Yellow-wood or Satinwood (*Xanthoxylum cribrosum*) is a native of Florida and the West Indies. There are other botanical sources. The yellow or orange-colored woods are hard, heavy, close-grained, durable, and beautifully figured. Pieces from San Domingo and Jamaica are particularly beautiful and bring the highest prices. Satinwood is very valuable and is seldom used, save in the finest cabinet work and furniture.

A valuable list has been prepared by Mell under the title "Cabinet Woods of the Future."[3]

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[1] "The China Wood Oil Tree," Fairchild (United States Bureau of Plant Industry, Circular No. 108); Files of "Oil, Paint and Drug Reporter;" etc.

[2] Missouri Botanical Garden Bulletin (August, 1915, p. 107); The Properties of Balsa wood," Carpenter (Proceedings, American Society Civil Engineers, May, 1916).

[3] "Cabinet Woods of the Future," Mell (American Forestry, Vol. XVI, No. 12.

EUCALYPTUS

Eucalyptus

The Eucalypts, locally known as Stringybarks, Ironbarks, Mahoganies, Box and Gum trees, are natives of Australia and the neighboring islands.[1] The genus is now represented by cultivated specimens on each of the continents, where, in some places, it has influenced topographical and other conditions to a remarkable degree[2]. The Riviera, the Campania, the Nilgheri Hills in southern India and parts of Algeria, Brazil, and California have been practically transformed by Eucalyptus trees.

Eucalyptus trees are noted for their rapid growth, fine appearance, great size, tough and durable woods, and their influence upon sanitation.

Rapid Growth.—This is shown by specimens of the Blue Gum (*Eucalyptus globulus*) that have lengthened more than two feet in a single month. In three years, a tree of this species attained a diameter of about nine inches. A Pasadena tree was five feet thick at the end of twenty-five years, while some specimens in Santa Barbara that were twenty-five years old compared in general development with oaks that were over two hundred years old.

Appearance.—The trees of some species are very attractive in form. Some of the trees blossom during droughts when other flowers are scarce; others blossom twice a year; and still others blossom all the time.

Size.—The enormous size is seen in specimens of the Peppermint tree (*Eucalyptus amygdalina*) that have grown to heights of over four hundred feet and are the tallest, although not the largest, trees known to man.

Character of Woods.—Eucalyptus woods are tough and hard to season but some of them are very valuable. The working qualities of Australian grown Jarrah, Karri, Tuart, and Red Gum woods (*Eucalyptus marginata, Eucalyptus diversicolor, Eucalyptus gomphocephala,* and *Eucalyptus rostrata*) are such that these woods are highly prized in many localities. In London and in Paris, blocks of Jarrah and Karri woods have been used to pave streets subjected to heavy traffic.

REFERENCES.—Works of von Mueller; Report J. Ednie Brown, Forest Commissioner of Western Australia; Works of Abbot Kinney (Press Baumgardt, Los Angeles); Ingham (California State Agricultural Experiment Station, Bulletin No. 196); "Eucalypts Cultivated in the United States," McClatchie (United States Bureau of Forestry, Bulletin No. 35, 1902); "Utilization of California Eucalypts," Betts and Smith (United States Forest Service, Circular No. 179); "Eucalypts in Florida," Zon and Briscoe (United States Forest Service, Bulletin No. 87, 1911); "Yield and Returns of Blue Gum in California," Woodbury (United States Forest Service, Circular No. 210); "Eucalypts," Pinchot (United States Forest Service, Circular No. 59 Revised, 1907).

Influence upon Health.—Improvement in the health of residents has followed the introduction of the Blue Gum (*Eucalyptus globulus*) in malarial districts such as some in the vicinity of Rome. It is possible that these fortunate results may have been influenced to a slight extent by medicinal compounds in the foliage, but it is much more probable that they were due to the fact that the leaves of this species evaporate large quantities of water, and thus reduce the moisture conditions necessary for the growth of mosquitoes.

The genus may be summarized from the viewpoint of the living tree and from the viewpoint of the woods as follows:

Eucalyptus Trees Grow Rapidly.—Some of them grow where those of other species will not; some form windbreaks and forest cover; some serve in landscape effects; some afford honey and many yield oils. The hard, tough woods present an unusual range of possibilities. McClatchie enumerates twenty-five ways in which these woods have been used in Australia: six species are valued for bridge timbers, five for piles, nine for paving, eight for posts, three for railway ties, four for car building, five for lumber and shingles, seven for carriage parts, two for cooperage, and two for handles. Thus far, comparatively little eucalyptus lumber has been produced in this country, but experience is sufficient to show that some kinds of eucalyptus can be used in place of other woods that are now used in the United States for piles, posts, poles, crossties, mine timbers, paving blocks, insulator pins, furniture, finish, veneers, cooperage, vehicle stock, and tool handles. Eucalyptus woods are hard to season. The structure is complicated and the woods are full of water. This is particularly true of woods produced in the United States where the trees are yet comparatively young. No really satisfactory method of seasoning the woods of the species thus far introduced into North America has yet been worked out on a commercial basis. The colors of the woods vary; shades of yellow, brown and red predominate.

The evergreen leaves exhibit many tints, normally of the colors gray, blue, and green. The characteristic odor is the only point in common between the leaves of young and old trees of some species. The genus includes nearly two hundred and fifty species.

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[1] The nomenclature is confusing. There are eleven Stringybarks, eight Ironbarks, nine Red Gums, and twelve Blue Gums. The Blue Gum (*Eucalyptus globulus*) is the species commonly referred to when the Eucalyptus is mentioned in North America.

[2] Eucalyptus trees do not grow well in the United States outside of California, Arizona, New Mexico, Texas, and Florida and their success in New Mexico, Texas, and Florida has not been remarkable. The Florida climate is favorable most *but not all* of the time. The climate of Southern California is more equable and this district must still be regarded as the only real North American locality.

Blue Gum, Fever Tree. *Eucalyptus globulus*

Nomenclature.
Blue Gum (local and common name). Fever Tree, Balluck (Australia).

Localities.
Native of Australia; acclimated in southern California and elsewhere in frostless regions throughout the world.

Features of Tree.
Sometimes three hundred or more feet in height; three to six feet in diameter; bark varies with age and environment; the form and color of the leaves which are sometimes twelve inches in length, vary with age; characteristic odor.

Color, Appearance, or Grain of Wood.
Heartwood straw color; sapwood lighter; complicated cellular arrangement; indistinct annual rings.

Structural Qualities of Wood.
Hard and heavy; the cellular structure is such that the wood is hard to split and work after it has been seasoned; the American product is hard to season, possibly because the trees are comparatively young and full of water. Not durable in contact with the soil.

Representative Uses of Wood.
Principal experience is abroad, where foreign-grown pieces are used for rollers, paving-blocks, ship-building, carriage parts, and fuel. In the United States, pieces boiled in water, and then in linseed oil, are used for insulator pins on telegraph poles; in California, the wood is used for piles and mine-timbers; an important fuel in southern California.

Weight of Seasoned Wood in Pounds per Cubic Foot.
43 to 69 (Mueller). 57 to 69 (Laslett). 47.9 (Betts & Smith).[1]

Modulus of Elasticity.
1,712,000 (Average of 17 tests of California-grown specimens).[1]

Modulus of Rupture.
12,400 (Average of 17 tests of California-grown specimens).[1]

Remarks.
It should be noted that the name Blue Gum is applied to at least eleven other species. This Blue Gum is the Eucalyptus of California.

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[1] United States Forest Service, Circular No. 179, p. 12.

Red Gum. *Eucalyptus rostrata*

Nomenclature.
Red Gum (local and common name).

Localities.
Australia. Acclimated in California and elsewhere.

Features of Tree.
One hundred or more feet in height; the tress are often crooked; the bark, when young, is red.

Color, Appearance, or Grain of Wood.
The color of the heartwood varies from light red to dark blood-red; the color darkens with age; close-grained; the cellular arrangement is complicated.

Structural Qualities of Wood.
Strong, hard, and heavy; said to resist attacks of shipworms and termites; pieces cut from American trees are hard to season; capable of receiving a high polish.

Representative Uses of Wood.
Principal experience is abroad, where foreign-grown pieces are used for posts, bridge-timbers, short beams, ship-timbers, ties, and paving-blocks.

Weight of Seasoned Wood in Pounds per Cubic Foot.
55.6.[1]

Modulus of Elasticity.
1,201,000 (Average of 9 tests on California-grown specimens).[2]

Modulus of Rupture.
12,369 (Average of 9 tests on California-grown specimens).[2]

Remarks.
A Commission on State Forests and Timber Reserves in Melbourne gave as its opinion that Red Gum is the "most important tree in the State, on account of its durability and the many uses to which it (the wood) is put." Von Müeller wrote of Red Gum as "perhaps the most important of the entire genus." The best grade of lumber is obtained from trees over one hundred years of age. It is believed that Red Gum trees will succeed well in California, but the wood thus far produced in that region is hard to season, possibly because the trees are comparatively young and full of water.

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[1] United States Forest Service, Circular No. 179, p. 28.

[2] United States Forest Service, Circular No. 179, p. 16 and 28.

Jarrah. *Eucalyptus marginata*

NOMENCLATURE.
Jarrah (local and common name).
Mahogany Gum (Australia).

LOCALITIES.
Western coast of Australia; some specimens acclimated in California.

FEATURES OF TREE.
Ninety to one hundred or more feet in height; two to five feet in diameter; branches concentrated at tops of trees.

COLOR, APPEARANCE, OR GRAIN OF WOOD.
The reddish-brown wood resembles Mahogany; it also resembles Kauri wood.

STRUCTURAL QUALITIES OF WOOD.
Heavy, somewhat oily, non-absorbent, does not take fire easily, durable in contact with the soil; it may be polished; it wears thin evenly, and is said to repel marine and land wood-borers.

REPRESENTATIVE USES OF WOOD.
Ship-building, dock and bridge-timbers, paving-blocks.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.
65 (Ednie-Brown).[1]

MODULUS OF ELASTICITY.
2,080,000 (Ednie-Brown).[1]

MODULUS OF RUPTURE.
8,900 (Ednie-Brown).[1]

REMARKS.
The principal timber tree of southwestern Australia. The wood is often confused with that of the Karri. von Mŭeller calls it the least inflammable of woods.

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[1] Report on Forests of Western Australia, Presented to Parliament, 1896.

Karri. *Eucalyptus diversicolor*

NOMENCLATURE.
Karri (many localities). White Gum (Australia).

LOCALITIES.
Australia and New Zealand; some specimens acclimated in California.

FEATURES OF TREE.
Sometimes three hundred and fifty feet in height; from four to eighteen feet in diameter; a straight, graceful tree, the lower branches of which are often one hundred and fifty feet from the ground; smooth, yellow-white bark.

COLOR, APPEARANCE, OR GRAIN OF WOOD.
Heartwood is reddish-brown; complicated cellular arrangement.

STRUCTURAL QUALITIES OF WOOD.
Hard, heavy, tough, elastic, non-absorbent, and durable; difficult to work; wears evenly; possesses a characteristic odor.

REPRESENTATIVE USES OF WOOD.
Heavy timbers, railway ties, piles, marine work, paving-blocks, masts, and lumber.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

63 (Ednie-Brown).[1]

MODULUS OF ELASTICITY.

2,890,000 (Ednie-Brown).[1]

MODULUS OF RUPTURE.

8,000 (Ednie-Brown).[1]

REMARKS.
The name *diversicolor* is due to the fact that the upper and lower sides of the leaves differ in color from one another. It should be noted, however, that this characteristic is not confined to this particular species of this one genus. The Karri was once named *Eucalyptus colossea* because of its great size. This Karri is quite distinct from the Kauri (*Dammara australis*).

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[1] Report on Forests of Western Australia, Presented to Parliament, 1896.

Tuart. *Eucalyptus gomphocephala*

NOMENCLATURE.
Tuart (local and common name). Tooart (Australia).
Tewart (Australia). White Gum (Australia).

LOCALITIES.
Australia; acclimated elsewhere.

FEATURES OF TREE.
Sometimes one hundred and fifty feet in height; four to six feet in diameter; a straight trunk, with grayish-white bark; bright, cheerful appearance.

COLOR, APPEARANCE, OR GRAIN OF WOOD.
The heartwood is of a light-yellow color; close-grained; the cellular arrangement is complicated.

STRUCTURAL QUALITIES OF WOOD.
Strong, tough, rigid, hard, heavy, and durable; seasons well; is hard to split and work.

REPRESENTATIVE USES OF WOOD.
Keele, buffers, stern-posts, frames, wheel-hubs, and shafts.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

67 (Ednie-Brown).[1]

MODULUS OF ELASTICITY.

2,300,000 (Ednie-Brown).[1]

MODULUS OF RUPTURE.

9,300 (Ednie-Brown).[1]

REMARKS.
In California, trees have reached heights of eighty feet within twenty-four years. The wood is one of the strongest of all those used in construction.

[1] Report on Forests of Western Australia, Presented to Parliament, 1896.

Other important Eucalypts are as follows:

Sugar Gum (*Eucalyptus corynocalyx*).—This is one of the Eucalypts that has succeeded in California. The tall, erect trees resist drought, but are less able than Red Gum trees to withstand frost. The trees blossom profusely for several months. The hard wood is of a yellowish-white color.

Giant Eucalypt or Peppermint Tree (*Eucalyptus amygdalina*).—This is the tallest, although not the largest, of trees known to man. The leaves possess an odor that resembles that of peppermint. The woods are less desirable than those obtained from other Eucalypts.

Manna Gum (*Eucalyptus viminalis*).—The usually erect trees resist comparatively low temperatures almost as well as Red Gum trees. They grow rapidly, are thrifty, and yield woods that vary in color from light brown to yellowish-white.

Ironbark or Stringybark (*Eucalyptus macrorrhyncha*).—The durable, dark gray, fibrous bark is used locally for roofing, while fibers drawn from the bark are used in making string. The hard, durable wood is employed for lumber, shingles, and fuel.

Red Mahogany or Red Gum (*Eucalyptus resinifera*).—This tree yields a hard, heavy, durable, rich red wood, the appearance of which suggests Mahogany. The wood is used for shingles, posts, piles, and paving-blocks, and is suitable for use in furniture.

CHAPTER VIII

Non-banded Trunks and Woods

Monocotyledons

The trunks from which non-banded woods are obtained grow in thickness from the *inside*. With several exceptions these trunks increase principally by the expansion of cells already formed.[1] There are no layers or concentric bands, such as characterize the woods of the other group. On the contrary, the wood-elements are distributed in such a way as to appear as dots over the cross-sections. The trunks normally attain maximum diameters quite early, and, unlike Banded trunks, do not continue to increase throughout their lives. The trunks are enclosed by integuments that bear but slight resemblance to bark. The few forms that yield structural woods are associated with the tropics. Of these, the Palms and Bamboos are examples.

The classes of wood-elements that exist in Non-banded woods are the same as those that exist in Banded woods. Some classes of cells may be modified as they exist in certain groups of Monocotyledons, just as they are also modified in some groups of Dicotyledons and Conifers; but, as far as known, there are no cell forms that are peculiar to Non-banded woods alone. The hardest parts of Non-banded stems are at their surfaces, while the softest parts are at their centers. In many cases, as with Bamboos, the tissues at the center are quite lacking.

The quantity of structural material obtained from the Monocotyledons is comparatively small. Yet the group as a whole, with some forty families, including numerous genera and about twenty thousand species, is highly important. The grasses, including corn, wheat, rye, sugar-cane and bamboo; and the Palms, including many valuable trees, are of this group.

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[1] The Yucca and the Dragon-tree are Monocots which grow by a cambium region just within the cortical region.

PALM

Palmaceæ

More than one thousand species of Palms, grouped in the family Palmaceæ, are distributed over the tropical and semi-tropical regions of the eastern and western hemispheres. The Washington Palm (*Washingtonia filifera*), and several Palmettoes (*Sabal palmetto, Thrinax parviflora,* etc.), yield woods that are used in the United States; but the rule is, that the trees, rather than the woods, are valued in this country.[1]

The wood is soft, light, weak, non-coherent, and more or less porous. Large fiber-bundles contrast sharply with the surrounding tissue, and cause sections to present a spotted appearance (see preceding figure 2). Palm wood is comparatively safe from the attacks of shipworms, which are not "worms" but mollusks. These mollusks line the surfaces of their tunnels with shell, for which the weak and porous wood is, apparently, an insufficient foundation.

The long leaf-stalks of the Washington Palm are worthy of attention. The material of which these stalks are composed resembles that of which Bamboo is composed. The stalks are seldom used, although they present what is, weight for weight, one of the strongest of all materials.

Two roughly cured stalks were tested. The central portions of each specimen broke, leaving the edges, which stripped, without signs of fracture. In one case the Modulus of Rupture was 11,370 and in the other case it was 10,150. The figures were averaged for the entire sections, including the parts that stripped without breaking. The strength, which would doubtless be increased by selection and appropriate seasoning, is even more significant when the very light weight of the material is remembered.

Sudworth[2] enumerates the following palms as attaining to the dignity of trees in the United States:

Sargent Palm (*Pseudophœnix sargentii*).
Fanleaf Palm (*Washingtonia filifera*).
Royal Palm (*Oreodoxa regia*).
Cabbage Palmetto (*Sabal palmetto*).
Silvertop Palmetto (*Thrinax microcarpa*).
Silktop Palmetto (*Thrinax parviflora*).
Mexican Palmetto (*Sabal mexicana*).

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[1] Many Palms seen at pleasure resorts in the South have been transplanted and are not native in those localities.

[2] "Check List" (U. S. Forestry Bulletin No. 17).

Washington Palm. *Washingtonia filifera Wendl.*

Fanleaf Palm. *Neowashingtonia filamentosa Wendl.*

NOMENCLATURE (Sudworth).

Fanleaf Palm, Washington Palm, Desert Palm (Cal.). California Fan Palm, Arizona Palm, Wild Date (Cal.).

LOCALITIES.

California.

FEATURES OF TREE.

Thirty to sixty feet in height; one and one-half to three feet in diameter; the fan-shaped leaves rise in a tuft from the summit of the trunk; the largest of the United States palms.

COLOR, APPEARANCE, OR GRAIN OF WOOD.

Light greenish-yellow to dark red; unstable, fibrous, and coarse.

STRUCTURAL QUALITIES OF WOOD.

Soft, light, shrinks in seasoning, unstable, hard to work.

REPRESENTATIVE USES OF WOOD.

Fuel.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

32.

MODULUS OF ELASTICITY.

MODULUS OF RUPTURE.

REMARKS.

This is the most popular of the palms used in California for landscape effects. The wood has but little value, but the light, tough, flexible, and stringy leaf-stalks possess characteristics that are worthy of notice. The results of experiments upon seasoned stalks are noted in the preceding introduction. The name "Wild Date" should not cause these trees to be confused with true Date Palms (*Phœnix dactylifera*).

Date Palm (*Phœnix dactylifera*). These trees, which grow in semitropical regions in the East, have been naturalized in Arizona, California, and Florida. In the East, the Date Palm is valued not only because it yields fruit, syrup, and vinegar, but because its wood is employed in carpentry and simple furniture; the leaves are used in making fans, baskets, cord, and paper.[1]

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[1] "Arabia," Zwemer; Swingle (Year Book, United States Department of Agriculture, 1900, pp. 453, 490); Toumey (Arizona Experiment Station, Bulletin No. 29).

Cabbage Palmetto. *Sabal palmetto Walt.*

NOMENCLATURE (Sudworth).

Cabbage Palmetto, Palmetto (N. C., S. C.).
Cabbage Tree (Miss., Fla.).
Tree Palmetto (La.).

LOCALITIES.

Central-Atlantic, South Atlantic, and Gulf Coasts of the United States; the West Indies.

FEATURES OF TREE.

Thirty to forty feet in height; one to two and one-half feet in diameter.

COLOR, APPEARANCE, OR GRAIN OF WOOD.

Light brown; fibrous and coarse.

STRUCTURAL QUALITIES OF WOOD.

Soft and light; repels marine wood-borers.

REPRESENTATIVE USES OF WOOD.

Used locally for piles and docks.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

27.

MODULUS OF ELASTICITY.

MODULUS OF RUPTURE.

REMARKS.

Other Palmettoes grow in the United States. Among them are the Silver Thatch or Silktop Palmetto (*Thrinax parviflora*), the Prickly Thatch or Silvertop Palmetto (*Thrinax microcarpa*), and the Mexican Palmetto (*Sabal mexicana*).

YUCCA

Yucca

This genus includes about thirty species and many varieties. Of the species which grow in the United States, the Tree Yucca or Joshua tree and eight others assume the habit and attain the size of small trees. The Yuccas are among the exceptional Monocotyledons that increase in diameter through the instrumentality of a cambium layer.[1] Several of the Yuccas are cultivated because of their beautiful lily-like flowers.

Yucca wood is coarse and fibrous. Direct vertical cleavage is lacking. The fibers interlace so that thin sheets of rotary cut wood can be selected which bend almost as readily as thick felt. Yucca wood is used in special objects such as souvenirs, splints and artificial limbs. Eight species noted by Sudworth are as follows:

Joshua tree (*Yucca arborescens*).
Spanish Bayonet (*Yucca treculeana*).
Spanish Dagger (*Yucca gloriosa*).
Mohave Yucca (*Yucca mohavensis*).
Aloe-leaf Yucca (*Yucca aloifolia*).
Broadfruit Yucca (*Yucca macrocarpa*).
Schott Yucca (*Yucca brevifolia*).
Yucca (*Yucca constricta*).

[1] See also "Textbook of Botany," Strasburger (p. 145).

Joshua-tree, Yucca. { *Yucca arborescens Torr.* / *Yucca brevifolia Engelm.* }

NOMENCLATURE (Sudworth).

Joshua-tree, The Joshua, Yucca, Yucca Tree (Utah, Ariz., N. M., Cal.).

Yucca Cactus (Cal.).

LOCALITIES.

Central and Lower Rocky Mountain region.

FEATURES OF TREE.

Twenty-five to forty feet in height; six inches to two feet in diameter; a thick, outer cover or bark.

COLOR, APPEARANCE, OR GRAIN OF WOOD.

Light brown to yellowish white; fibrous and coarse; interlaced cellular arrangement.

STRUCTURAL QUALITIES OF WOOD.

Light, soft, and spongy; flexible in thin sheets.

REPRESENTATIVE USES OF WOOD.

Small objects, as souvenirs; paper-pulp, splints and artificial limbs.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.

23.

MODULUS OF ELASTICITY.

MODULUS OF RUPTURE.

REMARKS.

Artificial limbs are made by bending veneers of Yucca wood over moulds; strong cements are employed, and the forms that result are strong, tough, and very light. The sheets of flexible Yucca which are sold in souvenir stores are rotary cut.

BAMBOO

Bambusa

These giant grasses grow in China, Japan, and other tropical and semi-tropical regions, and, in some places, even extend over into the temperate zone. In the United States they have succeeded as far north as the Carolinas.[1, 2]

Bamboo stems often attain heights of seventy feet and diameters of five or six inches. They grow with surprising rapidity; a Philippine specimen grew two feet in three days,[3] while some Florida specimens reached heights of seventy-two feet in a single season. The stems of Bamboo may be compared with those of asparagus, in that both are more or less tender when young, and much more hard and fibrous when old. Stems that grow in a few weeks may require three or four years to season or harden.

Those who use bamboo value it highly. The pieces are often employed without splitting. Sometimes, while yet green, they are split and flattened into rough boards, which, although they split everywhere nevertheless hold together. Johnson notes that "Bamboo is just twice as strong as the strongest wood in cross-bending, weight for weight, when the wood is taken in specimens with square and solid cross-sections."[4] The manipulation of this valuable material is not yet understood in the United States, but some of the many ways in which it is used abroad are summarized as follows:[5]

"The Chinese make masts of it for their small junks, and twist into cables for their larger ones. They weave it into matting for floors, and make it into rafters for roofs. They sit at tables on bamboo chairs, eat shutes of bamboo with bamboo chop-sticks. The musician blows a bamboo flute, and the watchman beats a bamboo rattle. Criminals are confined in a bamboo cage, and beaten with bamboo rods. Paper is made of bamboo fiber, and pencils of a joint of bamboo, in which is inserted a tuft of goat's hair."

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[1] "Grasses. This is one of the largest and probably one of the most useful groups of plants, as well as one of the most peculiar. It is worldwide in its distribution, and is remarkable in its display of individuals, often growing so densely over large areas as to form a close turf. If the grass-like sedges be associated with them there are about six thousand species, representing nearly one-third of the Monocotyledons. Here belong the various cereals, sugar canes, bamboos, and pasture grasses, all of them immensely useful plants" ("Plants," Coulter, pp. 240–241).

[2] Fernow notes that "In addition to the genus *Bambusa*, the genera *Arundinaria*, *Arundo*, *Dendrocalamus*, and *Guadua* are the most important" (United States Forestry Bulletin No. 11, p. 29).

[3] "Inhabitants of the Philippines," Sawyer (Scribner, 1900, p. 5).

[4] "Materials of Construction" Johnson (John Wiley & Sons, 1897, p. 689).

[5] "Cycle of Cathay," Martin (Fleming H. Revell Company, 1899, p. 172). See also "New Granada," Holton (Harper Bros., 1857, p. 109); "Bamboo and its Uses," Kurz (Calcutta, 1876); "The Bamboo Garden," Mitford (Macmillan, 1896); "Japanese Bamboos," Fairchild (United States Bureau Plant Industry, Bulletins Nos. 42–43); etc., etc.

Bamboo. *Bambusa vulgaris*

NOMENCLATURE.
Bamboo (local and common name).

LOCALITIES.
Widespread throughout the tropics and semi-tropics; acclimated in Florida.

FEATURES OF TREE.
Seventy-five feet in height; four to six inches in diameter; glazed, greenish, jointed stems, delicate branches and leaves; extensive roots.

COLOR, APPEARANCE, OR GRAIN OF WOOD.
Yellowish brown; fibrous and coarse; moderately thin walls surround central canals which are broken by joints.

STRUCTURAL QUALITIES OF WOOD.
Light and elastic; works easily.

REPRESENTATIVE USES OF WOOD.
Posts, poles, troughs, pies, utensils, roofing, frames of aeroplanes, and paper.

WEIGHT OF SEASONED WOOD IN POUNDS PER CUBIC FOOT.
Variable.

MODULUS OF ELASTICITY.
2,380,000 (Johnson's "Materials of Construction," p. 689).

MODULUS OF RUPTURE.
27,400 (Johnson's "Materials of Construction," p. 689).

REMARKS.
Bamboos are not trees, although they are as tall as trees, but may be described as wood-producing grasses. Bamboos grow rapidly. A stem may reach its full height in a single year, but must then stand for three or four years in order to season and harden.

Rattan. Rattan is obtained from several sources. One species (*Calamus rudentum*) is a climber, the stalks of which although not over one inch in thickness, are sometimes three hundred or more feet in length as they fall and ascend in festoons from tall trees. Another species (*Rhapis flabelliformis*) yields erect canes which grow in thick tufts. Pieces obtained from both climbing and ground rattans are tough, light, long, strong, and pliable. Locally, rattan is used for making houses, bridges, matting, hats, baskets, and cordage. In most civilized countries, split rattan is superseding willow for furniture, fancy carriage bodies, chair bottoms, and the like. The best rattan comes from Borneo.

CHAPTER IX

Special Properties of Woods due to Their Organic Origin. Chemical Composition of Woods. Physical Properties of Woods: Descriptions of Weights and Moduli Employed. Moisture in Woods; Influence of Moisture, Antiseptics, and Heat upon the Physical Properties of Woods

All materials are studied from the viewpoints of chemical composition and of physical properties, but organic materials are also studied from the viewpoint of special or additional properties due to their organic origin. It is because of these additional traits or properties that wood and other organic materials are more complex and variable than inorganic materials.

SPECIAL PROPERTIES OF WOODS DUE TO THEIR ORGANIC ORIGIN

Cellular structure, inflammability at ordinary temperatures, and the qualities that attract and nourish micro-organisms have no counterparts among the inorganic materials. For example, wood and other organic materials as a class take fire readily under ordinary conditions and often liberate volumes of inflammable gases by means of which fires are spread, whereas stones and metal do not. Also the rotting of wood is due to the activities of bacteria which do not attack inorganic materials.

Besides these there are other characteristics, less definite but of at least equal importance. It is the result of "life" or physiological processes upon the chemical composition and physical properties of woods and other organic materials, that causes these materials to be so variable. Not only do chemical and physical properties of woods vary with species, but they also vary with the age and health of individual trees from which the pieces are cut.

CHEMICAL COMPOSITION OF WOODS

From the standpoint of chemistry also, woods are complex and variable. Outer or living portions of a tree trunk contain nitrogeneous food-materials and others, such as starches and sugars; while the inner parts, in which life-processes have ceased, contain other substances. The chemical composition of wood cut from young trees differs to some extent from the chemical composition of wood cut from older trees. Variations are also due to species. Chemical Elements, Organic Compounds, and Inorganic Compounds must all be noted.

Chemical Elements.—Wood is composed principally of carbon, oxygen, hydrogen, nitrogen, potassium, calcium, magnesium, phosphorous, and sulphur. The relative qualities are much in the order named. The greater part of all wood is made up of carbon and oxygen. These elements with hydrogen constitute about ninety-seven per cent. of dry wood.[1]

Ordinary woods contain about 25 per cent. by weight of water. The remainder of 100 pounds of such wood, that is 75 pounds, contains about 37 pounds of carbon, 32 pounds of oxygen, 4 pounds of hydrogen, and 2 pounds of the other elements together. None of the elements noted above are taken up by the tree in the form or combination in which they are eventually assimilated. Carbon, hydrogen, and oxygen are obtained jointly from carbon dioxide and water. Nitrogen is absorbed in the form of nitrate and to a limited extent as ammonia; while potash, calcium, magnesium, phosphorus, and sulphur are taken up in the mineral form.[2]

Organic Compounds.—Wood-substances must be distinguished from the secretions that permeate them. The cells, of which all woods are composed, are made up as follows: (1) The walls of the cells include bundles of a definite substance known as cellulose. (2) The bundles of cellulose are embedded in materials known collectively as lignin. (3) The cells normally contain such substances as water, protoplasm, gums, resins, tannin, etc., etc.

Cellulose.—This is the substance of which the walls of all plant-cells are commonly composed. Flax fiber and cotton wool are almost pure cellulose. The chemical formula for cellulose, which is $C_6H_{10}O_5$ or, better still $(C_6H_{10}O_5)_n$, is the same as that of starch, but cellulose differs from starch in that it resists alcoholic fermentation. Plants themselves, however, and the

[1] Wood dried at about 300°F. contains about 49 per cent. of carbon, about 44 per cent. of oxygen, about 4 per cent. of hydrogen and about 3 per cent. of the other elements noted. See also "Timber," Roth (United States Division of Forestry, Bulletin No. 10, p. 51), etc.

[2] See also "Outlines of Botany," Leavitt, pp. 229–239.

fungi that cause decay are both able to convert cellulose into starch and then change the starch into the various forms of sugar.[1]

Lignin.—At first the cells are soft and delicate, but eventually the cell-walls become tough and woody and the protoplasm disappears. These changes are due to the appearance of the lignin and the process is known as lignification.

Lignin is harder and more elastic than cellulose. It forms the characteristic part of the woody-cell and a large part by weight of ordinary wood.[2] The chemical composition has not been satisfactorily established, but is variously given as $C_{18}H_{20}O_8$ and $C_{19}H_{18}O_8$. Lignin differs from cellulose principally in its proportion of carbon.

It is not known whether the composition of lignin is the same in all woods. The difference between hardwoods and softwoods seems to bear some relation to differences in proportions of cellulose and lignin rather than to differences in the composition of these compounds. As a general rule the harder the wood the larger is the proportion of lignin.

Associated Materials.—Chemical differences due to species are influenced less by the differences that exist in the walls of the cell-structures than by the differences that exist in the composition of the materials that are contained in, or are associated with, the cell-structures. The composition of the walls is fairly constant for all species, but the composition of the numerous gums, resins, tannin, and other associated materials is not constant.[3]

Sap.—This is as necessary to plant life as blood is to animal life. The ascending, or "crude" sap, contains various minerals and nitrogenous nutriment derived principally from the soil, while the descending, or "elaborated" sap, contains the more complex organic preparations that have been completed in the foliage through the instrumentality of the chlorophyll. The influence of sap on decay is considerable. In the sap are sugary and other substances that attract and foster the microorganisms that cause decay. It is the presence of watery sap that makes necessary the curative processes included under the term "seasoning."

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[1] "Timber," Roth (United States Forestry Division, Bulletin No. 10, p. 51).

[2] Lignin is contained in and forms the characteristic part of bast-cells.

[3] See also "Microchemistry of Plant Products" Stevens ("Plant Anatomy," pp. 330–367); United States Dispensatory; etc.

Protoplasm.—The viscid semi-fluid substance that exists within young cells contains carbon, hydrogen, oxygen, and nitrogen, with traces of sulphur, phosphorus, etc. This is the substance in which all plant-structures originate. The name is from the Greek *protos* (first) and *plasma* (formed matter).[1]

"The albuminous substances which compose protoplasm differ from the carbohydrates produced by assimilation, in containing a considerable proportion of nitrogen often with some sulphur and phosphorus. It is in the formation of these nitrogenous, or albuminous, matters that the nutrient mineral salts are put to use. Where this final step in the production of proteid matter is taken is not definitely known. It may be that it is in the green tissue of the leaf, or it may be at all growing points."[2]

Inorganic Compounds.—The mineral constituents of wood are the parts that have been absorbed from the soil and then prepared for assimilation in the foliage. Much of this mineral matter remains in the foliage and is returned again to the soil when the leaves fall in the autumn, so that the net loss to the soil, caused by the tree, is inconsiderable. The quantity of mineral matter retained in the tree is very small when compared with the quantity of carbon that is gathered by the tree from the atmosphere.

The principal inorganic compounds present in wood are sulphates, phosphates, chlorides, and silicates of potash, calcium, and magnesium, and frequently nitrates of these latter elements. In addition, the basic elements, particularly potash and calcium, may be found combined with organic acids, such as citric, malic, tartaric, and oxalic. The larger number of chemical elements are within this group, but their total quantity is insignificant. The quantity varies between one-half of one per cent. and five per cent., according to soil, climate, and other factors. The average is about three per cent.

When wood is heated, about one-fourth of its weight is given off as water. The volatile, inflammable gases then separate from the carbon which burns and releases the mineral matter as ash. The principal inorganic compounds found in ash, as distinct from wood, are sulphates, carbonates, silicates, and chlorides of potash, calcium and magnesium, and usually, considerable

[1] "Wood," Boulger (London, Second Edition, pp. 5 and 6.).
[2] Outlines of Botany," Leavitt (p. 236).

quantities of free lime also. The sulphates and carbonates of potash and calcium usually predominate.[1]

PHYSICAL PROPERTIES OF WOODS

It is necessary to distinguish between the physical properties of woods and the physical properties of stones and metals. The variations due to life processes, age, and other physiological causes noticeable in the properties of woods, are without equivalents among the properties of the inorganic materials.

The cellular structure of wood, and its influence upon physical properties, must be constantly remembered. This influence is due to (*a*) the character of the cell-elements of which wood is composed, (*b*) the arrangement of the cell-elements, and (*c*) the characteristics and quantities of compounds, such as water, that are often associated with the cell-structures without being actually part of them.

The subject will be divided as follows: (1) The physical properties themselves will be enumerated or described. (2) The attempts that have been made to measure these properties as they exist in woods will be considered. (3) The changes produced by certain agents will be noted.

DESCRIPTIONS OF PHYSICAL PROPERTIES.—The first or qualitative part of the subject is not difficult. Some important properties are Strength, Rigidity, Elasticity, Resilience, Hardness, Ability to Hold Fastenings, Weight, Specific Gravity, Density and Porosity, Conductivity and Resonance.

Strength.—Strength has two meanings. There is the general meaning and the meaning as the word is used in mechanics. In the latter case, strength refers to properties by which resistance is offered to the application of outside forces. An outside force is opposed by an inside resistance, and any change that may take place in the shape of the body to which the force is applied is referred to as a "*deformation.*"

The five kinds of deformation commonly recognized are extension, compression, bending, twisting, and shearing. Extension and compression are results of direct forces acting parallel to the axis of the specimen, while bending and twisting are due to forces that are perpendicular to the axis of the specimen. Shearing may occur under the application of forces longitudinally or transversely. A deformation is said to be "elas-

[1] See chapter entitled "Destruction of Wood by Burning."

tic" when the body in which the deformation takes place tends to recover its original form after the force that caused the deformation has ceased to act.

The resistance offered to the forces that cause any or all of the forms of deformation is known as *Strength*. A material is said to be *strong*, or it is said to possess a certain amount of *tensile strength*, or a certain amount of *compressive strength* as the case may be. The term *elastic strength* is used to denote the resistance that is offered to forces that produce the greatest amount of elastic deformation. The *ultimate strength* of any material is the greatest resistance that the material can offer to any kind of deformation.

Modulus of Elasticity.—Within certain limits, a definite relation exists between the resistance that develops in a body and the deformation

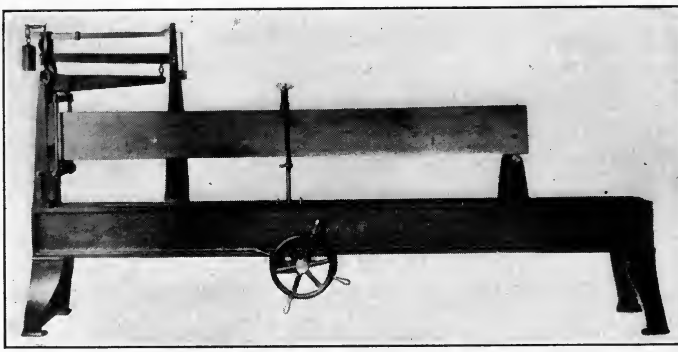

FIG. 31.—Machine for testing light wooden beams.[1]

that accompanies it. It happens that within these limits, the ratio between the unit-resistance and the unit-deformation in tension, is usually the same as the similar ratio in compression. This important ratio is known as the "*Modulus of Elasticity.*"

The Modulus of Elasticity expresses a law, first announced by Robert Hooke in 1675, that every solid is perfectly elastic up to a certain limit known as the elastic limit. The proportion is expressed as follows: *The elongation or compression of a specimen one inch in sectional area: the original length of that specimen::the weight necessary to produce the elongation or compression: the weight that would, theoretically, produce an elongation equal to the original length of the specimen;* or

The Modulus of Elasticity =

$$E = \frac{\text{Load per unit of cross-section}}{\text{Elongation or compression per unit of length}}$$

[1] Tinius Olsen, Philadelphia, Pa.

or $E = \frac{Pl}{Ae}$ in which E = The Modulus of Elasticity in pounds per square inch, P = the total load in pounds, l = the length in inches, A = the area of cross-section in square inches, and e = the elongation in inches.

The meaning of The Modulus of Elasticity may also be expressed by the statement that it is the weight or force that would elongate a specimen of unit-area to twice its original length, if the specimen remained perfectly elastic.

The Modulus of Elasticity of any material is determined experimentally with the aid of machines prepared for that purpose. Typical specimens are selected, measured and then subjected to loads sufficient to cause deformations. The loads and deformations are measured and the moduli are found by proportion as above.

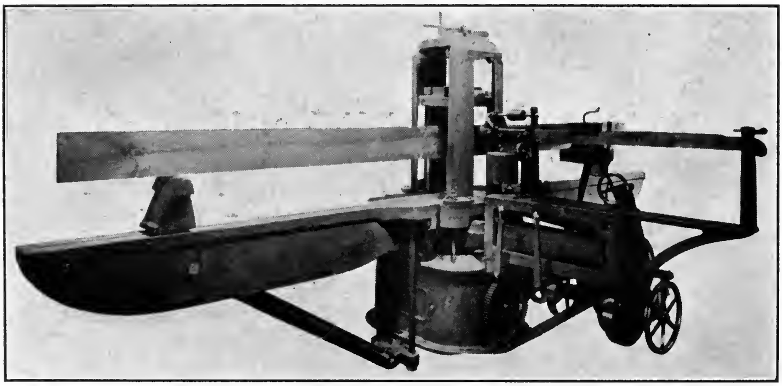

FIG. 32.—Machine for testing heavy wooden beams.[1]

Modulus of Rupture.—This is another measure of primary importance. This modulus for tension, compression, or shear, is the load that will rupture a bar of unit-section of the material in question. In other words, it is the maximum unit-stress sustained by the material just before rupture, or

Modulus of Rupture =

$$R = \frac{\text{Maximum load in pounds}}{\text{Cross-sectional area of specimen in square inches}}.$$

Rigidity.—There is the general meaning, and the definition as the word is sometimes used in mechanics and engineering.

General Meaning.—Rigidity is here the opposite of flexibility. A rigid body is one that is tense or stiff. Such a body is not easily deformed. From this point of view, rigidity and stiffness are the same.

[1] Tinius Olsen, Philadelphia, Pa.

Engineering Definition.—Rigidity is the property by which a body resists change of form when acted upon by an external force; the amount of force and the nature of the deformation are not regarded. The form of a perfectly rigid body could not be changed by the application of an external force, but a perfectly rigid body does not exist. The distinction between rigidity and stiffness as these terms are used in mechanics, should be noted. From this point of view, rigidity is the property by which a body resists deformation, regardless of the nature of the deformation; while stiffness is the property by which a body resists elastic deformation.

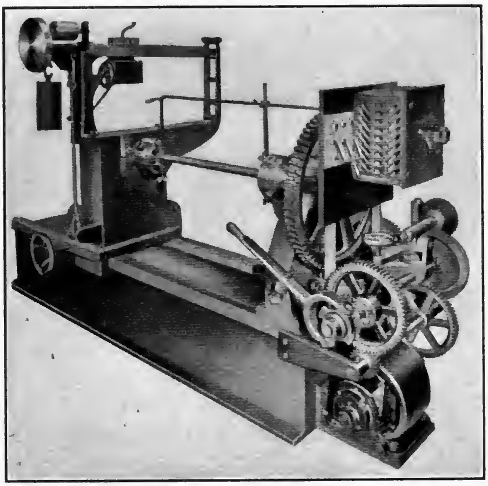

FIG. 33.—Olsen machine for making tortion tests.

Elasticity.—Elasticity has a popular meaning, a general meaning, and a meaning as the word is used in physics, engineering, and mechanics.

Popular Meaning.—The term elasticity is often used to denote the property by which a body sustains a large amount of deformation and regains its original form after the force that caused the deformation has been removed. Indiarubber is a very elastic material from this point of view.

General Meaning.—Elasticity is the property by which a material tends to resume its original form after the forces that caused it to leave the original form have ceased to act. The difference between this definition and the one that precedes it lies in the fact that in the present case the *amount* of the deformation is not material.

Meaning in Physics.—A body is said to be perfectly elastic when the work done in producing a deformation in the body equals the work done when the body recovers its original form. A perfectly elastic body does not exist. There is always some motion between adjacent particles whenever a material suffers deformation and this causes friction and loss of work. Ivory is more elastic than Indiarubber from this point of view.

Meaning in Engineering.—The material of which a body is composed is said to be perfectly elastic for all forces equal to or less than a certain applied force, when the body having been deformed by that force succeeds in recovering its original form after the force has ceased to act.

Resilience.—This property is intimately connected with elasticity. The name resilience has several meanings, as springiness, the power of springing back, and the power of resuming a former shape. Resilience also stands for the amount of work accomplished by a body when recovering from a deformation.

Johnson[1] defines resilience as "the springing back of a deformed body after the deforming force has been removed. As used in mechanics, however, it is the work done by the body in this springing back, which is the same as the work done on the body in deforming it, so long as this is inside the elastic limits. Beyond the elastic limit, the work of deformation always exceeds the work given back by the body. The body then does not fully recover its initial position, shape or dimensions. Sometimes the work of deformation, whether inside or beyond the elastic limit, is spoken of as the resilience, but this is improper. *The resilience proper is the amount of work or energy in foot-pounds, which can be stored in an elastic body up to a given stress per square inch, and which can be given out again by the body as useful work, if desired.*"

Hardness.—This is the property by which a material resists indentation and abrasion. Hardness is influenced by density and weight. Lignumvitæ, greenheart, osage orange, and some of the eucalypts are very hard woods. Poplar and white cedar are soft woods.

Resistance to abrasion has been determined by pressing blocks of wood against revolving discs covered with sandpaper. The amounts worn from the ends of the blocks have been taken as measures of the hardness of the specimens. The proper abrasive, the speed of the disc, the pressure and other details are important. Indentation testing machines are also used. Tests to determine the hardness of commercial woods have been begun by the United States Department of Agriculture.

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[1] "Materials of Construction," p. 75, 1908 edition.

Ability to Hold Fastenings.—This characteristic property contributes very largely to the usefulness of wood as a material of construction and may also be a measure of durability, as is shown in the case of railway ties which often fail because they cannot hold spikes. The spikes are driven so many times that the ends of otherwise good ties become cut and useless.[1]

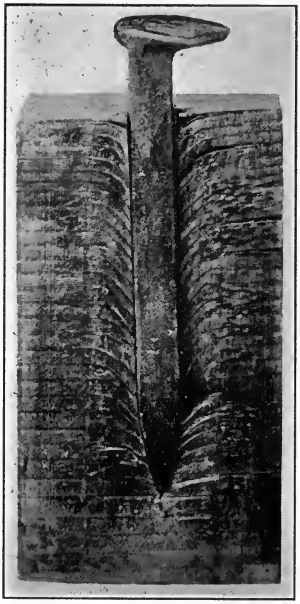

FIG. 34.—Displacement caused by common spike. Photograph, Spencer Otis Company.

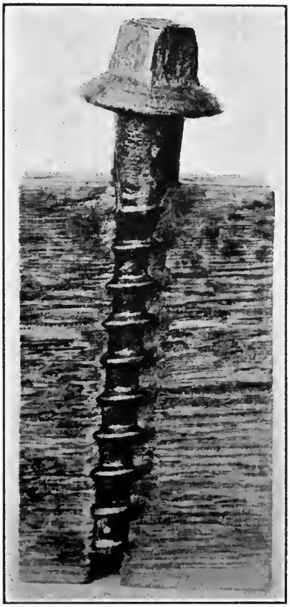

FIG. 35.—Displacement caused by screw spike. Photograph, Spencer Otis Company.

The ability to hold fastenings is due principally to friction; in some cases, although to a less extent, it may also be due to adhesion.

Nails cut, break, bend, and compress the fibers of the pieces into which they are driven. The mutilated fiber-extremities react and present roughened surfaces that press upon the surfaces of the nails. Pressure is also exerted by the fibers that have been bent and forced aside.

The forces required to withdraw nails bear some resemblance to those required to drive them and vary with the character of the nails, the character of the wood, and the direction of penetration. (1) It is

[1] European engineers sometimes use wooden dowels that are screwed into spaces cut for them in the ties. The spikes are driven into the dowels and the dowels are replaced when they become cut so that they cannot longer hold the spikes. (See United States Forest Division, Bulletin No. 50, p. 64).

harder to drive and withdraw rough, blunt nails than to drive and withdraw nails that are smooth and sharp. (2) Hard woods like oak offer greater resistance to penetration and withdrawal than softer woods like poplar. (3) It is easier to drive nails with the grain than across it, and it is easier to draw nails that have been driven with the grain than to draw those that have been driven across the grain.

A series of experiments upon The Holding Power of Railroad Spikes, conducted at the University of Illinois,[1] indicates as follows:

1. The maximum resistance to direct pull varies from 6,000 pounds to 14,000 pounds for screw spikes, from 3,000 pounds to 8,000 pounds for ordinary spikes when driven into untreated timbers, and from 4,000 pounds to 9,000 pounds for ordinary spikes when driven into treated timbers.

2. The direct pull required to withdraw ordinary spikes ⅛ inch varies from 2,000 to 3,000 pounds for untreated timbers, and from 2,500 to 3,500 pounds for treated timbers.

3. The direct pull required to withdraw ordinary spikes ¼ inch varies from 3,000 to 5,400 pounds for untreated timbers and from 3,800 to 5,900 pounds for treated timbers.

4. Timbers having loose fiber-structures have lower resistances to direct pull than timbers having compact fiber-structures.

5. The amount of withdrawal which must occur for ordinary spikes to develop the maximum resistance is less for soft woods than for hard woods.

6. Spikes driven into treated timbers offer a greater resistance to direct pull than spikes in untreated timbers, and the difference between this resistance for treated and untreated timbers is greater for soft woods than for hard woods.

7. The difference in the resistance to direct pull for the different sized spikes in use (9/16 inch, 19/32 inch, and ⅝ inch) is very small.

8. The resistance of ordinary spikes to direct pull varies directly as the depth of penetration, neglecting the tapering point.

9. Blunt-pointed and bevel-pointed spikes have a slightly greater resistance to direct pull than chisel-pointed spikes.

10. For withdrawals less than ¼ inch, ordinary spikes which are driven into bored holes have a little greater resistance to direct pull than spikes driven in the ordinary way.

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[1] University of Illinois Bulletin, Vol. III, No. 18, Webber.

See also "Substitution of Metal for Wood in Railroad Ties," Tratman (United States Forestry Division, Bulletin No. 4, 1890); "Crosstie Forms and Rail Fastenings with Special Reference to Treated Timbers," von Schrenk (United States Forestry Bureau, Bulletin No. 50, 1904); "Holding Force of Railroad Spikes in Wooden Ties," Hatt (United States Forest Service, Circular No. 46, 1906).

11. The resistance to direct pull for re-driven spikes is from 60 to 80 per cent. of the resistance of newly driven spikes.

12. The efficiency of screw spikes to resist withdrawal is nearly twice as great as that of common spikes.

13. The resistance of ⅝-inch spikes to lateral displacement is slightly greater than that of 9⁄16-inch spikes.

14. The resistance to lateral displacement increases with the depth of penetration, but the increase is negligible for depths of penetration greater than 4 inches.

15. Screw spikes are more efficient than ordinary spikes in resisting lateral displacement.

Fig. 36.—Metal tie plate. Photograph, Spencer Otis Company.

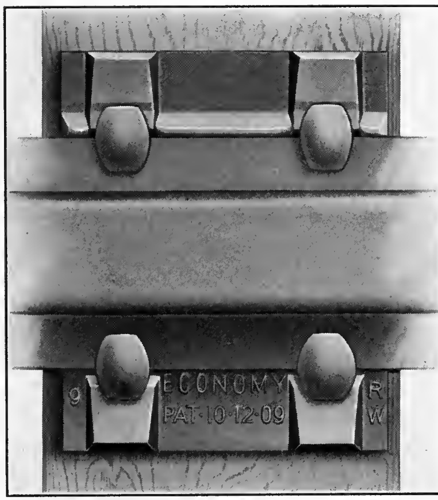

Fig. 37.—Rail resting on tie plate. Photograph, Spencer Otis Company.

Weight, Specific Gravity, Density.—The weight of a body is the downward or specific force of that body. The specific gravity of a piece of wood is the ratio of the weight of a given bulk of that wood to the weight of an equal bulk of water. Density and weight may be interchangeable.

The wood tissues in the cell-walls of all species weigh about the same; but the woods themselves vary considerably. Similar volumes of woods of different species contain more or less cell-wall tissue as the case may be. The greater the proportion of cell walls and the smaller the proportion of air spaces, the greater the density, and therefore the weight of the wood. Density and weight may thus be indications of hardness and strength. On the other hand, the smaller the proportion of cell-wall material and the larger the proportion of air spaces, the smaller the density, the weight, and the strength of the wood. Light woods are porous and buoyant.[1]

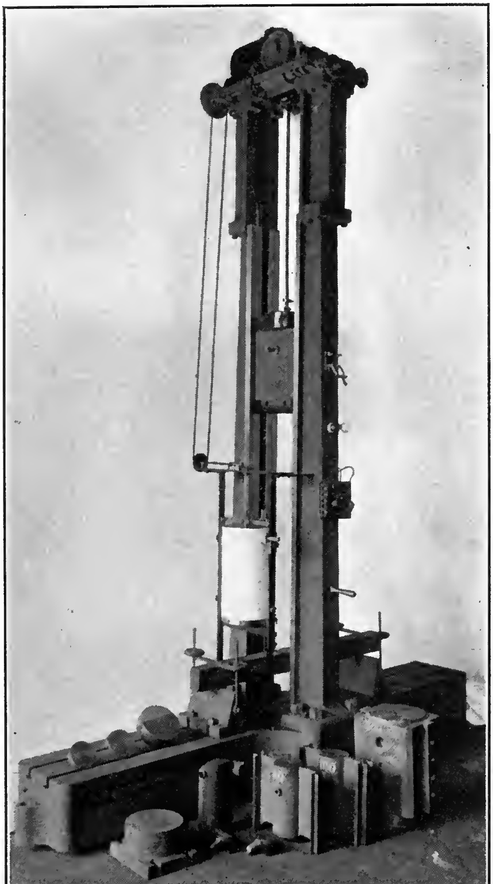

FIG. 38.—Turner impact testing machine.

Not only does the weight of wood depend upon the character and quantity of the woody tissue, but it also depends upon the water, gums, resins, and other substances that may be associated with the woody tissues. The principal weight variations observed in woods are due to

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[1] See index, "Density Test."

the presence of water. Half of the weight of live sapwood may be made up in this way. There is less water in heartwood, and more in young and vigorous trees than in those that are older and less healthy. All trees contain more sap at some seasons of the year than at others. Woods that are apparently dry contain some water. The influence of water is so important as to warrant further attention.[1]

As indicated, the weight of dry and clean wood is normally a sign of strength. A heavy piece of oak is usually stronger than a lighter piece; and, unless the extra weight is due to abnormal quantities of resin, a heavy piece of yellow pine is stronger than a piece that weighs less.

It will be remembered that the quantity of water contained in a piece of wood will vary with the proportions of sapwood and heartwood, and with the state of the weather. The proportion of water in wood is usually greater than in the surrounding air. The quantity is not constant, but, varying with humidity, amounts to about twelve per cent. of the weight of the dry wood. The weight of wood is usually calculated from small, sound specimens, which have been dried in a kiln at a temperature of 100 degrees C. until they reach a weight that does not vary.

The comparative weights in pounds per cubic foot of some broadleaf woods are as follows:

Name		Weight pounds
Balsa	*Ochroma lagopus*	7
Cork (from cork oak)	*Quercus cuber*	14
Missouri corkwood	*Leitneria floridana*	18
White Pine	*Pinus strobus*	24
Catalpa	*Catalpa speciosa*	25
Cypress	*Taxodium distichum*	29
Douglas Fir	*Pseudotsuga mucronata*	32
Sycamore	*Platanus occidentalis*	35
Longleaf pine	*Pinus palustris*	38
Maple	*Acer saccharum*	43
Locust	*Robinia pseudacacia*	45
Mahogany	*Swietenia mahagoni*	45
Red Oak	*Quercus rubra*	45
White Oak	*Quercus alba*	50
Hickory	*Carya alba*	51
Live oak	*Quercus virginiana*	59
Ironbark	*Eucalyptus leucoxylon*	70
Lignumvitæ	*Guajacum sanctum*	71
Greenheart	*Nectandra rodioei*	72
Ebony	*Diospyros ebenum*	73

[1] See index, under "Moisture." See also Roth, United States Forestry Division, Bulletin No. 10.

Porosity, Penetrability.—A porous substance is one that can be penetrated by another substance. It is one that is pervious or full of pores. Weight and density are both influenced by porosity.

The porosity of wood depends upon the character and arrangement of the cell-elements of which it is composed, and also upon the characteristics and quantities of foreign materials that may be present, such as water and resin; and, since the content of water may vary, permeability may vary also.

Heavy, dense woods are much less permeable than are light, loose-structured woods; while clean and seasoned woods are more permeable than woods that are resinous or green. Sapwood is more permeable than heartwood. A study of the porosity of woods is closely associated with a microscopic study of their cellular structure.[1] The permeability of wood has an important bearing upon its response when treated with solutions designed to prevent decay.

A series of experiments conducted to determine facts with regard to the permeability of woods resulted in the statements that follow:[2]

1. "All woods in the fresh, green state are impenetrable to gases even under high pressures, except through the open vessels in the angiosperms[3] and the resin-ducts in the conifers where these are not clogged by tyloses or resin. The same is true as regards liquids, except that water solutions may gradually seep through the membranes. Since it is the wood-fibers and the tracheids which form the main part of the structure of wood, impregnation of the vessels or resin-ducts would be of little or no value of itself in preservative treatment. The above is due to the fact that every cell is a closed vessel completely surrounded by its primary wall.

2. Whenever wood seasons (beyond its fiber saturation point), whether naturally or by artificial means, narrow microscopical slits occur in the walls of the fibers and tracheids which render them penetrable to gases and liquids. These slits do not re-unite when the wood is re-soaked although they may close up somewhat. The greater the degree of dryness, the more penetrable the wood becomes.

3. Steaming green wood produces a somewhat similar effect but to a

[1] American Railway Engineering Association, Bulletin No. 107, January, 1909.

[2] American Railway Engineering Association, Bulletin No. 120, February, 1910.

[3] Woods from Broadleaf trees.

less degree unless the wood be subsequently dried also. The reason then, that absolutely green wood cannot be successfully treated with preservatives is due, not so much to the fact that the wood contains water, but because the cell-walls are unbroken and therefore impenetrable. Just what pressure these walls would resist it is impossible to state, but it seems probable that it would run into the thousands of pounds per square inch."

The influence exerted by tyloses upon porosity is very marked. These obstructions, which exist in the large vessels of a number of the broadleaf woods and in the resin-ducts of some of the needleleaf conifers, and, which are often visible to the unaided eye, tend to block up the passages through which foreign fluids, such as antiseptics, are otherwise largely introduced. Weiss separates some of the broadleaf woods into three groups, depending upon the presence or absence of tyloses, as follows:[1]

Tyloses Absent. The maples, birches, blue beech, flowering dogwood, holly, silverbell, black and water gums, black and red cherry, basswood, persimmon, honey locust.

Tyloses Few. Yellow buckeye, beech, red gum (sap), yellow poplar, magnolias, sycamore, black cottonwood, eucalyptus (blue gum), white and Oregon ashes, and the elms.

Tyloses Abundant. Largetooth aspen, hardy catalpa, desert willow, green, pumpkin and blue ash, mocker nut, water pignut, shellbark, bitternut, nutmeg and shagbark hickories, butternut, black walnut, red mulberry, blackjack, white, Garry, overcup, valley, bur, cow, post and swamp white oaks, black locust, and osage orange.

Cleavability.—When applied to wood this term denotes the ease with which the longitudinal fabric of the wood can be separated. The cleavability of wood is opposed by cohesion and by some phases of the cellular structure of the wood. Cleavability is influenced by temperature. It is less when it is extremely cold.

Conductivity.—This is the property by which heat, electricity, and sound are transmitted or conveyed. It is well known that wood is a poor conductor of heat and a good conductor of sound, particularly in the direction of the length of the pieces.

Dry wood is an almost perfect non-conductor of electricity, but green or wet wood presents a comparatively low resistance to the passage of electricity. The results of experiments con-

[1] From examinations by Eloise Gerry, United States Forest Products Laboratory.

ducted to determine the electrical resistance of woods treated with zinc and other preservatives are as follows:[1]

1. The resistance of timber varies directly with the length and inversely with the cross-section.
2. The resistance varies almost inversely with the amount of moisture present, between the limits of 15 and 50 per cent.
3. The resistance is lowest when measured along the grain, and highest when measured tangentially to the growth-rings.
4. When treated with a soluble salt such as zinc-chloride, the resistance varies approximately inversely as the amount of the salt present.
5. Treatment with such a soluble salt does not change the behavior of the resistance with respect to the percentage of moisture present. Only the amount of the resistance is changed.
6. The resistance of timber varies almost inversely with the temperature between the limits of zero and 50 degrees C.
7. The resistance of non-porous woods, such as the pines, is higher than that of porous woods, such as the oaks and red gum.
8. Treatment of timber by different creosote processes does not greatly change the natural resistance of the timber.
9. The conductivity of wood is due primarily to the presence in the pores of an electrolyte formed by an aqueous solution of the salts found in the natural timber, or of these salts and others artificially introduced.

Conductivity is diminished by porosity and increased by density and by water. It is less when the wood is diseased.

Resonance.—Strictly speaking, resonance is the property by which sound is repeated or sustained. Occurrences in other branches of physics, as electricity, are similar to those in acoustics and have warranted an extension of the term to include cases in which sound plays no part. Hering expresses the wider meaning of the term resonance as follows:

> "If any rhythmic action in one body excites rhythmic action of like periodicity in another, whether in connection with the first body or apparently separated from it, the second body is said to be in resonance with the first."

The meaning of "resonance" is limited to the acoustic property when the word is used in connection with wood.

Pores, pith-rays, and other irregularities that occur in broadleaf woods, interfere with the resonance of such woods and for this reason broadleaf woods are commonly less resonant than are

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[1] "The Electrical Resistance of Timber," Butterfield, Engineering News, April 6, 1911.

some of those of the coniferous series. All woods are more resonant when they are dry. Spruce is one of the most resonant of woods and is used for sounding boards in pianos and violins.

"If a log or scantling is struck with the axe or hammer, a sound is emitted which varies in pitch and character with the shape and size of the stick, and also with the kind and condition of wood. Not only can sound be produced by a direct blow, but a thin board may be set vibrating and be made to give a tone by merely producing a suitable tone in its vicinity. The vibrations of the air, caused by the motion of the strings of the piano, communicate themselves to the board, which vibrates in the same intervals as the string and re-enforces the note. The note which a given piece of wood may emit varies in pitch directly with the elasticity, and indirectly with the weight, of the wood. The ability of a properly shaped sounding board to respond freely to all the notes within the range of an instrument, as well as to reflect the character of the notes thus emitted (*i.e.*, whether melodious or not), depends, first, on the structure of the wood and next on the uniformity of the same throughout the board. In the manufacture of musical instruments all wood containing defects, knots, cross grain, resinous tracts, alternations of wide and narrow rings, and all wood in which summer and spring wood are strongly contrasted in structure and variable in their proportions, is rejected, and only radial sections (quarter-sawed, or split) of wood of uniform structure and growth are used.

"The irregularity in structure, due to the presence of relatively large pores and pith-rays, excludes almost all our broadleaved woods from such use, while the number of eligible woods among conifers is limited by the necessity of combining sufficient strength with uniformity in structure, absence of too pronounced bands of summer wood, and relative freedom from resin.

"Spruce is the favored resonance wood; it is used for sounding boards both in pianos and violins, while for the resistant back and sides of the latter, the highly elastic hard maple is used. Preferably resonance wood is not bent to assume the final form; the belly of the violin is shaped from a thicker piece, so that every fiber is in the original as nearly unstrained condition as possible, and therefore free to vibrate. All wood for musical instruments is, of course, well seasoned, the final drying in kiln or warm room being preceded by careful seasoning at ordinary temperatures often for as many as seven years or more. The improvement of violins, not by age but by long usage, is probably due, not only to the adjustment of the numerous component parts to each other, but also to a change in the wood itself, years of vibrating enabling any given part to vibrate much more readily."[1]

[1] "Timber," Roth (United States Division Forestry, Bulletin No. 10, pp. 24, 25).

Hygroscopicity.—This is the property by which dry wood absorbs water from the air, loses it when dried again, and then gathers new supplies when the wood is re-exposed. Hygroscopicity diminishes the value of wood, since variations in moisture are accompanied by changes in volume. A door will stick during the summer when outdoor air has free access to the house, but will loosen during the winter when the windows are closed and the house is heated. Contraction and expansion may be repeated so many times as to interfere with strength. A piece of wood affected in this manner has not decayed but rather may be said to have aged. The tendency is greatly reduced when woodwork is protected with oils, paints, and varnishes.

Color.—Color is a physical property. This is so regardless of the chemical means by which it is brought about. The color of wood, which is due to the presence of pigments manufactured by the tree during its lifetime, differs with species, and is more or less characteristic of them, so that it may be of considerable assistance in identifying woods.

In practically every species the wood first formed is almost colorless. But later, as the wood changes from sapwood to heartwood, the characteristic pigments appear in the heartwood. Tints frequently vary as woods are cut from younger or older trees. When woods are exposed to the weather, chemical changes take place in the pigments, which then become darker. Prolonged immersion in water also causes woods to become darker. Some pigments are of such a character that they can be removed when the woods in which they were formed are soaked in water, and many pigments removed in this manner are used as dyes. Disease, such as "bluing," may cause colors in woods.[1]

Color may or may not be desirable. One of the factors that causes many woods to be preferred in indoor finish is color; and, where natural color is lacking, it is often obtained artificially by means of stains. Color is not desirable in spokes, handles, and wood used for paper pulp.

MEASUREMENTS OF PHYSICAL PROPERTIES.—This second part of the subject is more difficult than the first. It is easy to describe qualities as such, but it is not as easy to measure such qualities serviceably where the material is as variable as the one in question.

Not only do wood-specimens cut from trees of the same species

[1] See also "The 'Bluing' and the 'Red Rot' of the Western Yellow Pine," von Schrenk (United States Bureau of Plant Industry, Bulletin No. 36, 1903).

vary with age, soil, and environment, but pieces cut from the same tree vary with water, imperfections, and proportions of sapwood and heartwood. Moreover, the properties of the same piece of wood may vary from day to day as the result of ordinary changes in the amount of moisture in the atmosphere. It is obviously easy to measure the strength of a specimen that has once been selected, but very difficult to secure the specimen if it is to stand for the species as a whole.

A test designed to measure strength or any other property, includes three parts or operations: (1) A specimen that will represent the material must be selected; (2) the specimen must be prepared for the test, that is, it must be reduced to exact dimensions; (3) the prepared specimen must be tested in a machine designed for that purpose. The difficulty is encountered under the first heading.

The physical properties of woods are often measured, but comparatively few of the results obtained agree closely with one another; variations of as much as one hundred per cent. are not uncommon. All specimens are tested in practically the same manner so that the discrepancies must be due to the fact that the specimens are seldom selected and prepared upon a common basis. Differences which existed in the properties of several specimens of Eucalyptus wood are shown by the tables on pages 253 and 254.

The principal points upon which engineers have not agreed when selecting and preparing test-specimens of wood relate to *standards for moisture* and *sizes of test-specimens.*

(1) **STANDARDS FOR MOISTURE.**—Wood-elements become soft, swollen and pliable where they are wet. Seasoning expels some of the moisture and brings a larger number of wood-elements within a given space. The wood is then stronger and more rigid. These matters may cause the strength of wood to vary as much as four hundred per cent. A standard is therefore necessary. In tests conducted for the National Forest Service, Professors Fernow and Johnson adopted twelve per cent. by weight of dry wood as their standard.[1]

(2) **SIZES OF TEST-SPECIMENS.**—It is easier to select representative samples of stones and metals than to select samples of woods in which conditions with regard to age, grain, moisture, imperfections and proportions of heartwood are all approximately similar.

[1] See index for "Moisture in Wood" and "Seasoning in Wood."

Tables Showing Variations in Results of Tests of Woods.[1]

Strength of small, clear pieces of Blue gum (Eucalyptus globulus). (Arranged according to locality of growth. Specimens are 2 by 2 inches in section.)

	Condition of seasoning	Moisture Per cent.	Weight per cubic foot		Bending					Compression parallel to grain		Compression perpendicular to grain		Shearing	
			As tested Lb.	Oven dry(a) Lb.	Number of tests	Fiber stress at elastic limit Lb. per sq. in.	Modulus of rupture Lb. per sq. in.	Modulus of elasticity 1,000 lb. per sq. in.	Elastic resilience in. lb. per sq. in.	Number of tests	Crushing strength Lb. per sq. in.	Number of tests	Strength at elastic limit Lb. per sq. in.	Number of tests	Strength parallel to grain Lb. per sq. in.
SHIPMENT FROM TREE CUT NEAR SANTA MONICA, CAL.															
Average	Green	77.8	66.0	45.2	52	5,135	9,880	1,504	1.05	111	4,150	......	....	26	1,326
Maximum	do	111.1	68.6	50.1	......	7,350	11,920	2,020	2.28	......	5,315	......	....	......	2,005
Minimum	do	58.8	61.8	38.5	......	1,360	6,550	950	.27	......	2,120	......	....	......	810
Average	Air dry	19.2	47.9	45.6	17	7,560	12,400	1,712	1.91	19	6,205	19	1,056	205	1,738
Maximum	do	29.0	51.5	......	......	9,320	16,510	2,200	2.84	......	7,610	......	1,433	......	3,100
Minimum	do	11.4	41.4	......	......	5,590	10,470	1,180	.79	......	4,800	......	552	......	1,100
SHIPMENT FROM TWO TREES CUT AT BERKELEY, CAL.															
Average	Green	43.8	61.8	52.3	19	8,616	13,887	2,789	1.55	17	6,158	17	1,415	38	1,725
Maximum	do	53.5	67.4	55.6	......	10,300	15,500	3,520	2.43	......	7,070	......	1,679	......	2,522
Minimum	do	36.4	56.8	47.2	......	6,550	12,270	2,042	.80	......	5,310	......	1,247	......	1,291
Average	Air dry	23.4	59.8	56.6	22	9,960	15,560	2,187	2.57	22	8,092	24	1,505	36	2,030
Maximum	do	24.4	79.6	......	......	12,230	18,160	2,750	4.18	......	9,950	......	2,050	......	2,500
Minimum	do	18.6	50.1	......	......	7,420	12,720	1,566	1.45	......	6,020	......	975	......	1,447
SHIPMENT FROM TREES CUT AT COLEGROVE, NEAR LOS ANGELES, CAL.															
Average	Green	71.0	68.2	48.6	27	5,820	10,400	1,386	1.41	31	4,725	32	1,221	60	1,602
Maximum	do	109.4	74.3	61.4	......	8,010	13,800	1,754	2.45	......	6,230	......	2,476	......	2,320
Minimum	do	.45.0	52.0	40.4	......	4,330	7,740	916	.78	......	3,400	......	522	......	882

[1] Footnotes see next page.

TABLES SHOWING VARIATIONS IN RESULTS OF TESTS OF WOODS.[1]—(*Continued*)

	Condition of seasoning	Moisture Per cent.	Weight per cubic foot		Bending					Compression parallel to grain		Compression perpendicular to grain		Shearing	
			As tested Lb.	Oven dry(*a*) Lb.	Number of tests	Fiber stress at elastic limit Lb. per sq. in.	Modulus of rupture Lb. per sq. in.	Modulus of elasticity 1,000 lb. per sq. in.	Elastic resilience in. lb. per sq. in.	Number of tests	Crushing strength Lb. per sq. in.	Number of tests	Strength at elastic limit Lb. per sq. in.	Number of tests	Strength parallel to grain Lb. per sq. in.
SHIPMENT FROM TREES CUT NEAR ELWOOD STATION, CAL.															
Average......	Green......	87.2	67.6	44.2	22	6,217	10,996	1,523	1.45	20	5,102	19	1,286	19	1,636
Maximum....	do........	115.3	71.4	48.6	......	8,030	12,400	1,817	2.25	......	5,920	......	1,597	......	2,000
Minimum....	do........	74.0	65.2	36.9	......	3,150	8,040	1,025	.38	......	4,090	......	920	......	1,230
SHIPMENT FROM TREE CUT NEAR ELWOOD STATION, CAL.															
Average......	Green......	61.5	69.3	52.6	38	9,650	14,850	2,115	2.53	36	6,770	33	1,415	30	1,796
Maximum....	do........	97.8	71.8	58.8	......	12,800	17,900	3,194	4.59	......	8,090	......	2,130	......	2,070
Minimum....	do........	47.3	63.3	40.1	......	6,330	11,000	1,215	1.33	......	4,150	......	1,060	......	1,470
ALL SHIPMENTS COMBINED															
Average......	Green......	69.9	66.9	48.2	158	6,907	11,800	1,788	1.58	215	4,919	101	1,329	173	1,625
Maximum....	do........	115.3	74.3	61.4	......	12,800	17,900	3,520	4.59	......	8,090	......	2,476	......	2,522
Minimum....	do........	36.4	52.0	36.9	......	1,360	6,550	916	.27	......	2,120	......	522	......	810
Average......	Air dry...	21.6	54.6	51.8	39	8,914	14,183	1,980	2.28	41	7,218	43	1,307	241	1,782
Maximum....	do........	29.0	79.6	......	......	12,230	18,160	2,750	4.18	......	9,950	......	2,050	......	3,100
Minimum....	do........	11.4	41.4	......	......	5,590	10,470	1,180	.79	......	4,800	......	552	......	1,100

a The values in this column are based on a swelling of 21.8 per cent. volume when the moisture is increased from 0 to the fiber saturation point or above. The fiber saturatiou point is taken as 30 per cent. moisture.

[1] Tables by Betts & Smith from United States Forestry Service Circular No. 179.

Large Test-specimens.—It is hard to select large pieces of wood upon a common basis. Most large pieces are individual rather than representative and tests of such pieces yield results for the pieces thus broken rather than results that represent the species at large. On the other hand, tests of large pieces are useful because they show the results of imperfections.

Small Test-specimens.—The fact that small pieces are abnormally perfect causes them to yield results that are larger than those observed in actual practice. But such pieces possess the advantage that it is easier to select them upon a common basis. The results of tests upon small specimens agree more nearly with one another and are practical in that they make comparisons possible.

Large and Small Test-specimens.—The purpose for which the test is to be made should be considered. If the examination is to be exhaustive, large and small pieces should both be tested.

The differences that exist between the physical properties of woods and the physical properties of ordinary inorganic structural materials, may be epitomized as follows:

1. Stones and metals possess physical and chemical properties, while woods possess physical and chemical properties and also other properties that result from physiological processes.

2. The properties that result from physiological processes cause woods to vary. Pieces cut from the same tree differ from one another, while the same piece may vary from day to day as water is absorbed and dispelled. Changes in woods are caused by seasoning and the application of preservatives. Stones and metals are much more homogeneous and constant.

3. It is comparatively easy to select representative samples of stones and metals, but it is not easy for the average experimenter to select samples of woods upon a common basis as to moisture and imperfections.

4. Engineers have agreed to a greater extent upon specifications for testing stones and metals, and to a less extent upon specifications for testing woods.

5. Stones and metals are often tested by those who use them. Woods are less often tested by those who use them. In the case of woods, the results of tests conducted in Government or other laboratories are often preferred when such figures are employed at all.

6. Tests of stones and metals when conducted upon a scientific basis, give helpfully practical results. The coefficients of safety are here comparatively low and constant.

7. Tests of woods when conducted upon a scientific basis do not give equally practical results. The coefficients of safety are high and variable. Results obtained in this way are not satisfactory criteria of the actual working strength of the pieces.[1]

Two facts are emphasized: One is that the basis upon which the sample is selected and prepared is of unusual importance in the case of a substance as variable as wood; and the other is

FIG. 39.—Dorry machine for making abrasion tests.

that all figures obtained for woods should be used with the very greatest caution. Such figures should never, under any consideration, be used with the confidence that is warranted in connection with figures obtained similarly for the more homogeneous stones and metals.

The tests made to obtain values for the physical properties of woods can be arranged in several groups, each one depending

[1] For discussion of factors of safety and safe working stresses for structural timbers, see Report of Committee on Wooden Bridges and Trestles, American Railway Engineering Association, Bulletin No. 107.

primarily upon the way in which the test-specimens were selected. These groups are as follows:

1. Many experiments have been performed from time to time that have not been characterized by any particular method or principle such as underlie the investigations that will be described in the succeeding paragraphs. Details as to the selection of specimens are incompletely given or are entirely lacking. The botanical accuracy of the specimens is open to doubt in many cases. Major attention was given to the manipulation of the specimens in the testing machines. Properties other than strength and weight were seldom noticed. All of the experiments that are not alluded to in the descriptions that follow are included in this group.

The results of the experiments included under this head differ widely from one another, but some of them are helpful for special reasons; for example, Laslett and Rankin's experiments were performed principally upon foreign woods.

2. Experiments were conducted for the Tenth United States Census, by Sharpless, at the Watertown Massachusetts Arsenal. Botanical accuracy was assured, but in other respects the selection of specimens was not guided by factors that would now be considered. So far as is known, most of the specimens were from the butts of trees. Nothing is known of moisture conditions save that specimens were carefully seasoned. About twelve hundred specimens, representing over four hundred species, were tested. This allowed only two or three tests for each species.

The series is valuable because it includes almost all American species, and the results arrived at are often quoted. It is well to note that part of the results of these experiments were originally reported in the metric system. Coefficients were originally computed in kilograms and millimeters, whereas weights were given in pounds. This has led to some confusion.

These experiments are characterized as follows:

Botanical accuracy was assured.
Methods of selection were not definitely described.
Moisture conditions were not standardized as far as known.
Small specimens alone were tested.
Few tests were performed.
A large number of species was covered.

These experiments were described originally in Vol. IX, Tenth United States Census; Executive Document No. 5, Forty-eighth Congress, First Session; Sargent's "Silva of North America" and "Catalogue of the Jesup Collection of Woods."

3. Some experimenters, while admitting the difficulties that have been noted, prefer to test large specimens because they are the ones employed in practice. One important result obtained by such experiments is the determination of the extent to which imperfections lower strength. Experiments conducted under this head are described in Professor Lanza's "Applied Mechanics" and in publications noted in the succeeding sections.

4. In a series of experiments conducted for the National Forest Service, then called the United States Division of Forestry, Professors Fernow and Johnson acknowledged the difficulties of selection that have been noted. Test-specimens were selected upon a common basis as to age, moisture, proportions of heart-wood, imperfections, and other matters, and about forty thousand tests were made, distributed over thirty-one American species. Both large and small test-specimens were employed.

The details considered and the methods evolved during this study were of such a nature as to influence all subsequent efforts. The study is disappointing, in that results were obtained for so few species.

The series is characterized as follows:

Botanical accuracy was assured.
Soil and forest conditions were noticed.
Test-specimens were from representative portions of trees.
Representative trees were selected.
Moisture conditions were standardized at 12 per cent. of the dry weight of the wood.
Small test-specimens and large test-specimens were used.
Studies of strength and weight were emphasized.
Many tests were made.
A small number of species was covered.
The records are complete and reliable.

These experiments were originally described in Circular No. 15 and other publications of the National Division of Forestry, in

Professor J. B. Johnson's "Materials of Construction" and in Professor Fernow's "Timber Physics," Parts 1 and 2.[1]

5. A series of experiments begun more recently (1902) by the National Forest Service, is distinct from the one referred to in the preceding articles as follows: The earlier study was characterized by emphasis laid upon strength and weight, while the later study is characterized by attention paid to other properties as well. Physical properties are studied, but, in addition to these, there are investigations of technological processes such as kiln-drying and the application of preservatives. The influences of some of these processes and materials upon physical properties have been investigated.

These tests may be grouped as follows: (1) Tests of life-sized pieces or market products, such as bridge stringers, railway ties, wheel spokes, and axe handles, intended to yield results upon which grading rules, specifications, and coefficients for design can be based. (2) Tests of smaller pieces selected upon the same basis as to silvi-cultural conditions, age, grain, imperfections, and moisture. The details of the tests are varied. The influence of speed of application of load, temperature, etc., is noted. All the conditions alluded to in the earlier part of this chapter have been provided for in these experiments, which are second to none in both scientific and practical importance.

These investigations, organized by Professor William Kendrick Hatt, have been described in the "Transactions of the American Society of Civil Engineers," Vol. LI, 1903; in the "Progress Report on the Strength of Structural Timber" (United States Bureau of Forestry, Circular No. 32, 1904); in "Instructions to Engineers of Timber Tests," Hatt (United States Forest Service, Circular No. 38, 1906); in the "Second Progress Report on the Strength of Structural Timber," Hatt (United States Forest Service, Circular No. 115, 1907); in "Strength Values for Structural Timbers," Cline (United States Forest Service, Circular No. 189); and elsewhere.[2]

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[1] Publications of the National Forest Service.

[2] See also report of the Committee on Wooden Bridges and Trestles of The American Railway Engineering Association, reprinted in Engineering News, March 25, 1909, and referred to in Engineering News, February 22, 1912, as probably the best compilation of safe values to be used for unit stresses in structural timbers.

Density Test for Grading Southern Hard Pine.—This test, which is employed to grade the various kinds of Southern Hard Pine timbers, is the result of a long investigation conducted by the United States Forest Service and the American Society for Testing Materials. The experiments showed that the strength of Southern Hard Pine timbers depends less upon peculiarities due to species than upon the cellular structure of individual pieces.

Until the Density Test was suggested no standard existed by which the quality of individual timbers could be determined accurately. The rule, which is characterized by brevity and simplicity, is as follows:[1]

DENSITY RULE FOR GRADING SOUTHERN HARD PINE

"Dense Southern yellow pine shall show on either end an average of at least six annual rings per inch and at least one-third summer wood, or else the greater number of the rings shall show at least one-third summer wood, all as measured over the third, fourth and fifth inches on a radial line from the pith. Wide-ringed material excluded by this rule will be acceptable provided that the amount of summer wood as above measured shall be at least one-half.

"The contrast in color between summer wood and spring wood shall be sharp, and the summer wood shall be dark in color, except in pieces having considerably above the minimum requirement for summer wood.

"In cases where timbers do not contain the pith and it is impossible to locate it with any degree of accuracy, the same inspection shall be made over 3 inches on an approximate radial line beginning at the edge nearest the pith in timbers over 3 inches in thickness, and on the second inch (on the piece) nearest to the pith in timbers 3 inches or less in thickness.

"In dimension material containing the pith, but not a 5-inch radial line, which is less than 2 by 8 inches in section or less than 8 inches in width, that does not show over 16 square inches on the cross-section, the inspection shall apply to the second inch from the pith. In larger material that does not show a 5-inch radial line the inspection shall apply to the 3 inches farthest from the pith.

"*Sound Southern yellow pine* shall include pieces of Southern pine without any ring or summer-wood requirement."

Von Schrenk comments upon these rules as follows:

"While the new rule may at first sight appear to be a somewhat radical departure from past standards, a careful study will show that

[1] "Yellow-Pine Timber Graded Without Guesswork," von Schrenk (Engineering News, February 24, 1916).

such is not really the case. The Density Rule, when applied to a mixed lot of the various Southern pine timbers of the several botanical species, will include most of the pieces of the true botanical longleaf pine in the grade hereafter to be known as "Dense Pine;" a smaller percentage of the denser pieces of loblolly, Cuban and shortleaf pine also will fall within the dense grade; and on the other hand, a small percentage of the more rapid-growing pieces of longleaf will be excluded, as will also a great majority of pieces of loblolly, Cuban and shortleaf.

"It should be clearly understood that the classes "Dense Pine" and the less desirable "Sound Pine" refer specifically to quality of density when considered from the structural or strength standpoint and that they replace the botanical terms hitherto used—longleaf, shortleaf, loblolly, etc.

"It should also be clearly understood that the usual specifications as to the percentage of heart and sap are in no way changed. In other words, where timber for long service is demanded, together with high strength qualities, Dense Pine should be specified with a minimum amount of sapwood, or what is known as heart timber.

"A feature of the new rule that particularly recommends it is that it is easy of application. For the first time there is available for classifying structural timbers a rule which is based on actual measurement and which has nothing to do with catch-judgment or feeling. Numerous diagrams and illustrations in the Southern Pine Association's density rule book show how simple is the method and how effectually disagreements are eliminated."

THE WEIGHTS AND MODULI THAT APPEAR IN THIS BOOK ARE:

First.—Those derived from experiments conducted by the National Forest Service and placed in the "fourth group" explained above. These figures, as far as they exist, occupy the leading spaces in the tabulated descriptions of species under the titles "Weight," "Modulus of Elasticity," and "Modulus of Rupture." The spaces set apart for these figures are left vacant for other insertions where results under this group have not been reported.

Second.—Those derived from experiments conducted at the Watertown Arsenal by the Tenth United States Census and placed in the "second group" explained above. These figures appear in the spaces that follow those set apart for the Forest Service figures or their equivalents.[1]

All coefficients are in pounds per square inch; fractions of pounds in weight and the lower figures in coefficients have been omitted as superfluous.

[1] Authorities responsible for figures other than those mentioned above are given in connection with the figures employed.

INFLUENCE OF MOISTURE, ANTISEPTICS, AND HEAT UPON THE PHYSICAL PROPERTIES OF WOODS

MOISTURE IN WOOD.—Moisture exerts a very real effect upon the physical properties of wood. Many of the variations so noticeable in these properties are due to this cause. Moisture also acts upon woods in other ways; for example, woods suffer from micro-organisms that are assisted in their life and growth by the presence of moisture.

It is convenient to distinguish between the kinds of moisture that may be present within woods. The moisture may be sap, introduced while the tree was alive. Or, the moisture may have been introduced later after the tree was cut down, as when finished timbers are exposed to the weather. Other moisture may be impure; but sap, a vital fluid necessary to the life of trees, contains preparations that are of an organic putrefactive nature; and these, more than other impurities, seem to attract micro-organisms, or else assist their progress after they have once entered the wood.

The *quantity* of the moisture and its *distribution* are both important.

Quantity of Moisture.—One-half of the weight of live sapwood may be water. There is less water in heartwood than in sapwood, and more in young and vigorous trees than in those that are older and less healthy. All trees contain more sap at some seasons of the year than at others; and all woods, even when well seasoned and apparently dry, contain some water. The porous structure of clean wood permits water to pass in and out, so that in the same piece, the quantity of water may vary from day to day.

Influence of Season of Cutting.—The influence which the season of cutting exerts upon wood may be noted in this connection. The usual preference exhibited for winter felled timber has several causes. (1) It is thought by many that the quantity of moisture in a tree is so much less during the winter that the quality of the wood is affected. (2) Others prefer the winter for felling because fungi are then less active and there is less danger of infection before the log can be cut up in the mill. (3) Yet others regard the quality of the wood itself as better during the winter season. (4) In the North, lumbermen prefer the winter season for cutting because transportation problems in the forest are then more easily met. These points will be considered separately:

First, there is fully as much sap in a tree during the winter as during summer. Its composition may vary, but its total amount is, if anything, greater during the winter.[1] Second, it is true that fungi are less active during the winter season and that there is less danger of freshly cut wood becoming infected and consequently weakened at that time. Third, with the exception of the outer sapwood, no real difference exists in the quality of the trunk during the winter and the summer. Fourth, this point is one of convenience and has nothing to do with the quality of the wood.

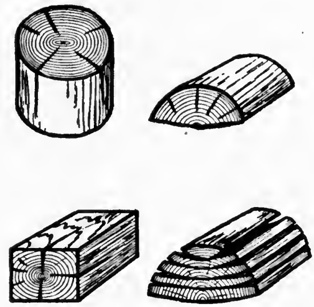

FIG. 40.—Defects due to unequal shrinkage.[2]

Of the above points the second only need be considered as a factor influencing the quality of wood. As a matter of fact if summer felled logs and winter felled logs could both be immediately cut up into lumber as soon as they were felled, and if the wood in each case could then be promptly and equally seasoned by the same process the two kinds could not be distinguished from one another.

Distribution of Moisture.—The practical importance of this subject will be appreciated when it is remembered that the principal difficulty encountered by those who season woods arises from attempts to expel moisture evenly from all parts of a piece in which it does not exist evenly.

Distribution may be studied from the standpoint of the entire piece, and it may be studied locally as it relates to the wood-elements. The distribution throughout the entire piece is such that there is more water in the sapwood than in the heart. Moisture is distributed throughout the wood-elements, so that some of it occupies the cavities in the wood-elements and some saturates the walls of the wood-elements.

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[1] "Sap in Relation to the Properties of Wood," Record (Proc. American Wood Preservers' Association, Baltimore, Md., 1913, pp. 160–166).

[2] Acknowledgments to United States Forestry Division, Roth, Bulletin No. 10, pp. 33 and 35.

Influence of Moisture.—There are three ways in which moisture influences woods: (1) moisture causes weakness and otherwise affects the physical properties of woods; (2) moisture influences distortion; and (3) moisture is a factor in decay.

INFLUENCE OF MOISTURE ON PHYSICAL PROPERTIES OF WOODS.—Wood-elements are swollen and pliable when they are wet. Seasoning expels moisture and brings more of them within a given space. The woods are then drier and stronger. Seasoning may increase strength as much as four hundred per cent.; and comparatively weak wood, such as pines, may be thus rendered stronger than better woods, such as oaks, that have not been seasoned.

The influence of moisture upon the strength of wood has been summarized by Tiemann:[1]

> "As the moisture of a piece of wood is reduced by drying, the strength of the wood increases, and as moisture is re-absorbed, the strength, up to a certain limit, is again reduced. So great, indeed, is the effect of moisture, that under ordinary conditions it outweighs all other causes that affect strength, with the exception, perhaps, of decided imperfections in the wood."

An exception must be noted. It is hard to dry a large timber that is full of knots and other irregularities without some injury to the piece as a whole; and this injury may offset much of the improvement that takes place otherwise through seasoning. To prevent decay, all wood should be dry, and all wood-elements and most timbers are stronger when they are dry; but the net strength of a very imperfect piece may not be always greatly increased by drying.

The Influence of Moisture upon Distortion.—The changes that take place in the form of a piece of wood are due to the discharge of water from the wood-elements. The fact that moisture is not distributed evenly throughout the wood, and the further fact that wood-elements vary in their character and arrangement are important in this connection.

When a wood-element shrinks the principal change takes place in its thickness, and the least change takes place in the direction of its length; the length shrinkage of a plank can usually be practically disregarded. Wood-elements near the surface of a log

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[1] "Effect of Moisture Upon the Strength and Stiffness of Wood," Tiemann (United States Forest Service, Bulletin No. 70).

contain more moisture than those within; and the sides of planks exposed to the weather may shrink differently than those protected.

Horizontal wood-elements usually shrink differently from the vertical wood-elements that are bound together by them. Severe strains at right angles to one another are then developed and the separations that take place are known as checks. Most needle-leaf woods shrink evenly, but it is often harder to expel moisture from broadleaf woods, such as oaks, that are characterized by complex fiber arrangements without some injury.

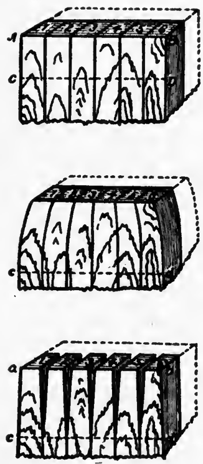

FIG. 41.—Result of unequal shrinkage. The formation of checks.[1]

Influence of Moisture upon Decay.—Decay is due to the action of certain micro-organisms that require moisture for their development, and that cannot live when it is absent. Decay is not inherent in woods; dry woods do not decay. Decay may proceed when the moisture is pure, but sap, as distinct from pure water, contains compounds that attract or that add to the activity of the forms that cause decay.[2]

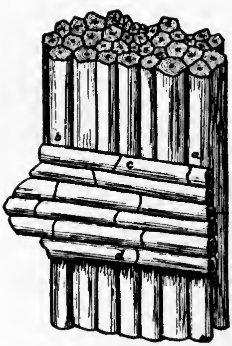

FIG. 42.—The relation of horizontal wood-elements to vertical wood-elements. *b*, *a* are vertical wood-elements, while *c*, *d* are cells of a pith-ray.[1]

Influence of Antiseptics and Preservative Treatment Upon the Physical Properties of Woods.—The physical properties of woods may be influenced by (1) the antiseptic, and by (2) the process employed to introduce the antiseptic.

The effect of creosote upon the physical properties of woods is negligible or beneficial. But zinc chloride and some other preservatives designed to benefit woods in some ways may injure them in others. Not only can a concentrated solution of zinc chloride injure tissues with which it comes into contact, but the timber as a whole may

[1] Acknowledgments to Roth (United States Division Forestry Bulletin No. 10, p. 34).

[2] See index, "Fungi," "Fungus Diseases of Woods," etc., etc.

be weakened by the addition of water. Otherwise, experiments indicate that the presence of zinc chloride will not weaken woods subjected to static loading, although the indications are that pieces that have been subjected to zinc chloride treatment become brittle under impact.[1]

As distinct from the preservative, a process may be harmful whenever excessively high temperatures are employed. If an appropriate process is selected, and if proper care is observed while it is being applied, the wood will not suffer.

Influence of Heat upon Physical Properties.[2]—Dry heat must be distinguished from wet heat. Dry heat much in excess of 212 degrees expels some of the volatile products of the wood and the wood then becomes correspondingly weak and brittle. The equivalent of moist heat is not known. Up to a certain point high heat, either in steam or in dry air, produced the following results upon wood:

"(1) It permanently reduces the moisture content below that of ordinary air-dried wood when again exposed to the air, at the same time rendering it less hygroscopic, so that it is less susceptible to changes in the humidity of the air; (2) the moisture condition of the fiber-saturation point is changed, being reduced by high temperatures with dry air or superheated steam; (3) the strength of the wood is increased, except in the resoaked condition."

Woods deteriorate, or fail, from *use, exposure, age, decay, fire, marine life,* and *land life;* and they are defended more or less successfully by *seasoning, internal treatment,* and *external treatment.* These subjects will be treated separately in the chapters that follow.

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[1] "Experiments on the Strength of Treated Timber," Hatt (United States Forest Service, Circular No. 39, p. 21); "Crosstie Forms and Rail Fastenings with Special Reference to Treated Timbers," von Schrenk (United States Bureau of Forestry, Bulletin No. 50); "A Primer of Wood Preservation," Sherfesee (United States Forest Service, Circular No. 139, p. 9); see also chapter entitled "Preservatives Applied within Woods," etc.

[2] See index, "Failure of Wood Because of Fire."

CHAPTER X

Failure of Wood Because of Use, Exposure, Age, and Decay

The changes that take place as a result of use, exposure, and age, are distinct from those that take place as a result of disease. Changes due to the former causes are of a *mechanical* nature; the wood-elements remain healthy but they separate more easily from one another. The changes due to decay are of a *chemical* nature; disease causes wood to break up into other compounds.

FAILURE DUE TO USE.—The mechanical deterioration of wood is influenced by the way in which it is used. Flooring is worn by abrasion. The life of a railway tie may be measured, by the speed, weight, and volume of traffic that passes on the rails above. Ability to hold fastenings is a factor in the life of wood when in some positions. Thus wood may wear out before it rots. Deterioration due to use is opposed by physical properties such as strength, hardness, rigidity, and weight.

FAILURE DUE TO EXPOSURE.—Woods may deteriorate as the result of simple exposure to the weather. Expansion and contraction due to extremes of temperature and the presence or absence of water cause wood-elements to loosen from one another. Deterioration takes place more gradually when woods are protected from the weather. Wooden roof-trusses in European churches have remained good during many centuries.

FAILURE DUE TO AGE.—Woods "age" much more rapidly when out of doors. Old wood becomes brittle and is then known as "brashwood." In a living tree age seldom acts alone, but, by lowering the vitality of the tree, makes it possible for disease to enter where resistance has been overcome. There is probably no such thing as the natural death of a tree in the forest and it is equally true that woods seldom fail in construction, simply because they are old. The vitality, soundness or resistance of a piece of wood may be roughly estimated by twisting a shaving of it between the fingers.

FAILURE DUE TO DECAY. FUNGOUS DISEASES.—Trees in the forests, and woods waiting to be used, or already in constructions, are susceptible to diseases that cause losses so serious as to constitute one of the greatest drains upon the timber resources of the world.

All wood, whether employed in railroad ties, telegraph poles, bridge, mine or house timbers, are susceptible to the same or similar diseases. Wooden warships once suffered more from them than from the guns of the enemy. It is said that wooden ships have failed after seven or eight years of service. Selection, seasoning, and the attention paid to protection makes it possible for woods to last longer at the present time; yet even now woods exposed to the weather endure for a comparatively short time, while the premature failure of beams in protected places is not uncommon.

Many names refer to practically the same causes of deterioration in wood. Wet-rot, dry-rot, disease, decay, mildew, soft-rot, canker, bluing, rust, bot, dote, mould, and other terms are thus employed. The results indicated by all of these names are due to the presence of bacteria or fungi.

Fungi.—These non-seedbearing plants differ from ferns and mosses, which are also non-seedbearing plants, in that the latter require light and contain the green substance chlorophyll which serves in the preparation of plant food; whereas the former, that is fungi, are without chlorophyll and do not require light. Fungi cannot draw their food from air and soil like ordinary plants and must therefore attach themselves to appropriate substances from which they can draw their food. Fungi are destructive rather than constructive and in this respect resemble animals rather than plants.

References.—"Outlines of Botany," Leavitt; "Fungous Diseases of Plants," Duggar; "Diseases of Economic Plants," Stevens and Hall; "Flowerless Plants," Bennett (Gurney & Jackson, London); "Fungous Diseases of our Forest Trees," Halstead (3rd Annual Report Penn. Dept. of Agriculture); "Diseases of Trees," Hartig; "Diseases of Plants Induced by Cryptogamic Parasites," Tubeuf and Smith; "Studies of Some Shade Tree and Timber Destroying Fungi," Atkinson (Cornell Exper. Sta. Bulletin No. 193); Bulletins American Railway Engineering Association; "The Discovery of Cancer in Plants" (The National Geographic Magazine, Vol. XXIV, No. 1, 1913); etc.

PLATE V. FUNGOUS DISEASES OF WOOD

FIG. *A*.

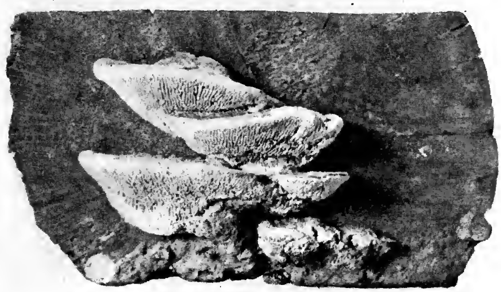

FIG. *B*.

FIG. *A*.—Fruiting Bodies of Fungus (*Fomes fomentarius*) (*a*).
FIG. *B*.—Fruiting Bodies of Fungus (*Daedalea quercina*) (*b*).

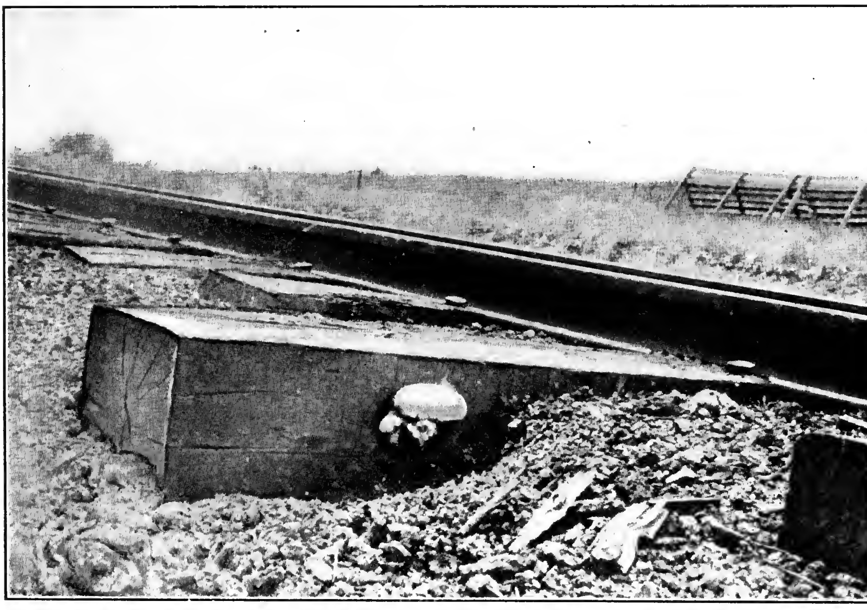

FIG. *C*.

FIG. *C*.—Fruiting Body of Fungus (*Lentinus lepidus*) on Red Fir Railway Tie (*c*).

(*a*) and (*b*) From "Diseases of Deciduous Forest Trees," von Schrenk and Spaulding (United States Bureau of Plant Industry, Bulletin 149). (*c*) From "Seasoning of Timber," von Schrenk (United States Bureau of Forestry, Bulletin 41).

(*Facing page* 268.)

Plant Life Has Been Divided in Many Ways.—The Linnæan classification separates all plants into Phanerogams, or seed-bearing plants, and Cryptogams, or non-seedbearing plants. The Cryptogams are again divided into one part, sometimes called the higher, which includes the ferns and mosses; and another part, sometimes called the lower, which includes the algæ, lichens, and fungi.

The fungi are divided into saprophytes and parasites according as they derive food from dead or living tissues. Some species are capable of existing as both saprophytes and parasites and for this reason some authorities (see Tubeuf and Smith, p. 3) separate fungi into true and hemi-saprophytes and true and hemi-parasites. There are sub-divisions in each case.

A piece of mouldy bread may be studied in this connection with profit. Such bread first emits a characteristic odor, then becomes discolored, and is eventually destroyed. Minute threads of the "mould" penetrate throughout the mass and their extremities eventually appear upon the surface of the bread as a delicate felt or fur. These extremities finally swell, burst, and liberate countless spores, some of which find a congenial substratum, germinate, and produce similar results.

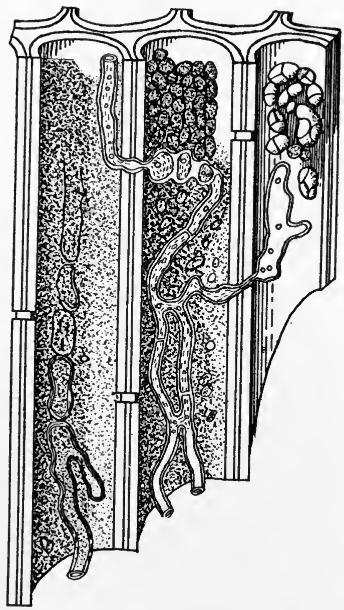

Fig. 43.—Mycelial threads of wood-destroying fungus (*Nectria cinnabarina*) in maple wood.[1]

The swollen ends of the extremities are the "fruiting bodies" of the fungi within the bread. In the same way the toadstool-like growths seen on rotting trees or timbers are the "fruiting bodies" of fungi that have entered such trees or timbers. Fruiting bodies are not always easily evident, and those of some fungi are quite obscure. An individual fungous thread or filament is called a "hypha," while masses of the threads or "hyphæ" form what is known as "mycelium." Bread, wood, or other sub-

[1] Acknowledgments to Roth (United States Division of Forestry, Bulletin No. 10).

stances that have become infected are the "hosts"[1] of the fungi that have gained entrance to them.

Fungi attack woods through the action of solvents called "enzymes," some of which dissolve cellulose, while others dissolve lignin, starches, sugars, and other compounds. The removal of any one of these constituents from the wood results, ultimately, in the total destruction of the usefulness of the wood. The general form of the diseased piece may be retained but its properties have been affected. Some of these wood residues are comparatively dry and brittle while others are moist, soft, and sponge-like.

Some fungi attack live trees. Others attack dead trees, and yet others attack woods employed in construction. Some kinds of fungi prefer conifers and others broadleaf trees. Bark, heartwood, and sapwood all have their enemies. Some fungi attack many species of trees or woods, while others attack only one or two species.

Fungi are very numerous. Many thousands of species are in existence. The subject is not a simple one; and the majority, who are not experts in this subject, find it more helpful to consider *the few conditions under which all fungi act* than to acquaint themselves, with the idea of identifying all of the many forms that cause the failures so constantly observed.[2]

Conditions Under Which All Fungi Act.—All fungi require moderate quantities of heat, air, and moisture for their development. They do not do well when excessive quantities of these agencies are present; nor do they do well when the said agencies are completely absent.

1. *Influence of Heat upon Fungi.*—Growth is retarded and fungi are sometimes completely killed by high heat, that is by temperatures much beyond one hundred and seventy degrees. Many fungi are killed by the process of kiln-drying, but some are rendered inert by this process for the time being only. The growth of fungi is also retarded by cold, that is by temperatures much below thirty-five degrees.[3] Fungi are not killed by any

[1] This term is usually restricted to the living organism upon which a parasite grows. Saprophytes grow upon a "substratum."

[2] Fungi do not confine themselves to plants. "Ringworm" as seen in man is due to a fungus parasite (*Trichophyton tonsurans*).

[3] These temperatures are approximate. It is not necessary to go below the freezing point to retard the growth of fungi.

degree of natural cold, no matter how extreme, but their activities cease, or are restricted, while such low temperatures continue.

2. *Influence of Air upon Fungi.*—The activity of fungi is more or less opposed by an abundance of pure air on the one hand, and by vacuum on the other. A moderate amount of air is necessary for their growth.

3. *Influence of Moisture upon Fungi.*—Wood will not decay while it is quite dry; neither will it decay as long as it remains saturated with water.

These facts explain why woods last better in cold climates and on well-drained hills, and why decay goes forward more rapidly in warm, moist climates, and in mines. A railway tie fails sooner than a beam that is raised up from the ground because the "medium" conditions of heat, air, and moisture are more nearly secured in positions where ties are employed.

Fungous diseases may be considered as they attack trees in the forest, and as they attack woods ready for, or already in, construction.

Fungous Diseases of Trees.—These diseases are here described for the sake of completeness, and because some of them produce results that are evident in merchantable lumber. Some of the fungous diseases that attack living trees are similar to the fungous diseases that attack woods in constructions.

Trees become infected through wounds such as the borings of insects and injuries caused by falling limbs and by pruning. There is sometimes an intimate connection between the attacks of insects and those of fungi. Some insects transfer the micro-organisms to trees mechanically. Sap as distinct from pure water is an important agent in the growth of disease that has once entered the tree.

The health of a tree is important. Good health increases resistance to disease, which resistance is less where health is lowered, as it may be by poor soil, by lack of light, and by the attacks of insects. Old trees succumb more easily than younger ones, but there is probably no such thing as the natural death of a

See also "Diseases of Trees," Hartig; "Diseases of Plants Induced by Cryptogamic Parasites," Tubeuf and Smith; "Disease of Taxodium known as Peckiness," von Schrenk (Contribution 14, Shaw School of Botany); "Fungus Diseases of Forest Trees," von Schrenk (United States Department of Agriculture Year Book 1900); "Diseases of Deciduous Forest Trees," von Schrenk (United States Bureau of Plant Industry, Bulletin No. 149 which also contains extensive bibliography); etc.

tree. To preserve health, some trees protect the raw surfaces of wounds with their own gums or resins. Intentional wounds, such as those caused by pruning, should be coated with tar or paint.

The fungi that attack trees may be divided as they attack the foliage, the roots, or the trunks of the trees.

Diseases of Foliage.—Leaves that have been attacked by spot, mildew, or rust, cannot adequately perform their duties and the preparation of wood is correspondingly interrupted. The foliage of the Soft Maple (*Acer saccharinum*) is thus subject to attack by a fungus called *Phyllosticta acericola.* Chestnut foliage is similarly victimized by the fungus *Marsonia ochroleuca,* and other fungi are associated with other trees.

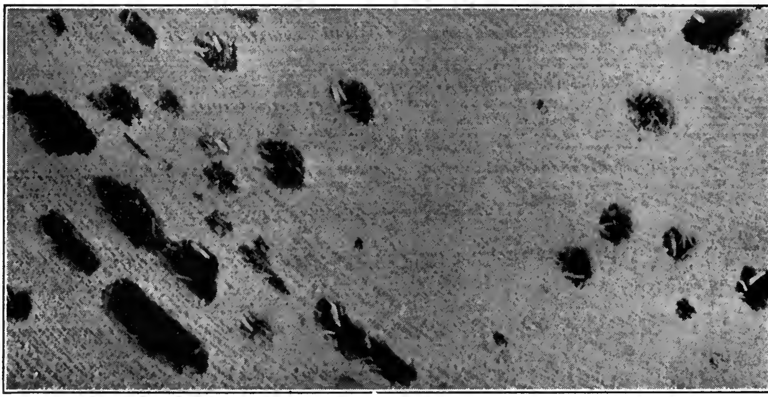

FIG. 44.—Section of wood cut from cypress after attack by wood-destroying fungus (*Dædalea vorax*).

Diseases of Roots.—Certain fungi attack the roots of trees. For example, the fungus known as the southern root rot (*Ozonium omnivorum*) attacks the roots of oaks and elms, and also those of some smaller plants as cotton. When the roots of trees are diseased, the wood making in the trunk is correspondingly retarded. Hartig states that barren places in forests are often caused by root fungi.

Diseases of Trunks—The trunks of live trees have many enemies. Cypress and Incense Cedar are sometimes attacked by the fungus *Dædalea vorax* that causes peculiar cavities in the wood. The Bull Pine (*Pinus ponderosa*) is subject to attack by the fungus *Ceratostomella pilifera* that causes the wood to become blue. The bark of the chestnut is subject to the bark disease (*Disporthe parasitica* or *Endothia gyrosa var parasitica*), which eventually kills the tree. Hardy Catalpa, White Ash, and other trees have special enemies.[1]

"The chestnut blight appears to confine itself to attacks upon species of the genus Castanea. It was first recognized in 1905 in trees near New York City but has now spread into many States and has practically killed all of the trees that have been attacked. If the trunk is the part affected, the tree is killed perhaps in one season, but if the small branches are attacked, the tree may survive for several years. The spores produce running sores and the trunks or branches that have been girdled by these sores assume a characteristic appearance. One of the most easily detected symptoms is the growth of sprouts or "suckers" below the girdling lesions of the trunk and branches as well as at the base of the tree."

Fungous Diseases of Structural Wood.—The term "structural woods" here includes woods that are ready for construction and those that are finally in place. Life-processes have ceased in the woods that are now referred to, which may be either seasoned or green. The fungous enemies of such material are very numerous, and, just as conditions were noted under which all fungi thrive regardless of their species, so here it is more practical to note all of the ways in which timbers are exposed and to then study the influence that each one of these exposures exerts upon the life of fungi.

Structural woods may be exposed in four ways. They are as follows:

First.—Woods may be *coated* by paint, metal, plaster, or similar materials.

Second.—Woods may be *coated,* that is enclosed, by earth or water.

Third.—Woods that have *not been coated* may be exposed to the weather.

Fourth.—Woods that have *not been coated* may be protected from the weather.

The "medium conditions" of heat, air, and moisture mentioned as necessary for the development of fungi are secured in the first

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[1] "Disease of Taxodium known as Peckiness," von Schrenk (Contribution 14, Shaw School of Botany); "Two Diseases of Red Cedar," von Schrenk (United States Division Vegetable Physiology and Pathology, Bulletin No. 21); "Diseases of Bull Pine," von Schrenk (United States Bureau of Plant Industry, Bulletin No. 36); "Diseases of the Hardy Catalpa" (United States Bureau of Forestry, Bulletin No. 37); "Diseases of White Ash," von Schrenk (United States Bureau of Plant Industry, Bulletin No. 32); etc., etc.

and third exposures. Woods are comparatively safe when in the second and fourth exposures.

First Exposure.—Paints and other impervious coatings protect from outside conditions but are detrimental if moisture and impurities are within the wood when it is coated. Coatings seal up the moisture and impurities, and a condition known as "dry-rot" is likely to occur. It should be noted that the name dry-rot refers to the *results* of the disease. The wreckage is dry and chalky but the fungi that caused this wreckage could not have lived without some moisture.

The application of paint to an organic substance such as wood must be distinguished from the application of paint to an inorganic substance such as iron. The principles that here apply with woods resemble those that apply when fruits or meats are placed in cans. Air-tight coatings should not be placed around any of these organic materials unless they have first been sterilized, cured, or otherwise prepared.

Second Exposure.—This exposure is distinct from the one that precedes it in one vitally important particular. Paints and metals are practically inert, while mud and water are not. Mud and water protect from outside influences but at the same time dilute or cleanse away such impurities as have remained within the wood. Even green woods are safe while under water, and not only this, but changes take place that render them more durable after they have been removed from the water.[1]

Woods do not no mally decay while submerged in mud or water. Records show that woodwork has lasted in this manner for over a thousand years, and there is no reason why it should ever decay while thus protected. The softening or physical disintegration that takes place under some conditions is not decay.

Third Exposure.—The third exposure is associated with what is commonly known as "wet-rot." The fungi that act when uncoated woods are exposed to the weather seem to require or to tolerate larger quantities of moisture than those accountable for the changes known as dry-rot.

The medium moisture conditions necessary for the growth of fungi in this position are supplied in two ways: (1) Excessive quantities of water may be applied intermittently as with marine constructions that are exposed between the tides, or (2)

[1] See index for "Water Seasoning."

PLATE VI. PORTION OF FLOOR BEAM AFTER ATTACK BY DRY ROT FUNGUS

Lifeless Condition of Wood is Shown by Detached Material at Bottom of Picture.

(*Facing page* 274.)

smaller quantities of water may be present constantly as when timbers rest upon damp soil, and when they are exposed to the moist atmosphere of mines.

The Influence of Top Soil.—This is so great that the expression, "durable in contact with the soil" is often used as a measure of the durability of wood. Surface soil is dangerous for several reasons. It is damp, and comparatively warm, and it *restricts* the air but does not cut it off entirely. Micro-organisms are present in the soil near the surface.

The effect of contact with top-soil is shown in the case of posts and other timbers placed upright in the ground. Decay usually begins in the parts of these timbers that are nearest to the surface of the ground and later extends upward and downward from the surface as conditions permit.

The tops of posts and similar timbers resist because they are drained and well ventilated, and the bottoms resist if they are driven down deep enough to escape the conditions that prevail at the surface. A beam raised a short distance from the ground lasts longer than one lying on its surface, because, although the space between the timber and the soil may not be more than a few inches, it is enough to secure some drainage and ventilation.

Some woods noted for extreme durability, average durability, and perishability when in contact with the soil, are noted below. Weiss estimates[1] that most of the woods in the first column will

Very durable woods	Durable woods	Perishable woods
Black Locust	Chestnut	Ash
Catalpa	Douglas Fir	Balsam
Cypress	Longleaf Pine	Basswood
Greenheart	Southern White Cedar	Beech
Lignumvitæ	White Oak	Birch
Mesquite		Cottonwood
Mulberry Red		Hemlock
Northern White Cedar		Loblolly Pine
Osage Orange		Lodgepole Pine
Redwood		Red Oak
Western Red Cedar		Sitka Spruce
		Sycamore
		Tupelo
		Western Yellow Pine
		White Spruce

[1] "Preservation of Structural Timber," Weiss (p. 275).

probably last more than twenty-five years when in contact with the soil; that most of those in the second column will last between ten and twenty-five years, and that most of those in the third column will fail in less than ten years.

Fourth Exposure.—Uncoated woods do not normally decay as long as they remain protected from the weather in dry, ventilated places. On the contrary, the quality of wood is likely to improve under such conditions, for reasons that are given in the section devoted to "Natural Seasoning." Many of the timbers seen in the covered wooden highway bridges that were erected in this country, in some cases more than one hundred years ago, are yet sound. Unpainted wooden roof-trusses have lasted for many centuries in European churches.

Evidence of Disease in Wood.—Disease becomes apparent in many ways. Some woods discolor, others swell and soften, while yet others become dry and brittle. Clots of hyphæ sometimes fill cracks or appear beneath the bark of logs. Thick masses of orange, pink, or gray material often extend like giant cobwebs between rotting timbers in mines. Piles, ties, and mudsills may be sound without but soft and spongy within. Sometimes this order is reversed.

Methods of Treatment.—Preventative methods are much more valuable than curative methods. It is usually impracticable to attempt to control disease that has once started. It is said that acid solutions will counteract some kinds of fungi. Disease caused by lack of ventilation can sometimes be prevented from spreading rapidly by providing for ventilation.

Methods of Protection.—Fungous diseases are contagious and for this reason diseased woods should usually be destroyed. The means by which woodwork may be more or less successfully defended against fungus diseases are as follows: (1) Selection: Woods that have the fewest fungus enemies should be selected. (2) Seasoning: Resistance is greatly increased by seasoning. (3) External treatment: Paints and other coatings may be used to shut out the micro-organisms that cause disease. (4) Internal treatment: Woods may be saturated with antiseptics. These subjects are treated elsewhere under appropriate titles.

CHAPTER XI

Failure of Wood Because of Fire. Wood as an Agent in Conflagrations. Fire Protection

The fact that wood is inflammable is of far-reaching importance. The direct losses caused by the burning of finished products and of live woods in the forests, and the indirect losses caused by the communication of fires from burning wood to other property cannot be estimated. A large part of the world's increment of wealth is burned up every year, and an undue proportion of this loss occurs in the United States, where large quantities of wood are used in construction.

Wood is a principal agent in conflagrations for the reason that it is the only one of the primary structural materials that takes fire at ordinary temperatures. Stones and metals may fail because of fire, but they do not contribute directly to flames. Many attempts have been made to use other materials in place of wood in naval and house architecture and even the earliest of these attempts were due to the fact that *wood will burn*.

References.—"Fire Protection of Mills," Woodbury (John Wiley & Sons, 1895); "Contributions of Chemistry to the Methods of Preventing and Extinguishing Conflagrations," Norton (Journal of American Chemical Society, Vol. XVII, 1895); Publications of National Board of Fire Underwriters; Publications National Fire Protection Association; Files of Insurance Engineering; "Process of Fireproofing Wood for the Woodwork of Warships," Hexamer (Engineering News, March 23, 1899); "A New Investigation of the Fireproofing of Fabrics," Whipple and Fay (Part of "The Safeguarding of Life in Theatres," Freeman, Transactions of the American Society of Mechanical Engineers, Vol. 27, 1906); "Waste of Our National Resources by Fire," Baker (Proceedings of Meeting called jointly by the American Society of Civil Engineers, the American Institute of Mining Engineers, the American Society of Mechanical Engineers, and the American Institute of Electrical Engineers, published in pamphlet, 1909); "The Enormous Fire Waste of the United States," Cochrane (Scientific American, June 15, 1912); "Fire Prevention and Fire Protection," Freitag (John Wiley & Sons, 1912); "The Modern Factory," Price (John Wiley & Sons, 1914); "Tests on Inflammability of Untreated Wood and of Wood Treated with Fire-retarding Compounds," Prince (Report on Uses of Wood, National Fire Protection Association, 1915).

Fire losses are greater in the United States than in any other country. The direct losses now exceed two hundred million dollars every year. In its relation to the building operations of the country this is equivalent to the destruction of one house out of about every four built.[1] This loss, which is about equal to the total value of all gold, silver, copper, and petroleum produced in the United States in a year, and which is many times greater than the interest on the National debt, is one of the factors in the present high cost of living. The sum mentioned does not include indirect losses, or losses by forest fires.

The direct fire losses in the United States for thirty-six years (1875–1910 inclusive), as estimated by the National Board of Fire Underwriters, were as follows:

1875	$78,102,285	1889	$123,046,833	1903	$145,302,155
1876	64,630,600	1890	108,993,792	1904	229,198,050
1877	68,265,800	1891	143,764,967	1905	165,221,650
1878	64,315,900	1892	151,516,098	1906	518,611,800
1879	77,703,700	1893	167,544,370	1907	215,084,709
1880	74,643,400	1894	140,006,484	1908	217,885,850
1881	81,280,900	1895	142,110,233	1909	188,705,150
1882	84,505,024	1896	118,737,420	1910	214,003,300
1883	100,149,228	1897	116,354,575		
1884	110,008,611	1898	130,593,905		
1885	102,818,796	1899	153,597,830	*Over five billion dollars direct losses in thirty-six years.*	
1886	104,924,750	1900	160,929,805		
1887	120,283,055	1901	165,817,810		
1888	110,885,665	1902	161,078,040		

Fire losses are increasing faster than the population of the country is increasing, that is, the number of fires per capita is increasing.

The indirect losses that take place as a result of fire must be considered also. Such losses include the costs of maintaining fire departments and water supplies for purposes of fire fighting, excessive insurance and losses in rents and business. It is estimated that in 1907 the *total* direct and indirect losses from fire amounted to $456,485,900, a sum almost half as great as the value of the new building constructions for that year. That is to

[1] "Proceedings of the Forty-ninth Annual Meeting of the National Board of Fire Underwriters," p. 19. Report "National Conservation Commission, Section of Minerals," Washington, December, 1908.

say, during that year about one billion dollars was expended upon new buildings and construction work, and approximately half of this increment was destroyed by fire. Such a sum is greater than the true value of the real property and improvements in any one of the States of Maine, West Virginia, North Carolina, North Dakota, Alabama, Louisiana, and Montana.[1]

There is also the loss of human life. According to the United States Census, 6,000 persons died of burns and 10,000 persons were badly injured by the same cause during 1906.

All comparisons in connection with this subject are startling, yet all of them are conservative. Baker estimates that the buildings destroyed every year in the United States if placed upon lots with an average frontage of 65 feet, would line both sides of a street long enough to extend from New York to Chicago.[2]

"Picture yourself driving along this terribly desolated street. At every thousand feet you pass the ruins of a building from which an injured person was rescued. Every three-quarters of a mile there is the blackened wreck of a house in which some one was burned to death."

"Imagine this street before the fire touched it, lined with houses, stores, factories, barns, schools, churches. Suppose the fire starts at one end of the street on the first day of January and is steadily driven forward by a high wind, just as actually happens in a conflagration. Building after building takes fire; and while the fire fighters save some in a more or less injured condition, the fire steadily eats its way forward at the rate of nearly three miles a day, for a whole week, for a whole month, for all twelve months of the year. And at the end of 1907 did the conflagration end? No; it began on a new street, a thousand miles long, which was likewise destroyed when 1908 was ended. And this same destruction is going on today."

The gravity of the situation is also expressed by Merrill as follows:

"Fifteen years is a brief space of time in the history of an organization; it is briefer in the history of a nation. Yet for our country, this period includes the San Francisco, Baltimore, Chelsea and Bangor conflagrations, the Windsor, Iroquois, Collingswood, Boyertown, Slocum,

[1] "The Enormous Fire Waste of the United States," Cochrane (Scientific American, June 15, 1912).

[2] Proceedings of meeting called jointly by The American Society of Civil Engineers, The American Institute of Mining Engineers, The American Society of Mechanical Engineers, and The American Institute of Electrical Engineers, March 24, 1909.

Lenox, Cherry, Newark, Chicago Stock Yards and Asch disasters; not a day without its long list of properties destroyed and not a month without record of the sacrifice of human life. It marks a burnt offering of more than two thousand million dollars worth of our created sources, and the lives of more than twenty thousand of our people."[1]

A comparison between per capita losses in some European countries and those in the United States is as follows (National Board of Fire Underwriters):

Austria (1898–1902)	$0.29	Italy (1901–1904)	$0.12
Denmark (1901)	0.26	Switzerland (1901–1903)	0.30
France (1900–1904)	0.30	United States	2.50
Germany (1902)	0.49		

In other words, the average per capita loss in six leading European countries is *thirty cents*, while the average per capita loss in the United States is *two dollars and fifty cents.*

No country, however rich, can afford to suffer such losses indefinitely; yet no great decrease can be expected until the average building in the United States is as good, from the fire-resisting viewpoint, as the average building in European countries. Most of the structures erected to meet first needs in the United States were built of wood; and this, with the indiscriminate use of wood in construction at the present time, is the principal explanation of why losses in this country have been and are so heavy. The policy in Europe is to *prevent* fires; but in this country, until recently, chief attention was given to perfecting apparatus and organizations by which fires might be *extinguished.*

The present subject is part of the general field of Fire Protection. The behavior of wood while burning and its influence upon the situation as a whole must be comprehended, but some knowledge of the wider field of which the present subject forms a part will also be of service. The notes that follow will relate to (1) *Wood as an Agent in Conflagrations* and (2) *Some Principles of Fire Protection.*

WOOD AS AN AGENT IN CONFLAGRATIONS

This part of the subject divides itself as it relates to *the burning of wood, the attempts to prevent wood from burning,* and *the methods used to extinguish burning wood.*

[1] The great conflagrations that have taken place in the last and present centuries are listed on p. 272 of World's Almanac, 1911.

THE BURNING OF WOOD.—Wood consists of a definite chemical compound known as cellulose, permeated by materials collectively known as lignin, and secretions such as resins, coloring matter, and water. Or, in terms of inorganic chemistry, it consists of carbon, oxygen, hydrogen, nitrogen, and small amounts of mineral salts that exist in the ash.

Upon burning, wood first gives off some water, after which inflammable gases separate from a solid base of carbon; the carbon is next largely consumed and leaves a residue of ash, which is composed of metallic salts that were originally present, together with carbonates formed during the burning. Wood deteriorates and may then take fire spontaneously[1] when subjected to comparatively slight elevations of temperature for long periods. In most cases, however, wood takes fire from flame communicated directly. Complex changes take place in wood as the result of heating without access of air. They are described as follows:[2]

"When wood is heated in retorts, the moisture is driven out, but no decomposition occurs until the temperature approaches 160 degrees C. Between 160 degrees and 275 degrees C. a thin watery distillate is chiefly formed; above 275 degrees the yield of gaseous products becomes marked, and between 350 degrees and 450 degrees liquid and solid hydrocarbons are extensively formed. Above this last temperature little change occurs, and charcoal, containing the mineral ash, remains in the retort.

"The fraction between 160 degrees and 275 degrees is called pyroligneous acid, and contains the important liquid distillates, methyl (wood alcohol), acetic acid, together with acetone, methyl acetate, allyl alcohol, phenols, and a great many other substances.

"The fraction between 275 degrees and 450 degrees contains both aromatics (*i.e.*, benzene derivatives) and paraffine hydrocarbons. Its most important constituent, from a commercial point of view, is the creosote oil, containing guaiacol, creosol, and other phenols of high molecular weight.

"The variety of wood used affects the amount of distillate. Deciduous trees, especially birch, oak, and beech, are preferred. Coniferous woods afford less acid (watery) distillate, but more of the higher fractions containing turpentine and resin."

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[1] Wood should not come into contact with steam or hot water pipes and should not be placed too near registers; otherwise deterioration and spontaneous combustion may result. See also "Spontaneous Ignition of Wood," Fairweather (Insurance Engineering, September, 1908.)

[2] Quotation from Thorp's "Outlines of Industrial Chemistry."

ATTEMPTS TO PREVENT WOODS FROM BURNING

Many attempts have been made to prevent woods from burning. The ancient Greeks used alum for this purpose; and later attempts were associated with methods designed to protect woods from decay. At the present time the most intelligent efforts are those that have followed great theater fires, and much of the literature upon this subject relates to efforts that have been made to protect the woods and fabrics used in theaters. The tendency now is to eliminate woods and other combustible materials for theater buildings.

Woods treated with certain chemicals are referred to as "fireproofed woods," but this is inaccurate. All woods burn under the right conditions, and, at best, it is possible only to retard oxidation, and to obstruct for a little the escape of volatile gases that are active agents in spreading fires. Correctly speaking *fireproofed woods* do not exist; it is, however, correct to speak of methods that *retard* burning. Protective methods are of two kinds: fire-retarding chemicals are applied *internally* and *externally*.

INTERNAL PROTECTION.—The attempts made to protect woods from fire by injecting fire-retarding chemicals into them have not yielded satisfactory results; yet the fact exists that such attempts have been made and a statement with regard to this form of protection is, therefore, necessary.[1] The subject will be divided as follows: the materials known as fire retardants, the processes used to introduce these materials within the woods, and the selection and preparation of woods that are to receive the fire-retardant chemicals.

Fire Retarding Materials.—Alum, boric acid, borax, sodium tungstate, water glass, magnesium phosphate, aluminum sulphate, ammonium chloride, ammonium sulphate, ammonium phosphate, "Paris theatre solution," "Chicago solution," and many other mixtures and compounds have been considered or used to retard the burning of fabrics and the burning of woods. Some of these substances serve because they decompose and liberate gases that smother flame. Borax owes its efficiency to other properties; it melts easily and then flows in thin films that cut off the supply of oxygen from burning wood.

[1] Fireproofed woods were used in ships, notably after the war with Spain. A small quantity of fireproofed wood has been used in the finish of special buildings. At the present time the demand for such material is limited.

The value of ammonium phosphate as a fire retardant has been recognized for many years. In his report upon the burning of the Iroquois Theatre, Freeman states that no one of the many salts or mixtures tested was found to be so good. The properties and behavior of this salt are described in the following quotation.

"First, it has a little tendency to gather dampness, and to dry this out absorbs a little heat. Next, as the heat rises, ammonia is given off, and the thin film of this repels the oxygen of the air. When the ammonia is gone we have left the ortho-phosphoric acid, which in liquid form covers the surface and preserves it from oxidation under increasing heat. At 300 to 400 degrees Fahrenheit this decomposes, giving off water; at higher temperatures it gives off its remaining water. In all of this disassociation it absorbs some heat until we have left, at full red heat, fused metaphosphoric acid as a liquid film surrounding the fixed carbon remaining from the destructive distillation.

"On the other hand, the phosphate of ammonia has its disadvantages. A manufacturing chemist, perhaps of the widest experience of any in this country in the practical chemistry of the phosphates, warns me that for its best efficiency it must be applied in a strong or saturated solution, but, if very strong, it may in time disastrously affect the strength of the fiber, that it is somewhat deliquescent, has a tendency to develop fungous growth, that in time it may part with a portion of its ammonia, becoming the acid ammonium-phosphate which has a tendency in presence of moisture to attack metals, while in a warm atmosphere the free phosphoric acid attacks some colors."

The result of a series of experiments upon the comparative worth of the several chemical substances and mixtures used as fire retardants, conducted by Whipple and Fay, is summarized as follows:[1]

(*a*) That inert chemical substances can exert but very slight fire-retarding action.

(*b*) The fire-retarding action of salts which depend for fire-retardant quality only upon their water of crystallization, like potash, alum, sodium phosphate and borax, is slight and unimportant, although somewhat superior to that of inert substances.

(*c*) Fire retardants of the class which suffer chemical decomposition under heating are decidedly more efficient than those which depend on the driving off of water of crystallization, but still far less efficient than the class that follows.

(*d*) The most efficient salts are those which on decomposing leave

[1] "A New Investigation of the Fireproofing of Fabrics" contained in "The Safeguarding of Life in Theatres," Freeman (pp. 57–65).

behind a non-volatile residue which is fluid at the temperature of the burning canvas, and covers the charring fabric with a thin glaze which prevents further access of air; and, of this type, phosphate of ammonium was found to be the best.

It is necessary to distinguish between chemicals injected into woods as fire retardants and those that are applied within woods for other purposes. The latter are antiseptics, and woods are the better for their presence; but as distinct from these the salts which are applied as fire retardants attract water and in this way injure woods.

Processes Used to Apply Fire Retardants Within Woods.—The methods used to introduce fire retardants within woods are the same as those employed to introduce antiseptics within woods. There should be deep impregnation and the wood must not be injured. Processes are of two kinds: there are some that do not include pressure, and others that do include pressure. Solutions may be applied by dipping, brush-applications, and the open tank process; or they may be forced in by pressure applied within cylinders.

Preparation of Woods to Receive Fire Retardants.—Woods should be dry and receptive if fire retardants, or any other chemical substances, are to be introduced within them. Some attention should be paid to selection; it should be remembered that woods differ in receptivity and that some woods, such as California redwood, take fire less easily than others.

EXTERNAL PROTECTION.—Many attempts have been made to prevent or retard the burning of wood by means of coatings, and at least one of these attempts has succeeded sufficiently to serve practically in construction.[1] The properties of the *materials* employed, the *methods* by which they are applied, and the preparation of *woods* to receive them, must be considered.

Materials.—Fire-retardant coatings are of many kinds. An ideal fire-coating is one that resists the disintegration and distortion due to high heat and sudden cooling, and one that will not conduct heat. The materials available for this purpose do not meet these requirements satisfactorily, but they do resist the action of fire longer than other materials. Asbestos, the so-called fireproof paints, and certain metals, are used in fire-coatings.

Asbestos.—The name asbestos is applied to several products, as Canadian asbestos or chrysotile, which contains about fifteen

[1] See description of fire doors and fire shutters.

per cent. of water, and tremolite, a fibrous calcium silicate, which contains no water. Canadian asbestos, so largely used in the United States, loses strength and is otherwise altered by temperatures, just below red heat, that are sufficient to expel the water of crystallization.[1]

The fact that common asbestos becomes brittle and loses strength when subjected to comparatively low temperatures has discouraged its use in making curtains to isolate the woodwork and other inflammable materials used in theaters, and such curtains although still used, are no longer regarded as the best form of protection.[2] Tenacity is less important if asbestos is to be used as a pigment in paint.

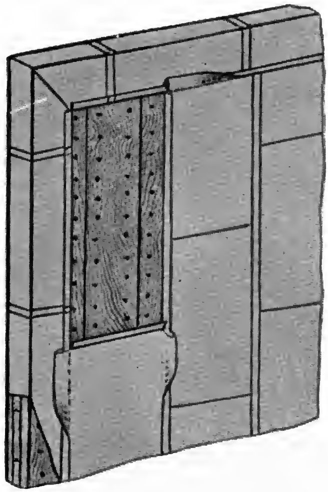

Fig. 45.—Corner of tin-clad fire door.

Fireproof Paints.—Fireproof paints differ from ordinary paints chiefly in that they are not themselves inflammable. These paints offer momentary but sometimes sufficient resistance to very small fires, such as flames from burning matches. But they do not resist fires that have gained headway or created appreciable draughts. It is obvious that crusts less than one one-hundredth of an inch in thickness cannot aid effectively any attempts to prevent conflagrations.

Lime and asbestos are common pigments, while glue and water-glass are common vehicles. Oil should not be used. A number of mixtures purchased in open market were found upon analysis[3] to consist chiefly of slaked lime, powdered asbestos, alum, gypsum, and glue. A cold water paint containing a lime, asbestos, or magnesium base, and casein or glue as a binder, is doubtless as good as any. Although the National Fire Protection Association considers well-made whitewash a good fireproof coating,

[1] About 600 degrees C.

[2] Steel now enters into the construction of the best curtains for proscenium openings.

[3] Whipple and Fay Report.

the use of whitewash for this purpose is not general. Some fire-retardant paints are said to be composed of easily fusible glass mixed with ordinary paint.

Metals.—Wood is sometimes enclosed by metal. Combinations of wood and tin, such as are used for fire doors and fire shutters, have resisted where solid metal has buckled and failed.[1] Tin is superior to paint in that it resists for some time even when exposed to severe heat, whereas paints offer but momentary resistance even to very small fires. Paints soon blister and chalk under the influence of heat.

Methods Used to Apply Fire Coatings.—Fire-retardant paints are applied to surfaces of wood in the same way as other paints. That is, it is important that the wood should be clean, dry, and receptive; that the brush should be held at right angles to the surface, and that the paint should be laid on with strokes parallel to the grain of the wood.[2]

Tin can be applied to wood in such a way that *the two together* offer a very real resistance to fire. Tin will warp, and wood will burn, but the two, when used together in standard fire doors, have lasted long enough to save buildings. They have retained the shapes of the openings, even after the wood within has charred and failed. Standard fire doors are made of not less than three layers of seven-eighths-inch wood. The tin covers overlap at all points so as to protect fastenings and resist strains.[3]

The principles that apply when woods are to be coated with ordinary paints and varnishes apply equally when they are to receive fire coatings. All woods should be well seasoned, dry, and clean, if they are to receive coatings of any kind, and no wood that is moist, knotty, or resinous should ever be used in any fire door or fire shutter. Moisture if present would cause decay, while, if a fire should take place, moisture and resins would form hot gases that would burst through the tin. Clean, dry, white pine is used in the best fire doors.

Methods of Testing "Fireproofed" Woods.—Small specimens are usually burned in laboratories[4] and the intervals that elapse before they are charred or consumed are taken as measures of their resistance. Although encouraging results are obtained in

[1] See descriptions of fire doors.

[2] See "Paints and Varnishes Applied to Surfaces of Woods."

[3] See Rules and Requirements National Board of Fire Underwriters.

[4] Bunsen burners are commonly employed.

PLATE VII. APPEARANCE OF FIRE DOORS AFTER FIRE

(*Facing page 286.*)

this way, such tests have very little practical value save as they enable comparisons, because all wood whether protected or not will burn if the draught is sufficient.

The way in which results are influenced by methods is shown in the case of some experiments upon so-called fireproofed canvas prepared for use in the scenery of theatres. These experiments are described as follows:[1]

"In the effort to more nearly follow practical conditions, one set of tests was developed on the line of my earlier stovepipe experiment by burning fireproofed canvas within a piece of five-inch stovepipe two feet long lined with asbestos." "Six strips of the canvas, thoroughly treated with the different solutions, were placed three-fourths of an inch apart and ignited by burning one ounce of excelsior. *In every case the canvas burned completely to ash in from three-fourths of a minute to one and one-half minutes, with flames which often extended two feet above the top of the stovepipe.* Tests in the stovepipe apparatus on the efficiency of different flameproofing chemicals were made comparable by taking the same quantity of canvas in each and by lighting the fire with the same quantity of combustible."

METHODS USED TO EXTINGUISH BURNING WOODS.—Although the methods used to extinguish all fires are the same, yet there is good reason for associating such methods with the burning of wood.

As already stated, in Europe the policy with regard to fires is to endeavor to prevent them. Less wood is used in Europe and the losses there are smaller than in the United States, where larger quantities of wood are used and the losses that take place by fire are larger. In the United States, until recently, more attention has been given to perfecting apparatus and organizations designed to extinguish fires, than to means by which the fires might be prevented.

Fire departments in Europe are inferior to those in the United States, because less need exists for fire departments in Europe. Those who visit European cities for any length of time are impressed by the fact that fire engines are so seldom seen. During ten years passed in French and German cities Norton saw fire engines called out five times.[2] American efficiency in the

[1] "A New Investigation of the Fireproofing of Fabrics" contained in "The Safeguarding of Life in Theaters," Freeman (pp. 57–65).

[2] Journal of the American Chemistry Society (Vol. XVII, No. 2).

field of extinguishing fires is unquestioned; but this is because the demands upon firemen are so great in the United States.

Materials.—The materials used to extinguish fires act by excluding air from the substances that are burning. It is needless to say that water is the cheapest, most effective, and most widely available material for this purpose; it should not be forgotten, however, that other materials are sometimes used. Some of these are as follows:

Carbon Dioxide.—It is generally conceded that much of the value of this gas, when mixed with water as in the discharge from chemical extinguishers, is due to the power generated, which propels the stream. Carbon dioxide is usually used mixed with water. It is very rarely used by itself.

Sulphur Dioxide and Ammonia.—These gases extinguish fires but are seldom used because it is often inconvenient to obtain and apply them and because they endanger life. They serve because they displace oxygen but they cannot be used easily save in enclosed spaces of limited extent.

Carbon Tetrachloride.—The properties of this compound were known in the past but until recently its usefulness has been limited by its high cost. The development of electrolytic cells for the production of chlorine and caustic soda, with the consequent cheapening of chlorine gas, has recently opened the way for the cheaper manufacture of carbon tetrachloride.[1] Carbon tetrachloride is a clear, colorless, volatile liquid, having a specific gravity of 1.604 and a boiling point of 78 degrees C. It is non-inflammable, non-explosive, non-corrosive, and its vapors smother flame. It is a non-conductor and is particularly useful in the case of electrical fires, where water cannot be employed and where dry powders, such as sand, have previously been used. It is also serviceable in library fires, because it will extinguish flames produced by burning papers without injuring the papers as water would injure them.

Solids.—Flour, sand, and other solids are sometimes used in emergencies. Such materials are stored in cylinders and these "dry powder cylinders" are convenient and easily found receptacles for small quantities ofthe powders used. These cylinders are useful as far as they go but the y may do harm by causing a sense of security not warranted by the results obtained. The National Fire Protection Association reports as follows:

"In view of the fact that several so-called fire extinguishers, consisting generally of sheet-metal tubes filled with mixtures of bicarbonate of

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[1] Journal Industrial and Engineering Chemistry (January, 1910); Engineering News (March 16, 1911); Quarterly National Fire Protection Association (January, 1911); Catalogues Pyrene Manufacturing Company; etc.

soda and other materials in powdered form, have been widely advertised as suitable for use for fire-extinguishing purposes, we have to report that in our opinion all forms of dry-powder fire extinguishers are inferior for general use, that attempts to extinguish fires with them may cause delay in the use of water and other approved extinguishing agents, and therefore their introduction should not be encouraged."

Methods or Devices for Applying Materials.—Water is applied by steam fire engines and other devices commonly associated with the elaborate fire departments of cities. Tanks placed at high elevations are often useful where natural head is not available. Chemical engines, sprinklers, and fire pails are also employed.

Chemical engines are tanks containing bicarbonate of soda dissolved in water, and commercial sulphuric acid (oil of vitriol) stored separately but also within the tank. The carbon dioxide which results when these compounds come together creates the force by which the contents of the extinguisher is discharged.[1]

Automatic sprinkler systems consist of pipes arranged on the ceilings of rooms within the structures to be protected. Waterways in these pipes are closed by small discs which are held in place by easily fusible solder. In case of fire the solder melts, water flows upon the fire, and an alarm is rung. There are many other important details,[2] some of which are noted later in the present chapter.

Portable chemical fire extinguishers differ from the larger chemical engines that have been described in that they are easily carried from place to place, and very easily manipulated. The copper receptacle, coated with tin, is designed to hold about three gallons of water, and to resist a pressure of about four hundred pounds, although the pressure seldom exceeds eighty pounds. The quantities of acid and soda are adjusted so that the pressure, when they come together, is not greater than the cylinders can bear. The solution that leaves the extinguisher should be alkaline rather than acid, since acid solutions are more liable to damage the materials upon which they are thrown. Extin-

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[1] Requirements for Proper Installation of Chemical Fire Extinguishers (Published by The New York Fire Insurance Exchange,1913).

[2] Rules and Requirements of the National Board of Fire Underwriters for Sprinkler Equipment, 1913.

guishers should be recharged at stated intervals; their contents should always be fresh and active.[1]

The extinguishers become active when they are inverted. The stopper then drops away from the mouth of the acid flask. The acid mixes with the soda solution, and the conditions necessary for operation are obtained. Extinguishers should not be inverted until operators are in the presence of the fires, since the streams last only about eighty seconds. They should be stored in conspicuous places, where those who are to use them can find them easily. Care should be taken so their contents will not freeze.

Fig. 46.—Section through portable fire extinguisher.

Fire pails are less effective than chemical extinguishers, because their contents cannot be propelled as accurately or as far. Fire pails should be painted red so that they can be identified if thoughtlessly removed from their accustomed places for other service. They should always remain in the same conspicuous and convenient places, and care should be taken to prevent their contents from freezing. The pails should be inspected frequently as a safeguard against leakage and evaporation. The value of fire pails has been described as follows:[2]

A pail of water is the best fire extinguisher yet devised. It costs little; its use is understood by everyone; it is easily kept ready for use; and its effect, if used at the proper moment, may be better than the work of an entire fire department five minutes later. The value of fire pails has come to be recognized, not only by the insurance community and by practical firemen, but also by all other persons having a care for the safety of life and property. Accordingly, it is a common practice for property owners, of their own accord, to have pails of water ready, in

[1] The directions that appear upon extinguishers of a certain approved type are as follows: "Fill the receptacle with two and one-half gallons of water, add two and one-half pounds bicarbonate soda; stir well to dissolve. Fill to acid line with four fluid ounces of sulphuric acid and place stopper in bottle, and bottle in cage. Screw cap down tight. Protect from freezing. If used, clean well and recharge. Discharge, clean well and recharge yearly. Record date when charged." See also "Requirements for Proper Installation Chemical Fire Extinguishers" (Published by New York Fire Insurance Exchange, 1913).

[2] "Requirements for Proper Installation of Fire Pails" (Published by The New York Fire Insurance Exchange, 1909).

case of fire; in addition, the officers of local fire departments use their authority to bring this about, and fire insurance organizations have not been lacking in encouraging the insuring public to equip their premises with this simple means of fire protection.

The New York Fire Insurance Exchange, in common with other insurance organizations, has placed a premium on fire-pail equipments by granting a liberal reduction in rates, where the premises of an assured contain fire pails, maintained in a manner which assures a fair probability of their being ready for use when needed. Fire pails are useful only when they are filled, within easy reach, and near at hand; and in order to provide some guarantee of efficiency, the fire insurance community has been obliged to adopt certain rules regarding fire pails, and to make a proper observance of these rules a condition to granting the reduction in rates. These and similar fire insurance rules are the result of more than fifty years' experience with the insuring public, who, with the best of intentions, frequently install costly fire protection equipments, and then take no steps toward keeping them in condition for use when fire occurs.

In the case of fire pails, for example, it has been found advisable to require that the pails be painted red, with the word "FIRE" or "FOR FIRE ONLY" in black letters of a certain size. The red color is useful because of its general association with fire; it helps to make the pail clearly visible when wanted; and, with the word "FIRE," is a constant reminder that the pail is there for a special purpose, the putting out of fire, and is not to be taken away or used for ordinary purposes. The placing at a medium height is devised to permit of grasping the pail without spilling half its contents; if a pail is placed more than five feet high, it is likely to be out of the reach of the average person; and if set lower than two feet, it is likely to be overlooked or to be knocked from its position. The use of an iron pail in preference to a pail of wood or other material, is a matter of service and economy, in addition to the greater likelihood that an iron pail will be found serviceable when suddenly wanted for use. The requirement of a stated number distributed in groups throughout the entire premises, is framed to provide that pails shall be within a hand's grasp, and not be distant anywhere from 50 to 200 feet at a time when a tiny flame is rapidly growing into a formidable blaze. The insistence of a permanent setting, such as hooks or shelves, is intended to make sure that the pail will be given a fixed position, which will become familiar to the occupants who, in time of excitement, can rely on finding pails in a definite spot. The regular re-filling is a common-sense precaution to make sure that the pails shall contain water. Such rules as these are part of the usual discipline maintained in establishments which have in view a careful management of the property, and they are published in the belief that a proper observance of them will tend to reduce the loss suffered by the community from the effects of fire.

When fire pails are located where there is a liability of the water being frozen in cold weather, it is recommended that 2 pounds of chloride of calcium or salt (the chloride of calcium is preferable), be placed in each pail. For casks the quantity recommended is fifty pounds for each cask. It is necessary that the chloride of calcium or the salt be dissolved by thorough stirring.

Organization.—It should be remembered that fire losses are caused by failure and the misuse of apparatus as well as by its absence. The efficiency of the best apparatus is limited by the way in which it is used, and, for this reason, the highest efficiency is seldom obtained outside of large cities where there are paid fire departments. The danger from fire is less where those in charge of apparatus are taught how to use it before an actual emergency takes place. A plan of action should be formed and all details be considered before a fire takes place.

SOME PRINCIPLES OF FIRE PROTECTION

For completeness some space is given to the general field of Fire Protection.

It was stated that the policy in Europe is to prevent fires, but that in this country, until recently, the principal demand has been for means to extinguish them, and that this difference explains why losses are so much greater in this country than in others. Fires may be prevented by eliminating the factors that are known to cause them, one of which is wood.

One reason why preventive practices are emphasized in foreign countries is because wood is less plentiful in such countries. These practices were not introduced suddenly, but grew, little by little, as local supplies of wood gradually decreased. It was the law of necessity that, in Europe, caused the substitution of non-inflammable materials for wood, and already the same law is beginning to serve similarly in the United States.

The conditions in Europe and in this country differ in that larger proportions of what may be called "final constructions" exist abroad where civilization is older. That which is regarded as mere neglect or misfortune here, is considered there more as though it were a crime. The police in Berlin have very real authority over every detail that is likely to increase danger from fires, while citizens of France are held legally responsible for fires that pass from their own homes to those of others.

Preventive practices in the United States had their origin in the factory districts of New England, and some of the best and most modern details in this field have been evolved by manufacturers in those sections. The National Fire Protection Association, the National Board of Fire Underwriters, Factory Mutuals, and other organizations now exist to study causes and suggest methods by which fires may be prevented.

The organizations alluded to occupy a field in this country that suggests the one occupied by paternal governments abroad. Very much has been accomplished by them already, but improvement to the point of the average conditions that exist in older countries cannot be hoped for for some time to come. Many structures that were erected to meet first needs in the United States have already given way to others, better and more permanent, but much remains to be done. The rebuilding of a country is a very slow process.

It will be remembered that the preceding section was devoted to a study of the material *Wood* when burning, and that the text was presented under the titles "Burning of Wood," "Attempts to Prevent Wood from Burning," and "Methods Used to Extinguish Burning Wood." As distinct from this, the subject of Fire Protection is devoted to a study of burning *Buildings* and the parts of this subject will be grouped as they relate to (1) "Burning of Buildings," and (2) "Method by which Buildings are Prevented from Burning."

Burning Buildings.—Such fires may be classified as they originate within the buildings, or as they are transferred from without. The latter are known as "exposure fires," and a large proportion of the destruction that takes place in this country is of this type.

The superiority of the average European building, from the fire standpoint, is shown by the fact that a larger proportion of the fires in Europe are confined to the buildings in which they start. Aside from fires due to warfare, the great conflagrations that have taken place in all Europe during several centuries have destroyed less property than those that have taken place in the United States alone during a single century.

The destructive temperatures in burning buildings vary between 1,500 degrees Fahrenheit and perhaps 2,500 degrees Fahrenheit. Drafts and air currents must also be considered. Materials may be injured not only by heat, but, also by sudden cooling, as when streams of water are applied to them suddenly while they are hot.

Methods By Which Buildings Are Prevented From Burning.—It is doubtless true that in the United States some general fires have been prevented by the presence of parks, streets, and other open spaces, and by the moderate heights of structures; but great fires, that have few counterparts in European history, have taken place in Portland, New York, Chicago, Boston, Jacksonville, Paterson, Baltimore, San Francisco, and Chelsea.

The first real attempts to reduce fire losses came when brick and stone were used instead of wood for outside walls. Walls of brick and stone were made to support floors and roofs of wood, and buildings of this kind resisted better than those of the earlier type, because they offered more resistance to outside fires.[1]

Later attempts included the use of iron and steel, but these materials were not protected as they are at the present time. The high conductivity of iron and steel, and their tendency to expand under comparatively small increases of temperature caused these unprotected beams and columns to bend and collapse even in very small fires. Buildings constructed in this manner were but little better than those of wood.

Buildings are now designed to stand against both inside and outside fires. A fire may destroy the inflammable contents in a room or other section of such a building, but it will not normally reach over into another room or section of the building. Details relating to materials, design, special devices and the care of the buildings after they are erected are all important. It should be constantly remembered that the building may be strictly fireproof but that its contents, as distinct from the building itself, may be inflammable, and that such contents, if too great in quantity, may cause the destruction of the building.

Materials.—It is obvious that the best way to prevent a structure from burning is to build it of something that will not burn. Yet it must be remembered that some materials that do not burn are not to be regarded as fireproof. A really fireproof material will not only resist the disintegrating and distorting influences due to high heat and sudden cooling, but it will not conduct heat.

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[1] $68,000,000 of the total loss in the United States in 1907 took place in buildings composed of brick, concrete, stone, and similar materials; while the loss in wooden buildings during the same year was over twice as much, or about $148,000,000.

Metals.—Iron and steel are poor fireproof materials when used alone. This is because they warp and conduct heat, and it is only after they are protected by non-conducting substances that they become valuable in fireproof constructions.

Natural Stones.—Stones differ greatly in their ability to stand against heat. Granites disintegrate because they contain water, and because the component minerals do not have the same coefficients of expansion and contraction under heat and cold. Limestones lose their carbon dioxide and are reduced to ordinary building lime under the influence of heat. Most sandstones stand against fire better than all limestones, and far better than all granites.

Artificial Stones.—The properties of brick are influenced by the properties of the clays used in their manufacture. Good brick is one of the best of all fireproof materials. Enamelled brick is often very good. Terra cotta, whether used in bricks, or for ornamental work, or as a protective coating for iron and steel, is a very valuable fire-resisting material. Concrete possesses the additional advantage that it can be laid without joints.

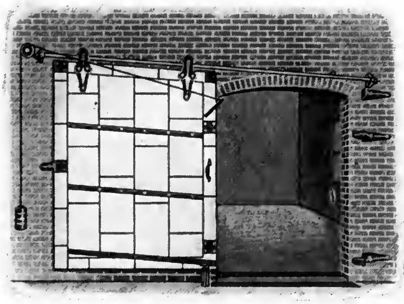

Fig. 47.—Passage protected by duplicate fire doors.

Combinations.—The best results are obtained by the use of all-metal members protected by brick, terra cotta, concrete, or other non-conducting materials. Hollow brick, terra cotta, and concrete, are used for walls, floors, and ceilings.

Influence of Design, Special Devices, Etc.—An ideal building has outside walls of brick. Its frame is made of steel or iron covered with some material that will stand against heat. Floors and roofs are built of hollow tile, terra cotta, concrete, or other non-conducting or fire-resisting materials. All stairs, elevators, and dumbwaiters are enclosed by brick shafts with standard, tin-clad fire doors in all openings. Wells for light are enclosed by brick, and the windows in the wells are of wired glass in standard metal frames, and these materials are also used in outside windows. Standard fire doors, or their equivalents, are used in door openings. A low building is safer than a high building. An ideal building is restricted in height and floor areas so that all parts can be swept by fire streams under prevailing pressures. Heights and areas can be increased if the entire building is protected by automatic sprinklers.

Roofs.—Roofs are either fireproof, semi-fireproof, or inflammable. Roofs covered with slate, tile, and some special materials are in the first group; while those made of tin or corrugated iron spread upon wood are in the second group. Shingled roofs, which are in the third group, are highly inflammable. A large proportion of all outside fires are caused by sparks lodging on roofs.

Door Openings.—Fire doors, designed to obstruct the passage of heat and flame through door openings, are used in pairs, one door being placed at each one of the two surfaces of the wall through which the opening extends. Automatic doors, that close when the heat becomes sufficient to fuse a link of special metal, are generally recommended. Latches, locks, hinges, slides, and other details are highly important. The efficiency of the standard fire door is expressed in the following quotation.[1] "Recent tests and investigations indicate that for openings of ordinary size the so-called standard tin-clad door and shutter, all things considered, furnishes the most reliable protection, particularly when the exposures are severe. The superiority of this type is very largely due to its efficiency as a non-conductor of heat. This offsets, in a large measure, inherent defects in other respects, such as the bulging of the plates by the gases generated from the inflammable materials now used in its construction, the falling down of the core after it has been reduced to charcoal, and its comparative lack of endurance under severe exposures."

Window Openings.—Water curtains and iron shutters were formerly used to protect window openings, but these devices have given way to standard fire shutters, and wired glass windows. Tin-clad fire shutters are similar to the standard fire doors that have been described; while the wired glass is used, as has been noted, in metal frames. The requirements of both inside and exposed fires must be recognized.

The value of wired glass windows in resisting the action of moderate fires depends upon the character of the glass and sashes. Glass softens and drops away when a temperature of about 1,500 degrees F. is reached. Sashes and frames are made of hollow steel and other metal. There are three types: the pivoted sash, which is automatic, the double hung sash, and the casement sash. Locks, hinges, and other hardware are important factors. Ordinary putty must not be used.[2]

Fire Shutters.—The principal difference between fire shutters and fire doors is noted in the rules prepared by the National Board of Fire

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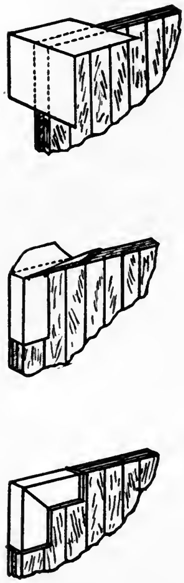
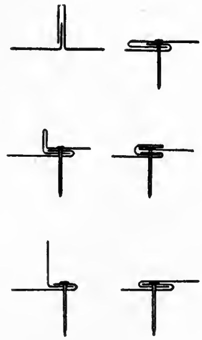
[1] Abstract of Committee Report presented at annual meeting of National Fire Protection Association, New York City, May 23–25, 1905 (Engineering News, Vol. 53, No. 22). Also Rules and Requirements for the Construction and Installation of Fire Doors and Shutters recommended by the National Fire Protection Association (Edition of 1906).

[2] Rules and Requirements of the National Board of Fire Underwriters for the Manufacture of Wired Glass and the Construction of Frames for Wired and Prism Glass used as a Fire Retardant.

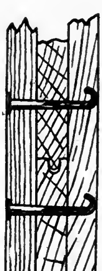
PLATE VIII. DETAILS OF TIN-CLAD FIRE DOOR



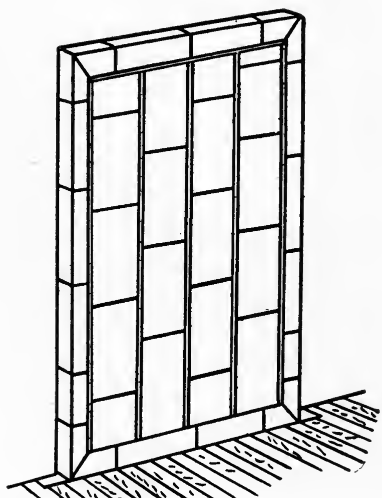
(*a*) Application of Tin to Corners of Fire Door.



(*c*) Method of Joining and Fastening Tin.



(*b*) Method of Holding Layers of Core together by Clinched Nails.



(*d*) The Completed Door.

(*Facing page* 296.)

Underwriters as follows:[1] "Construction to be the same as for fire doors, except that only two thicknesses of ⅞ inch boards are required. Layers of boards to be at right angles."

Automatic Sprinklers.—It is a important to have fires discovered and extinguished while they are small, and apparatus designed with these ends in view may be properly classed among preventative devices.

General information with respect to automatic and open sprinkler equipments, prepared by the National Board of Fire Underwriters, is as follows: [2]

1. *Preparation of Building.*—Many buildings require preparation for sprinkler equipment. All needless ceiling sheathing, hollow siding, tops of high shelving, needless partitions or decks should be removed. Necessary "stops" to check draft, necessary new partitions, closets, decks, etc., should be put in place so that the equipment may conform to the same. The top flooring should be made thoroughly tight.

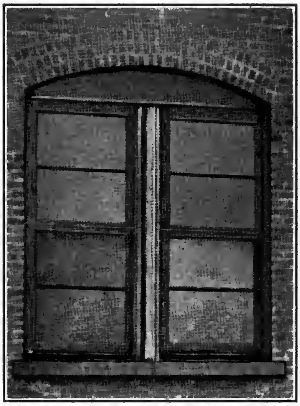


Fig. 48.—Wired glass window in metal sash. [3]

2. *Accessory Woodwork.*—Sprinkler equipments require accessory woodwork, dry pipe valve closets, ladders, anti-freezing boxing for tank pipes, etc. This work should be promptly attended to if not let with sprinkler contract.

3. *Drapery and Sheathing.*—Paper or similar light inflammable ceiling sheathing is objectionable and unnecessary. Where floors leak dirt, an acceptable sheathing may be made of lath and plaster, matched boards or joined metal. All channels back of sheathing to be thoroughly closed between timbers or joists. Sheathing to be tightly put together and kept in repair. In mill bays, sheathing to follow contour of timbers without concealed space.

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[1] Rules and Requirements for the Construction and Installation of Fire Doors and Shutters as recommended by the National Fire Protection Association (Edition of 1906).

[2] Rules and Requirements National Board of Fire Underwriters governing the Installation of Automatic and Open Sprinkler Equipments as recommended by the National Fire Protection Association (Edition of 1913).

[3] This window was in Newark works of Sherwin-Williams Company. The picture shows appearance after fire had destroyed adjacent works of Consolidated Color and Chemical Company. The fire did not pass through this window, although the heat was sufficient to burn the paint from frame and sash (Insurance Engineering, November, 1907).

4. *Vertical or Horizontal Drafts.*—Floor or wall openings tending to create vertical or horizontal drafts, or other structural defects that would prevent the prompt operation of automatic sprinklers by preventing the banking up of the heated air from the fire, should be properly "stopped" in order to permit specific control by the local sprinklers. Satisfactory curtain-boards and other draft-stops must be provided to overcome such structural defects.

5. *Clear Space Below Ceilings.*—Full effective action of sprinklers requires about 24 inches wholly clear space below roofs or ceilings; this loss of storage capacity should be realized in advance of equipment.

6. *Experienced Workmen Recommended.*—Sprinkler installation is a trade in itself. Insurance inspectors cannot be expected to act as working superintendents, nor correct errors of beginners. Sprinkler work should be entrusted to none but fully experienced and responsible parties.

7. *All Portions of Buildings to be Protected.*—Experience teaches that sprinklers are often necessary where seemingly least needed. Their protection is required not alone where a fire may begin, but also wherever any fire might extend, including wet or damp locations.

8. *Degree of Protection.*—A maximum protection cannot be expected where sprinklers are at more or less permanent disadvantage, as in the case of stocks very susceptible to smoke and water damage, buildings having deep piles of hollow goods, excessive drafts, explosion or flash fire hazards, or large amounts of benzine or similar fluid.

9. *Necessary Cut-offs.*—Sprinklers cannot be expected to keep out fire originating in unsprinklered territory. Stringent measures should be used to properly cut off all unsprinklered portions of buildings or exposures.

10. *Communications.*—When a building fully equipped with sprinklers communicates with another not so equipped, the openings must be protected by standard fire doors on both sides of the walls, one of which must be automatic.

11. *Protection Against Exposures.*—The danger of sprinkler protection being impaired by exposure fires should be reduced by providing adequate shutters, wired glass or open sprinkler protection at exposed windows.

Signals.—There are automatic and non-automatic signals. An automatic thermostat alarm depends upon the opening and shutting of an electric circuit in a thermostat. Such alarms are used in connection with automatic sprinklers. Non-automatic alarms should be practical, conveniently located, and easily understood.

Care or Maintenance of Structures.—The contents of a building are as important as the building itself. The building may be composed of materials that will not burn, yet it may be injured or even destroyed by fires in contained oils, cotton, or similar stores. The quantity of such inflammable stores should always accord with the capacity of the building to resist fires and with its capacity to isolate them so that they will not spread from one section to another.

Cleanliness and Order Are Imperative.—Trash should not be permitted to accumulate. Oiled rags or waste should be destroyed, or kept in metal boxes. Matches should also be stored in metal boxes. Smoking must often be prohibited. Systematic inspection is usually necessary. Managers should be held responsible by night as well as by day. It is not enough for them to employ watchmen. They should be certain that such assistants, who are usually selected for physical rather than mental gifts, really perform their duties. Watchmen work alone and without direct superintendence, and, for this reason, their duties should be planned for them.

Watchmen's Recorders.—The services of watchmen are systematized by means of mechanical devices known as recorders that compel the watchmen to visit certain stations at certain stated intervals. These recorders are of three kinds. There are portable time recorders, stationary time recorders, and central office recorders.[1]

Portable Time Recorders.—The recorder resembles an alarm clock and contains a paper dial, turned by clock movement, upon which an impression is made whenever a key is used. There are several such keys, with but one recorder, which last is carried by the watchman, while the keys are chained at the several stations to be visited. The records shown by the paper dials indicate the time when each key was used. This system is simple and economical in its first cost, but it is objectionable because of the weight of the recorder and because of the fact that watchmen sometimes obtain duplicate keys.

Stationary Time Recorders.—In this system there is one key and several recorders. The watchman carries the key and the recorders are fixed at the stations. Some recorders contain paper record forms which are collected in the morning, and others are wired so that the records are received on a single dial in the superintendent's office. A stationary time recorder system is good because watchmen do not have to carry the more or less heavy recorders, and because it is difficult to tamper with the records. The weak points are the increased first cost, and the labor required to collect the records in the morning. When such labor is rendered unnecessary by connecting the recorders with the superintendent's office, there is extra cost for wiring.

Central Office Systems.—The central office system enables a superintendent, located at a central office, to reach and control the movements of his men at all times while they are on duty.

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[1] New York Fire Insurance Exchange Bulletin, No. 5. Also literature published by Newman Portable Clock Company, American Watch System, etc., etc.

CHAPTER XII

Failure of Wood Because of Animal Life. Marine and Terrestrial Forms. Methods of Protection

The forms of animal life that attack woods may be divided according to their habits or environment into marine woodborers[1] and terrestrial woodborers.

The quantity of wood destroyed by marine woodborers is considerable, but the proportion is much smaller than it was when wood was used more extensively in marine constructions. The total value of wood destroyed by marine borers is much less than the total value of woods and living trees destroyed by terrestrial borers.

MARINE WOODBORERS

The harm done by these borers has not always been measurable by direct costs, since it is recorded that owners of wooden ships once discriminated against harbors in which numbers of these pests were known to be present.

Most perforations found in timbers that have been in sea water are attributed to the Teredo navalis, probably because this shipworm was one of the first to be studied and was the one selected for description in some of the earlier text-books. The Teredo navalis is worthy of the attention it receives, but it must not be forgotten that there are other marine woodborers.

THE SHIPWORM (*Teredo, Xylotrya,* etc.).—This is a general name that applies to several species of mollusks of the genus Teredo, together with other species in other genera. The mollusks known as shipworms are characterized by the fact that they bore in wood, and are represented, along the north-central Atlantic Coast, by species of the genus Xylotrya.

Shipworms are widely distributed throughout the waters of the tropics, and are present in smaller numbers in cooler waters of temperate regions. They inhabit European waters from Sweden

[1] The first part of this chapter is based upon the author's paper entitled "Marine Woodborers" published by the American Society of Civil Engineers (Transactions, Vol. XL, 1898). Some of the pictures prepared for the original paper are used with the permission of the said Society.

to Sicily, and are also found in the vicinity of Bermuda, the West Indies, New Zealand, and Australia. In the United States they exist from Maine to Florida, and along the Pacific Coast as far north as Alaska. The United States Fish Commission reports their distribution in local waters to be as follows:

Teredo navalis, between Florida and Cape Cod. *Teredo norvegica*, Cape Cod northward to Maine. *Teredo megotara*, New Bedford, south to South Carolina. *Teredo dilatata*, Massachusetts to South Carolina. *Teredo thompsoni*, Massachusetts. *Xylophaga dorsalis*, North Atlantic. *Xylotrya fimbriata*, Long Island Sound to Florida.

Form.—The form of the shipworm is shown in the picture. It is a long, worm-like organism of which the posterior end *s* remains at the outer surface of the timber, while the other or anterior end *B* occupies the inner extremity of the tunnel. The two horn-shaped structures *s* are the free extremities of otherwise united tubes, known as siphons, that pass throughout the entire length of the shipworm to the vital organs and boring shell at *B*. These horn-shaped extremities are the only parts of the shipworm that can extend outward beyond the wood, and are therefore the only parts that are evident to the casual observer.

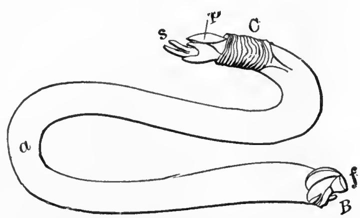


FIG. 49.—The shipworm.

A general idea of the form of the shipworm may be gained by examining the ordinary long, or soft-shelled, clam (*Mya arenaria*) so familiar to residents of New England. This clam possesses a very long worm-like neck penetrated by two parallel tubes or siphons through one of which water, oxygen, and food pass inward, while through the other exhausted water and débris pass out. It is also helpful to examine the common razor clam (*Ensis directus*) which, besides siphons, possesses a powerful, muscular club-shaped foot or sucker that enables it to bore into the sand. The long and razor clams and the shipworm are all true mollusks, and each one suggests a worm only because the part that surrounds the siphons is soft and cylindrical.

The parts of the shipworm that are important in the present connection are the body, siphons, collar, pallets, boring shell, foot, and lining shell. These parts will be considered separately.

The Body.—The translucent substance of which the body is composed resembles the living substance in the body of the oyster. In some species, in addition to their normal functions of respiration, the gills perform the important office of sheltering the embryo. The nervous system is well developed. Vital organs, such as the liver, are protected by being enclosed within the boring shell. The stomach is not distinguished by any peculiarity. There is a long intestine.[1]

The Siphons.—The siphons extend through almost the entire length of the body. One of them conveys the oxygen, water, and infusorial food to the digestive organs; while the other conveys the exhausted water, excretions, and wood particles from the excavation to the free water without.

FIG. 50.—Siphon extremities extended beyond the surface of the wood.

The siphons are joined together for most of their length, but separate as they pass outward at their extremities, *s*, and are then capable of being thrust out and withdrawn through the orifice in the wood. They are the only parts that can be seen from the outside of the wood. It will be noted that these extremities must always remain at the orifice to the tunnel.

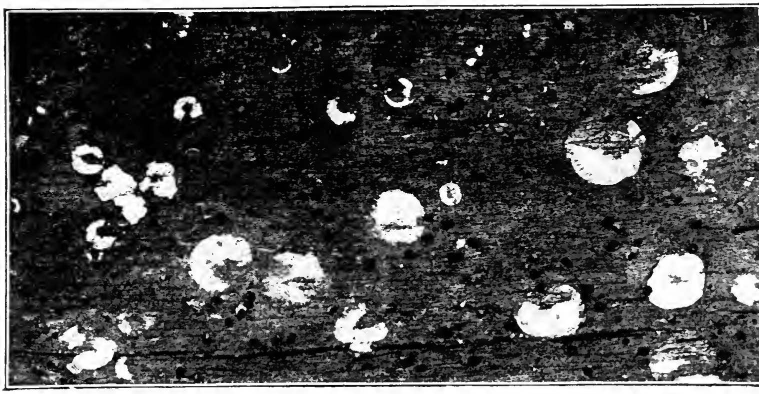
When the conditions are favorable, the extremities of the siphons are extended out to their full length beyond the surface of the wood. Otherwise, they are withdrawn and there is then but little evidence that the shipworm is within the piece. The picture shows the siphons as they appeared fully extended after several consecutive days of warm weather.

The Collar.—The collar *C* is a muscular, wrinkled membrane that extends around the posterior portion of the shipworm at the point of union between the siphon and the body proper, and forms a connection between the body and the calcareous lining of the tunnel. This is the only place at which the body of the shipworm is not free and separated from its surroundings. The collar includes several well-defined muscles and these act upon the small shells known as pallets by which the entrance to the perforation may be guarded.

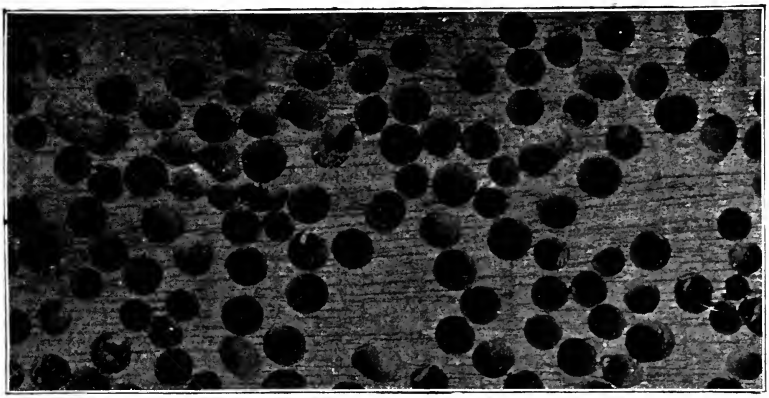
FIG. 51.—Pallets.

The Pallets.—The two shells or plates, located at *p* and called pallets, are broad, slightly curved and flattened at the top and contracted at

[1] Sigerfoos (Circular Johns Hopkins University, June, 1896).



Surface of Wood recently Occupied by Shipworms. Life Size.



Section Parallel to Face Shown in Preceding Figure. Life Size.

Vertical Section through Preceding Figures. Life Size.

(*Facing page* 302.)

the bottom where they pass under the collar. When the siphon extremities are withdrawn into the body, the tops of the pallets are brought together over them and protect them. These shells are sometimes confused with the boring shells, which are quite distinct, and at the other end of the body. Details differ with species.

The Boring Shell.—The principal or boring shell *B* is small and very beautifully formed. The two parts together are nearly as long as they are broad, and present an irregular triangular appearance when observed from the side. They close tightly at the hinge and at the side opposite. As distinct from this, however, an open space at the top permits the body to emerge while a similar opening at the bottom is for the foot or sucker. The shells of young shipworms are much larger in proportion than those of older shipworms, and when the worm is very young, it is for a short time entirely enclosed in its shell.

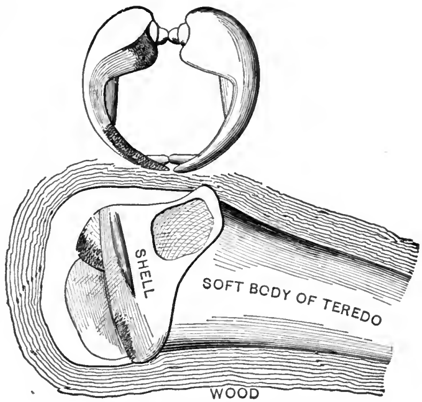


Fig. 52.—The boring shell.

The Foot.—The foot, which in form resembles a pestle, is a short, stout, muscular organ, broadly truncated or rounded at the end, and so arranged that it can exert a powerful suction upon anything to which it is attached. The extent to which this cupping action assists the excavating has probably been underestimated.

The Calcareous Lining.—Calcareous material deposited upon the woody surface of the tunnel forms a smooth lining along which the body of the shipworm can pass as it contracts or expands. This shell-like tube is distinct from the pallets and from the boring shell. Its thickness, which varies with species, is sometimes so slight that the shell is detached by the slightest shock, and many specimens, exhibited in museums, do not show the lining for this reason. The lining is sometimes very thick. The shipworm can rarely advance through the wood very far in a straight line, but is forced to pass here and there so as to avoid obstacles such as cracks, knots, and the tunnels of its companions. In such cases, the linings are curved as they wind in and out, and often so many are present that almost the entire content of the wood is occupied. Shipworms avoid seams and joints in wood, possibly because of their effect upon the calcareous linings.

Physiology.—Shipworms live principally, if not wholly, upon organic particles obtained from sea water. Particles of wood are sometimes found in their intestines, and it is not certain that these particles, cut from the burrows, do not serve in some minor way as food. It is certain, however, that the *principal* reason for the boring is to prepare a shelter.

FIG. 53.—End view of dissection shown in figure which follows. (Life size.)

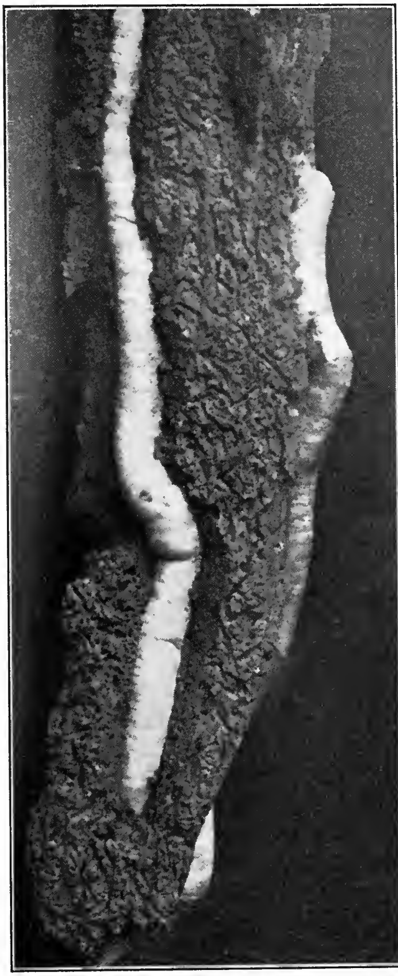


FIG. 54.—Dissection showing calcareous lining in wood. (Life size.)

A shipworm can live for a short time out of water. But, since it derives its sustenance from the water, it must have access to it much of the time. It does not have to be submerged all of the time, and can live and work under such conditions as exist between tide levels. It has been known to live for about two weeks in timbers that have been transferred from the sea to fresh water, and could possibly have lived longer than two weeks.

Many logs in a cargo of Central American woods recently received in New York, after a voyage of about two weeks, were found to be full of living shipworms that had gained entrance while the logs were waiting for shipment in the South. The shipworms were apparently in good condition when the timbers were removed from the hold of the ship. The wood itself, and the hold of the ship, contained considerable water, yet the logs were by no means submerged, and the fact exists that these particular specimens survived during a voyage of about two weeks. They were very numerous, so much so, that later the logs had to be removed from the yard because of the odor.

Reproduction and Development.—Most mollusks reproduce by means of eggs, which, in the case of some shipworms, are spherical in shape and greenish yellow in color. Shipworms are very prolific, the eggs of a single specimen being numbered by the million. The eggs are very hardy and many survive and yield young shipworms. A shipworm can swim at the end of about three hours after hatching and has a well-developed shell before the end of the first day.

The shipworm passes through several stages before it assumes the character and form of the adult. It is first covered with fine hairs or cilia, which enable it to swim. Soon most of the cilia are lost and the rudiments of a small bivalve shell appear. At first, this shell is heart-shaped and very small, yet it is large enough to enclose almost the entire body. The portion of the body that protrudes from the cell is fringed with cilia, and these enable it to continue to swim until it finally encounters a piece of wood.

The results of some observations upon the shipworm (*Xylotrya fimbriata*) at Beaufort have been summarized by Professor Sigerfoos as follows:[1]

"The free-swimming stage is reached in three hours, and a well-developed shell is formed in a day. We have no direct observations as to the time the ship larva is free-swimming. We may assume, I think, that it is at least a month, or it may be two. Most of its energies are devoted to locomotion during this period, but, after it has attached itself, all of its energies are devoted to forming its burrow and securing its food. Coming into contact with the wood, the larva throws out a single, long byssus thread for attachment and never again leaves its place. The newly attached larva is somewhat less than 0.25 mm. long. In twelve days it has attained a length of 3 mm.; in sixteen days, 6 mm.;

[1] Johns Hopkins Circular, June, 1896.

in twenty days, 11 mm.; in thirty days, 63 mm.; and in thirty-six days, about 100 mm., when it bears ripe eggs or sperm."

The time of reproduction is important. In the vicinity of New York, this takes place principally during the month of May; but it may continue, although to a less extent, throughout the greater part of the summer. In tropical countries, it probably goes forward throughout the entire year. Although the extreme life limit of a shipworm is unknown, it is thought that individuals can live for several years under favorable conditions. A shipworm may attain to a comparatively large size during a single season.

Influence of Temperature and Water.—In most cases shipworms are more plentiful where the water is not cold, and, for this reason, wood is destroyed more continuously and more rapidly in the tropics and semi-tropics. In the United States destruction is most serious along the entire Pacific Coast, as well as along the coast of the South Atlantic and Gulf States. Some shipworms are found, although they are much less active, where it is often extremely cold, as in Maine and Alaska.

Some shipworms thrive in pure sea water, while others do well in brackish, impure, or comparatively fresh waters. Sometimes the parts of timbers that are near the surface of the water are injured, and sometimes the parts that are down near the bottom. These and other differences are accounted for by the facts that there are many species of shipworms, and that differences sometimes exist between the qualities of higher and lower layers of water. For example, when fresh water from a river meets the heavier water of the sea, shipworms may sometimes be found near the bottom where the water is actually salt.

Some shipworms (*Xylotrya fimbriata*) survive in the brackish, polluted waters of New York Harbor, while other species that do not exist in these waters are present in the nearby ocean. Shipworms are very active along the north Pacific Coast but are said to be absent at some points near the mouth of the Columbia River because fresh water predominates at these points. A vessel carrying hardwood logs was wrecked in the vicinity of the Gulf of Mexico. The logs were conveyed to the sheltered, but brackish, waters of a creek where they remained for about six weeks. The pieces were attacked as soon as they were placed in the creek and the results were so noticeable that some borings were measured and are said to have been six inches in length. The wood that remained in the outer ocean was not injured.[1] The discrepancies between these incidents may be accounted for by the presence of different species of shipworms.

The belief that shipworms are influenced by impurities in water was expressed in Holland as early as 1733. It was noticed that comparatively little rain fell in years when shipworms were quite plentiful, and it was thought that the diminished volumes of river water during these years permitted larger quantities of salt to exist in the waters near the mouths of the rivers. Analyses proved that the proportions of salt did vary during the dry and rainy seasons.

Method of Attack.—While the shipworm is yet very small, it settles upon the surface of the wood and almost immediately begins to clear away a place through which to burrow. There is some controversy as to the method by which the burrow is excavated, but it is quite certain that the foot assists the shell. The details are not perfectly understood, but the facts are that the hardest woods are penetrated and that surfaces are cut as smoothly as though a sharp chisel had been employed.

Character of Excavation.—A shipworm is very small when it enters a piece of wood, but once within develops rapidly and then never leaves its burrow. The perforation through which the shipworm enters is very small, but the diameter of the boring increases rapidly, the average being reached at a point quite near the perforation through which the shipworm entered. A shipworm grows principally in length and must therefore tunnel to secure space for the increasing length of its body.

The shipworm does not encroach upon other tunnels because most of these tunnels are occupied by shipworms. It instinctively avoids knots, imperfections, bark, cracks, and lines of cleavage. Woods are not exempt from attack simply because they are hard.

Wood may appear to be sound and yet be so weak that it can be crushed by the hand. As much as fifty per cent. of the weight of a piece may be removed without much evidence upon the outside. Failures often come suddenly and without warning. The tops of piles thought to be in good condition are seen floating away. A freight train on the Louisville and Nashville Railway

[1] Reported to the writer by Messrs. Nesmith and Constantine of New York, 1897.

crushed through a trestle that had been standing about ten months and that had been frequently inspected.

Size of Borings.—The size of a boring depends upon that of the shipworm that made it, and the size of the shipworm depends upon its age and species. Five inches and as many feet may be regarded as minimum and maximum lengths. One-quarter of

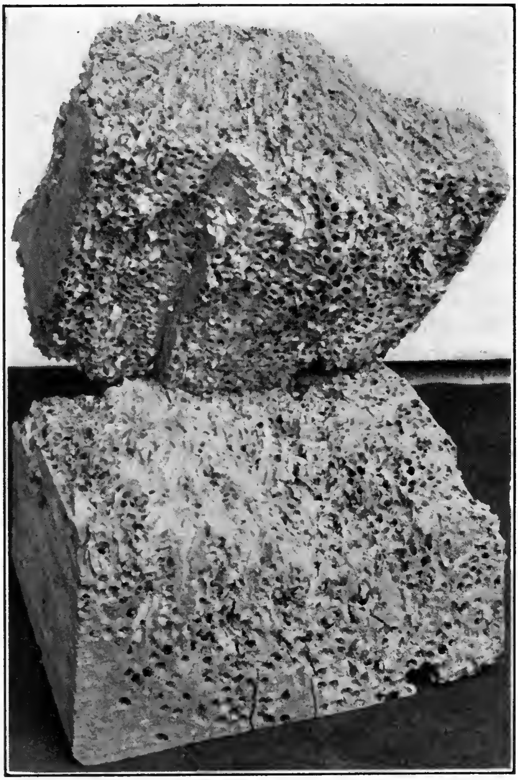


FIG. 55.—End of log of Panama mahogany destroyed in one season.

an inch is a small diameter from which measurements have been made up to one and one-eighth inches.[1] It is safer to disregard minimum possibilities in such a connection.

Rapidity of Work.—Evidence upon this subject is seldom accompanied by statements of conditions under which the results were accomplished, so it is sometimes hard to associate the boring

[1] Measured by the writer in a specimen from the North Pacific Coast.

PLATE X. WORK OF SHIPWORM—LARGE BORINGS

The large circle near the top of the picture shows a boring actually 1⅛ in. in diameter.

(*Facing page* 308.)

H W

L W

with the species that made it. The species of the woodborer, the location of the piece, the season, and the kind of wood in which the boring exists are all important.

Conditions that influence the growth of the shipworm influence the speed with which it works. Generally speaking, cold retards while heat expedites the work of excavation. A six-inch burrow may be driven in as many weeks so that a one-foot pile attacked on all sides can be destroyed in that length of time. On the contrary, other pieces remain practically intact for many years.

Wood has been found to contain shipworms after a submergence of eight days (United States Annual Report of Scientific Discovery of 1857). Six-inch piles were destroyed at Aransas Pass in six weeks; other piles in the same locality have lasted as long as three or four months (Report, Chief of Engineers, U. S. A., 1888, pp. 13, 14). Piles have been destroyed in one hundred days in Mobile Bay (Annual Report, Chief of Engineers, U. S. A., 1879, p. 937). Piles on the line of the Louisville and Nashville Railroad sometimes have to be replaced after six months service (Transactions, Am. Soc. C. E., Vol. XXXI, p. 221, Montfort). Unpainted spar buoys have a life of about one year in the vicinity of Cape Cod (Report to United States Fish Commission by Captain Edwards). Piles have been destroyed in the harbor of Galveston in three years (Report, Chief of Engineers, U. S. A., 1868, p. 512). Piles have lasted as long as twelve years in the harbor formed by the Delaware Breakwater (Annual Report, Chief of Engineers, U. S. A., 1871, p. 667).

Field of Attack.—The fact that a shipworm lives upon microscopic life present in sea water outside its burrow, makes it necessary for its siphon extremities to be located at the entrance to its burrow. This end of the shipworm being fixed as to position, the wood is removed inward from the surface to a distance measured by the increasing length of the shipworm.

The small portals to the burrows that are evident upon the outside of the timber (see Plate IX) do not necessarily mark the exact content of wood that is destroyed within; since, although one end of the shipworm must remain at the entrance to its burrow, the other can reach upward into the wood above the water, or downward into that below the mud. Shipworms have been known to work under pressures caused by twenty or twenty-five feet of water.

Woods Subject to Attack.—Immunity is sometimes claimed for some particular wood; but it is usually found that such a claim, based upon local conditions, is not generally substantiated. It is safer to assume that all ordinary woods may be attacked by these forms. Doubt may be felt with regard to some woods that contain repellent gums, resins, or bitter essences, and some palms that have open, porous structure; yet very few woods such as these are used in American constructions.

Woods are not safe simply because they are hard. Osage Orange, which is a very hard wood, has failed in several instances where it has been used for piles. A Commission appointed in Holland to investigate this question reported as follows:

> "Although we do not know with any certainty whether among exotic woods there may not be found those which resist the shipworm, we can affirm that hardness is not an obstacle that prevents the mollusk from perforating its galleries."

THE LIMNORIA (*Limnoria lignorum*).—This isopod crustacean, which has other names as the wood flea, sand flea, gribble, and boring gribble, is the principal one of several similar forms that attack woods when in sea-water. The Limnoria is much smaller than the shipworm, but it usually occurs in larger numbers and in some localities is almost equally destructive.

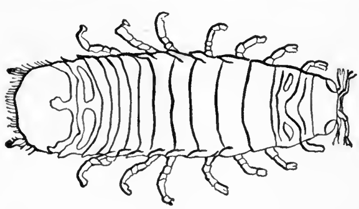


FIG. 56.—The Limnoria.

The Limnoria is found along the Atlantic Coast from Nova Scotia to Florida. It exists sparingly in Long Island Sound; but is abundant along the Coast of Massachusetts, and very destructive in the Bay of Fundy. It is also active in the north Pacific, as in Puget Sound and the Straits of San Juan de Fuca. It is said to exist upon the coast of Great Britain and in other European waters.

Form and Physiology.—The Limnoria is about as large as a grain of rice. The nearly straight sides are, in a general way, parallel to one another, while the ends are rounded. The upper and lower surfaces are flattened, the former being covered with small hairs to which more or less dirt often adheres. The body is made up of fourteen segments. To each of the seven segments that follow the head is attached a pair of short, stout legs terminating in claws, the shape of which suggests the small claws of the lobster.

The body of the Limnoria is grayish in color, and sometimes resembles the color of the wet wood so much that it is difficult to distinguish it. The Limnoria can swim, creep backward and forward, as well as jump backward by means of its tail. When touched, it rolls itself into a ball, and in this particular, as well as in general appearance, it resembles the common sow-bug.

The Limnoria differs from the shipworm in that quite certainly it is a vegetarian. The shipworm is sustained, at least for the most part, by microscopic life drawn from the sea water, but the Limnoria devours wood. Its tunnel affords both food and shelter.

Influence of Temperature and Water.—Limnoria are plentiful in some regions in the North where shipworms can exist but sparingly because of the cold. Limnoria require pure sea water and are seldom found in the comparatively fresh waters encountered near the mouths of rivers.

Method of Attack.—*Character of Excavation.*—The Limnoria attacks the wood by means of its mandibles or jaws. It prefers wet wood and succeeds in making a very clean-cut excavation.

The work of the Limnoria differs from that of a shipworm in that its tunnels terminate on the surface of the wood where they can be plainly seen, whereas those of the shipworm are for the most part concealed within the wood. The body of the shipworm cannot emerge from the wood within which it has located, while that of the Limnoria can pass freely in and out. The Limnoria frequently works in conjunction with the shipworm. It attacks the surface, while the shipworm takes away from the interior of the woodwork.

The numberless, smooth, clean-cut galleries are close together and the partitions that separate them are so thin that they cannot long resist the action of the waves. Later, the partitions are either washed away by the waves, or they decay. Fresh surfaces are then exposed and these are destroyed in the same manner. Layer after layer is removed until the timber is destroyed. The Limnoria can penetrate knots, but sometimes avoids them, when such hard portions stand out in relief as the other parts are destroyed.

Size of Borings.—The Limnoria is very small, but notwithstanding this fact, it is very destructive. The multitude of these woodborers compensates for their size. Each may be assumed to be from one-sixth to one-fourth inch in length and about one-sixteenth of an inch in diameter. The tunnels are about one-half of an inch in length and about one-tenth of an inch in diameter.

Rapidity of Work.—The Limnoria does not work as rapidly as the shipworm. The number of individual workers must in this

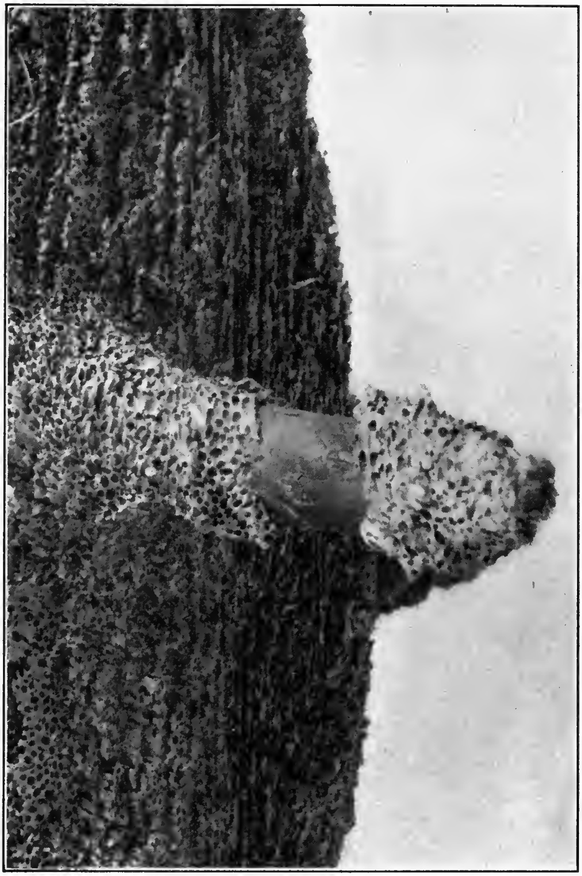
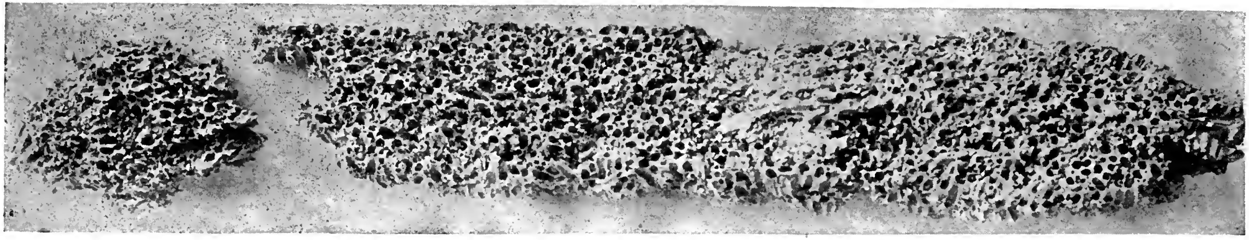


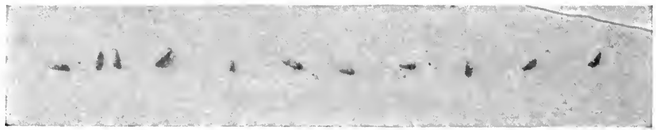
Fig. 57.—Knot showing surface from which work of Limnoria has been removed by waves. (Reduced.)

case be taken as a measure of the rapidity of destruction. The number of tunnels is more important than their depth. The thickness of a piece of timber may be reduced from one-fourth of an inch to as much as an inch in a year. Much wood used in marine constructions is in the form of piles that are necessarily exposed on all sides. The effective diameters of such pieces are,

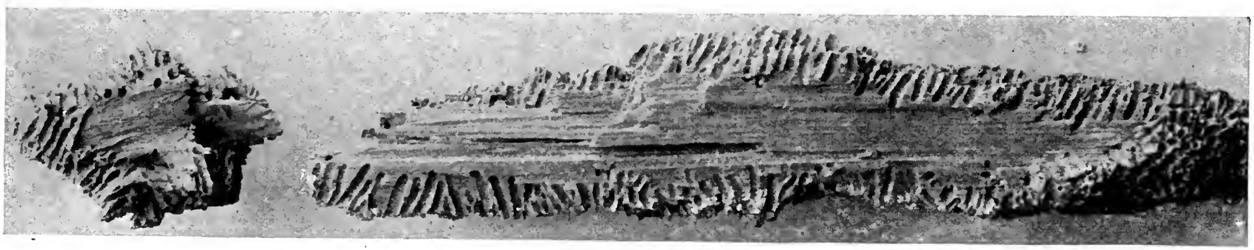
PLATE XI. WORK OF THE LIMNORIA



(*a*) Surface of Wood Occupied by Limnoria. Life Size.



(*b*) Limnoria Removed from Perforations Shown in Preceding Figure. Life Size.



(*c*) Section through Specimens Shown in Figure (*a*). Life Size.

(*Facing page* 312.)

therefore, reduced twice as rapidly as indicated by the figures noted.

Field of Attack.—The depredations of Limnoria are confined to a limited distance above and below the low-water mark. Where the variations of the tides are extensive, as in the vicinity of the Bay of Fundy, the range of the Limnoria is correspondingly great. It has been found, although rarely, at a depth of forty feet.

Woods Subject to Attack.—Most woods used by American constructors in waters where these forms are prevalent are subject to attack by them.

THE CHELURA (*Chelura terebrans*).—It is often stated that the Chelura is among the active enemies of woods; but efforts made to discover work actually performed by it have proved unfruitful, and it is not known where this form exists as a specimen and where it exists as a real pest. It is probable that some results attributed to the Chelura were actually caused by the Limnoria. The Chelura is also known as the wood shrimp.

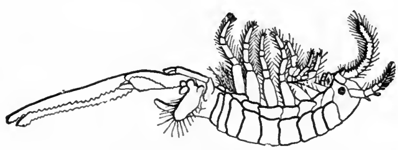


Fig. 58.—The Chelura.

Form and Physiology.—The Chelura is an amphipod crustacean. The form differs strikingly from that of the Limnoria, except in size, and resembles that of the ordinary shrimp. The body is semi-translucent and spotted or mottled with pink. There are three pairs of caudal stylets, the last of which is nearly as long as the body. The Chelura swims actively upon its back, and, like the sand-hopper, can project itself to a considerable distance when placed upon dry land. The Chelura resembles the Limnoria in that it also is a vegetarian. Its burrow affords both residence and food.

Method of Attack. *Character of Excavation.*—The work of the Chelura and that of the Limnoria resemble one another in so many particulars that the suspicion is warranted that the two forms have been confused with one another. In both cases, the wood is attacked from without, and numerous tunnels are driven until the weakened layer succumbs to the action of the waves. A new surface is exposed and this is eventually destroyed in the same manner. The few specimens observed do not warrant wide generalizations, but it is possible that the Chelura prefers the ofter portion of the annual layer, and that the tunnels are curved, because these points were noticed in the few specimens available.

Size of Borings.—The Chelura is somewhat larger than the Limnoria. The specimens seen were about one-third of an inch in length. The burrows were a little larger than those of the Limnoria.

Field of Attack.—The specimens observed were found at Provincetown, in wood located about ten feet below the low-water level.

MISCELLANEOUS. Fresh-water Woodborers.—The work of a fresh-water woodborer (*Sphæroma destructor Richardson*) in trestles of the Florida East Coast Railway resembles the work of the Limnoria, save that the burrows of the fresh-water borer are larger than those of the Limnoria. A yellow pine pile was reduced by them from a diameter of sixteen inches to one of seven and one-half inches in eight years.[1] Several kinds of fresh-water woodborers, some of them very large, have been found in Australian rivers.[2]

Barnacles (*Lepas antifera*).—Barnacles do not injure wood. On the contrary, they protect such parts as are covered by them from the attacks of marine woodborers. Barnacles attach themselves, singly or in clusters, to floating or submerged wood-work and are disliked by ship owners because bottoms covered in such a manner cannot move as rapidly through the water.

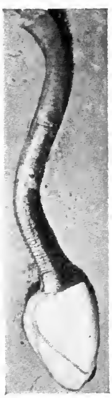


FIG. 59. Barnacle (Lepas antifera reduced one-half.)

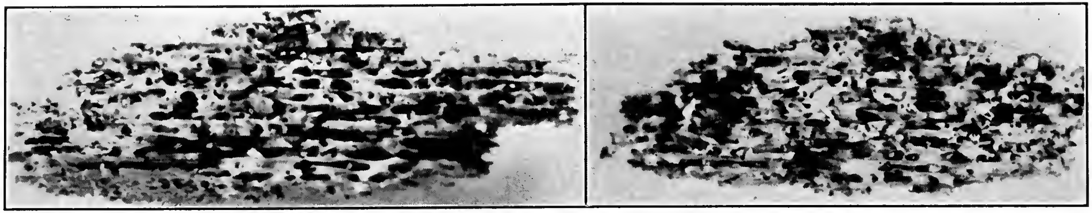
Stone-borers.—Stone-borers are interesting because they show the power of forms that are *apparently* feeble. The pholas or piddock (*Pholas dactylus*) is a typical species of the molluscan family Pholadidæ, which includes other stone-borers as well. The pholas bores in stone by opening its shell so as to grip the sides of the excavation. The long foot or pestle, similar to that of the teredo, is then thrust out and rubbed against the stone. The process is assisted by particles of sand or rock.[3]

[1] See report by Harriet Richardson (Biological Society, Washington, May 13, 1897).

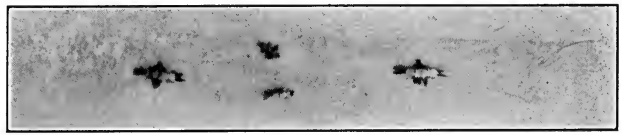
[2] Correspondence Professor Charles Hedley, Sydney, Australia.

[3] A cargo of marble wrecked in the North Atlantic was destroyed in one year by a boring sponge (*Cliona sulfurea Verrill*). The shells of live oysters are often attacked.

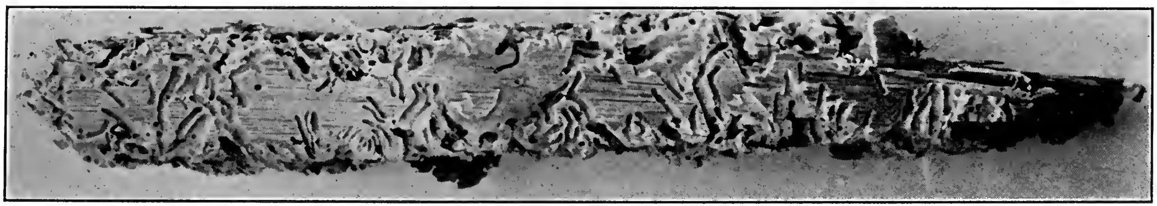
PLATE XII. WORK OF THE CHELURA



(*a*) Surfaces of Wood Occupied by Chelura. Life Size.



(*b*) Chelura Removed from Perforations Shown in Preceding Figure. Life Size.



(*c*) Section Shown through Specimen Corresponding to Figure (*a*). Life Size.

(*Facing page* 314.)

FIG. 60.—Stoneborer in sandstone. (Life size.)

PROTECTION FROM MARINE WOODBORERS

Many of the attempts made to protect woods from the attacks of marine woodborers have failed, but some have succeeded. The methods usually considered are as follows:

Removal During the Breeding Season.—This method, which may be used to protect such objects as buoys, bathing houses, and rowboats, is applicable only where the breeding season is short, as in the North.

Change of Water.—Wooden vessels attacked by sea woodborers are sometimes hauled into fresh or muddy waters. In the past several attempts have been made to protect special woodwork by surrounding it with fresh water.

Use of Selected Woods.—The few woods for which claims have been made are not generally employed in construction, and it is not urged that any one of these woods is always exempt. Thus far evidence favors palm and palmetto, probably because these woods have loose, open structures.

External Coatings.—This form of treatment is good because applications can be limited to the parts of timbers exposed to attack. The parts much above the high-water mark and those much below the mud line do not have to be protected. External coatings are defective in that they ultimately succumb to blows from waves, ships, and other floating objects.

(*a*) The bark sometimes left upon logs protects them as long as the bark remains intact. This is explained by the reluctance of shipworms to cross seams. The bark is soon loosened and removed by the waves.

(*b*) Planks joined closely over the surface of woodwork will protect it from shipworms as long as the planks remain.

(*c*) Copper and other metals have been used to enclose piles as well as the bottoms of wooden vessels. These coatings are expensive but do protect against all forms of marine woodborers as long as they remain intact.

(*d*) Teredo-nails or worm-nails, said to have originated with the Romans, resemble ordinary carpet, upholstery, and thumb tacks, in that they have short spikes and large, flat heads. These nails are driven close together until the wood is enclosed by the heads. Experiments with teredo-nails have been made by the New York Department of Docks.[1]

(*e*) Paraffin, tar, asphalt, paints, and other mixtures have been used to protect woods from marine woodborers, but usually do not remain long in place, since the coatings that are not softened by the water are likely to be removed by erosion. This form of protection should be frequently inspected.

(*f*) Coatings are sometimes reinforced by wire net or by burlap. A paraffin mixture reinforced by burlap has been used to protect piles by the California State Board of Harbor Commissioners, the Northern Pacific Railway, and the Great Northern Railway.

The bark was removed and the surface of the pile covered with a mixture of powdered limestone, clay, and paraffin. It was then wrapped in burlap; another coat of the compound was applied and wooden battens were nailed up and down to keep the coatings in place.[2]

(*g*) Portland-cement mortar has been applied to piles after they had been driven. This is a good method in that the cement can be limited to the parts that are in danger; but it has not proved adequate because the cement being comparatively brittle is in danger of being cracked and destroyed. The cement is applied in several ways. Piles are sometimes encircled by sewer pipes, the spaces between the pipes and piles being filled with cement. Sometimes iron moulds, which are removed as soon as the cement is set, are employed.[3]

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[1] See "Transactions American Society of Civil Engineers" (Vol. XXXI, p. 235). The "Dutch Waterstaat" specifies that nails must be well forged and not brittle. Diameters must be 3 cm. and lengths must be 4 cm. One kilogram must contain from thirty to thirty-four nails.

[2] "Engineering News," February 8, 1894.

[3] The Louisville and Nashville Railroad treated four thousand piles in this way, at an average cost of $1.25 per foot of length (Transactions American Society of Civil Engineers, Vol. XXXI, p. 225).

(*h*) Piles are also enclosed by sand. Sewer pipes are used and the spaces between pipes and piles are filled with sand instead of cement. The cost is less than for cement, while imperfections, serious enough to permit the sand to escape, are revealed by the settlement of the sand at the top. Piles treated in this manner are said to have been sound after twenty years of service.[1]

FIG. 61.—Piles protected by pipes and sand.[2]

(*i*) Protection is sometimes afforded naturally by oysters, barnacles, and other forms.

Preservatives Applied Within Woods.—Of the many mixtures that have been used to repel the attacks of marine woodborers, creosote alone deserves attention. Experience has shown that sufficient quantities of good coal-tar creosote, well applied to

[1] Transactions American Society Civil Engineers, Vol. XXXI, p. 221.
[2] Photograph by Lockjoint Pipe Company.

appropriate woods, will protect the woods from marine woodborers during terms that may be measured by the durability of the creosote. Creosoted piles have stood against the attacks of shipworms for as long as forty years. The failures that have taken place were, in almost every case, due to poor or insufficient creosote, or to poor methods of application. & treatment & handling

Substitution.—Substitution is not protection, but, in this connection, it is well to remember that other materials can often be used in place of wood. If iron had not so largely replaced wood in marine constructions, sea woodborers would require more attention than they now receive.

TERRESTRIAL WOODBORERS

The total losses caused by terrestrial woodborers are enormous. Many trees are completely destroyed by them. But, as distinct from trees, woods in construction do not suffer unduly from these pests. The losses in this direction are less than from fire or from rot.

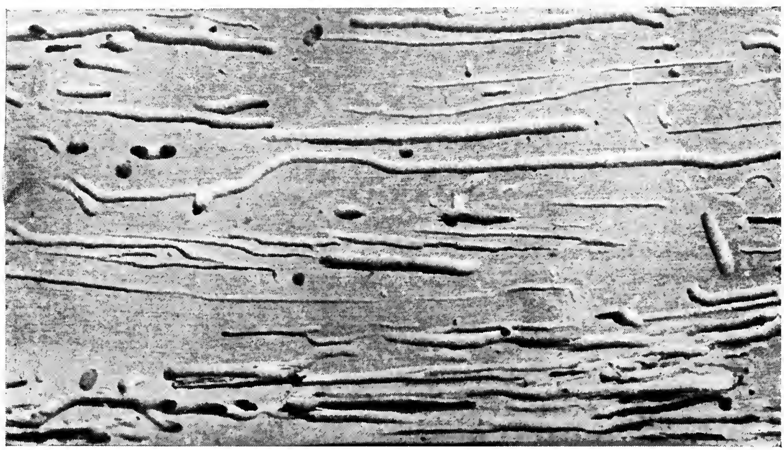
If plant products, growing and in storage, be included with live stock, the losses due to depredations of insects in general would compare with the yearly expenditures of the National Government. It has been estimated that the total injury to agricultural products in the United States by insects amounts to $700,000,000. annually.[1]

Terrestrial woodborers are too numerous for any save the most general notice. Most of them are insects, and it is, therefore, well to remember that all insects are grouped according to the way in which they develop from the egg to the adult. First, some insects develop with what is known as complete metamorphosis; second, others develop with incomplete metamorphosis; and third, still others develop without any metamorphosis.

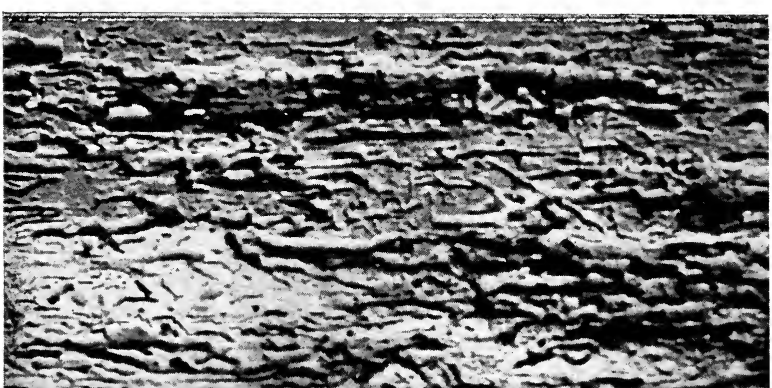
In the first case the egg liberates the larva, sometimes popularly known as "worm," which changes to the pupa, which in turn changes to the adult or imago. The Colorado potato beetle is an example. The egg, the thick larva, the pupa, and the adult beetle may often be observed upon a single potato plant. In the second case the egg liberates a form that closely resembles the adult, and this form, known as the nymph, changes directly

[1] Marlatt (United States Department of Agriculture Year Book, 1904, p. 461); also "Insect Injuries of Forest Products," Hopkins (United States Department of Agriculture Year Book, 1904, p. 381); "Guide to the Study of Insects," Packard.

Corner of Book Cover, Tarrytown, New York. Perforations Reduced One-half.



Whitewood Bureau Drawer-Bottom, New York City. Life Size.



Yellow Pine Base-Board, New York City. Life Size.

(*Facing page* 318.)

to the adult. The locust is one of the forms that develop with incomplete metamorphosis; the nymph of the locust is like the adult, save that it has no wings. In the third case, the egg liberates a form that resembles the adult in practically all respects save size. Development without metamorphosis takes place in but a single order of insects (Thysanura). The bristletails are examples.

Some insect woodborers attack the bark or wood of living trees while others are associated with woods that are ready for, or already in, construction. Some prefer sound and healthy woods, and others prefer those that are moist and decayed. Some insects are particularly associated with certain species of trees, and among these are groups known as hickory borers, elm borers, and the like. There are several hundred insect enemies of oak alone.

BEETLES (*Order Coleoptera*).—Beetles form what is known to naturalists as an Order.[1] This one includes almost one hundred thousand species; besides which, others are frequently discovered. Beetles undergo a complete metamorphosis. The larvæ are sometimes called grubs. Beetles have two horny sheaths or wing-covers that meet in a straight line down the back over a single pair of wings. Their mouths are formed for biting, and are sometimes so powerful as to be able to make an impression upon soft metal. Most wood-boring beetles attack live trees, but some attack woods in construction. Most of those that attack woods do so while they are in the larval condition, but some are harmful after they have become adults. It is common to refer to all woods that have been injured by beetles and other insects as "worm-eaten woods," even although the adult, as distinct from the larva, was responsible for the borings noticed.

Fig. 62.—Perforation in sheet-lead roof made by adult beetle.

The family Scolytidæ includes many forms that attack trees. Some bore in twigs and are known as "twig beetles," others bore in roots and are known as "root beetles," and still others attack bark and are known as "bark beetles." Some members of this family cut symmetrical grooves upon the outer surfaces of the

[1] The animal kingdom is divided into Phyla, Classes, Orders, Families, Genera, Species, and Individuals, the importance being in the order named.

sapwood of trees and are known as "engraver beetles." The powder-post beetles include many enemies of seasoned woods that attack house-trim, flooring, spokes, tool handles, and the like.

The larvæ of some beetles attack the paste, covers, and leaves of books as well as woodwork, and are often known as "book-worms." The worm-eaten appearance of furniture is often due to them. An instance is on record of a bedpost destroyed thus in three years. The name bookworm is not confined to any particular species but applies to any form of insect life that attacks the covers, leaves, or paste of books.[1]

Summary.—Although very numerous, beetles are principally harmful to living trees, and for this reason protective measures are almost wholly in the hands of growers, foresters, and horticulturists. The total amount of wood in construction that is injured by beetles is comparatively small. Engineers seldom attempt to protect woods from the attacks of beetles.[2]

MOTHS AND BUTTERFLIES (*Order Lepidoptera*).—Moths and butterflies undergo complete metamorphosis. Both forms possess four membranous, scaly wings, and in both cases the larvæ are often known as caterpillars. Butterflies fly by day, while moths fly by night, and there are also differences in the ways in which the wings are folded. Adult moths and butterflies do not attack trees or woods in construction, but the larvæ of some species of both are very destructive. With few exceptions, living trees, as distinct from woods in construction, suffer from their attacks.

The Gypsy Moth (*Porthetria dispar*).[3]—The destruction accomplished by the larvæ of this species, by their habit of feeding on

[1] The silver fish (*Lepisima saccharina*) often attacks paper.

[2] "Insects Injurious to Forest Products," Hopkins (United States Department of Agriculture Year Book, 1904, pp. 387–388); "A Revision of the Powder-Post Beetles of the Family Lyctidæ," Kraus and Hopkins (United States Bureau of Entomology, Technical Series No. 20, Part 3, 1911); "Principal Household Insects," Howard and Marlatt (United States Division of Entomology, Bulletin No. 4, pp. 76–78); etc., etc.

[3] See also "The Gypsy Moth," Forbush and Fernald (Massachusetts State Board of Agriculture, 1896); "Report on the Field Work against the Gypsy Moth and the Brown-Tail Moth," Rogers and Burgess (United States Bureau of Entomology, Bulletin No. 87, 1910); "Insects Affecting Park and Woodland Trees" (New York State Museum, Vol. I, pp. 79–84); "The Importation into the United States of the Parasites of the Gypsy Moth and Brown-Tail Moth," Howard and Fiske (United States Bureau of Entomology, Bulletin No. 91, 1911); etc., etc.

leaves, has been so great that, in Europe, it has been referred to as "the plague," and, in the past, it has been thought to be a scourge sent by the Almighty as a penalty for wrong-doing. The Gypsy Moth was brought to the United States in 1868, but remained unrecognized until 1889. The work of the National Government and of the different States in combating this pest has produced encouraging results.

The Goat Moth (*Cossus ligniperda*).—The young, which are said to remain in a larval condition for as long as three years, possess wedge-shaped heads with large, trenchant jaws, equipped with powerful muscles that enable them to cut into very hard woods. The Carpenter Worm is the larva of a beautiful gray moth (*Prionoxystus robiniæ*) with wings that spread over a distance of about three inches. The full grown larva, which is about two and one-half inches long, sometimes bores into trunks of oaks, maples, and locusts to such an extent that such woods have very little value later.

Fig. 63.—Queen termite (*Termes bellicosus*). (Natural size.)

Summary.—The larvæ of moths and butterflies are among the most dreaded insect enemies of living trees. Woods in construction are seldom injured. Protective measures are in the hands of foresters and horticulturists.[1]

TERMITES (*Order Isoptera*).—Termites are called "white ants" because they are of a dingy, white color, and because they live in communities as true ants do. Termites have thick waists and develop with incomplete metamorphosis, whereas true ants have slender waists and develop with complete metamorphosis. The mouths of termites are formed for biting. The American termite (*Termes*

[1] See also "The Gypsy Moth," Forbush and Fernald (Massachusetts State Board of Agriculture, 1896); "Report on the Field Work against the Gypsy Moth and the Brown-Tail Moth," Rogers and Burgess (United States Bureau of Entomology, Bulletin No. 87, 1910); "Insects Affecting Park and Woodland Trees" (New York State Museum, Vol. 1, pp. 79–84); "The Importation into the United States of the Parasites of the Gypsy Moth and Brown-Tail Moth," Howard and Fiske (United States Bureau of Entomology, Bulletin No. 91, 1911); etc., etc.

flavipes), the European termite (*Termes lucifugus*), and the African termite (*Termes bellicosus*) are important species.

Termites are encountered in the Northern States in hot-house plants, dead stumps, and under stones. They have destroyed live trees as far north as in the vicinity of Boston, but are more plentiful in the Southern States, and are very destructive in the tropics, where they occupy a position among land woodborers that compares with that held by shipworms among marine woodborers. Although termites sometimes attack live plants they seem to prefer tissues within which life processes have ceased, and house timbers, railway ties, and other structural pieces, as well as dead stumps, books, and papers, are subject to attack by them.

A floor in the National Museum at Washington was undermined several times by a colony of termites that could not be located, until it became necessary to replace the floor by one of cement. Termites have destroyed frame buildings in Washington and Baltimore. A school library in North Carolina was destroyed during the summer vacation. Humboldt explains the rarity of old books in Spain by the fact that termites are so active in that country.

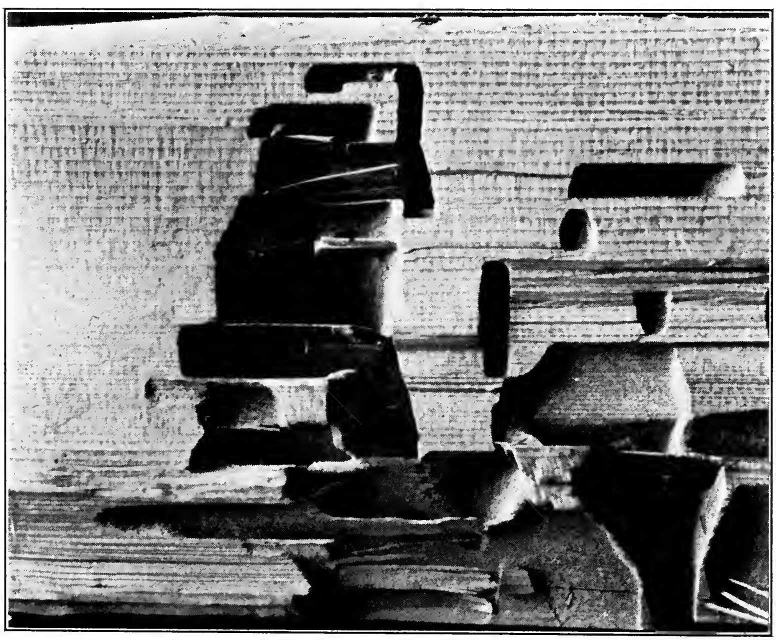
It is seldom urged that any wood is always exempt from the attacks of termites; but some, such as teak and redwood, seem to be more fortunate than others in this respect. Railway ties are not often attacked by termites, not because of the kinds of wood that are used but because of the disturbance caused by passing trains. Redwood stave pipes have resisted termites and other insects in the United States as long as the pipes remained wet.

Some methods employed to protect woods from termites are as follows: (*a*) Decayed wood that is likely to attract or shelter colonies of termites, should be removed. (*b*) When discovered, colonies of termites should be destroyed by the liberal use of steam, hot water, kerosene, or other agencies. (*c*) Saturation with good coal-tar creosote has preserved timbers from attack.

References.—"Dangers from White Ants," Hagen (American Naturalist, July, 1876, pp. 401–410); "Manual," Comstock (pp. 95–97); "Insects Injurious to Forest Products," Hopkins (United States Department of Agriculture, Year Book, 1904, p. 389); "Important Philippine Woods," Ahern (p. 91); "Principal Household Insects," Howard and Marlatt (United States Division of Entomology, Bulletin No. 4, pp. 70–76); "The White Ant," Marlatt (United States Division of Entomology, Circular No. 50, Second Series).

PLATE XIV. WORK OF LARGE CARPENTER ANT

(*a*) Pine Shingle from House on Long Island.



(*b*) Fence Post from New York City.

(*Facing page* 322.)

(*d*) As far as possible endangered structures should be surrounded by cleared spaces, and these should be covered with asphalt or gravel. (*e*) In the tropics, tables and other kinds of furniture are sometimes protected by placing the legs in small vessels containing oil. (*f*) Books and papers endangered by termites should be frequently inspected. (*g*) It is often best to replace woodwork with stone or metal.

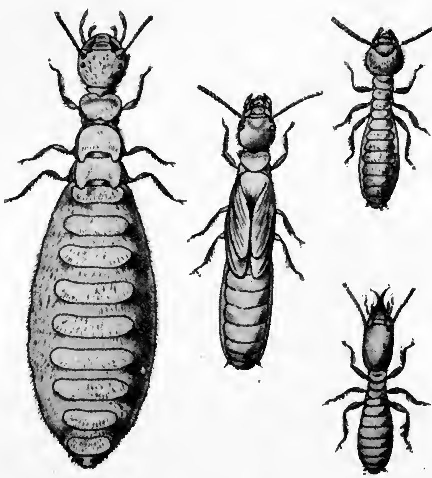


Fig. 64.—Termites (*Termes flavipes*). Queen, nymph of winged female, worker, and soldier. (Enlarged.) Marlatt (U. S. Division of Entomology, Circular No. 50).

Summary.—Adult termites are the principal terrestrial woodborers that attack woods in construction. Termites are occasionally active in the North, but are often exceedingly active in the tropics and semi-tropics. It is safest to replace wood by iron or stone wherever termites are known to be unduly active.

THE CARPENTER-BEE (*Xylocopa virginica*).—The carpenter-bee, which resembles the ordinary bumble-bee in size and appearance, is equipped with powerful jaws, and often attacks telegraph poles, fence posts, and house timbers. The tunnels thus formed may be one foot or more in length, and are used by the bees as nesting places. Some wasps attack wood.

THE LARGE CARPENTER ANT (*Camponotus herculeanus pennsylvanicus*).—As distinct from the termite this is a true ant, and like other ants it develops with complete metamorphosis. It seldom attacks sound trees, but does often attack some of those that have been wounded or are diseased, and also, sometimes, attacks woods in construction. McCook states that carpenter ants were responsible for "at least one accident" that occurred in connection with the wooden trestle bridges formerly used by the Pennsylvania Railroad Company.[1]

Ants offer one of the most perfect illustrations of communistic society. The State declares war, provides food, cares for the children, and owns all the property. Patriotism, loyalty, courage, and never-failing industry are exhibited. War, pillage, slavery, and disregard for the rights of other communities prevail. There are many species of ants, and each one is characterized by some peculiarity. Some are road builders; others live in large mounds; and some bore in decayed trees. Most ants tunnel.

Fig. 65. Tunnel of carpenter-bee in yellow-pine grape-arbor post, New York City.

METHODS OF PROTECTION

Injury from insects cannot be completely controlled. Man has not yet succeeded in eliminating a single species of insects. But as distinct from this, the enormous losses that now result from this cause would be greater than they are if man had remained inactive.

It is estimated that losses due to the Hessian fly have been reduced over $100,000,000 annually, and also that the rotation of corn with oats and other crops has reduced the damage done by root worms to the corn crop of the Mississippi Valley about $100,000,000 annually. $15,000,000 to $20,000,000 are saved annually by protecting apple trees from insects by means of sprays.

Defensive practice is almost wholly in the hands of foresters and horticulturists and is directed toward the protection of trees. Engineers seldom attempt to protect woodwork from insects other than termites, and the methods used to protect wood from these

[1] "Nature's Craftsman," McCook (pp. 126, 127).

PLATE XV. HIGH POWER SPRAYING APPARATUS IN ACTION

From "Report of Field Work against Gypsy Moth and Brown-Tail Moth," Rogers & Burgess (United States Bureau of Entomology, Bulletin 87).

(*Facing page* 324.)

insects resemble those used to protect it from marine woodborers and from rot. The value of birds as defensive agents against insects is beyond estimate. When birds are destroyed insects increase proportionately. This value of birds in maintaining the balance set by nature should be recognized by all. Some insects that prey upon other insects should be noted also. Some of these helpful insects directly destroy those that are harmful, while others destroy the harmful insects indirectly by depositing their eggs on, or in their bodies. These predaceous and parasitic insects are natural agents of great value in insect control.

CHAPTER XIII

Protective Methods—Seasoning

The term seasoning refers to certain processes designed to remove water from woods. Woods dry, shrink, and otherwise improve by these processes.

Improvement Caused by Drying.—The influence of moisture upon wood has already been considered.[1] Dry wood is stronger than green wood and much less liable to decay. All woods should be shrunk before they are finally placed in position.

Improvement Caused by Alteration.—Experience shows that other changes take place when woods are seasoned. Von Schrenk believes that albuminous substances, and possibly tannin, resins, and other incrusting materials are altered or recombined during these processes.[2] The reasons are not clear, but the facts are that additional changes do take place and that they are of such a nature as to suggest the changes that take place in fruits when they are "cured."

It is often hard to season wood without injuring it somewhat. This is because of (1) irregularities that exist in the arrangement of the wood-elements, and (2) irregularities that exist in the distribution of the moisture; as, for example, the difference in the amount of moisture in the sapwood and in the heartwood of a green log. It is easy to dry wood, but it is not always easy to dry it so that every part will shrink together. All methods are not

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[1] See Index.

[2] "Seasoning of Timber" (United States Bureau of Forestry, Bulletin No. 41, p. 9).

References.—"Timber," Roth (United States Division of Forestry, Bulletin No. 10, 1895); "Seasoning of Timber," von Schrenk (United States Bureau of Forestry, Bulletin No. 41, 1903); "Kiln-Drying Hardwood Lumber," Dunlap (United States Forest Service, Circular No. 48, 1906); "Principles of Drying Lumber at Atmospheric Pressure," Tiemann (United States Forest Service, Bulletin No. 104, 1912). See also catalogues of the B. F. Sturtevant Company, the Morton Dry Kiln Company, the Standard Dry Kiln Company, the American Blower Company, etc. "The Theory of Drying, etc.," Tiemann (United States Department of Agriculture, Bulletin No. 509, March, 1917).

suitable for all woods. Judgment and experience are required to select the proper method in any particular case.

Three groups of processes are employed to season woods. They are *natural-seasoning*, *water-seasoning*, and *kiln-seasoning*.

NATURAL SEASONING.—Just as certain fruits will either cure or rot, according to the way in which they are exposed to the weather, so, also, will certain woods. When woods are exposed under certain conditions in the open air, water is expelled and the changes that have been described take place.

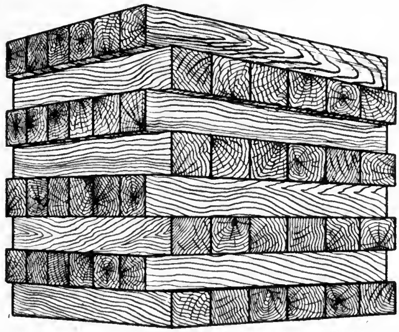

FIG. 66.—Close-piling. This encourages rot.

The details of exposure are important. A few woods do well under almost all conditions, but the rule is that close piling and contact with the ground encourage rot. Timbers should be raised from the ground and should be so piled that the air can circulate between them and they should remain in these positions during intervals that depend upon their shapes and sizes.

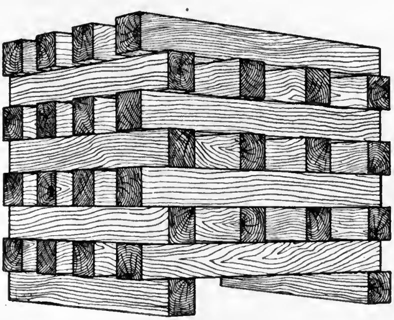

FIG. 67.—Loose-piling. This permits seasoning.

While it is often assumed that the best results are those obtained from natural seasoning, it should be remembered that the best results are not invariably thus obtained. The pieces within a pile may be well seasoned, and those without be warped and checked from having dried too rapidly. From two to four years must often pass before woods are completely dried by the natural method. It is expensive to hold stock so long, and it is dangerous because of fires. However, wood is normally improved, even although the process is not carried through to the end.

The extreme form of natural seasoning is practiced with pieces intended for musical and mathematical instruments, and wood engravings. On the other hand, most railway ties and other large construction pieces receive a minimum of attention. It seldom happens that these large pieces are completely seasoned; but the improvement that takes place while they are piled waiting for use is ordinarily very great, and, with this in view, such pieces should be piled loosely so that the air can circulate between them.

Natural seasoning requires so much time that it is usually combined with some other method. Before woods are thus seasoned they are often soaked in water; and sometimes drying commenced by this method is completed in a kiln. Natural seasoning, air seasoning, and yard-drying mean the same.

WATER SEASONING.—Logs are often stored under water. The tendency to crack that exists when they are exposed to the hot sun, and the danger from insects and from rot, are counteracted as long as they remain thus submerged.

Woods keep safely under water, and, at the same time, undergo changes that render them more durable after they have been removed from the water. They dry rapidly when brought again into contact with the air, and are then durable in proportion as they have been washed by the water. Water seasoning is usually combined with natural seasoning.

The water acts, first by excluding the air, and second by leaching out impurities. There is no reason why wood should ever decay while it remains under water. The softening or physical disintegration that may eventually take place is not decay. Logs are sometimes found buried deep in the mud of swamps. Pieces cut from such logs are often particularly prized because in the course of immersion they have been so thoroughly cleansed and rendered durable, and also because they have lost much of the natural tendency to warp.

KILN SEASONING.—Kiln seasoning originated with attempts to prevent warping and checking in special pieces. In the United States, nearly all hardwoods, save those in large construction pieces, are now cured by this method. Drying proceeds rapidly and details can be controlled in kilns as they cannot be in natural-seasoning or in water-seasoning.

There are many details and combinations, but the factors that influence design and operation in all cases are *temperature*, *moisture*, and *circulation*.

Temperature.—Heat may be dry or wet. In both cases, high temperatures should be avoided. Dry heat in excess of two hundred and twelve degrees is sufficient to expel some of the volatile constituents of the wood, which then becomes weak and brittle. The equivalent of this temperature in moist heat is not known. Temperatures of from one hundred degrees to one hundred and twenty degrees Fahrenheit are used in connection with green oak and some other difficult woods, while temperatures of from one hundred and sixty degrees to one hundred and eighty degrees Fahrenheit are employed with pine and cedar.

The temperature of the entire charge must be raised to a point at which the drying is to take place. The surface of wood heated in warm, dry air is liable to shrink before the heat has penetrated and acted upon

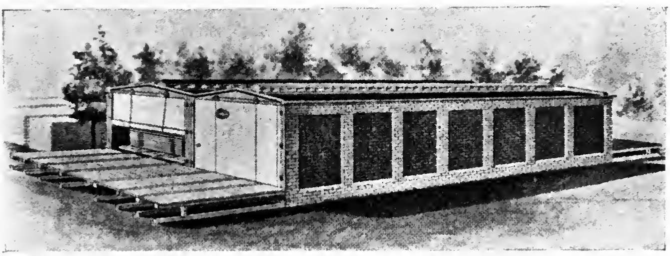

FIG. 68.—A kiln for drying wood.

the moisture that is within. Wet heat or steam adds to the moisture but assists because it keeps the surface soft and swollen until the heat has penetrated to the interior.

Moisture.—Natural moisture or sap must be distinguished from moisture that may be absorbed after the tree has been cut down. Most of the natural moisture is in the outer sapwood and this moisture is often retained, or even added to, with advantage, so that the outer wood will not shrink before the heat has penetrated to the moisture further in. This is particularly necessary in the case of oaks and other woods characterized by complex cellular arrangements.

Ability to season woods successfully in kilns depends upon ability to manipulate the moisture. Heat, circulation, and the kilns themselves are designed or directed with this end in view. Some processes include the addition of steam while others use only the moisture that has been evaporated from the wood. In other processes the moisture from the wood is removed by condensation upon the surfaces of pipes filled with cold water. Moisture is sometimes introduced by piling snow upon the lumber as it enters the "greenwood ends" of the kilns. Pieces must be piled so as to facilitate the escape of the moisture.

Circulation.—The air within a kiln does not remain motionless. On the contrary, it moves naturally because of the heat, or else the movement is induced by means of fans, and, in both cases, drying may be hastened or retarded by hastening or retarding the circulation of the air currents. Air currents may pass in at the bottom and out through the sides of the kilns, or they may pass through the kilns from one end to the other.

Forms of Kilns.—The principal features of all kilns are (1) the drying chambers in which the wood is stored,[1] (2) the furnaces for heating air or making steam, and (3) the devices for causing the air to circulate within the drying chambers.

There are kilns within which charges remain stationary, and others within which charges move through from end to end.

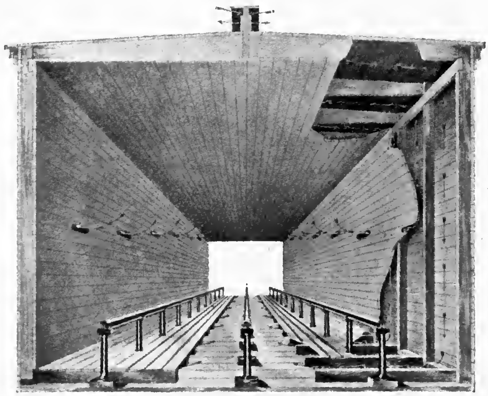

FIG. 69.—Interior of a drying chamber.

When the wood remains stationary, in what is known as a "charge kiln" or "apartment-kiln," the moisture in the air is removed little by little, and the mass is finally exposed to a current of warm, dry air. When the charge moves forward, in what is known as a "progressive-kiln," it advances through an air-current that contains most moisture near the entrance or "green-wood end" and least moisture at the other extremity where the wood emerges.

Kilns are also grouped according to the origin of the draft, which may be natural, if caused by pipes or radiators placed beneath the drying chambers; or it may be forced if the draft, heated outside the kiln, is forced in by a fan. As stated already,

[1] Drying chambers are from fifteen feet to one hundred and fifty feet in length and from ten feet to thirty feet in width. They are usually built of wood, but may be built of brick, or of concrete, as shown in the preceding picture.

the air currents may pass in at the bottom and out through the sides of the kilns, or they may pass through from end to end.

Kilns designed for natural draft are often known as "moist-air kilns," and those designed for forced draft as "hot-blast kilns," but these names refer to details of operation, rather than

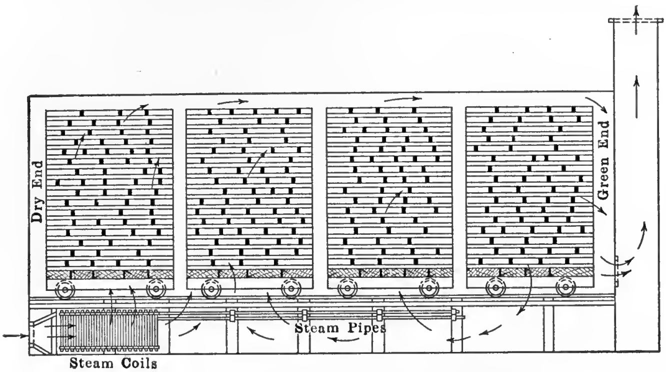

FIG. 70.—A scheme for a radiator kiln.

to methods of construction, since moist air may be used in kilns of either kind, regardless of the source of the draft.

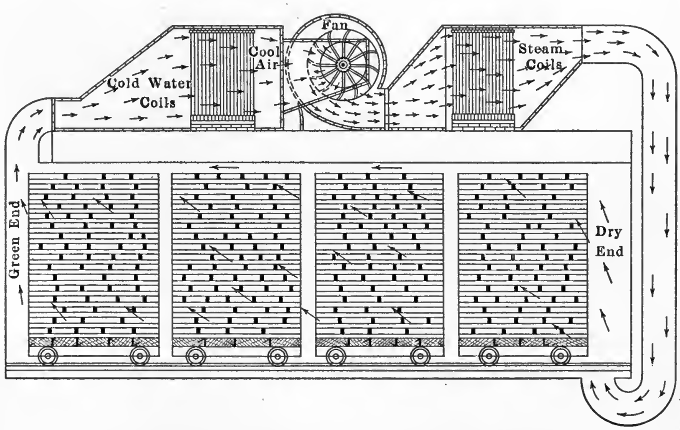

FIG. 71.—A scheme for a blower kiln.

Natural-draft kilns and forced-draft kilns are also sometimes referred to as "radiator-kilns" and "blower-kilns" respectively.

A scheme for a radiator or moist-air kiln designed for progressive operation is shown in the picture. The pieces that are to be seasoned are arranged upon trucks, which are then rolled into the kiln until it is full. After a sufficient time in the kiln, one truck with its charge is removed from the "dry-wood end," the others are moved forward, and a new charge is admitted at the "greenwood end" of the kiln. The ventilator shaft at the right is often dispensed with. The general direction followed by the air currents is shown by the arrows.

A scheme for a blower-kiln is also shown. The humidity is maintained by using the same air repeatedly. The saturated air drawn from the "greenwood end" at the left of the picture, deposits part of the moisture upon the cold water coils located at the left of the fan. The air then passes on through the fan and is re-heated by the steam pipes toward the right. The air is relatively dry and warm as it re-enters the dry end of the kiln.[1]

Operation.—The several parts of the process employed within a kiln of any kind may be grouped as they relate (1) to preparation and (2) to drying. First, the temperature of the charge must be raised to the point at which the drying is to take place, while the surfaces of the pieces that make up the charge remain or are rendered soft and permeable. Second, the drying is forced by means of the draft, but at such a rate that the moisture from within the pieces can move out fast enough to replace the moisture that escapes from their surfaces.

Preparation.—The charge or apartment kiln both prepares and then dries the wood before it is removed. Once within this kiln the wood is not removed until the process is completed. In the progressive system the wood is sometimes, but not always, prepared before it is admitted to the drying chamber. The auxiliary kiln, that is here sometimes used, should be placed as near as possible to the greenwood end of the principal kiln so that the charge will not be unduly chilled during transfer.

Drying.—The draft must be held back until the heat has penetrated within the pieces. Even then, it must not be forced unduly, or the surface moisture will escape too rapidly, and cause the surface wood to shrink before that inside has had time to dry. Case-hardening, honeycombing, checking, warping, or twisting may then result.

Difficulties.—In kilns, where drying is hastened, the difficulties that have been mentioned in connection with slower methods of seasoning become more pronounced. The situation has been expressed as follows:[2]

"In drying chemicals or fabrics, all that is required is to provide heat enough to vaporize the moisture and circulation enough to carry off the

[1] From United States Forest Service; Circular No. 48.

[2] "Kiln-Drying Hardwood Lumber," Dunlap (United States Forest Service, Circular No. 48, p. 5.).

vapor, and the quickest and most convenient means to these ends may be used. In drying wood, whether in the form of standard stock or finished product, the application of the requisite heat and circulation must be carefully regulated throughout the entire process, or warping and checking are almost certain to result. Moreover, wood of different shapes and thicknesses is very often differently affected by the same treatment. Finally, the tissues composing the wood, which vary in form and physical properties and which cross each other in regular directions, exert their own peculiar influence upon its behavior during drying. With our native woods, for instance, summer wood and spring

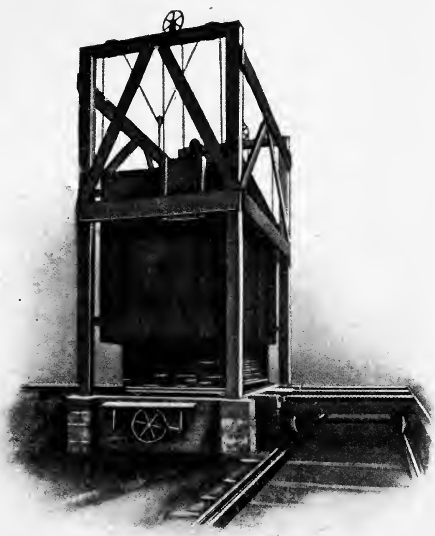

FIG. 72.—Auxiliary kiln for preliminary treatment.

wood show distinct tendencies in drying, and the same is true in less degree of heartwood as contrasted with sapwood. Or, again, pronounced medullary rays further complicate the drying problem. Plain oak and quartered oak require different treatment. Even in mahogany and similar tropical woods, which are outwardly more homogeneous, various kinds of tissues are differentiated."

The presence of knots, windshakes, frostshakes, and other defects add to the problem, which is to dry without distortion rather than simply to dry. The comparatively simple cellular structure of coniferous woods makes it easier to dry the woods of that series. The broadleaf woods as a group are more difficult, and some of them, such as the oaks, are particularly hard to dry.

Time Required.—The time required to kiln-season lumber depends upon the sizes, shapes, and species of the individual pieces. Some operators dry one-inch white oak planks in four or five days, while others require one or two weeks for the same woods, and still others need twice as long. Plain oak and mahogany dry with about the same speed; these woods require less time than quartered oak, and longer than ash, birch, and basswood.

PROTECTION OF SEASONED WOODS.—Dry woods should remain dry. Woods suffer if their cell structures expand and contract too frequently. The cell structures may remain healthy, but they separate more easily from one another, and eventually the piece as a whole is weakened. The influence of moisture upon the fungi that cause disease will be remembered. Seasoned woods that are to be exposed to the weather should be protected by coatings applied to their surfaces, or by antiseptics introduced within them.

CHAPTER XIV

PROTECTIVE METHODS—INTERNAL TREATMENT

PRESERVATIVE COMPOUNDS APPLIED WITHIN WOODS

Preservative compounds are applied within woods to produce results of several kinds. Sometimes, the object is to increase resistance to decay; sometimes, it is to repel the attacks of teredos and other live woodborers, and sometimes, the object is to retard fires. Preservatives *within* woods remain where paints on the *outside* would soften or be rubbed away. Paints would fail if applied to woods used in marine positions or in railway ties, whereas preservatives injected within woods have succeeded in such positions.

Preservative chemicals were first applied within woods in England. The diminished supply of wood, and the early rotting of their wooden ships, caused the English to practice within this field more than one hundred years ago. The beginning of real activity, however, was connected with the development of railways (1830–1840).

REFERENCES.—"Antiseptic Treatment of Timber," Boulton (Proceedings Institution of Civil Engineers, London, 1884); "The Preservation of Timber," Report of Committee (Transactions American Society of Civil Engineers, 1885); "Wood Preservation," Flad (United States Forest Service, Bulletin No. 1, 1887); "Preservation of Railroad Ties," Curtis (Transactions American Society of Civil Engineers, Vol. XLII, 1899); "Proposed Method of Preservation of Timber with Discussion," Kummer (Transactions American Society of Civil Engineers, Vol. XLIV, 1900); "Hand-book of Timber Preservation," Samuel M.Rowe (Author's Edition, 1900); "Preservation of Railway Ties in Europe," Chanute (Transactions American Society of Civil Engineers, Vol. XLV, 1901); "Timber Tests and Discussions" (Transactions American Society of Civil Engineers, Vol. LI, 1903); "Decay of Timber," von Schrenk (United States Bureau of Plant Industry, Bulletin No. 14); "Recent Progress in Timber Preservation," von Schrenk (United States Department of Agriculture, Yearbook, 1903); "The Inspection of Treatment for the Protection of Timber by the Injection of Creosote Oil," Stanford (Transactions American Society of Civil Engineers, Vol. LVI, 1905); "The Preservation of Structural Timber," Weiss (McGraw-Hill Book Co., 1915); Bulletins of American Railway Engineering Association; "Handbook" (1916) and other Publications of the American Wood Preservers Association; also, other Publications of United States Department of Agriculture; etc., etc.

The field of wood preservation has not been occupied to the same extent in the United States as in Europe. Woods have been more plentiful in the United States, where, consequently, the demands for construction have hitherto been along extensive, instead of intensive, lines.

A study of the subject of wood preservation from a local standpoint was inaugurated by the American Society of Civil Engineers in 1880, and the report issued by this Society five years later is yet recognized as text. The study thus commenced was continued by the United States Department of Agriculture, which, having organized a Division of Forestry, issued its first bulletin in 1887. The situation in the United States today suggests the situation as it was in England some years ago; save that English engineers were obliged to learn from the beginning, whereas Americans have profited from successes and failures of a century of European practice.

The price of wood is advancing in the United States; and, dependent upon this, the practice of wood preservation is rapidly becoming more general. Prior to 1901 only fifteen timber preserving plants were in operation, while, during the six successive years, this number was increased to fifty.[1] Nearly ten per cent. of the total number of railway ties recorded as having been purchased during 1905 received preservative treatment of some kind.

A French authority states that one hundred and sixty-seven wood-preserving substances or processes were tried or introduced prior to 1874,[2] while Weiss enumerates two hundred and sixty-eight patents granted in the United States alone in this field since that year.[3] Most processes and chemicals included in these and other lists have, however, been abandoned. In 1885, the Committee of the American Society of Civil Engineers reported fully upon only four preservatives and processes; and, in spite of the time that has elapsed since this report was rendered, these four are yet regarded as the most important.

It is hardly probable that many methods now unknown will be successfully introduced in the future, because years must elapse before the efficiency of a material or a method can be proved by

[1] Hale (United States Forest Service, Circular No. 43, p. 6). Weiss enumerates one hundred and ten wood-preserving plants as existing in the United States in 1914 (pp. 255–258).

[2] "Traite de la conservation des bois," Paulet (Paris, 1874).

[3] "Preservation of Structural Timber," Weiss (1915).

actual tests. Woods are more costly and chances less warranted than in former years. As distinct from the development of new practices, however, it is probable that in the future more attention will be given to perfecting practices already known, and, that results obtained in the United States, will ultimately be more uniformly satisfactory than at the present time.

The subject is one that requires attention along three lines, namely: the *materials* used to preserve woods, the *processes* used to force such materials into the woods, and the *woods* that will best receive and respond to the preservative materials thus used.

PRESERVATIVE MATERIALS

Salt, formaldehyde, lime, sulphate of iron, tannin, oils, arsenic, and many other substances have been tried or considered for preserving woods. Of this entire series copper sulphate, zinc chloride, mercury bichloride, and creosote, either separately or in combinations, have succeeded best; while of this smaller list, zinc chloride and creosote are now most used.[1]

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[1] The following list is taken from "Handbook on Wood Preservation" (American Wood Preservers' Association, p. 27, 1916). It enumerates some of the substances which have been proposed as means of protecting wood against destruction by fire, fungi, and woodborers:

Aluminum sulphate
Animal oils
Barium carbonate
Barium sulphate
Borax
Cedar oil
Copper sulphate
Creosotes (coal-tar, water-gas-tar, wood, petroleum)
Crude oil
Fish oil
Glue
Gums (various)
Iron sulphate
Lime hydrate
Linseed oil
Magnesium sulphate
Mercuric bichloride
Molasses and low syrups
Petroleum oils
Potassium carbonate
Potassium nitrate
Resins
Sodium carbonate
Sodium chloride
Sodium fluoride
Sodium muriate
Sodium sulphate
Sulphuric acid
Tannin
Tar
Tartaric acid
Vegetable oils
Wax
Whale oil
Zinc chloride
Zinc sulphate

Wood preservatives may be divided as they do, or do not, dissolve in water. First, the salts of metals dissolve in water, and, for this reason, eventually escape if used where it is wet; but second, creosote, which is an oily mixture, does not dissolve in water. Creosote is much more permanent in its effects than are the salts of metals. It should be remembered that the influence of any chemical may continue for a short time after the removal of the chemical.

TANNIN ($C_{14}H_{10}O_9$).—Tannin is an antiseptic and coagulant. Tannin and tannic acid are the same.[1] Tannin is present in parts of many trees and doubtless influences the natural durability of woods. It is used in the preparation of leather, as well as in the artificial preservation of woods, although, in the latter case, it is used only in combination with other substances.

Tannin serves in this connection, together with glue, in what are known as the "zinc tannin processes." The leather-like solids which result during these processes from the action of the tannin upon the glue, fill up the pores of the wood and retard the escape of zinc chloride, which is soluble in water.

COPPER SULPHATE ($CuSO_4.5H_2O$).—This is the blue vitriol of commerce. Chapman experimented with wood soaked in copper sulphate as early as 1816. Boucherie, who concerned himself with methods for forcing preservatives into woods rather than with the preservatives themselves, after employing various antiseptics, finally pronounced in favor of copper sulphate; and in consequence of this, the name of Boucherie is associated with copper sulphate and also with the process used for introducing it into wood. Copper sulphate is a very valuable wood antiseptic but it dissolves readily in water and escapes easily from the wood. It is decomposed when brought into contact with iron. Very little of it is now used in wood preservation in the United States.

MERCURY BICHLORIDE ($HgCl_2$).—The application of mercury bichloride in wood preservation was first suggested by John Howard Kyan in England in 1833. Mercury bichloride is the most active of all wood preservatives in use. Very small quantities are effective, and because the quantities needed are so small the actual cost, although considerable, is not as great as at first appears. It dissolves in boiling water, and once within the

[1] In the strictly chemical sense, tannic acid is not a true acid, but an anhydride of an acid, belonging to the class of phenols. Tannin is therefore the more nearly correct name. The two terms refer to the same substance.

wood, resists the actual moisture of reasonably dry places much longer than do copper sulphate and zinc chloride. On the other hand, mercury bichloride attacks iron;[1] in spite of the small quantities necessary it is comparatively costly, and it is very poisonous to human beings.[2]

ZINC CHLORIDE ($ZnCl_2$).—Zinc chloride, which is obtained by dissolving metallic zinc in hydrochloric acid, is a cheap and very good wood preservative, its toxic effects upon wood-destroying fungi being about equal to those of creosote; also it has an affinity for wood fiber into which it penetrates to a considerable depth. Its chief fault is that it attracts water and dissolves easily in it. Experience shows, however, that it will remain in timber in reasonably dry locations for many years. It cannot be used in marine constructions, but has caused railway ties which would normally fail in four or five years to remain sound for ten or more years. Many million pounds of zinc chloride are now used annually in the United States in treating wood.

Zinc chloride is the cheapest wood preservative practically available in this country, and in spite of defects that have led most European railways to cease using it, is highly regarded as an antiseptic that meets some temporary American conditions. Burnett first called attention to the value of zinc chloride as a wood preservative in 1838.

CREOSOTE.[3]—The name creosote applies to products derived

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[1] The reaction is as follows: $Fe + HgCl_2 = FeCl_2 + Hg$.

[2] The antidote, when this active poison is taken into the stomach, is fresh milk or else egg water made by dissolving three or four raw eggs in one quart of water.

[3] REFERENCES.—"Coal-tar and Ammonia," Lunge; "Causes Underlying the Limited Production of Creosote in the United States" (Forestry and Irrigation, October, 1906, pp. 482–484); "Fractional Distillation of Coal-tar Creosote," Dean and Bateman (United States Forest Service, Circular No. 80); "Quantity and Character of Creosote in Well-preserved Timbers," Alleman (United States Forest Service, Circular No. 98); "The Analysis and Grading of Creosotes" (United States Forest Service, Circular No. 112); "Volatilization of Various Fractions of Creosote after their Injection into Wood," Teesdale (United States Forest Service, Circular No. 188); "Modification of the Sulphonation Test for Creosote," Bateman (United States Forest Service, Circular No. 191). Other Publications of the United States Forest Service. Manual, 1911, and other Publications American Railway Engineering Association. Proc. American Wood Preservers' Association. Specifications American Telephone and Telegraph Company. "Coal-tar Distillation," Warnes (D. Van Nostrand Company, 1914). "Preservation of Structural Timber," Weiss (McGraw-Hill Company, 1915).

from water-gas tar and wood; but, in construction, unless otherwise noted, it now refers principally to a mixture distilled from coal-tar. Coal-tars vary and the mixtures obtained from them during distillation vary also. It is, therefore, particularly unfortunate that there can be no chemical formula for creosote. The value of creosote as a wood preservative was suggested by Bethell in 1838. Tar oil, heavy oil of tar, dead oil of tar, and coal-tar creosote are different names for the same material.

Water-gas-tar and wood creosotes are antiseptics, but their success with woods is not to be compared with that which has followed the use of coal-tar creosote. Wood creosote has a sweetish, burning taste, with an odor that resembles that of smoked

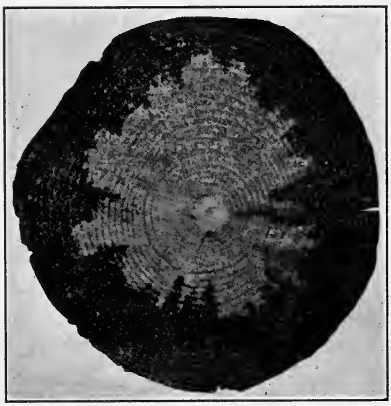

FIG. 73.—Cross-section of pole, showing penetration of creosote.

meat or fish.[1] Beef cured in wood-smoke owes much of its flavor, as well as its durability, to the influence of the volatile wood creosote present in the smoke. All creosote, whether made from wood, water-gas tar, or coal-tar, is poisonous to human beings.

Coal-tar creosote stands by itself among the wood preservatives. The others dissolve in water, but creosote, in addition to being an antiseptic, is nearly insoluble in water. Creosote prevents rot, and also protects wood from the attacks of terrestrial and marine woodborers. The salts of metals do not materially lessen the porosity of wood, but creosote, in sufficient quantities, fills and stiffens within the cell-structures, shuts off the air, with-

[1] For references with regard to wood creosote, see "Report on Wood Creosote Oil," Bixby (United States Forestry Bulletin No. 1); United States Dispensatory; "The Preservation of Structural Timber," Weiss (p. 86).

out which fungi cannot live, and is the only preservative in common use that keeps wood-fibers dry.

No real difference of opinion exists with regard to the value of creosote, the use of which depends almost entirely upon its availability and cost. In Europe, where creosote is comparatively plentiful and cheap, engineers use it for ties and in almost all wood-work that requires preservation. Americans now use it to prevent rot in railway ties, mud sills, bridge timbers, and paving blocks, and to protect timbers designed for marine constructions from teredos and limnoria. Creosote is not yet used as widely in this country for ties as it is abroad, but its use as a tie preservative is increasing.

As manipulated in gas works, mineral coal yields illuminating gas, ammoniacal liquid, coal-tar, and coke. Of these, the tar, which is a sticky black substance, is separated by distillations conducted between certain temperatures, into (1) light oils, that is oils lighter than water, (2) middle oils, (3) heavy oils, that is oils heavier than water, and (4) residue or pitch. The variable mixture obtained during the third distillation is called creosote. This is also shown on the diagram.

Coal

Gas — Ammoniacal Liquid — Tar — Coke

Light Oils — Middle Oils — Heavy Oils or Creosote — Pitch

The list that follows, although incomplete, is sufficient to show the complex nature of coal-tar.[1] As a matter of fact, almost two hundred definite chemical compounds can be separated when this material is subjected to destructive distillation.

When coal-tar is submitted to distillation and rectification, it yields, among others, the following products in varying proportions:[1]

1. Solids. Naphthalene, methyl-naphthalene, acetyl-naphthalene diphenyl, fluorene, anthracene, phenanthrene, fluoranthene, methyl-anthracene, retene, chrysene, pyrene, picene, and carbazol.

2. Liquids. These may be neutral hydrocarbons, acids, ethers of acids, or their bases. The neutral hydrocarbons are benzene, toluene, methyl-toluene, and iso-xylene, pseudocumene, mesitylene, and cymene. The acid constituents are phenol, orthocresol, paracresol, metacresol, phlorol, rosolic acid, pyrocatechin, and creosote, consisting of the methyl ethers of pyrocatechin and its homologues. There are also present,

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[1] "Coal-tar and Ammonia," Lunge (London) United States Dispensatory; "Coal-tar Distillation," Warnes (D. Van Nostrand Company, 1914).

probably in combination with the ammonia of the ammoniacal liquor, acetic, butyric, carbonic, hydrocyanic, sulphocyanic, and hydrosulphuric acids. The bases are ammonia, methylamine, ethylamine, phenylamine, pyridine, picoline, lutidine, collidine, leucoline, iridoline, cryptidine, acridine, coridine, rubidine, and viridine.

3. Gases. (*a*) Illuminating gases. Acetylene, ethylene, propylene, butylene, allylene, crotonylene, terene, and vapors of benzene, styrolene, naphthalene, methyl-naphthalene, fluorene, fluoranthene, hexane, heptane, and octane. (*b*) Heating and diluting gases. Hydrogen, marsh-gas (methane), carbon monoxide. (*c*) Impurities. Carbon dioxide, ammonia, cyanogen, methyl-cyanide, sulphocyanic acid, hydrogen sulphide, carbon disulphide, carbon oxysulphide, and nitrogen.

A highly prized creosote is obtained as a by-product from Newcastle coals burned in the vicinity of London. This creosote, known as "London oil," is thick and heavy. The English Midland districts produce lighter creosotes, known as "country oils." German creosote is much employed. Much, but not all, good creosote now used in this country is imported, the United States not yet having met the demand for this product. Also, much American creosote contains an excess of naphthalene.

Chemical, physical, and physiological results are brought about by the several ingredients that make up creosote. The wood is acted upon by the carbolic acid, cresylic acid, and associated antiseptics. The cells are treated by, or filled with thick, gummy oil and naphthalene, and the creosote, as a whole, is like camphor in that it is disliked by the lower forms of life.[1]

It should be noted that creosotes differ in their behavior when under water. Thick London oils have resisted disintegration in marine positions for forty years, while some American creosotes, applied under conditions that prevail in some parts of this country, have failed after having been exposed to the action of water for a few months.[2]

Creosote should be thick, since thin oil is correspondingly less stable. The specific gravity should be greater than that of water. The influence of temperature is important, because some of the ingredients, relied upon to solidify within the wood when they have cooled, do not distil save at high temperatures. Tidy wrote upon this subject as follows:[3]

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[1] "Descriptions of Creosote Best Suited for Creosoting Timber," Tidy (Appendix 7); Boulton on "Antiseptic Treatment of Timber," the Institution of Civil Engineers, London; "Coal-tar and Ammonia," Lunge (Third Edition, London, pp. 473–477).

[2] "Changes which take place in Coal-tar Creosote during Exposure," von Schrenk, Fulks, and Kammerer (American Railway Engineering Association, Bulletin No. 93, November, 1907).

[3] "Antiseptic Treatment of Timber," Boulton (The Institution of Civil Engineers, London, p. 51).

"Believing strongly as I do in the value of those constituents of the oil that are the most difficult to volatilize, I have deemed it right to suggest a clause to the effect that the creosote shall contain at least 25 per cent. of matters that distil over at about 600 degrees Fahrenheit."[1]

The ingredients or groups of ingredients in coal-tar creosotes that are thought in the United States to exert much influence in wood preservation are light oils, naphthalene, anthracene, or anthracene oils and tar acids. French engineers attribute much to the presence of tar acids, while in England, credit is given to acridine. Because of the complex nature of creosote and difficulties connected with analyses, most specifications omit mention of all but a few of the components and confine themselves to important characteristics and reactions that indicate the genuineness of creosote as a whole.[2]

Mixed Coal-tar Creosotes.—Pine resin has been used to thicken creosote designed for the treatment of paving blocks.[3] Coal-tar is often mixed with pure creosote, the defense being that the supply of pure creosote is insufficient. Other materials or mixtures are also used with pure creosote. It is needless to say that when pure coal-tar creosote, free from the mixture of other substânces, is specified that creosote only should be employed.

The fact that creosote is so variable renders the more necessary some form of specification or control. It is unfortunate that some compounds yet sold as creosote have so little to commend them beyond the name, since failures during this more or less formative period tend to retard the use of the legitimate mixture.

The properties of creosote are of vital importance. It should not be forgotten, however, that there are other factors that exert an equal influence upon the preservation of wood by creosote. The method of application is one of these factors. This should be such that deep impregnation, and the wide diffusion of the creosote, particularly through the outer parts of the timber, result. A poor quality of creosote well injected may yield better results than a good quality of creosote poorly injected.

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[1] Report of Tidy (Boulton on "Antiseptic Treatment of Timber," the Institution of Civil Engineers, London, p. 51).

[2] About 55,000,000 gallons of creosote were used in the wood-preserving plants of the United States during the year 1908. Of this amount, about thirty per cent. was produced in this country, while the balance, about seventy per cent., was imported principally from England, Germany, and Canada.

[3] See Creo-Resinate Process.

Specifications for creosotes are of two kinds. First, certain properties that the creosote should possess are specified; and second, methods of analysis by which the existence of these properties is proved or the properties measured, are specified. It is needless to say that these two fields depend upon one another and that the specifications often overlap.

Specifications for Creosote.—Creosote, once purchased largely on faith, is now bought under more or less rigidly enforced specifications. Controlling items regardless of the purposes for which the oil is to be used relate, principally, (1) to its origin, (2) to the limits of the distillation ranges, (3) to its specific gravity, and sometimes (4) to the percentages of several constituents.

(1) The origin of creosote is controlled by securing it from reputable dealers. (2) The determination of the temperatures between which certain fractions of the original bulk distil is of fundamental importance, since slight changes cause considerable variations to take place in the results of the analysis. (3) It is usually specified that creosotes should have specific gravities of from 101 to 112. (4) The percentages of certain components as tar acids and naphthalene are sometimes stated.

English practice is based upon the Tidy specification,[1] which is as follows: 1. "Creosote should be completely liquid at a temperature of 100 degrees Fahrenheit, no deposit afterwards taking place until the oil registers a temperature of 93 degrees Fahrenheit." 2. "The creosote should contain at least twenty-five per cent. of constituents that do not distil over at a temperature of 600 degrees Fahrenheit." 3. "The creosote shall yield a total of eight per cent. of tar acids."[2]

Of the specifications employed in the United States those prepared by The American Railway Engineering Association, The American Telephone and Telegraph Company, and The United States Forest Service, are, on the whole, most important.

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[1] See Boulton on "Antiseptic Treatment of Timber" (The Institution of Civil Engineers, London, p. 51). Several characteristic European specifications appear with Chanute's paper "Preservation of Railway Ties in Europe" (Trans. American Society of Civil Engineers, Vol. XIV).

[2] Some American and foreign specifications are shown in comparison with one another in a paper entitled, "Changes which take place in Coal-tar Creosote during Exposure," von Schrenk, Fulks and Kammerer (American Railway Engineering Association, Bulletin No. 93, November, 1907).

The specification prepared by The American Railway Engineering Association is as follows:

Standard Grade of Creosote Oil (*Also Known as No.* 1 *Oil*).—The oil used shall be the best obtainable grade of coal-tar creosote; that is, it shall be a pure product obtained from coal-gas tar, or coke-oven tar, and shall be free from any tar, oil or residue obtained from petroleum or any other source, including coal-gas tar or coke-oven tar; it shall be completely liquid at thirty-eight (38) degrees Centigrade and shall be free from suspended matter; the specific gravity of the oil at thirty-eight (38) degrees Centigrade shall be at least 1.03. When distilled by the common method—that is, using an eight (8) ounce retort, asbestos-covered, with standard thermometer, bulb one-half (½) inch above the surface of the oil—the creosote, calculated on the basis of the dry oil, shall give no distillate below two hundred (200) degrees Centigrade, not more than five (5) per cent. below two hundred and ten (210) degrees Centigrade, not more than twenty-five (25) per cent. below two hundred and thirty-five (235) degrees Centigrade; and the residue above three hundred and fifty-five (355) degrees Centigrade, if it exceeds five (5) per cent. in quantity, shall be soft. The oil shall not contain more than three (3) per cent. water.

In addition to the above standard specification, the two following grades can be used in cases where the higher-grade oil cannot be procured. It should be understood that where it is necessary to purchase grades No. 2 and No. 3 consideration should be given to the use of a greater quantity of creosote oil per cubic foot.

Specification for No. 2 *Grade Creosote Oil.*—The oil used shall be the best obtainable grade of coal-tar creosote; that is, it shall be a pure product obtained from coal-gas tar, or coke-oven tar, and shall be free from any tar, oil or residue obtained from petroleum or any other source, including coal-gas tar or coke-oven tar; it shall be completely liquid at thirty-eight (38) degrees Centigrade and shall be free from suspended matter; the specific gravity of the oil at thirty-eight (38) degrees Centigrade shall be at least 1.03. When distilled by the common method—that is, using an eight (8) ounce retort, asbestos-covered, with standard thermometer, bulb one-half (½) inch above the surface of the oil—the creosote, calculated on the basis of the dry oil, shall give not more than eight (8) per cent. distillate below two hundred and ten (210) degrees Centigrade, not more than thirty-five (35) per cent. below two hundred and thirty-five (235) degrees Centigrade; and the residue above three hundred and fifty-five (355) degrees Centigrade, if it exceeds five (5) per cent. in quantity, shall be soft. The oil shall not contain more than three per cent. water.

Specification for No. 3 Grade Creosote Oil.—The oil shall be the best obtainable grade of coal-tar creosote; that is, it shall be a pure product obtained from coal-gas tar or coke-oven tar and shall be free from any tar, oil or residue obtained from petroleum or any other source, including coal-gas tar or coke-oven tar; it shall be completely liquid at thirty-eight (38) degrees Centigrade and shall be free from suspended matter; the specific gravity of the oil at thirty-eight (38) degrees Centigrade shall be at least 1.025. When distilled by the common method—that is, using an eight (8) ounce retort, asbestos-covered, with standard thermometer, bulb one-half (½) inch above the surface of the oil—the creosote, calculated on the basis of the dry oil, shall give not more than ten (10) per cent. distillate below two hundred and ten (210) degrees Centigrade, not more than forty (40) per cent. below two hundred and thirty-five (235) degrees Centigrade; and the residue above three hundred and fifty-five (355) degrees Centigrade, if it exceeds five (5) per cent. in quantity, shall be soft. The oil shall not contain more than three (3) per cent. water.

The specification of the American Telephone and Telegraph Company[1] is as follows:

General.—The material desired under these specifications is that known as dead oil of coal-tar, or coal-tar creosote, obtained through the distillation of gas tar produced by the destructive distillation of bituminous coal, either in the manufacture of coal gas, or in the manufacture of coke by the by-product process. It shall be without adulteration. Information shall be furnished on request as to the origin of the oil and the names of the parties through whose hands it may have passed. A copy of any analysis of the oil that may have been made prior to its use shall also be furnished. The right is reserved to take representative samples of the oil and test the same wherever desired.

Requirements.—All dead oil of coal-tar furnished under these specifications shall conform to the following requirements:

First.—The oil shall have a specific gravity of at least one and three one-hundredths (1.03) at thirty-eight degrees Centigrade (38°C.).

Second.—The oil shall be thoroughly liquid at a temperature of thirty-eight degrees Centigrade (38°C.).

Third.—When one hundred grams of the oil are distilled in accordance with the requirements of the specifications for the analysis of dead oil of coal-tar or coal-tar creosote hereinafter referred to—

(*a*) Not more than five (5) per cent. shall distil off up to 205°C.

(*b*) Not more than thirty-five (35) per cent. shall distil off up to 235°C.

(*c*) The fraction coming over between 210°C. and 235°C. shall solidify on cooling to 20°C.

(*d*) Not more than eighty (80) per cent. shall distil off up to 315°C.

---

[1] Specification No. 3,340, dated March 11, 1911 (in force April, 1912).

(*e*) The oil shall not contain more than[1] two (2) per cent. of water.

(*f*) The quantity of tar acids present in the fractions distilling below 300°C. shall not exceed eight (8) per cent. (measured by volume) of the total sample distilled.

(*g*) The sulphonation residue from the fraction distilling between 300°C. and 360°C. shall not exceed twenty-five one hundredths (0.25) cubic centimeters.

Fourth.—The oil shall be free from acetic acid and acetates.

Fifth.—The constituents of the oil insoluble in benzol shall not exceed one (1.0) per cent. by weight.

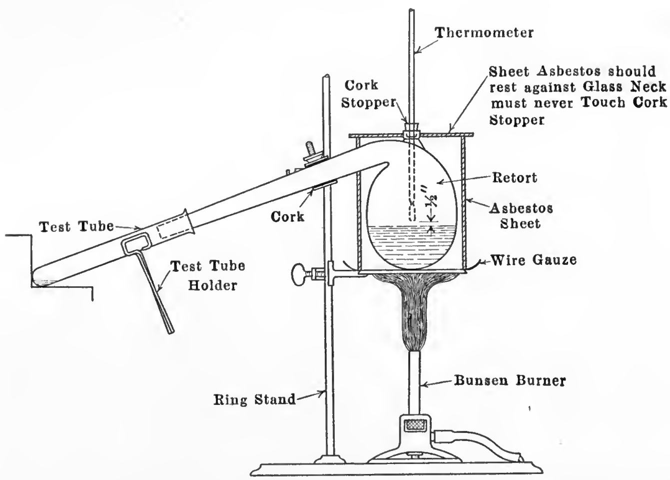


FIG. 74.—Apparatus for analysis of creosote used by American Telephone and Telegraph Co.

Analysis.—The oil shall be analyzed in accordance with the methods outlined in the Specifications for the Analysis of Dead Oil of Coal-tar or Coal-tar Creosote.

---

[1] NOTE.—When unseasoned timber is being treated for the Telephone Company by the cylinder pressure process, using steam for seasoning, the oil may contain not more than five (5) per cent. of water. But in case more than two (2) per cent. of water is present in the oil, the quantity of the preservative added to the timber shall be increased by an amount sufficient to ensure that the required amount of oil computed on a water-free basis has been taken up by the timber.

The United States Forest Service Specification for Creosote gives much attention to methods of analysis.[1]

Specifications for Analysis of Creosote.—The importance of details in analyzing creosotes has been mentioned. The methods and devices employed in determining the proportions of creosote separated between certain temperatures, the methods of measuring viscosity, and those employed to determine other properties, influence the results obtained. This is partly shown in the quotation that follows:[2]

> "The most important part of a creosote analysis is the fractional distillation, since by this operation an approximate determination is made of the relative proportions of the most important substances in tar oil. There has been considerable divergence of opinion as to the best way of carrying out the fractionation of tar oils, some recommending a retort as a distilling vessel and certain temperatures for taking fractions, others recommending a distilling flask and a different set of temperatures."

The shape of the distilling vessel is important, since it exerts an influence upon the quantities and the constituents of the parts, or fractions that are distilled. It is also necessary to decide upon the limits of temperature and the number of these limits that are to isolate, or divide the parts or fractions.

The forms that follow show methods of reporting analyses. The first and second forms have been used to report the results of analyses in which the oil was divided into ten and eleven fractions, while the last form was used to report an oil that ran high in naphthalene.

---

[1] "Standard Method for Analysis of Coal-tar Creosote," von Schrenk, Fulks, and Kammerer (American Railway Engineering Association, Bulletin No. 65). See also American Railway Engineering Association Manual, 1911, p. 441. "The Fractional Distillation of Coal-tar Creosote," Dean and Bateman (United States Forest Service, Circular No. 80).

[2] United States Forest Service, Trade Bulletin No. 13; other references are United States Forest Service Circular No. 80; American Railway Engineering Association Bulletins No. 65 and No. 72; Specifications of the American Telephone and Telegraph Company, New York Telephone Company; also sources enumerated in preceding footnote.

Analysis of Dead Oil of Coal Tar

Sample No. 1 Date: 191 .
Manufactured by:
Purchased from:

Summary of Results

Specific Gravity at 38°C.:
Condition at 38°C.:

Fractionation

Weight of retort		Weight of retort and oil			
Fraction number	Temperature	Per cent.	Weight of vessel	Weight of vessel and contents	Weight of contents
1	170°C.				
2	170°C. to 205°C.				
3	205°C. to 210°C .				
4	210°C. to 235°C.				
5	235°C. to 245°C.				
6	245°C. to 270°C.				
7	270°C. to 300°C.				
8	300°C. to 315°C.				
9	315°C. to 360°C.				
10	Residue (in retort)				

Total per cents. found:

Loss per cent.:
Oil distilling below 205°C.: Per cent.
Oil distilling below 235°C.: Per cent.
Oil not distilling below 315°C: Per cent.
Water: Per cent.
Sulphonation residue: Cubic centimeters
Tar acids: Cubic centimeters
Insoluble in benzol: Per cent.
Acetic acid or acetates:
Condition of naphthalene fraction (210°–235°) when cooled to 20°C.

No. 2 .—DISTILLATION No. 23

Creosote 50 Date 3/ 1/ 17 Analyst——

No.	Temp.	Flask	Flask	Dist.	Per cent.	Character
1	170	49.53	47.34	2.19	0.876	1. Water—some naph.
2	170–205	47.11	45.49	1.62	0.648	2. Light oil—some naph.
3	205–210	42.80	40.77	2.03	0.812	3. Light oil—some naph.
4	210–235	86.45	51.97	34.48	13.792	4. Nearly solid.
5	235–245	71.44	46.34	25.10	10.040	5. Solid.
6	245–255	68.80	49.18	19.62	7.848	6. Semi-solid.
7	255–270	70.90	48.78	22.12	8.848	7. Very thin paste.
8	270–285	60.40	44.73	15.67	6.268	8. Very thin paste.
9	285–300	59.59	41.02	18.57	7.428	9. Thin paste.
10	300–320	80.82	52.38	28.44	11.370	10. Thick paste.
11	320–350	98.32	50.37	47.95	17.180	11. Solid.
Residue.....		128.55	97.32	31.23	12.492	Remarks: Oil almost liquid at 20°C.—Tar acids 5 per cent.
					99.608	

No. 3. REPORT OF TEST OF COAL-TAR CREOSOTE

Date: July 10, 1917. Analyst——

Sample from overflow pipe. Temperature, 48°C.

Oil supplied by—— Boiling, 210°C.

Specific gravity, 1.021. Melting point, 46°C.

Weight Retort 104.71 gr.

Retort and Contents, 204.47 gr. Contents, 99.76 gr.

Retort and Residue, 120.73 Residue, 16.02 gr.

DISTILLATION

Temp.	Fraction	Tube	Weight of tube and contents	Contents	Per cent. of whole
–170°	Phenols, hydrocarbons and water	22.44	22.33	0.09	0.09
170°–205°	Phenols and cresols...........	18.89	22.39	3.50	3.50
205°–210°	Phenols and naphthalene	20.25	27.43	7.18	7.20
210°–235°	Naphthalene..................	20.90	67.75	46.85	46.94
235°–240°	Naphthalene and anthracene oil	12.91	18.50	5.59	5.60
240°–270°	Anthracene oil...............	19.85	31.01	11.16	11.19
270°–316°	Anthracene..................	17.44	26.37	8.93	8.95
	Residue......................	.....	.....	.....	16.06
	Loss.........................	.....	.....	.....	0.47
	Total........................	.....	.....	.....	100.00

Time: { 40° to 210°......29 min. 235° to 270°.........27 min.
210° to 235°......21 min. 270° to 316°.........29 min. }

Percentage of naphthalene 53.34 per cent. (obtained by adding half of the percentage of the phenols and naphthalene, and naphthalene and anthracene oil fractions to the percentage of the naphthalene fraction).

Required Quantities of Creosote.—These depend upon the way in which the wood is used. For example, large quantities of creosote cannot be used in paving blocks because of the possibility that such blocks will annoy pedestrians by "bleeding" or giving up creosote when exposed to the sun. On the other hand, timbers that are to be submerged in marine positions require considerable quantities of creosote.

Practices differ with localities, woods, and the uses for which the woods are intended. In the United States, railway ties are sometimes treated with quantities as small as six or eight pounds to the cubic foot, although the usual local practice is to treat them with ten or more pounds to the cubic foot. Depending upon a wide range of conditions, piles are usually made to receive from twelve to twenty-four pounds to the cubic foot.

An eastern wood preserver advises as follows:

> "In this section of the country (New York) it is customary to subject a railroad tie to a treatment of eight to twelve pounds of creosote per cubic foot of wood. If we figure that a standard tie of seven inches by nine inches by eight feet six inches is being used, this would make a total injection of thirty to forty-four pounds of creosote oil into each tie, depending upon the treatment used. The treatment, of course, depends upon the conditions under which the tie is to be used, whether the conditions are severe or mild."
>
> "In northern waters, twelve to sixteen pounds of creosote oil per cubic foot of wood is considered sufficient for the protection of the piling. However, in the south, where the piling is subject to the ravages of the teredo, etc., it is considered good practice to creosote the piling to point of refusal, which is from twenty to twenty-four pounds per cubic foot."

It should be remembered that some engineers believe that much of the value of creosote depends upon the fact that it keeps wood-fiber dry, and, therefore, think that it should be used in comparatively large quantities, as in the so-called "full-cell" processes; while others regard its antiseptic value more exclusively, and, in ties, use smaller quantities, as in the "empty-cell" processes.

Distribution of Creosote.—Experience has shown that the distribution of creosote throughout every part of every piece is impracticable and unnecessary, but that the thorough penetration into the sapwood and *outer parts* is of vital importance. It is fortunate that sapwood, because of its comparative porosity, and because of its position upon the outside of the timber, receives creosote so much more easily than heartwood receives it.

The tendency of preservatives to lodge near surfaces indicates the desirability of framing timbers before they are treated. Europeans bore ties before they are treated, and finally insert wooden dowels into the borings; these dowels, and not the ties, receive the spikes.

MISCELLANEOUS MATERIALS.—Several proprietary wood-preserving compounds are in existence; these, although recommended for ties, are principally used for small pieces, or for fresh exposures where timbers are cut and framed upon the ground. Carbolineum, woodiline, spiritine, and others are of this group.

Carbolineum.—The base of this mixture is understood to be a modified coal-tar creosote that differs from ordinary creosote in that the lower distilling fractions have been largely removed. Several compounds are sold under the name "Carbolineum."[1]

Avenarius Carbolineum.—This mixture, invented by Avenarius in Germany, in 1869, has been upon the market since 1876. An analysis furnished by the manufacturer, published by Filsinger in the "Chemicker Zeitung" of April 18, 1891, and referred to in Lunge's "Coal-tar and Ammonia," is as follows:

ANALYSIS

Color	Red brown.
Specific Gravity at 62 degrees F.	1.128
Viscosity at 62 degrees F. (water 1)	10.00.
Mineral matter	0.03 per cent.
Flashing point	270 degrees F.
Burning point	370 degrees F.
Begins to distil at	445 degrees F.
Distils from 445 degrees to 520 degrees F.	10.6 Vol. per cent.
Distils from 520 degrees to 570 degrees F.	12.0 Vol. per cent.
Naphthalene (at 410 degrees to 446 degrees F.)	No separation.
Phenols (carbolic acid aac. Seubert)	0.00 per cent.
Residue	a clear red-brown thick fluid.

Avenarius carbolineum is described by the manufacturers as follows:[2]

"To give a short definition for Avenarius Carbolineum, we would say that it is a liquid oil from the very highest boiling and least volatile fractions distilled from coal-tar. It is of course a mixture of oils and

[1] The name "Carbolineum" was registered by Richard Avenarius at the Patent Office in Washington, see No. 14,048. The American Telephone & Telegraph Company purchase "Carbolineum" under the specifications included in the Appendix.

[2] Correspondence, February 24, 1912, quoted by permission.

not a single substance, but this mixture is rigidly controlled and the composition of this product held is more constant than any other oily wood preservative, insuring uniformity of composition and certainty of action."

PROCESSES USED TO INTRODUCE PRESERVATIVES WITHIN WOODS

The process is quite as important as the material. The impregnation must be deep and well distributed through the outer parts of the pieces, and the wood must not be injured by the processes used to secure this impregnation and distribution. Within limits, the same process may be used to introduce any preservative through any species of wood, but, in practice, certain processes have become more or less associated with certain preservatives. The process may be considered as it includes (1) the preparation, and (2) the impregnation of the wood.

Europeans once prepared practically all woods that were to receive preservatives by first steaming them. But, at the present time, much of the best European practice excludes the application of steam save to woods that are to receive watery solutions. The woods that are to receive creosotes are usually prepared by drying. In the United States, early practices included preparatory steaming, and it is yet thought to be better to steam the imperfectly seasoned woods that are presented in such quantities for treatment in the United States, than to hold them in the yard until they are dry.

The second part of the preservative process, that is, the part during which woods prepared by drying or by steaming are brought into contact with the preservative, may be carried out in many ways: woods may be dipped into or soaked in the preservative, or the preservative may be applied with a brush, or may be forced into the wood by pressure applied within a cylinder.

Regardless of details, all methods employed to introduce chemical compounds within woods may be grouped as they are (1) *Superficial Processes*, (2) *Non-pressure Processes*, and (3) *Pressure Processes.*

SUPERFICIAL PROCESSES

Many attempts have been made to introduce preservatives into woods without the assistance of pressure, and several of these attempts have yielded more or less final and satisfactory results.

DIPPING, SOAKING, BRUSH APPLICATIONS.—These methods are often applied to small pieces such as shingles and fence posts, and sometimes to larger pieces such as telegraph poles; but, in the latter case, they are normally considered where treatment is to be confined to certain parts of the timber. As for example, in the case of telegraph poles it is usually best to treat only those portions that are to extend into the ground.

Dipping and soaking include longer or shorter immersions in the preservative. Both practices are economical as to labor, while

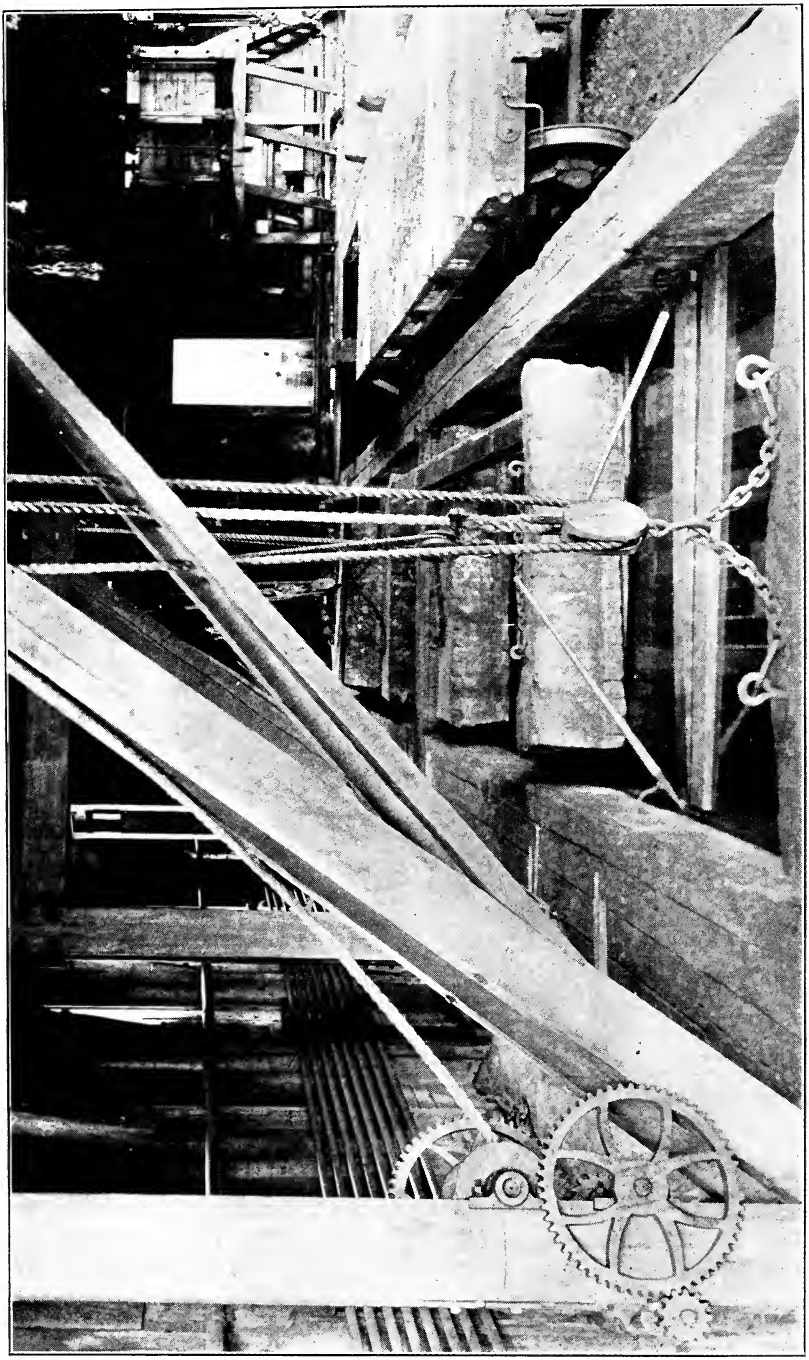
FIG. 75.—Treating poles by brush method.[1]

the latter has the advantage of giving the preservative a better opportunity to penetrate cracks and other places that cannot ordinarily be reached by brushes. When soaking is practised, the wood should remain in the preservative for at least fifteen or twenty minutes. Dipping should be repeated several times. The results from both processes are better when the preservative is heated.

[1] Acknowledgment to United States Department of Agriculture.

REFERENCES.—"Prolonging the Life of Telephone Poles," Grinnell (United States Department of Agriculture, Year Book, 1905); "Brush and Tank Pole Treatments," Crawford (United States Forest Service, Circular No. 104); "Wood Preservation in the United States," Sherfesee (United States Forest Service, Bulletin No. 78); "Preservative Treatment of Poles," Kempfer (United States Forest Service, Bulletin No. 84); etc., etc.

PLATE XVI. TROUGH EMPLOYED IN KYAN PROCESS



(Photograph by Berlin Mills Company, Portland, Maine.)

(Facing page 354.)

Brush applications cost more for labor than do dipping and soaking, but the large receptacles necessary for dipping and soaking are not required when preservatives are applied with brushes. In the latter case the warm preservative is brushed on much as paint is applied. The wood should receive at least two coats. The penetration is superficial, but the fact that the piece is surrounded by what is really a thin, antiseptic "case" is of assistance as long as the case can be preserved.

NON-PRESSURE PROCESSES

THE KYAN PROCESS.—This was probably the first wood-preserving process used in the United States, and it is yet among the best. But its usefulness is limited, because the preservative employed is so expensive.

The timbers are placed in open non-metallic troughs filled with mercury bichloride solution and are held below the surface of the solution by heavy weights such as large stones. The submergence thus obtained is continued for periods that depend upon the shapes and sizes of the timbers treated. Besides the trough, there are facilities for mixing and storing the solutions, but the entire plant is simple and very cheap. It is comparatively easy to obtain good results from the Kyan process in almost any locality. An ordinary oil cask is enough to hold several fence posts with sufficient solution to influence the portions with which the solution comes into contact.

It will be remembered that mercury bichloride dissolves in very hot water, and that the strength of the solution, which diminishes as wood is soaked in it, must be brought back to the required limit whenever necessary. It will also be remembered that mercury bichloride is poisonous to human beings,[2] and that it attacks iron. The Kyan method, which requires less expert care than any other, was suggested in 1832 by an Englishman named Kyan.

THE OPEN-TANK PROCESS.—Many attempts have been made to perfect this process which is designed to treat susceptible timbers without the aid of cylinders. The apparatus required is comparatively simple and the results obtained are more or less

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[1] From "Prolonging the Life of Telephone Poles," Grinnell (Yearbook of Department of Agriculture, 1905).

[2] If this poison is taken into the stomach the patient should receive quantities of fresh milk, or egg water, made by dissolving three or four eggs in one quart of water.

satisfactory. The open-tank process is particularly convenient when small quantities of impressionable woods are to be treated, or where the treatment is to be localized as at the ends of posts or poles. It has not yet been widely adopted, however, nor is it likely that it will ever be extensively employed by those who treat the largest quantities of woods.

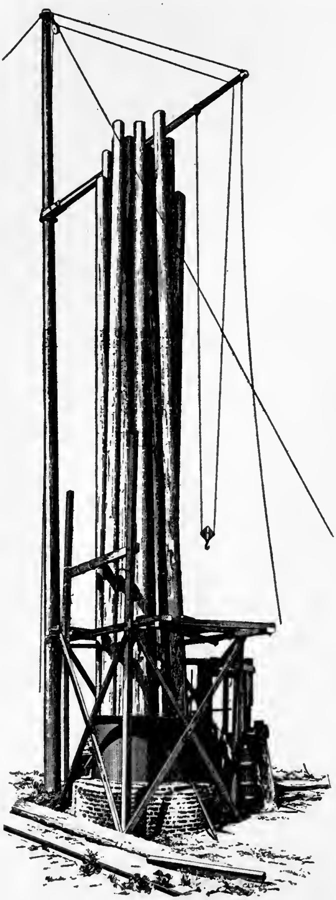


FIG. 76.—Open-tank for Butt treatment of long poles. From "Preservative Treatment of Poles," Kempfer (United States Forest Service, Bulletin No. 84).

The timbers placed in an open reservoir are treated with hot, and then with cool baths of the antiseptic solution. The changes of temperature may be obtained as follows: first, after the pieces have remained in the hot preservative for a sufficient time the fire may be withdrawn and the preservative allowed to cool; or second, the pieces to be treated may be transferred from a tank containing hot preservative to another tank containing cool preservative; or again after the pieces have remained for a sufficient time in the hot preservative the latter is replaced by the cooler liquid.

The time required for penetration varies with seasoning, species, and other factors, and in every instance, must be determined by actual test. It should be noted that sufficient penetration cannot be obtained from

REFERENCES.—"Prolonging the Life of Telephone Poles," Grinnell (United States Department of Agriculture, Year Book, 1905); "The Open-tank Method for the Treatment of Timber," Crawford (United States Forest Service, Circular No. 101, 1907); "Brush and Tank-pole Treatments," Crawford (United States Forest Service, Circular No. 104, 1907); "Wood Preservation in the United States," Sherfesee (United States Forest Service, Bulletin No. 78, 1909); "Preservative Treatment of Poles," Kempfer (United States Forest Service, Bulletin No. 84, 1911); "Preservation of Structural Timber," Weiss (1915); etc., etc.

a hot solution only. On the contrary, the absorption usually takes place during that part of the process where the oil is cool. The principal function of the hot bath seems to be to prepare the wood for treatment. A general case would be as follows: The preservative solution is heated to from 190 degrees to 210 degrees Fahrenheit. Timbers are then placed in the warm solution in which they are permitted to remain for from two to six hours, after which they are placed in the cool solution in which they remain for from two to twelve hours.

The tanks employed in experiments upon large poles have been of two kinds. In some, the bottoms are inclined so that poles can be placed in and withdrawn from the tanks without the aid of derricks or other machinery. This form is convenient, but does not represent an economical design for permanent installation, because the large surface of oil favors the evaporation of the preservative, and because only a few poles can be treated at the same time.

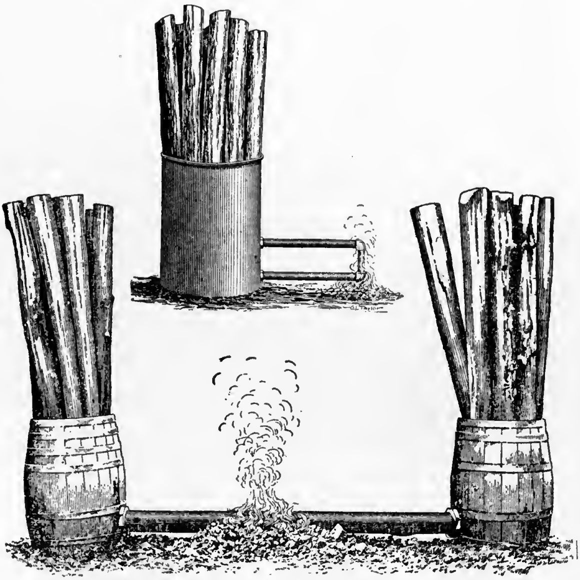


FIG. 77.—Simple apparatus for treating posts.[1]

Other designs provide cylindrical or rectangular treating tanks, in which the poles are placed vertically. Such tanks restrict the surface of the preservative exposed to the air and are thus more economical; but, these vertical tanks require derricks for handling the poles, and are usually intended to be operated in connection with the steam boilers em-

[1] From "Preservative Treatment of Farm Timbers," Willis (United States Department of Agriculture, Farmers' Bulletin No. 387).

ployed to heat the preservative. A storage tank, an oil pump, and an emptying tank can be added to the equipment if the amount of work contemplated and the time required for treating each charge are of sufficient importance to warrant their use.

The simplest kind of apparatus is sufficient where only a few short pieces of responsive wood are to be treated. That shown in the lower picture (see Fig. 77) is not likely to be satisfactory if used many times, because the connections between the pipes and wooden barrels cannot be prevented from leaking ultimately. A much better arrangement includes a light iron tank, about the size of an oil barrel, fitted with a U-connection of two-inch pipe, which projects out for a sufficient distance from the side of the tank, and to which the heat is applied. The first cost of this device is greater than the cost of that shown in the second picture but it is more economical if permanency is desired.

It will be remembered that woods differ in receptivity, and that some kinds receive solutions much better than others. This is shown in some results reported by Kempfer, as follows:[1]

Species	No. poles	Details of treatment				Average penetration inches	Averag absorption pounds
		Hot oil hours	Cool oil hours	Cold oil hours	Temp. hot oil degrees F.		
Chestnut	16	10	14	......	228	0.30	20.7
Chestnut	8	8	14	......	223	0.29	21.3
Chestnut	24	6	14	......	225	0.34	23.6
Chestnut	24	4	14	......	225	0.33	20.9
Chestnut	24	6	..	2	229	0.34	21.3
Chestnut	16	4	..	2	231	0.38	20.6
Western Yellow Pine	42	3	14	......	170–200	3.10	81.4
	56	3	14	......	170–200	3.30	55.5

A specification prepared by The American Telephone and Telegraph Company to guide the treatment of the butts of poles by the Open-tank Method is as follows:[2]

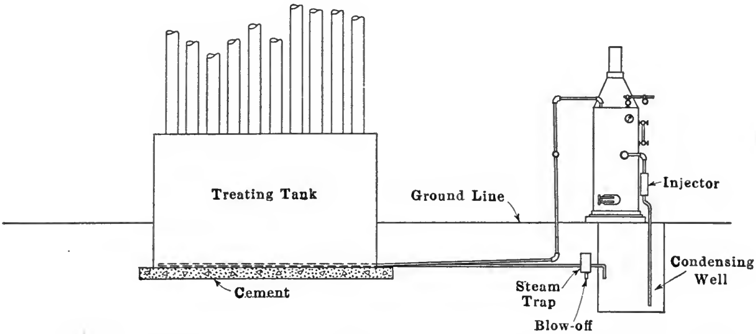
"*Method of Treatment.*

"*Length of Treated Sections.*—The poles shall be arranged in the tank so that all poles shall be covered, throughout the treating process, with oil for a distance from the butt end of not less than that given in the following table:

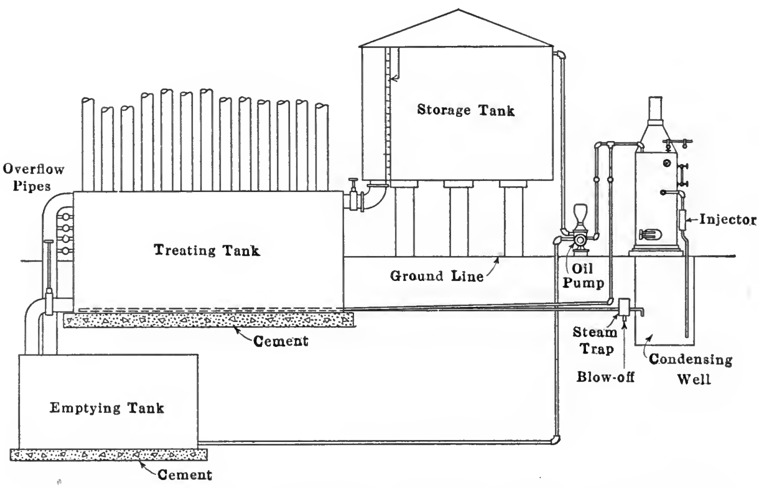
[1] Condensed from United States Forest Service, Bulletin No. 84, Tables Nos. 8 and 18.

[2] Specification 2,977, March 7, 1907 (in force April, 1912).

PLATE XVII. OPEN-TANK PROCESS APPLIED TO BUTT TREATMENT OF POLES



(*a*) Tank with Horizontal Bottom—The Poles Stand Vertically—The Process is Without Change of Oil.



(*b*) Tank with Horizontal Bottom—The Poles Stand Vertically—The Process is With Change of Oil.

Acknowledgments to American Telephone and Telegraph Company.

(*Facing page* 358.)

	Feet	Feet	Feet	Feet	Feet	Feet
Length of pole	25	30	35	40	45	50
Length of treated section from butt of pole	6.0	6.5	7.0	7.0	7.5	8.0

"*Hot-oil Treatment.*—The poles shall be kept in the bath of dead oil of coal-tar maintained at a temperature of not less than 212°F. for cedar, chestnut, and partially seasoned and green loblolly pine poles, or not less than 200°F. for seasoned loblolly pine poles, and not more than 230°F. for seasoned poles, for at least five hours, partially seasoned poles, for at least eight hours, and for green poles, for at least ten hours.

"*Cool-oil Treatment.*—At the completion of the hot-oil treatment, a sufficient quantity of cool oil shall be admitted to the treating tank to lower the temperature of the oil to at least 100°F. The level of the oil in the tank shall be maintained by means of an overflow outlet or an emptying pipe controlled by a valve. Poles shall be kept in the cool oil for at least eight hours.

"If it is not possible to lower the temperature of the oil as above described, the oil shall be allowed to cool by atmospheric exposure. In this case the poles shall be kept in the cooling oil until the temperature of the oil has dropped to at least 110°F., but in no case for less than ten hours.

"The treated section of the pole shall not be exposed to the air during any portion of the treating process.

"*Depth of Impregnation.*—All poles shall be treated so that the oil impregnation shall extend through the sapwood. One pole in ten shall be bored to ascertain the depth of penetration and such borings shall be made four (4) feet from the butt end. The bore hole shall be filled with hot dead oil of coal-tar immediately after the depth of penetration has been ascertained."

The advantages and limitations of the open-tank process have been summarized by Kempfer as follows:[1]

"The tests made by the Forest Service indicate that the sapwood of a great variety of species, including nearly all of our common native woods, when seasoned can be successfully impregnated by the open-tank process. The heartwood of many species offers considerable resistance to impregnation and cannot be so well treated without pressure. However, with the exception of a few species having an unusually narrow sapwood, it is believed that the thorough treatment of the sapwood portion of round timber will afford good protection to the entire stick. Since poles

[1] United States Forest Service, Bulletin No. 84, p. 17.

are almost always used in the round, the open-tank process is especially well adapted to the treatment of this class of timber. The apparatus required is comparatively simple and inexpensive, especially where but few poles are to be handled, and if desired can be made portable.

The open-tank process is not adapted to the treatment of woods which are difficult to impregnate, nor to unseasoned or partially seasoned wood, and as regards economy of operation, has not justified itself in plants designed for the treatment of the entire pole. The large amount of oil lost by volatilization from open tanks and the difficulty of accurately gauging and regulating the amount absorbed are other disadvantages."

PRESSURE PROCESSES

Pressure processes are usually employed when large quantities of wood are to be treated. Not only are such processes convenient and economical when practised upon a large scale, but the results obtained from them are commonly more complete and satisfactory. In practically all cases pressure is applied through the instrumentality of cylinders. An exception, the Boucherie process, which being of historic interest is noted for completeness, required pressure but did not make use of cylinders.

Use of Cylinders.—The use of cylinders is not confined to any single process or preservative. The Bethell, Burnett, Rütgers, Wellhouse, and other pressure processes all employ these devices. The cylinders, which are built of steel, are from five to ten feet in diameter, and from one hundred to as much as one hundred and eighty or more feet in length, while the thickness of the metal is such that working pressures of from one hundred and forty to two hundred and twenty-five pounds can be used with safety. Special doors, pumps, reservoirs, thermometers, gauges, and other parts complete the equipment.

Timbers to be treated in cylinders are arranged loosely on special cars so that solutions with which they will later come into contact may have the freest possible access to their surfaces. The charges are then weighed or measured, and are rolled into the cylinders, the doors of which are closed and bolted.

The manipulations that follow vary with process, preservative, peculiarities of wood, and the wishes of those in charge. In some cases hot air, vacuum, and solutions follow one another, while in others the order is steam, vacuum, and solutions.

The degree of impregnation is determined by gauges that connect with and show the level of the solutions in the cylinders.

A measured quantity of zinc chloride solution of known strength, if that salt is used, or of creosote, or other preservative, is passed into the cylinder and held there under pressure until the gauges show that the desired amount of preservative has been absorbed. The amount of absorption is also occasionally determined by weighing the wood before and after treatment.

It is necessary to consider the conditions of pressure, heat, and vacuum that exist during a process.

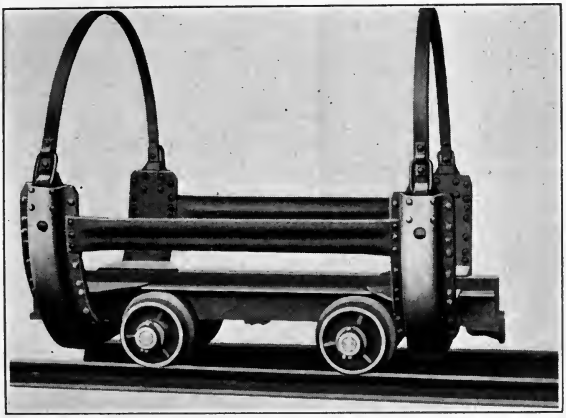


Fig. 78.—Pressed-steel car for cylinder-treatment of ties.[1]

Pressure.—Pressure produced by pressure pumps is used either before the preservative has been forced into the wood, or, later, as a means of forcing it into the wood. When pressure precedes saturation it is with the idea that the compressed air stored within the wood will act subsequently by driving out most of the free preservative. This detail is practised in the Rüeping and other so-called "empty-cell" processes. In the "full-cell" processes the pressure is applied with the preservative. It will be remembered that dry heat and steam may both be diffused by air pressure, which may be manipulated so as to assist in several ways. Pressures beyond one hundred and seventy-five pounds to the square inch are seldom required. The distinction between full-cell and empty-cell processes should be noted.

Heat.—Several results may be accomplished by manipulating heat in and out of cylinders. The heat may be wet or dry. Moist heat, that is, steam, expels moisture and impurities and cures green woods. Much American practice depends upon the assumption that woody cells receive foreign substances better when they become wet and distended by steam-

[1] Photograph supplied by Allis-Chalmers Manufacturing Company, Inc.

ing, although, as a matter of fact, experiments have shown that a larger degree of penetrability is secured when the wood is very dry. Long steaming is usually unnecessary and is often injurious. High heat, whether wet or dry, should be avoided. Dry heat, as applied in kilns, cures woods as well as shrinks them. When it is applied in cylinders to woods that are to receive preservative treatment, it acts by expelling moisture and by warming the woods so that they will receive the preservative better. Dry heat in excess of 212 degrees F. expels some of the volatile products of the wood, which then becomes correspondingly weak and brittle. The equivalent of this in moist heat is not known. When heat is carried to the point where charcoal is formed the durability of the wood is increased to some extent because the parts that are charred are sterilized. It is needless to say that charring is not practised with woods that are to receive antiseptics.

Vacuum.—When vacuum succeeds steam, it acts by withdrawing from within the cell-structures of the wood vapors that have been formed there by the steam. There is also a surprising quantity of half coagulated impurity that bears witness to the necessity of some such cleansing process. The results of vacuum applied to recently steamed green wood have been described by Andrews as follows:[1] "There is at this time no appreciable amount of moisture within the cylinder. The vacuum pump has worked a very few minutes, however, when the vapors, partly condensed in the pump, begin to pour from the nose of the pump, and they continue to come for hours, filling, if the wood is green, many barrels with sap."

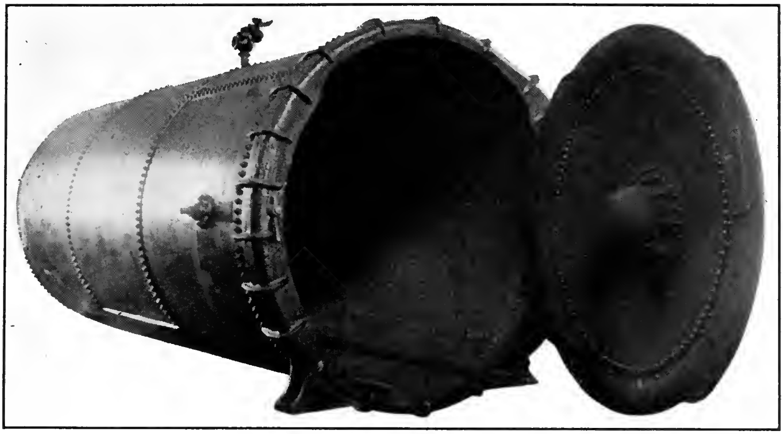
The so-called "*full-cell*" and "*empty-cell*" processes should be distinguished from one another. A full-cell creosote process is based upon the assumption that, besides acting as an antiseptic, creosote coats or fills the woody cells and keeps them dry; a relatively large amount of oil is here required. An empty-cell creosote process is based upon the assumption that the creosote acts principally as an antiseptic, and that more or less prolonged contact with it is sufficient; in this case much of the creosote forced into the wood is withdrawn and saved so that this process is less expensive.

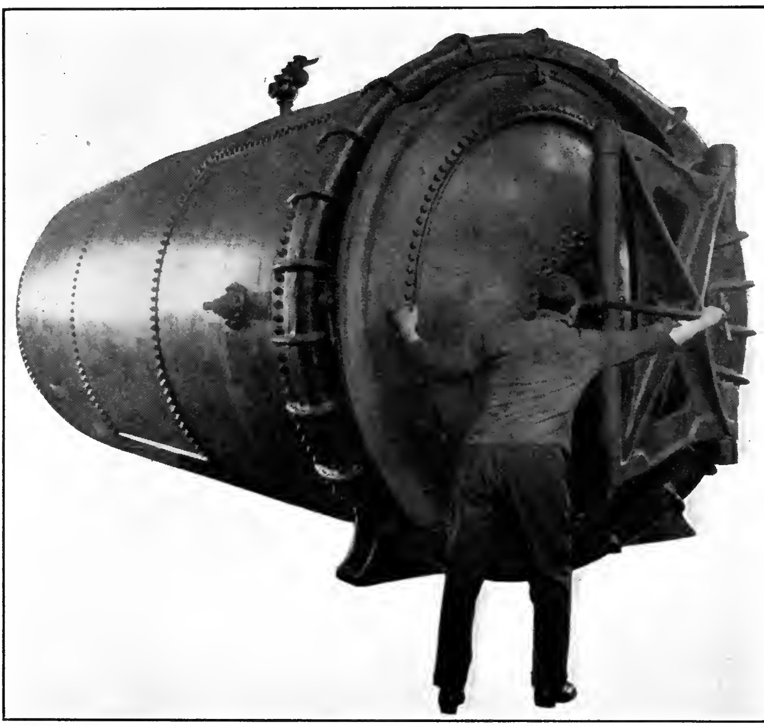
These terms are also used where other preservatives, besides creosote, are employed. General definitions would be as follows:

A full-cell process is one which *fills* the walls and the cavities of the wood cells with the preservative. A maximum quantity of the preservative is received in, and is retained by, the wood.

[1] "The Hayford Process and Apparatus for Preserving Timber," E. R. Andrews (Journal of the Franklin Institute, February and March, 1878).

PLATE XVIII. STEEL CYLINDERS DESIGNED FOR TREATING WOOD





(Photographs by Vulcan Iron Works.)

(*Facing page* 362.)

An empty-cell process is one by which the walls of the cells of the wood are *treated* with preservative. The cell cavities are *not left filled*. The preservative is forced into the wood, but much of it is then withdrawn. The amount retained is much less than in the case of the full-cell process.

THE FULL-CELL PROCESSES. The Bethell Process.—The Bethell Process of impregnation has always been associated with the use of creosote. The original patent taken out in England in 1838 did not include the word "creosote," but, instead, referred to a method by which any one of eighteen substances or mixtures might be introduced into wood. Creosote was an ingredient in one of the mixtures mentioned, and is yet the preservative associated with this process. A distinct feature of the Bethell Process as first practised in Europe was that the woods to be treated were not steamed, and this detail is yet practised where the process is exactly followed.

More or less completely seasoned woods are placed in cylinders, a vacuum is drawn by air pumps after which warm creosote is directed into the cylinder and held under a pressure of from one hundred to one hundred and eighty pounds until the required absorption has taken place. It is amusing to note than an early objection to this process was founded upon the fact that it forced "too much creosote" into the wood.

The Bethell Process was not at first accepted in the United States because it was costly, and because it was not designed to treat unseasoned woods. Andrews, writing in 1878, stated that this "defect" of the Bethell system had always been recognized in Europe, where ties and timbers intended for creosoting were stacked up for nine to ten months to season.

The Bethell was the original creosote process and it is yet the standard. The best results have been obtained through its instrumentality. But the fact that the process as first detailed abroad is suitable only for the treatment of seasoned woods, and the further fact that large amounts of oil are required, have led to some modifications.

In the United States the principal demand is for the treatment of green or imperfectly seasoned woods and with this in mind,

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References.—"Antiseptic Treatment of Timber," Boulton (Proceedings Institution Civil Engineers, London, 1884); "Preservation of Timber," Report of Committee (American Society of Civil Engineers, 1885); "Preservation of Structural Timber," Weiss (1915); etc., etc.

in 1872, Hayford suggested that woods be prepared by steam instead of by drying. With the difference noted the Bethell and Hayford processes are alike. The latter title is now seldom used, while the title "Bethell Process" has been extended in the United States to include the preliminary steaming of green woods, as well as the preliminary drying of seasoned woods.[1]

The London, Brighton & South Coast Railway Company apply creosote under a specification as follows:[2]

"The sleepers, when sufficiently dry, are to be placed in a wrought-iron cylinder, and, when closed, a vacuum is to be created by air pumps. The creosote, at a temperature of not less than 120 degrees Fahr., and not more than 150 degrees, is to be allowed to enter the exhausted cylinder, and afterwards is maintained there by pumping at a pressure of not less than 120 pounds to the square inch. The sleepers are to be kept under this pressure until each sleeper has absorbed at least three gallons of creosote on the average, the quantity to be ascertained by weighing. Any charge of sleepers not giving the average impregnation of at least three gallons is to be returned to the cylinder for further treatment."

The Eppinger & Russell Company employ details as follows: Wood is steamed at about twenty-five pounds pressure. The steam is succeeded by vacuum of about twenty-eight inches; the oil is then admitted and held under a pressure of from fifty to two hundred pounds, as the quality of the wood may indicate. Such minor changes are made from time to time as appear to be suggested from experience.[3]

A specification prepared by the Southern Creosoting Company of Slidell, Louisiana, is as follows:[4]

"*Steaming Process.*—The seasoning of the timber shall be accomplished by the direct application of live steam admitted into the treating cylinders. The steam gauge pressure in the cylinders shall be regulated according to the dimensions of the timber. During the process of steaming the cylinder must be frequently drained by a valve located at the lowest possible point. The steaming must continue from three to fifteen hours, according to the size of the lumber and the quantity of oil to be injected into it. At the end of the steaming period a vacuum shall be created in the cylinder, the temperature being at all times maintained

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[1] "The Hayford Process and Apparatus for Preserving Timber," Andrews (Journal of the Franklin Institute, February and March, 1878).

[2] In force February, 1916.

[3] In force December, 1915.

[4] In force January, 1916.

above the boiling point. The vacuum must continue until the gauge shows a reading of from twenty-two to twenty-six inches, and to be kept at that reading until no moisture comes from the bottom of the cylinder.

"After the material has been thoroughly seasoned and it has been ascertained that no sap or moisture remains in the cylinder, the oil shall be admitted at a temperature of not less than 120 degrees Fahr., which temperature shall be raised to not less than 185 degrees Fahr. under a pressure of not less than 125 pounds per square inch. The force pump producing this pressure shall be kept in operation until the established system of measurement shows the wood to have absorbed the desired quantity of oil.

"The pressure shall then be released and the timber completely treated shall be immediately removed from the cylinders."

The American Telephone and Telegraph Company applies creosote to timber other than Douglas fir under the very complete specification that follows.[1] The specifications do not cover the treatment of crossarms:

"*General.*—These specifications describe the processes to be used in impregnating timber, except crossarms, with dead oil of coal-tar and are intended to include all instructions necessary for the proper performance of the work.

"*Testing Facilities.*—The manufacturer shall provide and install such apparatus as is necessary to enable the inspector to determine that the requirements of these specifications are fulfilled. It is suggested that recording temperature and pressure instruments be provided.

"*Workmanship.*—All material shall be of the best quality unless otherwise specified herein and all workmanship shall be sound and reliable in character and of the best grade.

Materials

"*Timber.*—The timber subjected to the creosoting treatment shall conform to the requirements of the specifications and drawings furnished by the telephone company. All timber shall be framed, shaped, and bored before treatment.

"The material in each charge shall be in approximately the same condition so far as air-seasoning is concerned, and under no circumstances shall green, partially seasoned, or seasoned timber be treated together in the same charge.

"Two kinds of timber, for example yellow pine and black gum, shall not be treated together. When the southern yellow pines are treated, longleaf and Cuban pine shall not be included in charges with shortleaf and loblolly pines.

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[1] Specification 3,156, April 3, 1909 (in force April, 1912).

"Only one class of material shall be treated in any one charge, for example, poles and ducts shall not be treated together.

Dead Oil of Coal-tar.—The dead oil of coal-tar used in impregnating the timber shall conform to the requirement of the American Telephone and Telegraph Company's Specifications for Dead Oil of Coal-tar or Coal-tar Creosote. The telephone company shall have the right to take samples of the oil whenever its inspector shall elect. The sample of oil so collected shall be tested wherever the telephone company shall elect.

"*Quantity of Oil.*—All timber shall be so impregnated with dead oil of coal-tar that the average impregnation of the material in each cylinder load shall not be less than the quantity of oil called for in the specifications for the material or in the contract. The volume of timber and the quantity of oil absorbed shall be determined by the inspector. The inspector shall have access to all records of treatment.

"Excess of oil in one charge shall not be offset against a shortage of oil in another charge.

"The treating plant shall be equipped, to the satisfaction of the telephone company, so as to allow a close determination of the amount of oil injected into the timber.

"The quantity of oil injected into the timber, as determined by the volume of oil withdrawn from the measuring tanks, shall be based on the standard temperature of 100°F., and the quantity increased by an amount equal to 0.00044 of the required volume at 100°F. for each degree Fahrenheit of oil temperature above the standard temperature of 100°F.

"*Treatment*

"*General.*—The treating cylinder shall not be opened during the process of treatment.

"*Classification.*—For the treating process timber shall be classified as heavy or small.

"Heavy timber shall be understood to include poles and stubs; small timber shall, unless otherwise specified, include all other timber, except crossarms, ordered by the telephone company.

"*Steaming and Heating Process.*—Steam when used shall be maintained at a uniform pressure and temperature in the treating cylinder as indicated in the following table:

	Steam pressure		Steam temperature
	Not less than	Not greater than	Not greater than
For heavy timber	17 pounds	20 pounds	259°F.
For small timber	12 pounds	15 pounds	250°F.

"The temperature readings shall be taken by means of standard thermometers placed in the treating cylinder so that the bulbs thereof are within the shell.

"At the beginning of the steaming process the exhaust valve shall be open and shall not be closed until a steady flow of steam escapes through the valve. The duration of the steaming process shall be timed from the closing of the exhaust valve. The exhaust valve shall be opened and the condensation blown off at intervals during the steaming process.

"The duration of the steaming process shall be as directed by the inspector and shall depend upon the condition and character of the timber, but shall in no case be carried to such an extent as to injure the timber. The timber shall not be steamed in excess of the interval given in the following table:

	Green or very wet timber	Partially seasoned timber	Seasoned timber
For heavy timber.................	8 hours	5 hours	0 hours
For small timber..................	5 hours	3 hours	0 hours

"Seasoned timber shall not be steamed, but shall be heated in the treating cylinder. The temperature within the cylinder shall be maintained by means of the closed heating coils at a temperature of about 150°F.

For heavy timber.................... for at least 2 hours.
For small timber..................... for at least 1 hour.

"*Exhaustion Process. Green and Partially Seasoned Timber.*—When the steaming process shall have been completed the steam shall be blown off and the treating cylinder exhausted to a vacuum of at least twenty-four (24) inches at or near sea level, or proportionately less at higher altitudes. The vacuum shall be maintained at the above minimum for a period: for heavy timber, of not less than 2 hours; for small timber, of not less than 1 hour; and if necessary thereafter until the condenser discharge is clear. During the exhaustion process the temperature within the treating cylinder shall be maintained, by means of saturated steam in the closed heating coils, above that at which water would boil at that degree of vacuum.

"*Exhaustion Process. Seasoned Timber.*—With seasoned timber it is not required that a vacuum shall be drawn after the heating process and before the filling process, provided that the specified amount of dead oil of coal-tar is in the timber on its removal from the treating cylinder.

"*Filling Process.*—After the exhaustion process, the cylinder shall be completely filled, as rapidly as possible, with dead oil of coal-tar and in no case shall the flow of oil into the treating cylinder be stopped before the overflow of the cylinder. Pressure shall then be applied until the specified amount of oil has been forced into the timber.

"The total amount of oil forced into the timber shall be determined from the initial reading on the measuring tanks and the readings on the measuring tanks after the oil in the cylinder at the conclusion of the pressure process, including all drip from the timber, has been returned to the measuring tanks.

"The oil at introduction into the cylinder shall have a temperature of not less than 140°F. and not more than 175°F. The oil in the measuring tanks shall be maintained at a uniform temperature during the filling process.

"*Subsidiary Specifications.*—The following specifications of the American Telephone and Telegraph Company form a part of these specifications:

"Specifications for Dead Oil of Coal-tar, or Coal-tar Creosote.

"Specifications for Analysis of Dead Oil of Coal-tar, or Coal-tar Creosote."

The specification adopted by the American Railway Engineering Association is given on page 448 of the 1911 Manual published by that organization.

The Burnett Process.—This process, which was patented by Burnett in 1838, depends upon the use of zinc chloride. The immediate value of this salt as an enemy of wood-destroying fungi is about equal to that of creosote, but because the salt dissolves readily in water, the results are not as lasting. Neither is it known that zinc chloride repels the attacks of teredos and other shipworms.

The method of impregnation is similar to that employed in the Full-cell Creosote Process. The wood is steamed, partly dried in a vacuum of from twenty to twenty-five inches, and then treated with warm zinc chloride solution which is held under pressure until the required absorption has taken place. Here as elsewhere, results are influenced by attention paid to details. The object is to transfer the required quantity of antiseptic to the interior of the wood, and to secure the greatest practicable uniformity of distribution without injuring the wood.

References.—"The Artificial Preservation of Railroad Ties by the Use of Zinc Chloride," Curtis (Transactions American Society Civil Engineers, Vol. XLII, 1899); "Handbook of Timber Preservation," Rowe (Author's Edition, 1900); "On the Determination of Zinc in Treated Timbers," Fulks (American Railway Engineering Association, Bulletin No. 65, 1905); "Visual Method for Determining the Penetration of Inorganic Salts in Treated Wood," Bateman (United States Forest Service, Circular No. 190); etc., etc.

The Burnett Process is essentially a tie-preserving process and is not suitable for timbers that are to be exposed in marine positions. It is cheaper than creosoting, and particularly useful with ties which are to be exposed in climates and surroundings that are not too wet. Under such conditions the life of the ties is frequently doubled. A field of usefulness is with inferior woods that must now, with the scarcity of better kinds, be employed. It is needless to urge that prevention of decay should be adjusted as far as possible to the natural mechanical life of the tie and that expensive treatments are not warranted with ties that wear out before they rot. The Burnett and Full-cell Creosote Processes were compared by Chanute as follows:[1]

"An average life of ten to twelve years is being obtained by the use of zinc chloride in this country. It would be possible to obtain a life of fifteen to thirty years by the use of creosote, but it will be seen from the figures given[2] that this would cost three to four times as much as zinc chloride.

"We must be content, therefore, either to allow our cheap ties to decay in the good old way, or to adopt for the present some of the cheaper and inferior methods which will produce shorter lives than obtained in Europe."

The Burnett method is much used in the United States and Europe.

THE EMPTY-CELL CREOSOTE PROCESSES.—The Rüeping and Lowry processes have for their object the wide diffusion throughout the wood of limited quantities of creosote. In both cases air-seasoned wood is preferred, although in the Rüeping Process green woods can be and frequently are treated after they have been prepared by steaming and vacuum as in the Hayford Process.

The Rüeping Process.—This process is characterized by the use of compressed air, which is admitted to the cylinder and held there until the fabric of the wood is thoroughly penetrated. At

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[1] "The Preservation of Railway Ties in Europe," Chanute (Transactions American Society of Civil Engineers, Vol. XLV, p. 509).

[2] "The Artificial Preservation of Railroad Ties by the Use of Zinc Chloride," Curtis (Transactions American Society of Civil Engineers, Vol. XLII, pp. 288–374).

this stage the wood is sometimes described as being "filled with compressed air." Creosote is then admitted under a slightly higher pressure, the air in the cylinder gradually escaping. The pressure is then raised to about one hundred and fifty or more pounds, at which point it is made to remain for a sufficient time.

Finally, the pressure is released when the air which was first introduced within the wood expands and drives out much creosote. A vacuum which follows assists in this result. Considerable oil thus recovered is referred to as "kick-back." The penetration obtained during the Rüeping Process may be as deep as that secured during the Bethell Process, while at the same time much less creosote is required. The Rüeping Process is used extensively in the United States and in Europe.

The Rüeping Process is detailed by a railway company[1] located in the southeastern part of the United States, as follows:

"Compressed air is pumped into the main cylinder which is filled with timber, and into the Rüeping cylinder which is filled with creosote. This integral air pressure, which amounts to from twenty-five to seventy-five pounds per square inch, is the means by which the final amount of oil to be retained in the wood is regulated.

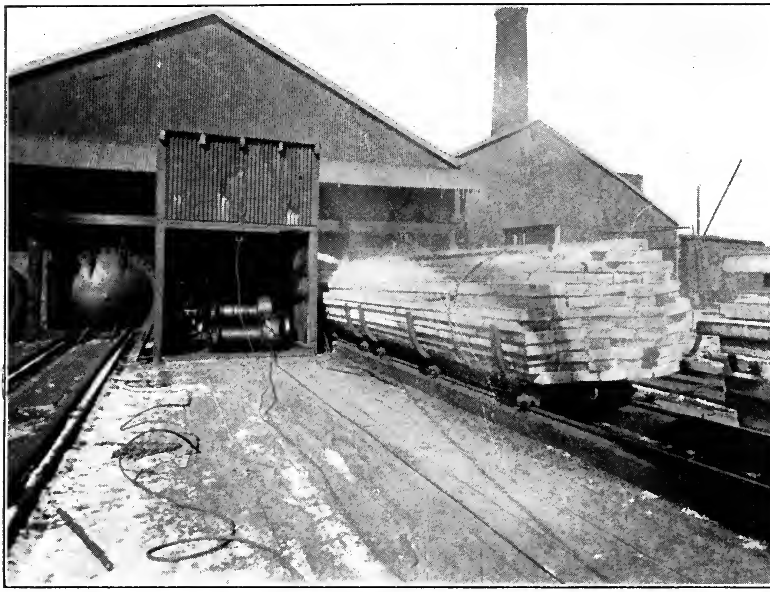
"The cylinder containing the timber and the Rüeping cylinder containing the creosote being under the same pressure, the oil in the Rüeping cylinder is directed into the main cylinder without decreasing the pressure in the latter cylinder. Additional pressure, amounting to about one hundred pounds, is now applied to the contents of the main or heating cylinder by means of pressure pumps. If the initial pressure was sixty-five pounds, the pressure would now be about one hundred and sixty-five pounds to the square inch. The amount of the pressure and the duration of the period during which it is applied are determined by experience.

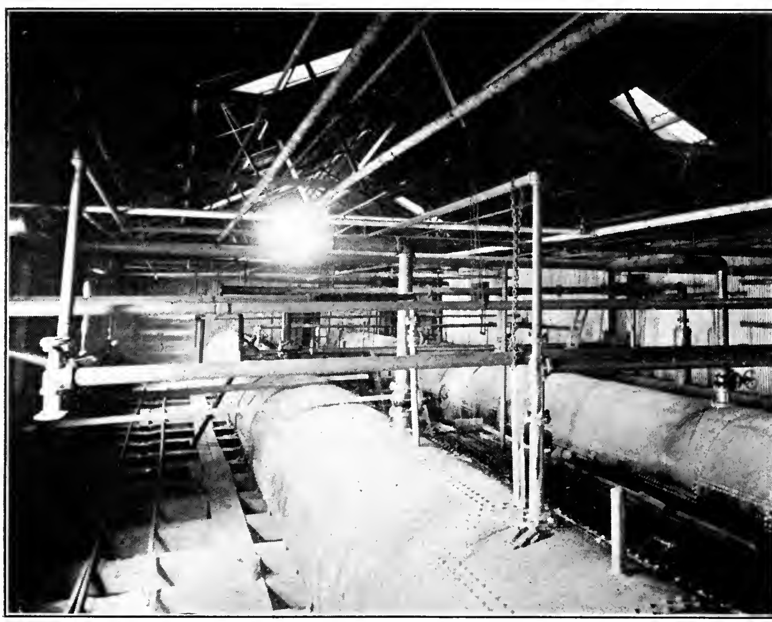
"On the completion of the pressure period a valve is opened and the pressure released. The one hundred pounds of pressure last applied is itself first released after which the initial pressure escapes. The initial pressure coming from the interior of the timber drives out the loose creosote and leaves only the walls of the cells coated. A vacuum is drawn and the charge is released."

The Lowry Process.—This process differs from that just described in that compressed air is not employed. The wood is first air-seasoned and the air present naturally in wood thus dried is assumed to be sufficient to drive out superfluous creosote

[1] The Charlotte Harbor and Northern Railway Company at Hull, Florida.

PLATE XIX. PLANT FOR CREOSOTING LUMBER





(Photographs by Eppinger & Russell Company.)

(*Facing page* 370.)

after the antiseptic has been introduced by methods similar to those used in the Rüeping Process. The Lowry Process also aims to secure a deep penetration of creosote with less oil than is required by the Bethell or Full-cell Process. The Lowry Process is extensively used throughout the United States.[1]

THE ZINC-CREOSOTE PROCESSES.—The Rutgers, Card, and Allardyce Processes make use of zinc chloride and creosote. The first-named antiseptic is used because it is cheap, and the last is used because, in addition to its intrinsic value, it retards the escape of the zinc chloride. The two preservatives are forced into the wood while mixed together in the form of an emulsion, or they are introduced separately one after the other.

In the Rutgers Process, the zinc and creosote are introduced while mixed together by means that resemble those employed to introduce pure creosote during the Bethell Process. In Germany, where every attention is paid to detail, the Rutgers Process has caused pine ties to last for from fifteen to eighteen years. The process has been practised successfully for about forty years.

The Card Process differs from the Rutgers Process in the means used to mingle the antiseptic liquids. These are first mixed together by forcing air through perforated pipes located at the bottoms of the mixing tanks; the agitation is then continued by means of centrifugal pumps. Further details resemble those followed in the Bethell Process. The best results are obtained with air-seasoned woods.

The Allardyce Process is planned so that the preservatives are introduced separately one after the other. First, a solution of zinc chloride is introduced into the wood by an air pressure of about 130 pounds per square inch. The cylinder is then drained and is refilled with creosote which is finally subjected to a pressure of about 180 pounds per square inch. The penetration of creosote is not great and the process itself is not extensively used at the present time.

THE ZINC-TANNIN PROCESS.—In the Wellhouse Process glue and tannin are used in attempts to retard the escape of zinc chloride. Otherwise, the Wellhouse and Burnett practices resemble one another. Both depend upon the preservative properties of zinc chloride; but in the Wellhouse Process glue and tannin, acting upon one another, form inert solids which obstruct the escape of the soluble zinc chloride. The Wellhouse Process is

[1] "Preservation of Structural Timber," Weiss (1915, pp. 59–60).

comparatively cheap and has succeeded in greatly increasing the length of life of some perishable woods. On the whole, however, the results secured from this process have not been as satisfactory as were at first hoped for.

THE BOILING PROCESS.—This process is largely used for the treatment of Douglas Fir. Either green or seasoned woods can be treated. The Boiling Process is described by Sherfesee as follows:[1]

"This process is used principally on the Pacific Coast, and for Douglas Fir, an exceedingly difficult wood to treat. The timber, usually green, is placed in the treating cylinder, which is then filled with creosote heated to a temperature slightly above the boiling point of water. This hot bath is continued for from several hours to more than two days, depending upon the size and condition of the timber. During the bath much of the water in the sap is driven off, together with the volatilized light oils. These vapors are caught in a condenser, the water is decanted off, and the oil is run back into the receiving tank to be used over again. Finally, an oil pressure of 100 to 125 pounds is applied, and, at the same time, the temperature of the oil is allowed to fall, thus forcing the preservative into the timber."

THE CREO-RESINATE PROCESS.—As first detailed, wood was subjected to dry heat, after which a vacuum was drawn. Creosote, resin and formaldehyde were then applied while mixed together. It is said that woods were hardened as well as preserved by this process, which has been extensively employed in the preparation of paving blocks.[2]

The Boucherie Process.—Cylinders were not employed in this process. The inventor first attempted to distribute preservative substances through the wood of standing trees by introducing the substances into the sap of the trees, and the process as patented called for the presence of sap or other moisture within the wood that was to be treated.

Several methods were ultimately suggested by Boucherie for forcing solutions into the woods after the trees had been cut down.[3] In the principal one, pressure was obtained by elevating the tank that contained the solution. The tank thus elevated was connected with a cap designed to fit over one end of the timber, and the antiseptic solution was passed

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[1] "Wood Preservation in the United States" (United States Forest Service, Bulletin No. 78, p. 15).

[2] Transactions of the American Society of Civil Engineers, Vol. XLIV.

[3] "Wood Preservation," Flad (United States Forestry Bulletin No. 1, p. 69).

from the tank through the timber until the moisture that emerged from the opposite end of the timber was proved by tests to be nearly pure.

The introduction of better methods led to the practical abandonment of the Boucherie Process even in France, where it was most practised. Criticisms were that the work had to be done in the forest, and that every stick of timber had to be handled separately. This would have prevented the method from being used upon a large scale, even if the results accomplished by it had been more satisfactory.

Experiments made more recently to determine whether zinc chloride solution and creosote could be forced into single pieces of wood by pressure obtained by the use of ordinary hand pumps, yielded results that were neither uniform nor satisfactory.[1] In this case, a steel cap was made to fit over the butt of the timber. The cap was connected with the pump and with the reservoir containing the hot preservative.

Although the Boucherie process can be used with other antiseptics, it is generally associated with copper sulphate.

SOME MISCELLANEOUS PROCESSES.

Charring.—Charring is an internal as well as an external process. Not only does the shell of charcoal protect from bacteria, but the wood beneath is more or less sterilized. Charring is defective because its field of application is limited, and because so much of the wood is destroyed.

Vulcanizing.—Destructive heat was not concentrated as in charring, but less heat was diffused throughout the wood by means of compressed air. The result was accomplished by placing the wood in cylinders and then subjecting it to dry heat with pressure. Chandler reported favorably upon this process, which is no longer practised upon a large scale. Vulcanized ties were used for some time on the New York elevated railways.

The Robbins Process.—This now historic method, from which much was expected, was designed to use a minimum of creosote in the form of vapor. The high temperature necessary to volatilize good creosote injures wood, and the process, which failed in practical tests, was long since abandoned. The Robbins Company was highly capitalized. A convention held in the Astor House in New York in 1869 was attended by delegates from Maine to California who referred to the inventor as a "great public benefactor." The expectations of those interested in this process were not realized.

The Seeley Process.—The charge was placed in a bath of hot creosote which was then more or less abruptly replaced by cold creosote. It was believed that the heat volatilized the sap in the wood, and that the

[1] "Prolonging the Life of Telephone Poles," Grinnell (United States Department of Agriculture, Year Book, 1905).

vacuum caused by the condensation of the vaporized sap when the cold creosote was introduced would draw quantities of creosote into the wood. The process was conducted in closed cylinders. It is interesting to compare it with the open-tank process.

The Powell Process.—Timber is boiled in a strong solution of sugar. It is claimed that seasoned woods are cured and the toughness is increased.

The Thilmany Process.—An injection of copper sulphate was followed by a bath of chloride of barium. An interchange of the constituents of these two salts, if brought together in the proper proportions, left the timber impregnated with chloride of copper and sulphate of barium. The insoluble sulphate of barium was relied upon to prevent the removal of the soluble chloride of copper.

The Hasselmann Process.—The wood was boiled in a solution of copper sulphate, iron sulphate, aluminum sulphate, and a small quantity of kainit. This method was first used by the Bavarian Government.

The Ferrell Process.—The salts selected recombine in the wood as in the Thilmany Process. The impregnation is manipulated from the ends of the pieces as in the Boucherie Method.

The Creoaire Creosote Process.—This process, which is designed to overcome the tendency of creosote to lodge near the surfaces of timbers, consists in subjecting woods, that have been creosoted, to a final air pressure, by means of which the creosote is driven in from the surface and deposited more evenly throughout the mass.[1]

WOODS THAT ARE TO RECEIVE TREATMENT

Some woods last naturally without treatment longer than other woods will last after they have been treated.

It is often well to consider the economy of treating non-durable woods that are tough and strong and that respond to treatment. For example, beech is desirable structurally save for the fact that it rots quickly in exposed places; yet it receives antiseptic solutions better than white oak receives them and, after being suitably processed, will last for a long time.

The results obtained with beech by the French are often quoted. Beech ties are seasoned for at least six months and are then kiln-dried for from sixty to eighty hours to expel the remaining moisture and to warm the pieces so that they will not chill the creosote. Each tie then receives an average of sixty pounds of creosote. Experience has led to

[1] Yet occasionally practised by the International Creosoting and Construction Company, Galveston, Texas.

the belief that such ties will last in the track for at least thirty years, and that they will finally fail by wear rather than by rot.[1]

The ability of wood to receive preservative treatment is influenced by the character and arrangement of its cell-elements. The presence of tyloses in the large vessels or pores of such woods as white oak and black locust interferes correspondingly with the treatment of these woods. As a rule, sapwood is more open to the passage of preservatives than is heartwood. Large quantities of yellow pine are now treated with preservative, while von Schrenk suggests, beech, maple, birch, red and swamp oaks, gum, hemlock, and even cottonwood as American species that should receive consideration in this connection.[2]

Individual pieces, as well as species, vary from one another in receptivity. For this reason, as far as possible, charges should be made up of pieces that are nearly similar to one another. Refractory pieces should receive such special attention as is necessary to overcome extra resistance.

The tendency of preservatives to lodge near the surface of pieces should be recognized, and, whenever possible, timber should be cut, shaped, or fitted before it is treated.

CONCLUSIONS

1. Cheap woods, or those used in inexpensive or unimportant constructions, are seldom treated with preservatives at the present time in the United States. Woods are now treated only when they become costly, or when they are to be used in works that do not permit renewals or repairs at reasonable prices.

2. Zinc chloride and creosote are used more than all other wood preservatives.

3. Zinc chloride is soluble in water, and therefore cannot be used with woods that are to be exposed in marine positions. Neither is it known that it protects woods against marine and terrestrial woodborers. The principal field of zinc chloride as a wood preservative is with railway ties that cannot be economically treated with the more expensive creosote.

4. Experience has shown that wood can be protected against rot, and against marine and terrestrial woodborers, by the intelligent use of sufficient quantities of good creosote.

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[1] "Preservation of Railway Ties in Europe," Chanute (Transactions American Society of Civil Engineers, Vol. XLV, 1901).

[2] United States Department of Agriculture, Yearbook, 1903 (p. 42).

5. Creosote is complex and variable. It should therefore be purchased from reputable dealers, and its properties should be controlled by specifications.

6. The details of wood-preserving processes call for knowledge, skill, and integrity on the part of the operator. A poor method well detailed may afford better results than a better method poorly detailed.

CHAPTER XV

Protective Methods—External Treatment. Oils, Paints, Varnishes, and Other Coatings. Their Application to Surfaces of Wood

Outside coatings not only protect from outside conditions, but at the same time seal up any moisture that may be present within the wood. Moisture thus enclosed makes rotting possible. Furthermore, since oil and water do not mix, paints will not behave in a satisfactory manner if applied to woods that are wet. It therefore follows that no coating of any kind should be applied to wood that is not dry and well seasoned.

External coatings, which are of many kinds, are employed both to beautify woods and to protect them against marine life and abrasion, as well as moisture and the decay caused by bacteria and fungi. Woods may be enclosed by metal, plaster, masonry, and charcoal, as well as by paints and varnishes.

A protective coating is not always decorative, but a decorative coating always affords protection. Paint is a *Material of Construction*, and its behavior in construction is quite as important as its color or appearance. The durability of any coating must generally influence that of the substance which it covers.

The cost of the most expensive coating is generally less than the present cost of the labor required to apply it, and the more intricate the surface, the greater the disproportion between the bill for labor and the bill for material. True economy consists

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References.—"White Lead and Zinc Paints," Petit (Scott, Greenwood & Sons, London, 1907); "Lead and Zinc Pigments," Holley (Wiley & Sons, 1909); "Linseed Oil," Ennis (Van Nostrand, 1910); "Chemistry of Paints," Friend (Longmans, Green & Company, 1910); "Materials of the Painters' Craft," Laurie (Foulis, London and Edinburgh, 1910); "German and American Varnish-Making," Bottler and Sabin (Wiley & Sons, 1912); "Technology of Paint and Varnish," Sabin (John Wiley & Sons, 1917); Files of Painters' Magazine; Oil and Color Trades Journal; Proceedings of the Paint and Varnish Society (London); Farben-Zeitung (Berlin); Engineering News; Engineering Record; Railway Gazette; Transactions American Society for Testing Materials; Journal Industrial and Engineering Chemistry (American Chemical Society).

in selecting the paints and other materials that last longest, so that there will be the longest possible intervals between renewals.

Woods that are to be coated may be within doors, protected from the weather, or out of doors, exposed to the weather. Polished surfaces, enamels, fine varnishes, and ordinary oil paints are common in the case of interior surfaces, while oil paints predominate in connection with exteriors, which are much simpler in their requirements. Ships, passenger cars, carriages, furniture, and some other constructions require special methods, that are distinct from the simple protection of ordinary woodwork by paint.

The behavior of a paint when applied to unpainted wood differs from its behavior when applied to unpainted metal. Paint sinks into the pores of clean, dry wood to an extent that is not possible with metal. Woods themselves differ in receptivity, the loose-grained species absorbing the paint more readily than do those with the closer grain.

PAINT.—A paint is a mixture of a vehicle and a pigment. Although oil, varnish, glue, or any other fluid that will cement solid particles together in a satisfactory manner, may be employed as a vehicle, linseed oil is the common vehicle in the paints that are used in construction.

A pigment is a more or less inert base that will join with oil to form a paint. The function of the vehicle is to cement and give strength, while the pigment serves to afford solidity, color, and hardness. White lead, zinc white, and the iron oxides are among the basic pigments that are commonly applied to woods.

A paint is a mechanical mixture or suspension, rather than a chemical combination. Paint, as a substance, fails when changes take place in the dried vehicle or binding material. As a coating, paint may fail by abrasion, as by rain or dust, by contraction, expansion, and cracking, or because it has been applied to surfaces that were not clean and dry.

VARNISH.—Varnish is obtained by dissolving resins in oil or spirit. Oil varnish differs from spirit varnish, in that oil takes a permanent place as part of the dried film; whereas spirit simply dissolves the varnish resins and then evaporates from them. The mixture that results, when pigment is added to varnish, is known as an enamel or varnish paint. In such paints, varnish, instead of oil, is the vehicle.

Varnishes are solutions, and thus differ from paints, which are mechanical mixtures. A paint may or may not be prepared by the consumer, but a high-grade varnish, which can be manufactured only by a chemical process, can seldom be prepared by the consumer.

The subject is one that must be considered in three parts, namely: the *materials of which paints and varnishes are composed;* the *methods used to apply paints and varnishes*, with the influence of such methods upon durability; and *the preparation of woods to receive paints and varnishes.*

MATERIALS USED IN PAINTS AND VARNISHES

OILS.—All oils used in constructions may be divided into three groups; solidifying oils, that can be used in paints because they change, upon exposure, into tough, leathery solids; non-solidifying oils, that are not used in paints and that are mentioned in this place only for completeness; and volatile oils or spirits, that serve to dissolve or to dilute paints.

Solidifying Oils and Driers.—Solidifying oils do not dry in the ordinary sense of the word, because of loss of water, but because of chemical changes which they undergo when they are exposed to the air at ordinary temperatures and in thin sheets. Oil from walnuts and oils from other sources possess this property, but oil from common flaxseed is preferred for ordinary conditions, both because it affords good results, and because it can be obtained in commercial quantities at reasonable cost. The Chinese Tung Oil is also very valuable.

Linseed Oil.—Linseed oil is drawn from the seed of the flax plant by hot or cold pressure, or by solvents, and is then treated to a process of purification. The tough, elastic, semi-translucent solid, into which this oil changes upon exposure, is known as linoxyn or oil-rubber.[1] This solidified or "dried" compound, although occupying smaller space, has increased in weight from ten to eighteen per cent., because of oxidation or other changes that have taken place.

Pure, raw linseed oil requires some days to solidify. This time may be reduced by boiling the raw oil with certain metallic salts, or by adding compounds, known as driers, to the raw oil. In each case the object

[1] Although linoxyn or oil-rubber is not nearly as elastic as true rubber, it has been used with true rubber. The "drying" or solidification of linseed oil has presented many problems and is described in "Some New Points in Paint Technology," Sabin (Laboratory Bulletin, January 31, 1911). See also "Linseed Oil," Ennis (D. Van Nostrand Company).

of the metallic salt, or other drier, is to act, as a catalyzer, by transferring oxygen from the air to the oil. Raw oil with added drier is often referred to as boiled oil, even although it has not been boiled.

Raw linseed oil penetrates better and is more durable than boiled oil, or oil to which a drier has been added; but, since the weather cannot be relied upon to remain clear long enough for raw oil to dry, drying should be hastened by adding the smallest possible quantity of drier to the raw oil.

A product prepared by heating refined linseed oil, without driers, until it has become thick and viscous, but not jelly-like, is known as lithographic oil. This product, the use of which is rapidly increasing, is employed in varnishes as well as in printers' ink.

Tung Oil, China Wood Oil, Elaeococca Oil.—This oil, which is derived from the seeds of the Tung Oil tree (*Aleurites fordii*),[1] has long been employed in the Orient, for waterproofing and other purposes. The Chinese have used it to waterproof their umbrellas, and to prepare paper so it could be used for glazing.

Tung Oil is a drying oil of the very first value; and its position as a Material of Construction is more and more realized in the United States, to which country large quantities are now brought every year. Within a few years it has largely displaced the use of linseed oil in the manufacture of certain varnishes, that are valued because they dry more rapidly than linseed oil varnishes, because they are not liable to crack, and because they ultimately present tough, durable, alkali-resisting, flat, that is not glossy, surfaces. Tung Oil is used in flat wall finishes and, in mixtures, to waterproof cements. The oil possesses a strong, characteristic odor which is largely removed during the cooking and manipulating that it receives while being manufactured into varnish. Sandalwood oil, cedar oil, citronella, and other chemical compounds are sometimes used in the attempt to smother this odor, but they do not succeed because they so largely evaporate.

Driers.—Driers should be purchased from reputable dealers, and should be used in the smallest possible quantities. Sabin states that although drier injures paint, yet "the lack of it is fatal, for paint must dry within a reasonable time." Driers carry oxygen throughout the depth of the coat. Oxides of lead and manganese are fundamental driers. Chemically, driers are catalytic agents.

A japan drier cannot be definitely distinguished from other driers, although the name japan usually refers to driers that, with other proper-

[1] "The China Wood Oil Tree," Fairchild (United States Bureau of Plant Industry, Circular No. 108); Files of Oil, Paint and Drug Reporter; "Index of Patents, Technology, and Bibliography of China Wood Oil (Tung Oil)," George H. Stevens and J. Warren Armitage (Published by Authors at Irvington and Newark, New Jersey, 1914).

ties, are characterized by the fact that they will harden into varnish-like films. Japan varnishes are called after the country in which they originated. The name japan may apply to a drier or to a varnish. Most driers are "proprietary mixtures."

Non-solidifying Oils.—Oils of this class are mentioned for completeness. These oils are not used in paints, but some semi-solidifying oils—that respond to the action of driers—are used for this purpose, particularly in prepared paint mixtures. Non-solidifying oils are used as lubricants which serve to fill the minute inequalities that exist on the surfaces of all machine materials and, therefore, should not under any circumstance solidify or "gum." Although lubricating oils are manufactured principally from petroleum, the group also includes whale, olive, lard, and many other oils.

Volatile Oils and Spirits.—Turpentine, benzine, benzole, and alcohol are the volatile oils and spirits most used with paints and varnishes. Turpentine contains a small proportion of gummy cementing substance that eventually becomes part of the finish. Benzine and alcohol vaporize completely without leaving residues.

The excessive use of volatile solvents injures paints because they thin the oils upon which paints depend for their strength. A thinned paint spreads easily and covers a greater surface, but the dried film is correspondingly thinner. A thinned paint dries rapidly, but is less durable. Turpentine may cause direct injury to exactly prepared paint mixtures, and should seldom normally be employed in any outside or weather coat.

Volatile solvents are of advantage when paints are to be applied to close-grained woods or to already existing hardened paint. Pure oil is too thick to sink sufficiently into many woods, while old paint is often so hard that paint without turpentine will not adhere.

PIGMENTS.—A pigment contributes thickness, opacity, hardness, solidity, and color. Oil binds the particles of pigment together, as stones are bound in concrete, and pigment thickens the oil. The hard particles of pigment assist the paint in resisting abrasion.

Oil shrinks in drying; and the minute openings that are formed would cause the coating to become porous, if it were not for the particles of pigment used to fill them. The openings are very small, and the pigment should be in correspondingly fine powder. Pigments are also relied upon to produce exact colors.[1] The principal pigments used in paints that are applied to woods are white lead, zinc white, the iron oxides, and carbon.

White Lead.—Approximately $2PbCO_3.Pb(OH)_2$. This opaque, heavy, white pigment is usually ground in a small quantity of oil and sold as a paste, with which the necessary additional quantities of oil are later mixed. White lead mixes well, works easily under the brush, and is in every way the most satisfactory of the white pigments, although less durable than some that are not white. Any tint may be produced by adding the proper pigment to a body paint of white lead.

White lead ultimately degenerates into a form that permits a chemical union to take place between it and the oil. This change takes place much more rapidly in some cases than in others. White lead lasts longer within houses, or in the country, than upon the outside of houses, or in the city. White lead "chalks" very rapidly near the seashore.

White lead as a coat fails, as other coats do, by contraction and expansion, with resulting cracking and peeling, much of which can be postponed by judicious mixing and application. In spite of defects, no other white base has as yet been discovered that presents many of the properties that render white lead so desirable.

Zinc White (ZnO).—Oxide of zinc is prepared by roasting metallic zinc, or non-sulphurous zinc ores, and by permitting the vapors that result in either case to combine with atmospheric oxygen. Zinc white is lighter, harder, whiter, and less changeable than white lead; but it requires more oil and does not spread as well as white lead; neither does it adhere as well as that pigment. Three coats of white lead are usually equal to five coats of zinc white. Zinc white and white lead may be mixed together with advantage.

Barium Sulphate ($BaSO_4$).—Barium sulphate, barytes, or heavy spar, is a heavy, brittle, white or light-tinted mineral that is capable of being ground to a smooth, colorless, and chemically inert powder. It is often affirmed that this substance is used as an adulterant; but, if this is so, it does not greatly injure the paint. It is a cheaper base than are lead or zinc pigments, but more coats are needed if the work is to present as solid and opaque an appearance. The field for pure barium paints has been limited.

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[1] The principal colors are produced by the following pigments:

White	White lead, zinc white.
Black	Lamp black.
Red	Red lead.
Blue	Ultramarine and Prussian blue.
Yellow	Chrome yellow (lead chromate $PbCrO_4$).
Green	Chrome green (chromium sesquioxide).
Brown, red-brown, etc	The siennas, umbers, etc.

A pigment should be opaque when it is wet. Even ground glass is white and opaque as long as it is dry, but loses much of its opacity when water is added. Barium sulphate, silica, and some other pigments otherwise satisfactory lose much in this connection when compared with white lead or zinc white, although otherwise some of them compare favorably with those pigments.

There are other white pigments. As some clays are used for making bricks, and others are used for making porcelains, so certain fine white clays, known as china clays, are dried, ground and used as pigments. Painters' silica and ground quartz are the same. Infusorial earth is too fine to serve as a pigment, but has been used with more or less success in fillers.

Red Lead (Pb_3O_4).—Red lead is made by oxidizing litharge (PbO), and often contains from one per cent. to as much as twenty-five per cent. of residual litharge. If much litharge is present, the linseed oil used in mixing does not change to linoxyn; but, in this case, a lead compound is apparently formed, and the oil and pigment harden, even although shut in from the air. True red lead, that is, red lead without residual litharge, and oil remain mixed for years without reaction. The United States Government now specifies that the product known as "red lead" must contain at least ninety-four per cent. of true red lead (Pb_3O_4), and, for some uses, specifies ninety-eight per cent. or even a larger proportion of true red lead. For under-water use red lead paints should be mixed with genuine boiled oil. Red lead paints usually adhere to iron with great tenacity. In the United States they are seldom used on wood, except as it contains pitch; but in foreign countries red lead paints are often used, as other paints are used, to prime woods.[1]

Iron Oxides (Fe_2O_3 and variously hydrated oxides).—Iron oxides may be natural or artificial. Natural oxides result from hematites and limonites. Those from the former mineral are harder, more costly to grind and have more or less dull, brownish-red colors; while the softer limonites present a series of somewhat lifeless yellows. Natural ores vary greatly in their adaptability for use as pigments, chemical and physical peculiarities being responsible for many grades and colors. Sienna is one of the most brilliant of these ferruginous earth colors. The ochres and umbers are also among them. Many natural ores are roasted before they are ground. Umber when thus roasted is known as burnt umber.

Ordinary iron oxide paints are applied to both woods and metals. They spread well, adhere firmly to wood and are very durable. They are often preferred for large surfaces of wood that are to be covered without much regard to color. Natural oxide paints are thus used on freight cars, sheds and barns; while the finer, more attractive grades, with some of those that are manufactured artificially, such as Tuscan

[1] See also "Red Lead," Sabin (Author's Edition).

and Indian reds, are used upon residences and passenger coaches. The field is a large one, and covers many grades or kinds of paint. Considerable quantities of oxide paints are used on steel structures, but such paints for this purpose are giving place in many sections to carbon paints.

Carbon (C).—Carbon is a chemically inert substance, and is, therefore, well adapted for use on iron. Lamp black, bone black, ivory black, and graphite are the forms most used in paint. Carbon is seldom used for the body of a paint to be applied to wood, but rather to tint such a paint. It is largely used on metal. Lamp black, obtained from the imperfect combustion of oil, is so bulky that a barrelful may weigh less than twenty pounds. It requires more oil than other pigments, and causes the paint to dry slowly, because of a small proportion of non-drying oil which it frequently contains; pure lamp black is neutral, and neither retards nor assists in the drying of the oil. A paint of lamp black is one of the most durable of all paints.

Common graphite is laminated even after it has been ground into small particles; and the manufacturers who use it state that the minute particles arrange themselves when in paint, overlapping one another much as scales do upon the sides of a fish. Certainly, the particles are very fine, and, regardless of their arrangement, the fact exists that some paints of this class are very durable when laid upon iron. Most American graphite is mixed so intimately with the rock in which it occurs that all of the rock cannot be removed. The silica present does not appear to exert an injurious influence, however. Personal preference must be exercised in choosing between the several forms of graphite and lamp black paints.[1]

FILLERS.—Woods are more or less porous, and should be primed before ordinary paints are applied to them, not only because paints of normal thickness cannot penetrate sufficiently to attach themselves to woods, but also because a porous wood tends to separate oil from pigment. The materials or mixtures used for priming woods should accord with the coatings that are to be applied later. Some mixtures will not adhere to others. Sometimes treatment that prepares for paint does not prepare equally for varnish, and sometimes the same treatment does for both. Oils, varnishes, thin paints, and prepared fillers are all used to prime or to fill woods that are to be painted or varnished.

Woods that are to be painted should be primed or filled with thin paint or pure linseed oil. Sabin states that "the best filler for wood that is to receive ordinary oil paint is a coat of linseed oil." This sinks into the wood and fills pores that might otherwise separate the oil from

[1] An interesting material, in the nature of an amorphous graphite, which is known as Acheson graphite, is manufactured from coal in electric furnaces by the Sherwin-Williams Company.

the pigment when the full paint is later applied. It affords a base to which the paint will adhere, and reduces the tendency to scale. Even pure oil is sometimes too thick and heavy to sink into some woods, and must be thinned by turpentine, in order to secure the proper degree of penetration. When pure oil is used for priming, it often becomes hard to determine whether some portion of the work has not been overlooked, since there is but little difference in the appearance of unprimed parts and parts primed with pure oil. The small quantity of pigment which is commonly added to the oil gives color to the wood and removes this danger. Moreover, a little pigment assists by penetrating and filling the pores of the wood.

A filler must be of such a nature that it will enter the wood, and then, like the cement used by dentists, dry without shrinking. Proprietary fillers are manufactured from silica, powdered bark, white lead, or other substances combined with oil or varnish. Paste fillers are better than liquid fillers, although the latter are more convenient.

Varnish itself is often used to fill woods that are to be varnished or polished, and is an excellent, although expensive, filler. A priming varnish should be thin, so that it will sink into the wood. Spar varnish is often thus laid directly upon wood that is to be exposed to the weather. Other coats of varnish are added until a firm and durable case is built up.

GUMS, RESINS AND VARNISHES.—True gums dissolve in water, while true resins dissolve in oil or spirit. There are also gum-resins, parts of which dissolve in oil and parts in water; and yet other exceptions, as india rubber, that dissolve in special solvents, such as carbon bisulphide.

The name resin is seldom heard among varnish-makers, and, commercially, the name gum is applied to many substances that are really resins. True gums, such as gum-arabic, are not employed in the manufacture of varnishes that are to be used on woods. A solution of true gum in water is called a mucilage.

Varnish resins have been roughly divided into fossil, semi-fossil, and fresh-product resins. The origin of many fossil and semi-fossil resins is uncertain. Amber is a fossil resin, while dammar, mastic, and pine resins are among the fresh-product resins.

Varnish resins may also be roughly divided into those used with oil and those used with spirit. Kauri resin is thus preferred in oil varnish, while shellac, dammar, and mastic are among those used in spirit varnishes. The distinction between oil and spirit as solvents has been noted in the section devoted to oils.

Most varnish resins are classified from the geographical or physical standpoint rather than from that of exact botanical origin. As the wood known in trade as "cedar" may come from several species, so varnish resins may be grouped by experts without reference to the trees from which they came. Amber is said to represent about fifty extinct botanical species. Time and the process of mineralization have doubtless obliterated many minor distinctions due to species.

Statements found in the literature of this subject are often contradictory and misleading, but it is certain that characteristics do exist that enable experts to classify these products and to estimate their value for varnishes. Resins are often called by different names in different places, but reputable manufacturers, guided by their own standards, make selections that enable them to present uniform and reliable varnishes.

Most fossil resins must be heated before the changes take place that enable them to yield to the solvents employed by varnish makers. Temperature, the proportions of resins and solvents, the combinations of resins with one another, and other details are important in the formation of tough, hard, durable, and otherwise desirable mixtures.

Amber.—This hard and costly mineralized resin is found in small, detached masses, in a few alluvial deposits. The total annual yield of the important Baltic field is said to be less than one hundred and fifty tons. The best pieces are used for ornamentation, beads, and the mouth-pieces of pipes, while refuse, or black amber, is said to be manufactured into special varnishes that can be used for the protection of oil paintings.

Copal.—This name is applied, without regard to botanical or geographical origin, to a wide range of resins used in the manufacture of varnishes. When classified geographically, copals take name from ports of shipment, and are described as Manila, Zanzibar, Sierra Leone, South American, or other copals. They are also sometimes divided into true and false copals, the former including the harder, more lustrous, and refractory products, and the other, those that are softer, more variable, and more easily dissolved. It will be seen that the name copal is a general one, the value of which cannot be exactly told save from its context.

Anime.—This is also a general name, which, although often seen, means very little to modern varnish makers.

Zanzibar.—This is one of the hardest, most brilliant, and most permanent resins available to varnish-makers. With other resins, it enters into the durable mixture known as "spar varnish;" and also into most of the good varnishes designed for interiors. It is an ingredient of some of the most satisfactory piano varnishes. Zanzibar resin is considered wherever a high degree of hardness, brilliancy, and permanence is desired.

Kauri.—Fossil kauri is collected by digging over fruitful areas from which parent trees have disappeared, while fresh kauri is obtained from the living Kauri Pine (*Dammara australis*). The best fossil-kauri is one of the most valuable constituents of good oil varnish, since it possesses the property of uniting with linseed oil more perfectly, and at lower temperatures, than most of the resins now employed in the manufacture of varnish.

Shellac.—This valuable fresh-product resin is obtained from deposits found upon twigs and small branches of certain East Indian trees (such as *Croton lacciferus*). The crude exudations known as lac are believed to have resulted from the stings of peculiar insects often found imbedded in the twigs and branches.

The exudations, which are divided, according to form, into stick lac and seed lac, are purified, melted, and finally spread upon flat surfaces to cool. The resulting sheets or shells are known as "shellac." Shellac is the principal constituent of sealing wax; and it is used for other purposes, but principally in spirit varnish.

Shellac is valued in construction because, when applied with alcohol, it is not influenced by any resins that may be within the wood. Oil paints should not be applied directly to resinous woods; and knots should always be coated with shellac before they are painted. Shellac varnish is valued in this field because it dries so rapidly that resins do not have time to mix with it. Shellac varnish is more or less influenced by water which leaves white spots wherever it is permitted to stand long upon the coat. Shellac is prepared by dissolving four or five pounds of shellac in a gallon of alcohol, and should be thinned whenever necessary.

Sandarack.—This fresh product resin is obtained from trees (*Callitris quadrivalvis*) which are native in Morocco and other districts along the north African coast. There are also independent Australian and Tasmanian sandaracks. It is a rather brittle and transparent product, and is used to some extent in the preparation of a fairly hard, pale, spirit varnish, suitable for light-colored woods. The resin is one of those used in finishing pianos.

Sandarack was known to, and was used by, the ancients in their ointments and incense. In powdered form it was once dusted over mural decorations, to which it was later fixed by the application of heated irons. Powdered sandarack was the English "pounce" that was applied from pounce or poncet boxes to paper from which erasures had been made.

Dammar.—Some of the rather soft, friable, white resins, classed under this name are said to be obtained from the species *Dammara orientalis*. As shellac is a type of the resins that serve with alcohol, so dammar is a type of those that serve with turpentine. Dammar is popular because of the ease with which it can be dissolved. It enters the whitest varnishes and is a medium in some white enameled paints. It is often hardened by the addition of other substances.

Mastic.—This fresh product resin is obtained, in part at least, from the species *Pistacia lentiscus*, which grows in many Mediterranean countries. It is fairly clear and brittle, but becomes white and plastic when masticated, hence the name mastic. It dissolves in volatile solvents and serves in spirit varnishes, some of which are used to protect oil paintings.

Rosin.—Common pine-rosin, or colophony, known as rosin, is one of the poorest and cheapest of fresh-product resins, and is obtained by distillation from crude turpentine. Rosin when hardened artificially serves as a base in most cheap varnishes. Rosin varnish, when first applied, appears brilliant and glassy, but soon fades; cracks appear, and the varnish eventually scales from the wood. The addition of oil will postpone this result.

The manufacture of varnish calls for strict integrity, as well as much skill, on the part of the manufacturer. A varnish of cheap pine-resin can be made to resemble, in appearance, one prepared from high-priced kauri. The proportions of oil and other solvents, and the uses to which the mixture is to be put, are also important. It is usually better to refer the use to which the varnish is to be put, to the manufacturer, who, upon receiving such a statement, will submit the mixture that is most likely to succeed.

Some Miscellaneous Materials.—Stains are dyes employed to change the natural color of woods. They do not conceal the woods as paints do, and differ from both paints and varnishes in that they do not form coatings. Stains influence durability only when their constituents possess preservative properties. They are of many kinds, but may be roughly divided as they are mixed with water or with oil. Stains are sometimes prepared by adding a little dry pigment, such as bismark brown, to shellac. The tints presented by most finished hardwoods depend upon the properties of the stains that are almost invariably used in finishing them.

Avenarius Carbolineum is an antiseptic wash or coating, the use of which has been attended with considerable success, particularly in the case of timbers that, after having been treated with creosote or some other preservative, must then be cut or fitted upon the ground. The manufacturers recommend the use of at least two coats of this proprietary mixture, which is said to consist of a "coal-tar distillate" with zinc chloride and other preservatives. It should be applied to dry and seasoned wood. Avenarius Carbolineum stains clean wood a nut-brown color.[1]

Whitewash, often used to whiten or to disinfect woodwork, is prepared by digesting fresh lime in water until the lime has thoroughly slaked; after the mixture has been strained into a clean vessel, it is ready for use. The addition of glue, salt, linseed oil, and some other materials, will render the coating more permanent, so that when dry, it will not rub off on objects that come into contact with it.

Kalsomine is a mixture of fine calcium carbonate of the grade known as Paris white, with glue, coloring matter, and water. Crude chalk, that is, calcium carbonate, in fine powder, is agitated in water. The coarsest particles settle first, while those that are finer remain longer in suspension. Paris white is one of the finest of the grades thus separated. Whiting is another grade.

Most "cold-water paint" contains small quantities of zinc oxide, combined with larger quantities of china clay and casein. As used, the latter substance dissolves in water but upon drying does not dissolve a second time. "Cold-water paints," which are more or less waterproof, are comparable with, although in many ways superior to, whitewash and kalsomine. They are not so smooth as kalsomine and differ from whitewash, in that they sometimes become mouldy when applied in damp places. For this reason, they should not be used in cellars.

METHODS OF APPLICATION

METHODS USED TO APPLY PAINTS.—The methods employed to apply paint to wood have a fundamental influence upon the durability of the coatings. The paint should be thoroughly mixed until it reaches an even, creamy consistency. Portions from the top and bottom of the same pail have less tendency to differ from one another if the paint is poured from pail to pail, back and forth, just before using.

Exposed woodwork should be painted in dry weather, when it is neither dusty nor very cold. It is important that the wood should be dry. A large proportion of all failures is due to the fact that paint is so often laid upon wood that contains some moisture. Paint should not be applied when the weather is foggy, nor should it be applied on frost crystals. Dry cold weather prevents paint from spreading evenly. Dust and grease also interfere with results in proportion to their quantities. Painting should always begin at the top of a building and should then progress downward.

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[1] Carbolineum Wood Preserving Company, New York City.

Direct sunlight, particularly during the summer, is detrimental. The heat of the sun is likely to cause the paint to form in drops or "tears," while its reflected light will influence the vision and judgment of the painters, who should be shifted backward and forward, morning and afternoon, with the intention of keeping them in the shade as much as possible.

The treatment required by new, clean wood that has never been painted, differs from that required by a surface that has been painted before. It is also well to distinguish between fine-grained and non-receptive woods, and coarse-grained and receptive woods. Such distinctions cause details to vary; but, in a general way, the practice of painting may be outlined as follows:

A surface of wood that is to be painted for the first time should be planed, sandpapered, or otherwise cleaned. The knots and other pitch wood that may be present are next covered with shellac; and if large knots, or other imperfections, exist, ample squares should be drawn around them and all material within the squares removed. The spaces left vacant should then be filled with matched squares of good wood. It would be impracticable to attempt to fill the irregular spaces left by imperfections with good wood.

The first or priming coat is now applied, after which all nail holes, and other depressions, are filled with white lead putty, which may be tinted so as to accord with the shade of the surrounding surface. Ample time is allowed for the work to dry, after which the first full coat of paint is laid on. This is succeeded by one or more final coats as desired. It is important that every coat should be thoroughly dry before the next one is applied. Paint shrinks in drying and every coat should have an opportunity to adjust itself.

Painting upon old paint is to be distinguished from painting upon new, clean wood. Two cases present themselves: first, the old paint, although on the whole firmly and solidly attached to the wood, must be removed for the sake of appearance, or because it is worn down or has failed in places; or, second, the old paint has chalked, cracked, blistered, or become loose.

It is always better to remove old paint; yet, if the paint adheres well, is solid, and in good condition, the cost of removing it is not warranted, and the new coats may then be laid over the existing work, as already noted. As distinct from this, however, old paint that has chalked, blistered, or otherwise failed, should invariably be removed, as it may be by scrapers, steel brushes, burning, or by paint-removing solutions. After the old paint is removed the cleaned surface is painted as though for the first time.

A failure occurring shortly after the application of new paint is often attributed to some defect in that paint; whereas, in many instances, it is the priming or old paint that is at fault. Paint shrinks in drying, and, if the older material is not firmly anchored, the new material is liable to pull it loose. The removal of old paint is very costly, yet it is cheaper to remove it if it is not in a fairly good condition.

The brush should be held at right angles to the surface so that the extremities of the bristles will force the paint into the pores of the wood. The strokes should be applied *with* the grain, and should be drawn out as far as possible so as to reduce the breaks in the lines of application. Paint is not distributed as evenly, nor will it adhere as well, unless these matters are attended to.

Paint is sometimes applied in the form of spray. Thin mixtures, water paints, and whitewash have been successfully applied over large surfaces in this manner. But, as distinct from thin mixtures, the attempts that have been made to apply thick paints by means of spray have often failed. Thick paints seem to require a different kind of handling, and are usually so much more costly that less waste is permissible. A machine for spraying paint that was perfected by the Pennsylvania Railroad Company was once described as being "economical as a labor-saving device as well as in saving of paint to a limited extent over brush work." This machine is still in service and giving satisfactory results.[1]

It is said that spray work compares best with hand work where there are corners or complicated surfaces. As against this, spray sometimes encloses air which interferes with solidity and adhesion. Experience is not sufficient to enable comparisons to be made between these two methods.

A general specification is as follows:

Stir the paint thoroughly. Do not attempt to stir through the bung hole of the package, but take out the head and stir with a stick that will reach the bottom. Finally, pour the paint backward and forward from pail to pail.

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[1] July, 1915. See also general index Engineering News, 1890–1899, p. 174.

After a storm do not apply paint until the wood has had time to dry. Never apply paint in damp, foggy, or frosty weather.

It is often advantageous to expose surfaces of smooth lumber to the weather for a little before painting. After the side of a house has received rain several times, the grain of the wood will rise a little; and then, after it has become dry, the paint will adhere better.

In painting begin at the top of the building and then progress downwards.

Knots and resinous places should be covered with shellac varnish. After which, to wood that has not been painted before, the comparatively thin priming coat should be applied. The priming coat may be prepared by adding raw linseed oil to some of the paint prepared for the later coats.

Seams and nail holes should be puttied after the priming has been applied. Every coat should be thoroughly dry before the coat that follows is applied. The paint should be rubbed out well in the brush. It should not be permitted to flow over the surface. A coat that is not brushed out thin will blister and peel away.

Judgment is required when painting a house that has already been painted, since different parts of such a surface may require different treatment. Cracked and loosened paint should be scraped away. Surfaces that are entirely bare should be primed as already noted. Existing paint that is hard, smooth, and firm should often be roughened with coarse sandpaper, since otherwise the new coat may not penetrate and adhere well to it.

A specification for somewhat finer work is as follows:[1]

General Conditions. Bids.—The owner reserves the right to reject any or all bids.

No Alterations.—No interlineations, erasures or alterations of any sort will be allowed unless duly noted and initialed by the architect.

Expert Work.—All work must be executed and completed according to the plans and specifications, under the supervision and to the entire satisfaction of the architect. All workmanship must be expert and thorough in every respect.

Extra Work.—No extra work will be accepted or paid for unless ordered in writing by the architect before it is done.

Surfaces Before Beginning.—No wood, metal, plaster, or other work can be painted or varnished until inspected and approved by the architect. No painting or varnishing of any kind is to be done on wet or damp surfaces. All work must be thoroughly dry, smooth and clean, and all scratches, bruises, cuts, pencil or finger marks or other imperfections must be obliterated before the first coat is applied. Metal sur-

[1] Slightly abridged from specifications prepared by Edward Smith & Company.

faces must be entirely free from rust, scale and oxidation as well as all other defects.

Woodwork Before Beginning.—All woodwork must be thoroughly seasoned, the surface must be even and thoroughly sandpapered before the first coat is applied.

Before Beginning Work.—The painter must inspect all the surfaces on which he is to work, before beginning, and if any of them are unsuitable he must immediately notify the architect. He must not begin until the surface is in proper condition.

Sandpapering.—All sandpapering must be done with the grain and dusted clean before applying any material over the sanded surface.

Priming Back of Woodwork.—Before bringing on the premises or immediately after, the back of all fine woodwork must be thoroughly painted.

Priming on Woodwork.—Dampness. No fine woodwork must remain on the premises over night without receiving the first priming or filling coat. Unless this coat is applied before delivery it must be done immediately after (to prevent absorption of moisture from new plaster or masonry, which causes warping, raising of the grain of the wood, etc.).

Second Coat Priming when Necessary.—If the first or priming coat has been removed by accident, sandpapering or otherwise, another must be applied to such places exactly the same as to new bare surfaces. No succeeding coat may be applied until all such defects have been corrected in the first or priming coat.

Puttying.—All nail holes and other depressions must be filled up level and smooth with white lead putty, after the priming or filling coat has been applied and is thoroughly dry. If the first coat has been removed or broken another priming or filling coat must be applied before puttying. All putty must be tinted with oil colors to the shade of the surrounding surface and subject to the approval of the architect.

Puttying on Filled Woodwork.—No steel putty knife must be used on filled woodwork. Only a hardwood stick, properly shaped, must be used on such surfaces.

Knots and Sappy Places.—All knots, sappy, or resinous places, if they are to be painted or enameled, must first receive one coat of the best shellac varnish, reduced to the proper consistency, before the first or priming coat is applied.

Each Coat to be Inspected.—Every coat must be thoroughly dry and approved by the architect before the next is applied. No coat will be counted or paid for without the approval of the architect.

No "Oil Rub" on Undercoats.—No oil of any kind will be allowed in rubbing undercoats. (A portion of the oil will remain on the surface or in the surface, no matter how carefully it is cleaned, and this is sure to injure anything applied over it.)

Seals and Labels.—All materials to be used must be on the premises when ordered, in original packages with seals unbroken and labels attached; and must be approved by the architect before they are used.

No Substitutes on Premises. Thinners.—No other materials of a similar nature will be allowed on the premises at any time. No turpentine or other thinners may be used except as per printed directions. All varnishes, enamels and other materials ready for use must be used exactly as received in sealed packages from the makers.

Invoices for All Supplies.—Invoices for full quantities of all materials needed for the work must be shown to the architect and approved by him before the work is paid for.

Quantities Required.—At least one gallon of material must be used for one coat on five hundred square feet of surface, except on bare wood. First coat on bare wood, plaster or cement, etc., requires at least one gallon of material to each three hundred square feet of surface.

Weights per Gallon.—White lead thinned down ready for use weighs about twenty pounds to the gallon. Paste wood fillers thinned down ready for use weigh about twelve pounds to the gallon.

Temperatures for Varnishing and Enameling.—All varnish and enamel coats must be applied and dry dust free between 60 degrees and 80 degrees Fahrenheit. (About 70 degrees Fahrenheit is the best temperature. Fifty degrees Fahrenheit, or even lower, is not always injurious, but the danger increases with the cold and the risk of poor results at low temperatures should be clearly defined and the responsibility for them placed beforehand. The danger continues until the coat is well out of "tack.")

Materials Required.—All varnishes, enamels, japans, dryers, fillers, stains, colors in oil, tinting colors, graining colors and similar materials must be those manufactured by———— ————. All linseed oil, white lead, white zinc and turpentine must be absolutely pure and of the best qualities.

Danger.—Oil, lead, zinc and turpentine are exceedingly important, and great care and vigilance are required to prevent the use of inferior or adulterated qualities of these articles.

Covering Capacity of Paints.—Paints vary in covering capacity. Results are influenced by the properties of the paints themselves, by the condition of the wood to which the paints are applied, and by the methods and personality of the painter. It is well to allow one gallon of thin, priming paint for every two hundred square feet of surface of open-grained wood, although it can be made to cover twice that amount, particularly if applied to close-grained wood. One gallon of ordinary paint should cover from three hundred square feet to five hundred square feet of plain surface that has already been primed. There are many exceptions to these general figures.

A certain amount of paint may be spread so that it will cover a very large surface; but, in this case, the coat is likely to be too thin. On the other hand, a coat of paint should not be too thick because a thick coat of paint is liable to peel. As a matter of fact, the thickest coat of paint that may be applied without danger of peeling is actually very thin, and the saving of a small quantity of material is less important than the length of time during which the coat can be made to last. With charges for labor as they are, paint should not only be selected with the idea of obtaining the longest possible term of service, but it should be applied with that object first in view.

Time Required to Apply Paint.—The time required to apply paint is influenced by the paint itself, the surface that is to be covered, and the habits of the painter. An intricate surface requires longer than one that is plain and flat. It takes longer to apply paint overhead than to apply it on a level with the body; and it is easier to work from a scaffold than from a ladder. Fine interiors call for more attention than ordinary exteriors.

Inquiries addressed to several railway companies brought replies indicating that a good workman should cover from fourteen hundred square feet to two thousand square feet of plain, flat, primed surface in a day of eight hours. Priming requires longer. At least ten per cent. of the time devoted to painting should be allowed for cleaning, sandpapering, puttying, and mixing. These figures, although based upon actual work, cannot be applied too literally, particularly to small pieces of work, or when fine surfaces are to be prepared.

Durability of Paints.—This varies greatly with materials, methods of application, use, and exposure. The need of judgment and integrity on the part of the painter is very great. Sunlight and rain are the common enemies of paint. White lead will last a century under cover, but fail in a few years when out of doors. Impure air, and moist gases such as come from locomotives, destroy paints more or less rapidly. The life of a coat of paint cannot be predicted, even when it has received the most intelligent attention. When the coat fails it must be renewed.

THE APPLICATION OF VARNISH.—Varnish may be used as paint is used, or it may serve in connection with the more complicated surfacing included within the meaning of the word polish. Although varnish is used in polishing wood, a varnished surface is to be distinguished from a polished surface.

Many of the details connected with wood finishing in which varnishes are employed are specially associated with certain kinds of work. The protection of a porch or mast differs from the requirements of a piano or a coach. Appearance is of much importance with most woodwork upon which varnish is employed.

The appearance of cabinet woods is influenced by fashion, and fashion changes so that the same wood is often finished in different ways at different times, even although the wood is to be employed for the same purpose. Mahogany may thus be finished with a bright luster; or it may be dull. Sometimes it is of a rich mahogany red, and at others it is yellow or dark brown. Oak is finished in many colors such as natural yellows, grays, greens, browns, and blacks. These results are obtained by the use of stains, varnishes, wax, and other materials, and by differences in methods of application.

The principal difference between a plain varnished surface and one that is polished is due to a distinction between the amounts and kinds of labor that are employed.

It will be remembered that woods are divided according as they are porous, like mahogany, or close grained, like maple. All woods must be dry, and all must be brought to a smooth, clean, even finish before they are treated in any way.

Plain Varnished Surfaces.—Varnish may be used as paint is used. It may be applied directly to filled or unfilled woods. The varnish need not be rubbed down and polished.

Filler may be used upon a surface that is to be varnished. The procedure resembles that associated with the preparation of surfaces for polishing, but is distinct in that, as stated, the varnish is not rubbed down and polished after it has been applied.

Varnish is often applied to otherwise unfilled wood, in which case the varnish itself acts as a filler.[1] The very durable and

[1] From correspondence with William H. Oliver: "In years past many of the wood polishers made their own filler, but it was even then thought that the better way to treat hard woods was to give them all the oil or varnish they would take. Each coat was sandpapered to the surface of the wood, and it was necessary to repeat the coats and the sand papering until the pores were thoroughly filled. Afterward, the necessary coats to preserve the wood and permit polishing and rubbing were added. I have always been of the opinion that if this course was generally followed at the present time better results would be obtained. I hold that in this way not only are pores filled, but the wood is better protected. It seems to me that wood thus treated is brighter and clearer than when ordinary paste filler

elastic mixture known as spar varnish is often used in this way upon masts, doors, porches and other exposed woodwork. When thus used, applications of this varnish are repeated until a sufficient body has been built upon the wood. A coat prepared in this way will not separate from the wood even when exposed to the most severe weather[1].

Polished Surfaces.—Although the engineer has less to do with polishing than with painting, the subject deserves attention sufficient to enable him to specify such fundamental factors as are necessary to secure the results he desires.

Close-grained woods are first treated with appropriate fillers. The unabsorbed portions of the fillers are rubbed away with rags or excelsior as soon as they have had time to dry, the movement being across the grain. The cracks and nail holes are next puttied; the surface is sandpapered, and, if a stain is desired, it is applied at this stage. Afterward, a thin coat of light-tinted or orange shellac is brushed on and the surface is again sandpapered. A coat of varnish is spread evenly over the surface, and is allowed to dry for two or three days. The surface is then attacked by powdered pumice, with oil or water, and rubbed with the grain, until, to all appearances, it is removed. Felt or haircloth is used in this operation.

Other coats of varnish are added in the same manner. Each one is allowed to dry thoroughly, and is then rubbed down to a smooth surface with powdered pumice. The polish is brought out by rubbing the last coat with rotten-stone instead of with pumice.

Details vary with fashions, finishers, and the necessities of the wood. Very smooth surfaces, such as those seen on pianos, are obtained by finally rubbing the surface with the palm of the hand. Oil and pumice give what is known as "oil-finish," while water and pumice give what is known as "water-finish." The appearance and wearing qualities of polished surfaces vary greatly. Some surfaces appear to be thick and glassy, while others are more solid, and subdued.

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is employed, and that it is better, also, for the life of the wood than a material is which simply coats the surface, but has no real penetrating power. . . . I have thought for some time that the filler generally used not only darkens light wood in time, but that it has some chemical action upon the varnish or shellac; but whether this is so I must leave for others to determine."

[1] See "Technology of Paint and Varnish," Sabin (First Edition, p. 299).

In the best work, the varnish penetrates deep into the wood. Such a surface is "case-hardened;" it wears evenly because the wood elements of the surface are filled and rendered compact by the tough hard varnish. In this case very little varnish remains on the outside of the wood, and, with ordinary use, the appearance of such a surface may improve with age. Where the work is inferior very little labor is bestowed upon the varnish. The superfluous varnish is not rubbed away, and no attempt is made to work the first coats into the fabric of the wood. In this case most of the varnish remains upon the surface of the wood; such a surface may be more or less attractive when new, but shortly scratches, chips and wears away.

As already stated, the appearance of a surface is influenced by its color as well as by its texture. The tints presented by most finished hardwoods are secured by the use of stains, and, in the best work, these stains are selected so as to accord with and emphasize such beauty as is due to the cellular structure or "grain" of the wood.

It is fundamental that stains shall be spread evenly. This is often hard to accomplish because different parts of a piece of wood are liable to vary in their density and ability to absorb. It is often necessary to retouch the wood here and there so as to offset such differences. Many stains darken with age, and it is usually easier to correct a tint that is too light than to correct one that is too dark.

The summary that follows was prepared by the foreman of a noted firm of cabinet makers.

"In order to secure a good piece of work: (1) Fill with the best filler; (2) color if necessary; (3) apply a thin coat of the best shellac; (4) apply three coats of the best varnish—allow each coat to dry for two days at least; (5) rub down each coat until a smooth surface is obtained with pumice stone and felt—allow one day to dry perfectly, then finish with rotten-stone, and, if a very fine surface is required, rub with the palm of the hand; (6) clean entire surface of work with a mixture of raw linseed oil and turpentine (equal parts), then take cheesecloth and rub perfectly dry. To obtain the best of work, it is absolutely necessary that the woodwork be perfectly smooth and well filled before the work is varnished."

Enameled Surfaces.—Varnish or enamel paint has been described as a mixture of varnish and pigment. In such a paint, varnish takes the place of the usual linseed oil, with the result that the paint, although more costly, is harder and more durable. A little varnish is often added to ordinary oil paint, the luster of which is thus increased. Enamel paint may be applied on wood or metal either indoors or out of doors. The paint may be laid on as described in the preparation of "plain varnished surfaces;" or, a real enamel may be built up by methods described in connection with "polished surfaces."

In the latter case, the wood, having been prepared and primed in the ordinary manner, is treated to two or three coats of flat white lead paint each one of which is permitted to dry thoroughly, and is then lightly sandpapered. One coat of zinc white paint is then applied, and, after it has become dry, is also sandpapered. The base thus prepared is covered with a coat of enamel paint which is later rubbed down with pumice stone and water, on felt, to a uniform and level surface. This is carefully washed free of all pumice with cold water, and is then wiped dry with chamois. One or two other coats of enamel paint are then applied in the same way. A surface built up in this manner is very beautiful, smooth, easily cleaned, neutral, and permanent. A base of birch or cherry thus enameled is usually more costly than a base of quartered oak or even mahogany that has been polished. The difference in cost is due to the excessive amount of labor required to build up good enamel.

Varnish is sometimes replaced by wax which causes an old, or "antique" appearance. The wood is first leveled, sandpapered, cleansed, or otherwise prepared; and is then stained and treated with shellac, varnish, or with both of these mixtures. Wax is applied and time is allowed for it to dry. The whole surface is then carefully rubbed with cheesecloth or some similar material. The shellac and varnish are sometimes omitted. Appearance is governed by these and other details.

MISCELLANEOUS.—Ships, cars, coaches and some other constructions, require special methods that are distinct from those by which ordinary woods are commonly protected.

Ship Painting.—Ordinary wooden hulls are protected much as wooden houses are protected. But, as distinct from these, many pleasure boats and war ships require special treatment. The vessels now referred to are those that are painted so frequently that excessively thick coats of paint would accumulate if ordinary methods were held to. In such cases, white lead is mixed with turpentine instead of with linseed oil. This produces a thin white coat that looks well for the time being, but that soon chalks, and can then be brushed away. Special paints have been designed to protect ship bottoms.

Coach Painting.—In this case, brilliant polishes have to resist severe exposure and constant washings. The influence of heat, cold, wet, and abrasion must be withstood. Coach painting occupies a field by itself.

Car Painting.—Methods employed in the shops of the Pullman Company are as follows:[1]

System for Painting Exteriors of Cars.

1. After the exterior of the car has been properly sanded and made ready for painting, dust off the car with a painter's duster, and then apply the priming coat, which should be well brushed into wood and allowed to dry three days.
2. Apply the filling coat, or the second lead.
3. Putty all nail holes and bruises the next day, and then allow the second lead and putty to dry two days.
4. Apply three coats of surfacer, one coat a day.
5. Rub down to a smooth surface with lump pumice stone or Eureka rubbing stone, and then sandpaper.
6. Apply the color course of two or three coats, one a day.
7. Ornament and letter and then apply three coats of Railway Body Varnish, allowing a day between coats for drying.

System for Finishing Interiors of Cars.

1. After the finish is properly cleaned and sandpapered, fill the pores with a wood filler and allow it to dry over night.
2. Sandpaper with No. 0 sandpaper; shellac and varnish it the next day and allow it to dry one day.
3. Apply the second coat of varnish and let dry one day.
4. Apply the third coat of varnish, letting it stand to dry two days before rubbing.
5. Rub with pumice stone and water and let dry one day before polishing.
6. Polish with rotten stone and oil.

OTHER COATINGS APPLIED TO SURFACES OF WOOD.—Metals are sometimes used to beautify woods and to protect them from decay; but they, as well as paints, seal up moisture that may be present, and should not be used save with woods that are quite dry and well seasoned. Wooden pillars are sometimes enclosed by metals, as are the bottoms of wooden ships.

The bottoms of posts and poles are sometimes charred. As has been explained elsewhere, high heat sterilizes the wood and

[1] In force January, 1912.

thus increases its durability; but, besides this, the coat of practically inert charcoal is also beneficial.[1] Charring can be localized, and is often practised with the ends of green posts that would otherwise rot rapidly near the surface of the soil. The upper portion of such pieces then have time to season naturally.

Fig. 79.—Failure of car post due to application of paint upon imperfectly seasoned wood.

Attention has been called to the fact that external coatings may assist wood by offering resistance to animal woodborers, fire, an abrasion, as well as to rot. Asbestos paint, in which water-glass is the vehicle and powdered asbestos the pigment, is thus used as a fire retardant. The water-glass fuses easily,

[1] See chapter, "Preservative Methods Internal Treatment."

and, when fused, flows over the burning surface, and for the time cuts off the volatile gases that cause flame.[1]

It will be remembered that so-called "fireproof paints" retard, but they do not prevent, burning. Some paints of this class act upon woods when in certain positions by lessening the ease with which such woods might take fire from small flames. It will also be remembered that wood covered with tin has resisted fire in conflagrations when solid metal has buckled and failed.

THE PREPARATION OF WOODS TO RECEIVE PAINTS, VARNISHES AND OTHER COATINGS

Coatings protect from outside conditions only. They do not protect from inside conditions, and may even do harm if moisture or impurities are not removed before they are applied. It is then much the same as when imperfectly cured fruits are sealed in cans. Decay can go forward within a can, and it can also go forward within a coat of paint. The condition known as "dry-rot" is observed where imperfectly cured woods are thus enclosed by paints or other coatings.

[1] See chapter, "Failure of Wood Because of Fire."

CHAPTER XVI

Adhesives. Cattle Glues. Fish Glues. Selection, Testing and Application of Glues

Glue is prepared from parts of animals. It is used to join pieces of wood together; and is also used in printers' rollers, emery wheels, book bindings, artificial leather, and for sizing cloths and papers. Kalsomine is a mixture of glue and Paris white. About ninety million pounds of glue are produced in the United States alone every year.

True glue is impure gelatine. Gelatinous pastes resembling jellies of weak glue, are formed by some vegetable products; but these pastes differ from true glues in that they do not resume their original forms when they become dry, neither do the dried products dissolve satisfactorily the second time. A jelly of true glue will dry into a substance that is practically identical with the original, and this substance will dissolve and then gelatinize a second time.

Glues and gelatines should be distinguished from one another. Both substances are obtained from the same sources, but the former is less definite in composition than the latter. Pure gelatine may be described as the essential part of glue, while glue may be described as impure gelatine. Ordinary carpenter's glue contains about fifty per cent. of pure gelatine which may be separated from the glue by laboratory treatment. As a matter of fact, commercial gelatine or isinglass, as distinct from pure gelatine, is usually prepared directly from special sources. The line of separation between some glues and some gelatines is hard to define.

References.—"Glue, Gelatine, Isinglass, Cements, and Pastes," Dawidowsky (Sampson Low, Marston, Searle & Rivington, London, 1884); "Glue and Glue Testing," Rideal (Scott, Greenwood & Company, London, 1900); "Glues and Gelatine," Fernbach (Van Nostrand Company, 1907); Files of Scientific American, Woodcraft, etc. Assistance has also been received from Messrs. Armour & Company, the American Glue Company, the Russia Cement Company, the Studebaker Corporation, Schmitt Brothers, The Flint & Horner Company, and other manufacturers and users of glue.

Gelatine, which is nearly colorless, nearly tasteless, and almost without odor, is used in medicines, photography, confections, and as an agent in clarifying liquids. As distinct from gelatine, glue possesses color, taste, and odor; but, because glue is used primarily as an adhesive, these properties do not diminish its value.

The exact chemical composition of pure gelatine has not yet been deduced, but analyses show that the ultimate composition is about as follows: Carbon, 50 per cent.; oxygen, 25 per cent.; nitrogen, 18 per cent.; hydrogen, 6.9 per cent.; sulphur, etc., traces. Rideal and Fernbach[1] call attention to the complex composition of gelatine. Beside albumoses and peptones, several varieties of chondrin, mucin, and other chemical substances may be present.

Glues and gelatines are derived from cattle and from fishes. Cattle glues are more largely used, and are usually intended unless fish glues are particularly specified. It should be noted that glues and gelatines do not exist as such in the tissues from which they are drawn, but that they are formed by the action of heat and water upon certain nitrogenous substances that are contained in, or that are a part of, these tissues. The fact that certain animal tissues can be made to yield certain products through the instrumentality of heat and water is known, but the nature of the changes which brings about these results is not known.

CATTLE GLUES

SOURCES.—The sources of cattle glue may be separated into three groups as follows:

Hidestock includes scraps and cuttings from tanneries, together with sinews, and pieces known as fleshings that are shaved from inner surfaces of skins. Hidestocks from horned cattle, sheep, rabbits, and other animals, yield glues that differ from one another in minor properties. The second group includes bonestock, that is, the bones of certain animals as horned cattle; and footstock includes the hoofs of horned cattle, pigs, and some other animals.

MANUFACTURE.—Clean hidestock is digested or "limed" in some weak alkali, as limewater, that attacks the fats, loosens the hair, and softens the tissues that contain the glue. After

[1] See text by these authors.

a sufficient time the alkali and impurities are removed by washing, and the soft and swollen residues are boiled in water. Each charge of stock is boiled several times, but the solutions are kept separate from one another since each one yields a different grade of glue. The best glue is that which comes from the first boiling.

Next, the glue solutions are poured into moulds and permitted to cool, and the blocks of jelly that result are cut into slices. The slices are arranged on nets of twine or wire designed to facilitate drying, and are dried in the open, or in cabinets where conditions may be more easily controlled. It is not easy to dry these jellies satisfactorily. Results are much influenced by temperature and humidity. Some difficulties are expressed in the following quotation:[1] "The glue-maker has all sorts of troubles. His best jelly may be hurt or ruined by the weather or by unwise liming or cooking. Anything will affect his glue and, for this reason, no two boilings can be alike."

Bonestock.—Clean bones are treated in either of two ways: First, They are boiled directly without prior treatment; or second, they are digested in weak acids that dissolve the lime and other salts. The acids are then neutralized and the cleansed residues are boiled in water. The solutions obtained from the bones of different species of animals yield different grades of glue.

Footstock.—This is washed and boiled without preliminary treatment. The solutions obtained by boiling the hoofs of different kinds of animals are kept separate from one another.

PROPERTIES.—Cattle glues are hard and tough. The taste and odor are characteristic, and the colors range through a series of more or less translucent grays and browns. Cattle glues soften and swell, but do not dissolve, when treated with cold water. They dissolve completely in hot water, and the resulting solutions eventually stiffen into jellies and pass into the original dry form of the glue. Cattle glue can be dissolved and dried many times; but each operation weakens the power of the glue, and a point is finally reached where the glue remains permanently in solution. Cattle glue also dissolves in acetic acid.

Many grades of glue are manufactured in the United States. Some are based upon differences that exist between the materials from which the glues are made; and others are due to differences of manufacture. Every maker produces a series peculiar to himself, and the properties of the grades that go to make up this

[1] "A Pot of Glue," Milligan and Higgins Company.

series sometimes change from day to day with the weather, or from other causes.

Glues differ in form as well as in character. Foreign glues are usually sold in square or oblong cakes, each of which is branded with the mark of the manufacturer. As distinct from this, glues made in the United States are usually broken into fragments, known as "flakes," and these are often ground into powder. There are also noodle, strip, ribbon, and some other forms.

Fig. 80.—Typical forms of domestic and foreign cattle glues. (Much reduced.) The cakes of foreign glue at the top of the picture show the brands of manufacturers.

Two reasons are given for the local custom of breaking the cakes of glue into fragments: The first is, that inequalities can be counteracted by judicious blending; and the second is, that it is easier for consumers to work with glues that have been broken for them. The viewpoint of the manufacturer has been expressed as follows:[1] "The boilings of glue

[1] "A Pot of Glue," Milligan and Higgins Company.

run from three to ten barrels, and, as said above, vary. But take ten boilings, say fifty barrels, and grind them together we can then give a man a sample behind which we can be sure of every pound; and we can make successive lots to match that one. It means uniformity, convenience, and economy." It is true that cattle glues must be broken before they are dissolved in water, but the convenience of having them broken by the manufacturer is sometimes offset by the greater ease with which fragments or powders can be mixed or even adulterated by unscrupulous dealers.

Comparison of Foreign and Domestic Glues.—Foreign manufacturers seldom employ as many kinds of stock, or produce as many grades of glue, as those who manufacture in this country. The foreign custom of presenting glues in unbroken or branded cakes makes it easier for consumers to identify foreign glues. Foreign makers give much attention to appearance; labor conditions are such that stock can be selected with greater care than in this country, and glue solutions are often clarified to such an extent that foreign glues are nearly, if not quite, translucent.

Aside from form and appearance, it is probable that the domestic product as a whole, is quite equal to the foreign product as a whole. It is true that the large number of grades of glue manufactured in the United States causes some confusion, since customers, who are often unable to tell one kind from another, must depend more largely upon those from whom they buy. But, on the other hand, the fact that there are so many kinds of glue is a source of strength, because it makes it possible for Americans to fill almost every need.

Special Forms.—Cattle glue is sometimes dissolved in acetic acid and then sold in the form of a liquid. Cattle glue may be rendered flexible by mixing it with glycerine and water, to which molasses, or sugar in some other form, is usually added. The proportions of ingredients vary according to the results desired; a mixture composed of one-half glycerine and one-half glue is fairly rigid. Flexible glue compounds are used in book bindings, printers' rolls, and for other purposes.

Failure of Glue.—Heat and moisture are common enemies of glue. All glues soften, more or less, under the influence of water; but some kinds offer more resistance than others. The grades that last longest when exposed to moisture are sometimes referred to as "waterproof glues," but should not be confused with special mixtures that are also known as "waterproof" or "marine glues." Resistance to moisture may be increased artificially by the application of formalin. The other common enemy referred to, that is, dry heat, causes some glues to shrink and become brittle.

Selection.—Glue may be perfectly good, yet may be unsuitable for the work in which it is employed. In the glues that are used in carpentry, it is important that adhesive powers should be highly developed; whereas in some other glues, that are valued for other purposes, other properties are at least equally important.

Taken all in all, the best glues with woods are those made from hidestock, although glues made from footstock are also prized in joinery, because the sinews that adhere to the hoofs yield material that possesses high adhesive value. Glues made from acid-treated bones appear well, but sometimes crack when used under conditions that exist in the United States, and, for this reason, are often less desirable in joinery than are some others.

All glues look much alike to casual observers. Those who use large quantities of this material learn by experience the kinds best fitted for their needs; but those who use glue only occasionally should refer their problems to reliable manufacturers, who will suggest the grades that are best fitted to meet their requirements.

APPLICATION.—The strength and durability of a joint are influenced by the way in which the glue is applied. The glue may be good and appropriate, but the joint will fail unless the glue is applied in the proper manner. Several details are important: (1) the glue must be carefully dissolved; (2) the wood must be ready to receive the dissolved glue; and (3) the wood and glue must be brought together in a way that has been shown by experience to produce lasting results.

1. Dissolving the Glue.—There are two parts to this process. First, the glue must be softened, and for this purpose, it is placed in from two to four times its weight of cold water. Broken glues must remain in the water for several hours, but ground glues often soften sufficiently in five or ten minutes. Second, after the removal of the excess water, the soft and swollen mass must be warmed until it is thoroughly dissolved. Care must be taken to avoid direct or high heat. Many devices are available to protect glue from excessive heat during this part of the process.

2. Preparing the Wood.—The wood should be clean, well-seasoned, and sufficiently warm. The surfaces of close-grained woods should be roughened, and the same treatment should be extended to other woods when necessary. The film that forms over the surface of melted glue when the warm solution is chilled by contact with the air is duplicated when the solution is applied to the normally cooler surfaces of woods. For this reason, cabinet makers warm pieces of wood that are to be joined by glue. Care is necessary here also, since high heat is injurious to wood as well as to glue.

3. Completing the Joint.—Penetration, warmth, and pressure are necessary. The glue must sink into the "take hold" of the wood. To bring about this penetration, the differences in penetrability of close-grained and hard-grained woods, must be kept in mind. The necessity for warmth has already been explained. Pressure is very necessary because some time must elapse before the glue can set sufficiently to hold the parts together; the parts are therefore held in presses during this interval. The object throughout is to bring the pieces together in such a way that the joint will be at least as strong as the wood.

A series of axioms relating to the application of cattle glues given by Fernbach is as follows:[1]

"When two surfaces of split wood are laid together, the hold of the glue is the same whether the fibers are laid parallel or crosswise to one another.

"The value of a wood joint is dependent upon the union of the glue with the fiber of the wood. For glue to be properly effective, it must penetrate the pores of the wood; and the greater this penetration, the more substantial the joint.

"All other factors being equal, glues that dry slowly are invariably stronger in the joint than those that dry rapidly.

"Except in the case of veneering, both surfaces of the wood should be properly glued before junction.

"Do not use thick solutions of glue for joint-work. They congeal too quickly, and hence fail to penetrate the pores of the wood, yielding, as a result, a weak joint. In every case, the glue must be worked well into the wood with a brush, much in the same manner as a coat of paint is applied.

"If glue is applied to *hot*, as distinct from warm, wood, all the water of the glue solution would be absorbed by the wood, leaving a thin inadhesive coating of glue at the surfaces of the joint, which, if made in this fashion, will hold only a limited time."

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[1] "Glues and Gelatine" (1907 Edition, p. 106).

The action of glue in a joint is thus described by Hewitt:[1]

"Glue forms a true solution with water at temperatures above one hundred and forty degrees Fahrenheit. It passes out of solution gradually as it cools below this point. The molecules of glue then join with one another and the water that is excluded occupies the vacant places in the resulting tissue.

"Glue should be in solution as it passes into the pores of the pieces that are to be joined. To insure this the temperature of the pieces should be raised to a point somewhat in excess of one hundred and forty degrees. The glue and water will then pass in together and a strong net work is formed as the glue separates from the water.

"Ordinary carpenter's glue contains from forty per cent. to fifty per cent. of pure gelatine. The balance is glue peptones, caused by gelatine breaking down at various stages. The true gelatine will not adhere if the glue is applied at temperatures below one hundred and forty degrees Fahrenheit. Some adhesion is caused by the peptone substances but the joint is not as strong as it should be. The matter is complex but the principle is that the glue or gelatine should be applied when sufficiently hot and concentrated."

PROTECTION OF JOINTS.—Since heat and moisture are the common enemies of glue, all joints in which glue is used should be protected from these known elements of failure as far as this is possible.

Protection from Heat.—Some glues resist the influence of dry heat better than other glues. It is probable that the best results, when this material is used with wood, are obtained by the use of selected glues made from hides. Bone glues are less stable, more likely to shrink and become brittle under the influence of dry heat.

Aside from the glue, the wood itself requires attention. It is necessary that the pieces to be joined should be dry and well-seasoned. Some failures of glued joints can be traced to the shrinking and warping of the woods themselves.

Protection from Moisture.—Resistance to moisture may be increased by the use of selected glues. Formalin, if used in this connection, should be applied after the joint has become dry. The glue may swell a little, but the antiseptic renders it comparatively insoluble, and glue treated in this way, never decays under ordinary conditions. After the work has become dry, it should be protected by paint or varnish.

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[1] Correspondence quoted by permission.

Joints can be protected so that they will resist seemingly adverse conditions for a long time. This is shown by boats manufactured by the Racine Boat Company. The hulls of these boats were built of layers of thin veneer glued crosswise upon one another, and it is said that they remained sound as long as they were protected by paints or varnishes. "The actual use of the boats demonstrated that they require considerable care. They could not be left in the water or sun indefinitely. The strong rays of the sun on the boats in the water would blister the veneer and the blisters would naturally form checks. This was overcome by putting on little copper patches. Boats that had good care have stood for twenty-five years. There are still some in existence and the owners write that they would not sell them for any cost."[1]

DURABILITY OF JOINTS.—The durability of a joint must be distinguished from the durability of the glue used in the joint. The glue itself may be good and appropriate, but the joint will fail if the glue has not been well applied, or if the joint has not been properly protected. Glue can be selected, applied, and protected in such a way that the work will last indefinitely.

FISH GLUES

SOURCES.—The dry forms known as isinglass are prepared from the swimming bladders of certain fishes. Dry fish glue or isinglass is seldom used in carpentry and is mentioned in this place only for the sake of completeness. Ordinary or liquid fish glues can be, but seldom are, prepared from isinglass. These forms are normally extracted from the heads, skins, and bones of cod, cusk, and other fishes.

The best isinglass is made from sturgeon in Russia. American isinglass is prepared from the swimming bladders of cod and hake; there are other sources in other countries. Isinglass is nearly colorless, and nearly tasteless, and is used chiefly in medicines, confections, and as an agent for clarifying liquids (see also "gelatine"). As cattle glues are normally solids, so fish glues are normally liquids. Much, if not most, of the liquid glue manufactured in the United States is drawn from the skins, bones, and other waste now separated from the flesh of cod before the latter is marketed. Many thousands of tons of this stock are produced on the New England coast alone every year.

MANUFACTURE.—Some liquid fish glues are prepared by boiling the sounds of cod and hake in water. But by far the larger part is prepared as follows: The heads, skins, and bones

[1] Correspondence with Racine Boat Manufacturing Company quoted by permission.

containing the glue are freed from salt and dirt and are then subjected to processes of extraction that resemble those employed in the preparation of cattle glues. Preservatives are

FIG. 81.—Fish sounds, Nova Scotia.

added, and the characteristic fish odor is disguised by adding essences. The results are not dried, but are marketed in liquid form.

PROPERTIES.—Fish glues are powerful adhesives, but they do not always sink easily into close-grained woods. The liquid form is convenient because it makes it possible to use the glue without further preparation. Fish glue is thick and often becomes thicker when cold; and, at such a time, it must often be warmed before it can be poured from the can or barrel in which it is stored. Small quantities of glue are easily thinned by the addition of water, vinegar, or acetic acid, or by warmth.

FIG. 82.—Typical fish glue.

Fish glues are particularly convenient with small or occasional pieces of work that must be undertaken where facilities for preparing joints of cattle glue do not exist. Their use with woods is limited because cattle glues are cheaper, and, in the majority of cases, sufficiently good. Large quantities of fish glues are employed for gumming labels, stay-papers, etc.

Selection.—Classification is based primarily upon the source of the glue, and secondarily, upon the body and color of the glue. The better grades, which alone should be used with woods, are made from the skins of cod and cusk, while less desirable grades are made from the heads, bones, fins and tails of the same fishes.

Fish glues are presented under labels and can, therefore, be readily selected by customers. Special problems should be submitted to manufacturers.

APPLICATION.—Fish glues do not have to be dissolved, and pieces of wood to be joined by them do not have to be heated. Aside from this, the application of these glues resembles that of cattle glues. In both cases, the glue should be made to penetrate as far as possible, and in both cases, the pieces to be joined should be held in place firmly until the joint has had time to set. Some directions prepared by the Russia Cement Company of Gloucester, Massachusetts, relating to the application of fish glues, are as follows:[1]

"The joint should first be made to fit as accurately as possible. A thin coating of glue is allowed to set which will take only a few minutes. While the glue is still tacky, another coating of glue should be used, and the joints rubbed together, plenty of time being taken to force out all the air, so that there will be no air bubbles, and so that the entire surface to be glued will be covered with a thin film of glue. Pressure should be used so that only a small amount of glue is left, as too much glue is injurious as well as too little. Pressure should be kept up until the glue is quite dry. If the above directions are followed, any piece of wood should give before the glue.

"There is a certain knack even in following the above directions, and the only way to obtain good work on animal as well as fish glue is by experience in the use of particular glues for particular woods, and this can only be acquired by time. There is no absolute rule which can be followed."

SOME USES OF GLUE

With woods, glues are used to wholly or partly replace nails; and they are also used in veneered or "built-up" work, such as is called for in cabinet making, parquet floors, and the bodies of fine carriages. The latter field is so important as to warrant notice. The fact that glues are used for other purposes than to join woods has already been noted.

VENEERS.—This term is applied to thin slices of wood that are later fastened to, or reinforced by, other pieces of wood. Veneers are cut with knives, or with saws. The first method, which is often preferred with more valuable woods, is comparatively economical as to material, while the latter method is

[1] Correspondence quoted by permission.

easier as to labor but causes much of the log to be lost in sawdust. Rotary-cut veneers are broad ribbons pared from the surfaces of revolving logs. There are also plain-cut and quarter-cut veneers which are prepared as is indicated by their names.

Veneers ordinarily vary in thickness between one-thirtieth of an inch and one-quarter of an inch. Veneers as thin as one two-hundredth of

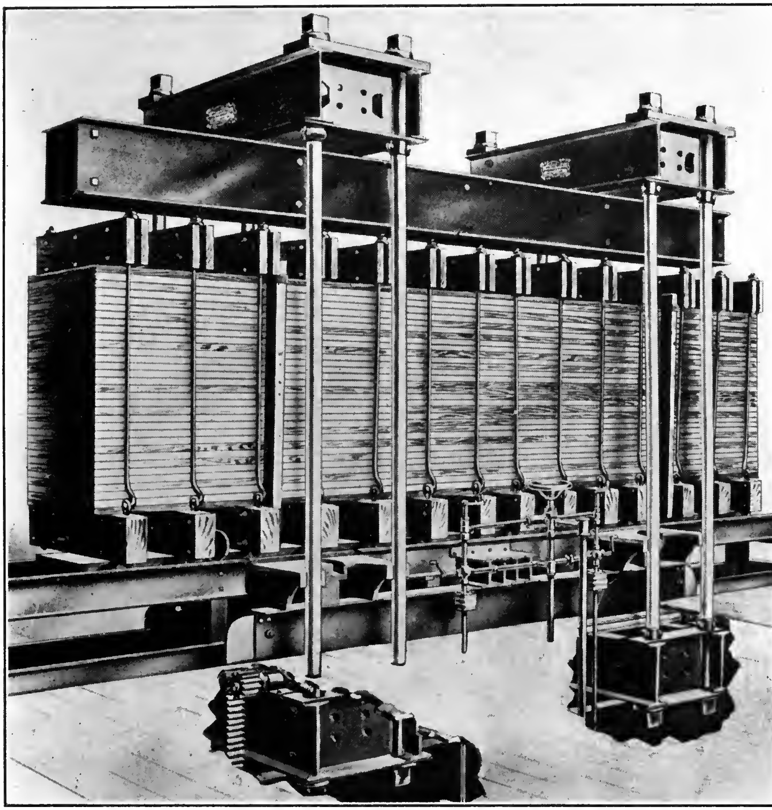

FIG. 83.—Large double-cylinder veneer press.[1]

an inch can be prepared, but the value of such sheets is lessened by the fact that the glues used to fasten them are liable to soak through and become evident on the outer surfaces. Most inside needs are met by thicknesses between one-thirtieth of an inch and one-eighth of an inch. Veneers that are to be exposed to the weather should be thicker than one-eighth of an inch. Veneers that are one-quarter of an inch or more in thickness are usually classified as thin lumber.

[1] Photograph courtesy Hydraulic Press Manufacturing Company.

Preparation of Veneered Work.—The form to be covered is prepared of white pine, or some other clean, and uniformly grained wood that receives glue in a satisfactory manner. This foundation is termed the "core." Another piece, called the "caul," the surface of which coincides with that of the core, is then made ready. The pieces of veneer are fitted over the surface of the core, glued in place, and held there intimately by means of the caul. The entire series, composed of core, glue, veneer, and caul, is then placed in a press where it remains until the glue is dry. Curved, irregular, and intricate surfaces are correspondingly harder to prepare than plain surfaces.

FIG. 84.—Section through door stile.

Door frames are made by gluing strips of wood to one another and covering them with thick veneers, or "thin lumber." Chair seats are prepared by gluing layers of wood, of equal thickness, crosswise to one another. The names three-ply or five-ply are used where three or five thicknesses of wood are thus fastened together. The roofs of many carriages are made by covering three-ply roofing with heavy duck, slushed on and tacked at the edges. The use of veneers in building hulls of small boats has been alluded to.

Inlaid Work.—This is prepared by fastening a sheet of light-colored wood, such as holly, upon a similar sheet of darker wood, such as mahogany. A design is traced upon the upper sheet, and a sharp knife is passed over the design so as to cut through both sheets alike. The figures cut from the lighter-tinted wood are inserted within the corresponding vacant spaces in the darker wood, or *vice versa,* and the sheet with insertions is glued upon a

PLATE XX. APPLICATION OF GLUE IN LARGE CURVED JOINT

(Photograph by Kranich & Bach.)

(*Facing page* 416.)

core of seasoned wood. There are many details and applications.

Reasons for Preferring Veneered Work.—Some reasons for preferring veneered work are as follows:

Stability.—The natural tendency to warp and check is less when well-seasoned pieces of wood are glued crosswise to one another. Results obtained in this way are stronger, better, more rigid, and lighter in weight, than when solid wood is employed.

Appearance.—The best and most beautifully figured pieces of wood are often small. Such perfect, attractive, but small pieces can be sliced, and the slices joined together so accurately, over a core of some less desirable wood, that the seams cannot easily be

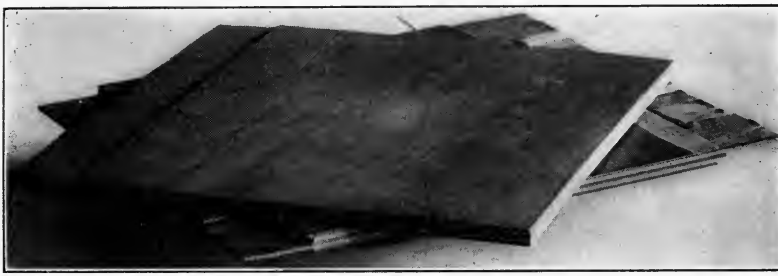

Fig. 85.—Portion of three-ply panel.

discovered. A large surface of perfect and uniformly beautiful wood is thus obtained.

Economy.—As a matter of fact, veneered work is usually more costly than solid work of equal dimensions. It is cheaper than solid work only when the saving of material is enough to more than offset the extra expenditure for labor. From the viewpoint of material, the case is the same as when one metal is plated with another; but from the viewpoint of labor, the cost of preparing, fitting, and gluing thin sheets of wood over a curved or irregular surface, or even one that is flat, is greater than the cost of preparing the equivalent in solid wood.

METHODS OF TESTING GLUES

Cattle Glues.—The adoption of a standard, the selection of a sample, and the estimate of the appearance, fracture, odor, acidity, grease content, viscosity, foam, and strength of the sample are important.

Standards.—Standards are necessary for purposes of comparison. The Cooper glues have been used for this purpose, since those who make these glues seem able to maintain very uniform products. It is said that the properties of these glues have remained constant during the last fifty years.

Samples.—The selection of any sample is important. In this case, portions drawn systematically from several parts of every package should be mixed, ground, mixed again, and then divided so that the final sample will weigh about six ounces.

If glues have been mixed, the parts should be separated from one another, and each part should be tested separately. The separation of separate fragments of dissimilar glues from one another is possible because of color distinctions that usually exist. It is not enough to accept the samples presented by agents; the final deliveries also should be tested.

Appearance.—Large and irregular air bubbles indicate decomposition. Smooth and glossy surfaces are desirable but not essential. The appearance of a glue may warrant its rejection.

Fracture.—Fractures vary with moisture and, therefore, with the weather and is seldom a criterion. Similar pieces break differently at different times. Glues made from acid-treated bones generally show bright, clean fractures.

Odor.—Odor may be due to the character of the stock; or, it may be due to deterioration in the glue. Glues made from goats, sheep, oxen, and other animals, sometimes possess characteristic odors, which are often changed as a result of boiling. The odor that arises from a hot solution of glue should indicate any decomposition that has taken place after the glue has been boiled.

Acidity.—The presence of acid is not an indication of the way in which the glue was manufactured, since a little acid is sometimes added after boiling. Sulphurous acid is often used to bleach glue and to prevent its decay. A slightly acid glue is often to be preferred.

Grease.—Grease is sometimes, but not always, undesirable. The properties of some glues, as those used for moulding, picture frames, and some other purposes, may even be improved by the presence of grease. Such desirability is influenced or determined by the form in which the grease exists, which may be in large globules, or in the form of an emulsion. Of these two forms the latter is less objectionable. The presence of grease may be detected as follows: A few grains of some aniline color that will dissolve easily in water are placed on a sheet of clean white paper. A flat brush is dipped in a warm solution of the glue, and then hastily drained. The brush is applied to the color so as to dissolve it, and is then, without being lifted, swept across the remaining surface of the paper. Any grease that is present will appear in the form of spots. Some experimenters prefer to mix the aniline color with the glue at the start. The presence of grease in fine emulsion is not always thus revealed, since part of it may escape notice if the globules are finely divided.

Viscosity.—A viscous liquid is one that moves slowly under the influence of any force. The molecules of such a liquid adhere to one another and do not move freely among themselves.

The degree of viscosity in a solution of glue is sometimes relied upon as an indication of strength, but is a dangerous criterion, since viscosity may be influenced by the presence of foreign substances. For example, a small quantity of alum will greatly increase viscosity without otherwise improving the glue.

The degree of viscosity may be measured by noting the number of seconds required for the passage of 50 c.c. of glue solution through the orifice of a standard burette, pipette, or other vessel. Armour & Company test solutions prepared by dissolving one part of the glue in five parts of water, and hold the solutions thus formed at temperatures of 150 degrees Fahrenheit while they are passing through the orifices.

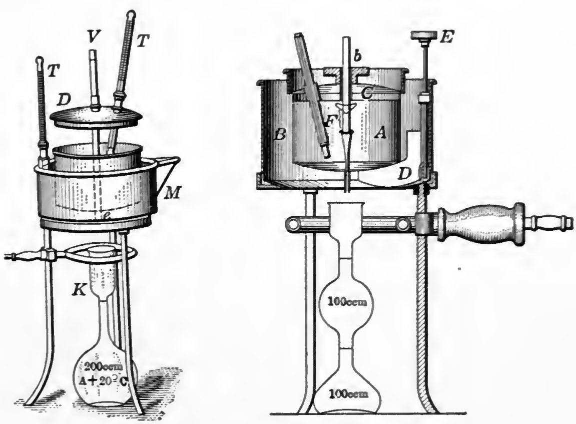

FIG. 86.—Engler's viscosimeter.

Foam.—Minute bubbles usually appear when a solution of glue is agitated. These may shortly break and disappear, or they may remain for some time; and, in the latter case, the presence of some foreign substance, such as lime-soap, may be suspected. "Permanent foam" may be desirable in the case of some confectioners' gelatines, but it is not desirable in the substances now being considered.

Foam is measured in specially graduated vessels. A hot solution of glue, placed in one of these vessels, is beaten or churned for some definite time, such as half a minute. Negligible quantities of foam will shortly disappear, while larger quantities of more "permanent foam" may reach to the various graduations in the vessel.

Strength.—The behavior of a piece of glue while being bent is sometimes taken as a criterion of its strength. It is true that a thin piece of good glue will sometimes bend almost double without breaking, and that, under the same circumstances, a sample of poor glue will sometimes break or crumble. But it is also true that some weak glues are flexible, and that some strong glues are brittle. It is not safe to estimate strength, even approximately, by the behavior of glue during bending.

A direct method of testing cements has been suggested by Ray.[1] Blocks of specially prepared porcelain are employed. One of the blocks resembles half of a cement briquette such as is specified for testing by the American Society of Civil Engineers, and two of the blocks, when joined together, resemble the complete form of the said briquette. The two blocks are glued together, and, after a sufficient time, are parted in a Fairbanks or other testing machine. It is hard to test glue in an ordinary wooden joint, because the glue in the joint is usually stronger than the wood. The wood fails first, and the test serves to determine the strength of the wood rather than that of the glue.

Strength is usually measured by comparing the solidity of a jelly made of the glue to be tested, with the solidity of a jelly made from glue of some standard make. The comparison may be made with a weighted plunger of some definite area; or, the jellies may be compared by pressing them, one after the other, with the finger. Fernbach, who has made many tests, regards the fourth finger of the left hand as being the most sensitive and, therefore, the most satisfactory for this work. On the whole, the jelly strength of a glue gives the best practical indication of its strength.

Fish Glues.—Less attention has been given to perfecting methods for testing fish glues. The means that manufacturers have for grinding these glues, and for judging their qualities, are apparently sufficient. The fact that fish glues are sold under labels is a safeguard to consumers.

[1] Thesis, New York University, 1902.

CHAPTER XVII

Indiarubber as a Structural and Machine Material. Sources, Preparation, Properties, and Uses of Indiarubber

The fact that rubber is used to some extent in construction, transportation, and manufacture, as in flooring, automobile tires, and belts, is sufficient to warrant its rating as a structural and machine material.

As sugar is known to exist in a variety of non-related and dissimilar plants, such as sugar beets, sugar cane, and sugar maple trees, so the constituents of the tough, impermeable, and very elastic substance known as Indiarubber, are known to exist in a number of plants that are not related to one another.

The trees, vines, and shrubs in which the constituents of Indiarubber are known to be present may be numbered by the hundred; but the trees, vines, and shrubs from which it is actually obtained in commercial quantities are comparatively few. The plants from which rubber is thus obtained grow in a belt that extends around the world. This belt includes parts of Mexico, Central America, South America north of Argentina, Africa from Cape Colony to Sahara, Oceanica, Java, Sumatra, Borneo, India, The Malay States, and the Philippines.

The constituents of Indiarubber exist in a milk-like fluid or latex that is present in and characteristic of most of the plants from which Indiarubber is obtained. The latex itself, the methods by which it is collected, and those by which it is made to yield rubber, are all-important.

References.—"Crude Rubber and Compounding Ingredients," Pearson (Indiarubber Publishing Company, New York, 1909); Files of Indiarubber World; Journal of Society of Chemical Industry; "The Culture of the Central American Rubber Tree," Cook (United States Bureau of Plant Industry, Bulletin No. 49); "Rubber Cultivation for Porto Rico," Cook (United States Division of Botany, Circular No. 28); "Indiarubber" (Special Consular Reports, Government Printing Office, 1892); "Guayule, A Rubber Plant of the Chihuahuan Desert," Lloyd (Carnegie Institution, Bulletin No. 129); "Indiarubber and Gutta Percha," Seeligmann, Torrilhon and Falconnet (Scott, Greenwood & Company, London, 1910); "Rubber," Schidrowitz (Methune & Company, London, 1911).

Latex.—This term applies generally to the milky juice secreted by certain shrubs, vines, and trees, In some cases the latex yields no rubber; in others it does yield rubber, but this is not

FIG. 87.—Appearance of Hevea rubber latex.

used.[1] Still other latex is known by experience to produce rubber satisfactorily.

[1] The latex of the common milkweed is a familiar example. When this fluid dries upon the fingers it yields an elastic, sticky substance which contains resins, other compounds and a residue, the empirical composition of which is the same as that of crude rubber.

Latex must be distinguished from sap. The latter fluid occupies a large proportion of the entire stem, and is common to all plants; while latex, which is restricted to certain species, is confined in delicate tubes that run lengthwise throughout the inner part of the bark. Sap is obtained by boring holes through the bark and outer sapwood; while latex is obtained by cutting across the bark alone.

The appearance of latex is similar to that of cow's milk. It is a thin, watery emulsion, made up of cream-like globules suspended in a thinner liquid of another composition. These two parts remain mingled in emulsion until certain physical or chemical changes cause them to separate. The creamy part of latex obtained from the plants of the Indiarubber series is the basis of indiarubber.

It is not known whether rubber exists as such in the latex, or whether it is due to recombinations caused by chemical or physical changes. It is enough to assume that rubber exists in the latex much as butterfat exists in cream, and that it is obtained from the latex by chemical or other manipulations that suggest the churning to which butterfat is subjected during the preparation of butter.

The proportions of rubber in the latex vary considerably. The composition of a sample of Ceylon Para latex, described in the Encyclopedia Britannica, was as follows:[1] Water, 55.15 per cent.; Caoutchouc (rubber), 41.29 per cent.; Proteids, 2.18 per cent.; Sugar, etc., 0.36 per cent.; Ash (salts), 0.41 per cent. The best latex may yield as much as 50 per cent. of rubber. Cook states that six pounds of fresh rubber were obtained from ten pounds of latex, but that this rubber shrank to three pounds before the end of the year.[2]

Collection of Latex.—Details vary with species and localities. Some plants produce larger quantities of latex and then require rest, while others yield smaller quantities at a time but yield these smaller quantities frequently. The comparative advantages of longitudinal, oblique, transverse, and spiral cuts, and of tools used to make these cuts, have received much attention. The object is to so adjust time and frequency of tapping with the peculiarities of species as to secure maximum yields during

[1] Quoted by permission of The Cambridge University Press.

[2] "The Culture of the Central American Rubber Tree," Cook (United States Bureau of Plant Industry, Bulletin No. 49, p. 75).

the longest possible terms with the least possible harm to the trees.

Pearson describes the collection of wild Para rubber as follows:

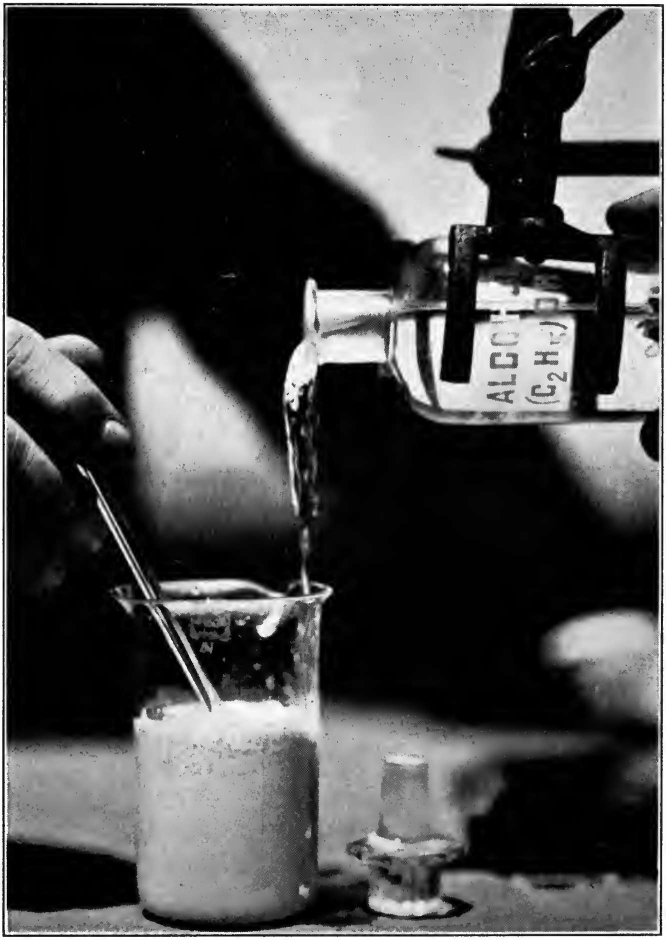

Fig. 88.—Application of coagulant (alcohol) to latex shown in preceding figure.

"A man locates from 100 to 150 rubber trees and cuts a narrow path through the jungle from tree to tree. He starts out early in the morning with a little hatchet and an armful of tin cups. He makes a few cuts on each tree and sticks the cups under to catch the latex. . . . The next day he goes through the same operation on the same trees, making fresh cuts. He continues this for several weeks, sometimes months. More than this, he taps the same trees year after year for many years."

Rubber Obtained from Latex.—The process by which rubber is obtained from latex is called coagulation. This term is used in all cases, even although the underlying changes may differ with

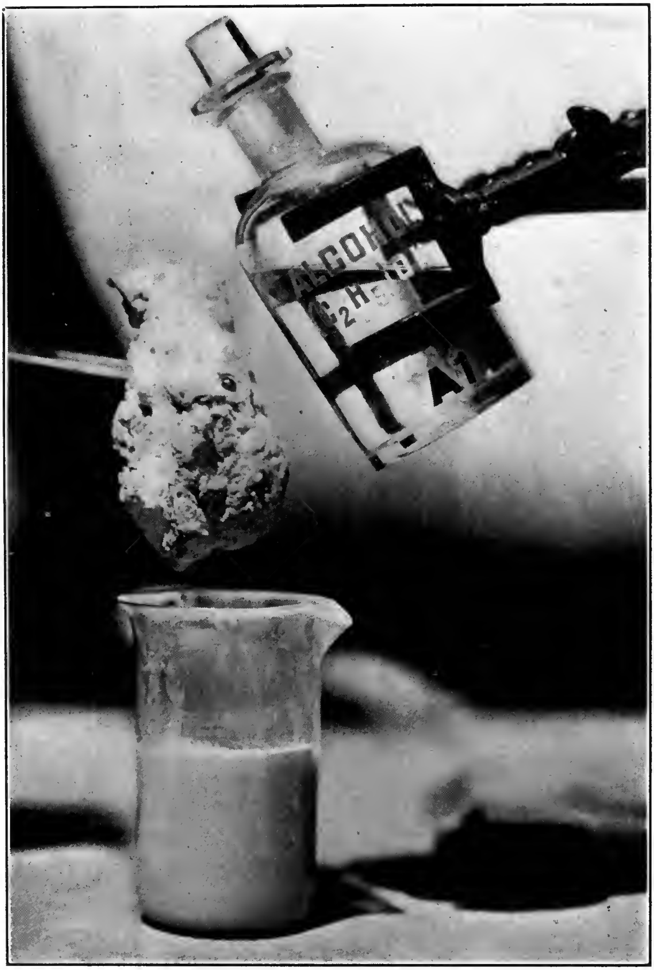

Fig. 89.—Result obtained by addition of alcohol to latex shown in Fig. 88. The white tint of the resulting rubber soon gave way to characteristic darker color and the mass became denser and much smaller.

the processes employed and with different species of latex. The phenomena of coagulation are not yet perfectly comprehended. Some kinds of latex coagulate spontaneously like blood, while others coagulate after fermentation like milk; still other kinds of latex coagulate after the addition of chemicals, and some do not coagulate at all. Among the materials and agencies employed to obtain rubber from latex are acetic acid, air, alcohol, alum, heat, lime, lime-juice, proprietary compounds, smoke and sunshine. The accompanying pictures show the effect of alcohol upon latex.

An exception to the rule that rubber is derived from latex should be noted. The rubber known as Guayule is distinct from most others because it is not derived from latex, the rubber existing *as such* in the cells of the plants. This rubber cannot be obtained by customary tapping and coagulating. It is either dissolved out by suitable chemical solvents, after the tissues in which it is contained have been ground in a mill; or else, the mass is agglomerated, either with or without the assistance of some substance like caustic potash that will attack the walls of the cells that contain the rubber.[1]

Much of the best wild Para rubber is obtained by exposing the latex to the smoke of burning palm nuts (usually *Attalea excelsa*). A wooden paddle is dipped into the vessel containing the latex and the thin layer that collects upon the paddle is exposed to the smoke. In some districts coagulation is obtained by spreading the latex over the banana-like leaves of a species of Calathæa, and then exposing it to the sun and air. Cook states[2] that the natives of Angola rely upon the fact that much Landolphia latex changes almost immediately upon exposure to the atmosphere, and obtain considerable rubber by smearing this latex over their bodies; the rubber is cut away as soon as the accumulation is sufficiently thick. There are many other ways by which latex can be coagulated.

GRADES OF INDIARUBBER. Indiarubbers may be grouped or classified in several ways. Some of these are as follows:

Geographical Classification.—From this standpoint rubbers may be classified according as they come from major areas such as the Para, Central American, African, and East Indian districts, and also as they come from fields within these major districts. Also rubbers are named from collecting stations, or trading points that are located within these minor fields.

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[1] "Guayule, A Rubber Plant of the Chihuahuan Desert," Lloyd (Published by Carnegie Institution).

[2] "Rubber Cultivation for Porto Rico," Cook (United States Division of Botany, Circular No. 28, p. 9).

Para rubber was formerly divided according as it came from the valley of the Upper Amazon and from islands in the Lower Amazon, into Upriver and Island Para. There are now Caviana, Cameta, Madeira, Manaos, Purus, and many other kinds of Para rubber. Central American Rubber, or "Centrals," includes Nicaraguan, Guatemalan, Mexican, Honduras, West Indian, and other yields; and each one of these includes others, as for example, Colombian rubber includes Cartagena, Panama, and other kinds. African rubber is divided according as it comes from French West Africa, Sierra Leone, Liberia, Gold Coast Colony, French Congo, Belgian Congo, East Africa, Madagascar, and other districts. East Indian rubber includes Rangoon rubber, which is a product of Burma exported through the port of Rangoon, Java rubber, and rubber from Borneo and other places.

Botanical Classification.—The plants known to contain rubber are too numerous to name in the present connection. The plants from which it is actually obtained in commercial quantities may be divided as they are trees, vines, and shrubs.

Tree Rubber.—The Para or Hevea Rubber Tree (*Hevea braziliensis*) stands first among all plants of every description that produce Indiarubber. This tree, which is the source of most Para rubber, is a native of Brazil but has been transplanted in many places on both hemispheres. Its value depends upon the quality of its rubber, and also upon the fact that it can be tapped every day for long intervals. Other important trees that yield Indiarubber are the Central American Rubber Trees (*Castilloa alba, Castilloa elastica* and others), and the Assam Rubber Tree (*Ficus elastica*) which is a native of India, Burma, and the Malay Archipelago.

Vine Rubber.—A large part of the supply from Africa is obtained from rubber-bearing vines and creepers, of which there are many species (*Landolphia owariensis, Landolphia heudelotii, Landolphia kirkii, Landolphia dawei, Landolphia thollonii* and others).

Shrub Rubber.—The Guayule (*Parthenium argentatum*) has already been mentioned.[1] This shrub flourishes over considerable areas in the dry regions of northern and central Mexico and in adjoining parts of Texas, Arizona, and New Mexico, and differs from most rubber producing plants in that the rubber exists *as such* in its cells. Special methods are employed to obtain this rubber, and their discovery has caused this shrub to become very valuable.

Crude and Refined Rubber.—The first term includes material as it arrives from the forests. Such rubber is distin-

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[1] "Guayule, A Rubber Plant of the Chihuahuan Desert," Lloyd (published by the Carnegie Institution, pp. 8, 9, and 177).

guished by the presence of smaller or larger quantities of twigs, bark, dirt, and other impurities that must be removed before the rubber can be used, after which removal the product is known by the second term, that is, as Refined rubber. The shapes of the pieces in which crude and refined rubber are presented are characteristic.

Fresh and Reclaimed Rubber.—The second term includes rubber obtained from worn-out and discarded rubber articles. This product is so important, that, for some time past in the United States, two pounds of it have been used to one of fresh rubber. Without Reclaimed rubber the shortage in the production of Fresh rubber would often have been serious. A mixture of fresh and reclaimed rubber is cheaper, and, in some cases, better than fresh rubber alone. Reclaimed rubber is often called according to its origin. Thus, there are tire-tread, hose, gumshoe, and other kinds of stock. The first term, that is, Fresh rubber, includes all that is not Reclaimed rubber.

Wild and Plantation Rubber.—Wild rubber is that which is obtained by more or less primitive processes from plants growing naturally in the forest. It is usually quite dirty and there are other defects, yet some of the best rubber is of this kind. At the present time, the larger part of the world's supply of rubber is Wild rubber.[1]

Plantation rubber is obtained from cultivated trees. Tapping, coagulating, and other details are attended to in a more or less scientific manner. Plantation rubber is frequently branded with the trademark of the planter who then assumes responsibility for the quality of his product. The quantity of this kind of rubber is increasing every year; yet, much remains to be learned with regard to it. It is known that some species do well in some localities, and fail utterly in others, and that some individual trees grow well and yet fail to produce satisfactory quantities of latex. There are many ways in which failures may take place, but, in spite of this, as the following table (Pearson) shows, rubber planting is increasing very rapidly in the Far East.

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[1] It should be noted that the wild rubbers received at the present time are for the most part Para rubbers, and that in spite of the crude methods employed to collect and prepare them, the various grades of Para rubber are quite good and uniform in quality. This cannot be said of much of the plantation rubber noted in the succeeding paragraph. Medium grade plantation rubbers often exhibit wide variability. High-grade plantation rubbers are, however, quite uniform in quality.

	Ceylon, pounds	Federated Malay States, pounds	Total, pounds
1903	41,798	....	41,798
1904	77,212	....	77,212
1905	168,547	228,800	397,347
1906	327,661	1,028,792	1,356,453
1907	566,080	2,089,085	2,655,165
1908	912,125	3,671,435	4,583,560
1909	1,372,416	7,390,643	8,763,059
To August 15, 1910	1,468,146	7,512,102	8,980,248

Classification Due to Form.—The sizes and shapes of pieces in which rubber is originally marketed vary greatly. Some forms are associated with peculiar processes or conditions, or with certain districts, or species. For example, much plantation rubber is received in rough-surfaced sheets known as crepe. Rubber from Sierra Leone is received in forms known as twists, cakes, and niggers. There are also many other forms, such as thimbles, balls, nuts, lumps, flake, paste, buttons, oysters, biscuits, tongues, blocks, worms, strips, sheets, scrap, and lace.

PREPARATION AND PURIFICATION OF RUBBER.—The process employed to free crude rubber from mechanical impurities is called washing. The rubber is first soaked in very hot water and is then passed again and again between corrugated rollers of special machines that tear and break it. At the same time streams of water are made to flow over the rubber and these streams carry away the impurities that are exposed by the tearing action of the rolls.

Rubber treated in this way is comparatively clean, but much water is retained. It is, therefore, submitted to the rollers of another machine which press it into comparatively thin sheets, in which form it is ready to be dried. The sheets are either dried slowly by natural means, or they are dried rapidly under high temperatures in rooms prepared for the purpose.

From this point details vary more greatly as different objects are to be attained. For example, the rubber must be "mixed." Aside from the sulphur used for vulcanization, rubber is seldom used alone, but other substances are added, the object being to reduce the cost of the rubber without destroying its usefulness, or to give it characteristics that cannot be secured in any other way. Sulphur, zinc white, white lead, whiting, oils, rubber substitutes, and many other materials and compounds are used in this connection.

Several machines are necessary. A warming mill or "warmer" is a set of rolls, within which steam circulates. The mill causes the rubber to become soft, homogeneous, and ready for mixing. The incorporation of the several ingredients with one another is accomplished in a mixing machine or "mixer" designed for this purpose. A "calender" is a mill by which the prepared rubber is formed into sheets from which it can be more easily made into the desired shapes and sizes. There are many combinations and details.

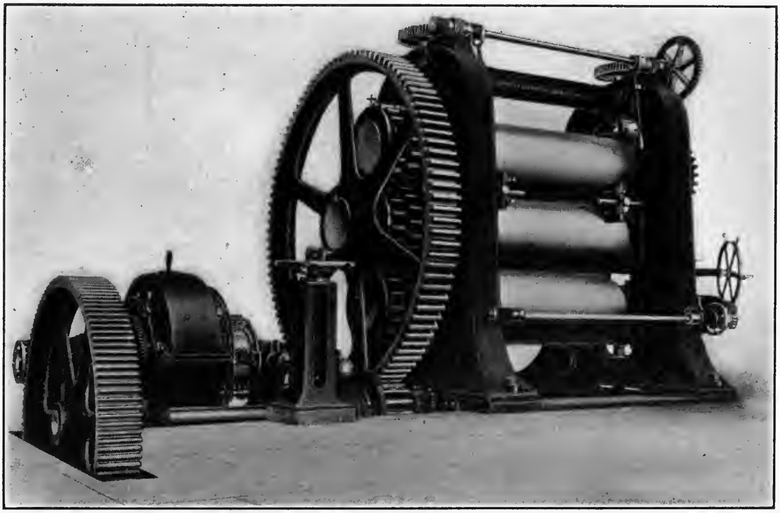

FIG. 90.—Calender with coil clutch motor drive.[1]

Vulcanization.—The fact that pure rubber is influenced by comparatively moderate changes of temperature led to experiments that resulted in the discovery of the process called "vulcanization." This discovery, made by Goodyear in 1844, consists, briefly, of subjecting rubber to the influence of sulphur. The exact nature of many details is not always divulged by manufacturers. Practically all rubber is now vulcanized.

The details of the processes employed to secure vulcanization vary greatly. Many objects are to be attained and details known to secure the results desired are followed. Primarily, vulcanization processes may be grouped as they are Heat Processes and Non-heat Processes.

[1] Photograph, Farrel Foundry & Machine Company.

Heat Processes.—The heat may be wet or dry. In the first case, articles, such as sheetings, are covered with French talc, so that they will not adhere to one another, or are wrapped in cloth, and are then subjected to the action of live steam. Time, temperature, and pressures, which latter are above that of the atmosphere, are important. In the second case, articles, such as shoes, coats, and other black goods, are cured in dry, hot air or are confined in moulds and then placed in a steam press. Sometimes rubber is cured and moulded at the same time. This is the case with rubber belts that are cured while being moulded between the platens of special presses.

About six per cent. of sulphur, based upon the weight of the rubber, is used in the vulcanization of the majority of articles prepared for mechanical purposes. Press-cured articles often contain as much as eight per cent. of sulphur. In the case of rubber shoes the amount of sulphur used is three per cent., based upon the weight of the rubber. Larger quantities are used in the preparation of the hard rubber known as "vulcanite" or "ebonite." As a rule more sulphur is used than is needed to combine with the rubber. The excess of uncombined sulphur that remains after vulcanization is distributed in extremely small globules throughout the mass, and eventually appears upon its surface as a grayish powder. In this connection, it should be noted that results are often influenced as much by the time and temperature of vulcanization as by the quantity of sulphur.

No action takes place between the rubber and the sulphur until the temperature reaches about 120 degrees C., and, even then, the action proceeds slowly; but the action goes forward more rapidly as temperatures increase, particularly in the presence of much sulphur. The temperatures required during the preparation of mechanical goods vary between 120 degrees C. and 150 degrees C. Hard rubber or vulcanite may require higher temperatures.

Non-heat Processes.—These are of two kinds: acid vulcanization is accomplished by dipping the prepared rubber in a solution of sulphur chloride and carbon bisulphide, and then treating it with an alkaline wash; while vapor vulcanization is obtained by subjecting the rubber to the fumes of sulphur chloride, later replaced by those of ammonia. Articles to be vulcanized by these methods must be thin, since otherwise the liquids do not penetrate. Cold vulcanization usually results in soft, velvet-like surfaces, but articles treated by this method are not always durable.

PHYSICAL AND CHEMICAL PROPERTIES OF RUBBER.—Crude rubber is tough, pliable, impermeable to water and gases, and a very poor conductor of electricity. Its most characteristic property is elasticity; that is, its ability to return to about its original dimensions after it has been stretched through a distance many times its original length.

The base of crude rubber is chemically Pure Rubber, which, in many places, is distinguished by the name Caoutchouc. It should be noted that the name Caoutchouc has two meanings. First, as already stated, the meaning is frequently restricted to chemically pure rubber; but, second, it is also used as a synonym for crude rubber; that is, for pure rubber with its associated compounds. The formula of pure rubber, or Caoutchouc, $C_{10}H_{16}$, is so approximate and general as to be of little use. The same formula applies to gutta percha.

Besides Caoutchouc, crude rubber contains resins, the functions of which are not understood, although it is probable that they exert an influence upon vulcanization. Nitrogenous substances, proteins, and peptones, the functions of which, like those of resins, have not been thoroughly investigated, are also present. Other ingredients may be grouped as carbohydrates, refuse, such as dust and bark, moisture, and materials or compounds introduced by coagulating processes. It should be remembered that crude rubber is, in large part, a mixture containing parts of practically all of the constituents that existed in the latex from which the rubber was prepared. From this viewpoint it may be regarded as, proportionately, a chemical combination within the mass of which other substances or compounds have become mechanically entangled. Analyses of crude rubber vary with the character of the latex from which it was prepared, and with the methods employed during the processes of coagulation.

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Crude rubber is influenced by moderate changes in temperature. Heat causes it to soften and become more or less sticky or "tacky"; sheets submitted to higher heat in dry-rooms designed to dissipate moisture absorbed during cleansing sometimes soften so greatly that they drop from the supports upon which they are hung. Crude rubber loses most of its elasticity when placed in boiling water, but hardens and becomes elastic again as soon as it is allowed to cool. It melts at about 250 degrees F. and becomes a viscous fluid that does not harden again; while higher temperatures cause decomposition with the formation of various liquid hydrocarbons. It is sensitive to low temperatures; and, when subjected to excessively low temperatures such as those caused by liquid air, it loses all elasticity and may then even be powdered.

Crude rubber is insoluble in water and alcohol, and is but slightly acted upon by dilute acids. The effect of dilute alkaline solutions is, however, quite pronounced. Such solutions exert a marked depolymerizing action upon the rubber, which becomes much softer, and if the subjection to the alkaline solution is excessive, stickiness and tackiness may result. Crude rubber is soluble in turpentine, petroleum spirits, carbon disulphide, carbon tetrachloride, and some other liquids the comparative importance of which is much in the order mentioned. These liquids are used, either alone or in mixtures, whenever it is necessary to dissolve rubber.

Crude rubber is subject to oxidation, which causes it first to become soft, and then to become hard, brittle, and useless. This phenomenon, which is technically known as "perishing," is thought to be influenced by light, heat, and the constituents of the rubber itself. Under certain conditions, vulcanized rubber behaves in a similar manner, but in such cases the changes are possibly influenced to some extent by fillers employed to secure certain physical characteristics.

Crude rubber responds to the influence of certain chemical substances. The changes that take place when rubber is joined with sulphur in vulcanization have been noted. These changes are of a chemical nature. As distinct from these changes, however, crude rubber is able to take up, more or less mechanically, certain powders, such as litharge, powdered coal, and the salts of aluminum and of iron, and to form with them homogeneous masses with colors and other properties influenced correspondingly by the character of the fillers used.

Some of the more characteristic mixing ingredients and fillers are as follows:[1] *Vulcanizing Agents;* sulphur and sulphur chloride. *Accelerators of Vulcanization;* litharge, calcium hydrate, magnesium oxide or carbonate. *Colorless Fillers;* whiting, barium sulphate, lithopone, French chalk, and zinc oxide. *Colored Fillers;* antimony, arsenic or mercuric sulphides, red lead, lead peroxide, ferric oxide, chromic oxide, lead chromate (cold cure), ultramarine, Prussian blue (cold cure), graphite, and lamp-black. *Organic Fillers;* paraffin wax, pitch, rosin, tar, and rubber substitutes (white and brown).

From a chemical viewpoint, vulcanized rubber is principally distinguished from crude rubber by being cleaner, as well as by the presence of sulphur and of fillers used to influence physical properties and give colors to final products. From the physical viewpoint, vulcanized rubber is much more stable than crude or pure rubber. It is not influenced by moderate changes in temperature, and is more elastic and in every way better than crude rubber. The improvement caused by vulcanizing is so great that practically all rubber is now subjected to this process. Vulcanized rubber may be soft or hard.

Soft vulcanized rubber, which is obtained by limiting the quantity of sulphur and by using comparatively little heat, is used for such articles as pencil erasers and tubing. Hard vulcanized rubber, obtained by using larger proportions of sulphur and higher degrees of heat, is called "vulcanite" and "ebonite." This product resembles horn or celluloid and is used for such articles as combs and buttons. The name "semi-vulcanite" is sometimes applied to products that stand between these extremes.

THE USES OF RUBBER.—Rubber is used in flooring, automobile tires, belts, and machine foundations. In electrical science, it is used as an insulating material; while its value as a waterproofing agent is of fundamental importance. It also enters into hose, surgical goods, sporting goods, cements and other groups of articles and compounds. For many purposes satisfactory substitutes for rubber do not exist.

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[1] See "Chemistry of Rubber," Porritt (p. 42).

Synthetic Rubber

Synthetic rubber is the result of a purely chemical process. In composition and in properties it is equivalent to, or the same as, natural rubber. Thus far synthetic rubber is a scientific truth rather than a practical success. The fact that artificial rubber can be prepared in laboratories, and that such rubber is practically identical with that obtained from trees, is beyond question; but the cost of such rubber is yet so high that very little of it is manufactured.

The ultimate value of synthetic rubber must obviously depend upon its cost and quality. Assuming the quality to be satisfactory, methods will have to be devised whereby parent substances can be prepared in larger quantities and more cheaply than at present. The problem is complicated by the fact that, with present knowledge, it seems necessary that parent substances should be particularly pure.

It has long been known that an intimate relationship exists between indiarubber and a group of substances, of which isoprene and butadiene are at present the most notable. In 1860, Williams isolated what is now known as isoprene, from products obtained from the destructive distillation of rubber. In 1875, Bouchardat suggested that under certain conditions isoprene might be converted back again into rubber. In 1892, Tilden discovered that some old specimens of isoprene obtained from turpentine had converted themselves into rubber without assistance; and, in 1909, Hofmann and others suggested the methods that are now employed.

Isoprene is obtained in several ways, as from fusil oil, and by condensing vapors of turpentine over iron at temperatures of from 55° degrees C. to 600 degrees C. (English patent 27908 of 1909). Butadiene is also obtained in several ways, as from products obtained by fermenting the dried pulp of potatoes (Detoeuf, Nature, 1912, p. 306). Of the two parent substances mentioned, isoprene is a colorless liquid-hydrocarbon in which the hydrogen and carbon exist in the same proportions as in ordinary rubber. The transformation of isoprene to rubber is obtained by placing isoprene, selected for its purity, under pressure, and then heating it, with or without the intervention of other substances. Or else, it is transformed by the influence of small quantities of other substances, as metallic sodium.[1]

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[1] Such a change is due to polymerization, which has been defined as the apparent fusion or union of two or more molecules, into a more complex molecule with a higher molecular weight and somewhat different physical and chemical properties (Century Dictionary).

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[1] The names "Division of Forestry" and "Bureau of Forestry" have been used by the National Government to denote what is now its "Forest Service."

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