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SELECTION OF WOOD FOR INDUSTRIAL USES

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Wise selection of wood for a given use necessitates first, the determination of the requirements of that use. Good engineering judgment and careful observation are essential to determine which properties are required for satisfactory service and which properties are the most important. The selection of the proper wood is primarily the responsibility of the engineer on the job, because the requirements of use vary with conditions in the plant, the quality of articles produced, and the conditions to which the articles will be subjected in service. The wood best adapted to a given use will, therefore, not always be the same. Ash and southern yellow pine furnish an example of widely different woods used successfully for the same article. Ash is used for bats for college, semiprofessional, and professional ball players. Southern yellow pine serves equally well as ash for bats for small boys of the grade-school age because for children's bats the strength and toughness requirements are not so high. The necessity for careful observation is illustrated in a mistake commonly made in selecting wood for diving boards. Decay-resistant woods are often selected because of the wetting to which the boards are subjected. Diving boards, however, usually fail mechanically in less than 2 years if they are subjected to continuous use, such as at popular public beaches. The selection of a comparatively high-priced, weak wood of high decay resistance in preference to a low-priced strong wood of moderate or low decay resistance, as is often done, is obviously wasteful, because the purchaser is paying for decay resistance, a property of little or no importance to the use requirement.

After the requirements of use are determined, the next step in the proper selection of wood is the determination of a wood with properties which best meet the requirements. Again, good engineering judgment is needed, since it is only in exceptional uses that one wood will excel all others in the properties desired. For example, two important requirements for ladder stock are strength for safety, and light weight for ease in handling. Spruce is light in weight but low in strength when compared

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with Douglas fir. For each particular type of ladder, it is necessary to determine the importance of the lightweight requirement. Furthermore, the wood best adapted to a use may be higher in price than one which does not meet the requirements so well. The question then is, how much more is the better wood worth? To evaluate the difference in properties, especially when they improve but do not increase the service life, calls for good judgment.

Investigations of the Forest Products Laboratory have resulted in the publication of much information on the properties of wood. This information furnishes a basis for the selection of the wood best adapted to a given use. A large number of the publications contain detailed data on such properties as strength, weight, decay, and painting characteristics. Recently there was published the Wood Handbook,² which gives under one cover the accumulation of information previously scattered through a number of bulletins. It contains information on strength, shrinkage, specific gravity, thermal conductivity, electrical resistance, and other properties in units and terms with which the engineer is familiar and knows how to use. No detailed discussion of these properties is possible or necessary in this paper.

Machining and Behavior Properties of Wood

Properties which are not so readily expressed in engineering terms often determine the selection of wood for industrial use. Little has been published on these properties, and it is only through the initiative of the present Wood Industries Division of the A.S.M.E. that any attempt has been made to measure and record them. The absence of engineering data on such properties has resulted in wide differences of opinion as to the extent to which individual species possess or do not possess merit for some particular use. Prejudice and misconceptions regarding such properties have been the cause of considerable loss and poor practice in the use of wood. Recently the Forest Products Laboratory has begun to attack the problem of measuring and recording these properties. The work is still in progress and new methods of measuring, as well as units for recording, have been and must continue to be developed. As a result of the work to date there are now available data which make possible a comparison of a number of hardwood species important in industrial use. The importance of these properties in the selection of wood for some of the industrial uses warrants a brief presentation of the more important properties so far studied.

²"Wood Handbook," by Forest Products Laboratory, U. S. Department of Agriculture, September 1935. For sale by the Superintendent of Documents, Washington, D. C., 25 cents.

Warping.--Warping is responsible for much waste in fabricating and for some unsatisfactory service. It is defined as: "Any variation from a true or plane surface. Warp includes bow, crook, cup, and twist or any combination thereof." The twist, cup, and bow of samples of southern and Appalachian hardwoods representative of the commercial run of the material were measured and the data combined into the index values shown in Figure 1. The results not only make possible a numerical comparison of species but also show that cross grain is the principal cause of warping, and woods with interlocking grain have the highest index.

Splitting in nailing.--The splitting of wood in nailing adversely affects the strength of joints. Splitting is controllable within limits by the shape of the point and the size of the nails. Additional nails will generally increase the strength of the joint. The splitting tendencies of species are, however, important factors in the selecting of wood for certain uses, notably frames to which upholstery is fastened in furniture and automobiles. Tests using seven-penny box nails in 3/8-inch material and varying distances from the ends resulted in the development of the index values shown in Figure 2. They are based on the number of complete or through splits. While the index figure may change materially under different test conditions, only minor changes in the relative position of species are to be expected under different test conditions. The application of these results should aid materially in reducing losses resulting from erroneous opinions based on casual observations.

Splitting in screwing.--The splitting of wood by screws adversely affects the strength of joints and fastenings. It is an important consideration in determining the size of lead holes in framing on which heavy doors are to be hung or where hardware is fastened to wood. Some woods which split readily with nails make a much better showing with screws.

The classification of the species in Figure 3 is based on the complete splits resulting from tests made under severe conditions, namely, with screws of several sizes driven into 3/8-inch stock near the end. The property is important in the manufacture of refrigerators, automobile body frames, boats, and agricultural implements.

Turning.--There is considerable difference in the character of surface obtained in turning different woods. The importance of turning qualities in the selection of wood lies in the amount of sanding required to make turnings acceptable and the number of culls. In the past turning qualities have been described only in general terms. The numerical values shown in Figure 4 were obtained with a modified back knife using specimens conditioned to 6, 12, and 20 percent moisture content. The results showed that some species, such as beech and pecan, turned well at any moisture content whereas other species, such as willow and cottonwood, give good turnings only at about 6 percent moisture content. The difference in species can be reduced by drying to a proper moisture content. The property is important in the selection of wood for furniture and interior trim.

Planing.--Much better technic is required with some woods than with others to obtain smooth surfaces with a planer. Species differences can be largely eliminated by proper control of speed, moisture content, and cutting angle. High cutter-head speeds (5400 rpm and 54 fpm feed) gave better results than low speeds (3600 rpm and 36 fpm feed). The numerical classification shown in Figure 5 is based on the chip marks, chipped, raised, and fuzzy grain that developed in planing samples at 6, 12, and 20 percent moisture content with a cabinet planer having knives set at a 30-degree angle and operated at the two speeds just mentioned. It is possible that additional work using different knife angles will show how to reduce further differences due to species. Good planing qualities are desired in practically all industrial uses of wood.

Odor and taste.--A tendency to impart odor or taste bars some woods from a number of industrial uses. The classification shown in Figure 6 is based on ash as 100 and is the result of tests in which butter was used as a test medium. Butter was used because of its susceptibility to contamination. Woods unsuited for use in butter containers can often be used safely when food does not come in direct contact with the wood such as in refrigerators. Any of the first six woods listed in Figure 6 can be used satisfactorily for butter containers. Service tests are required to determine the line between acceptable and unacceptable woods for other uses, but any wood acceptable for butter containers can be used safely for other purposes where a tendency to impart odor or taste is objectionable.

Bending.--Most hardwoods can be bent readily into a curved form. The comparatively low toughness of softwoods as a group makes them difficult to bend without excessive breakage. The bending index figures shown in Figure 7 are based on tests of specimens selected at random with only knotty, decayed, and checked pieces excluded. Many of the specimens would not be considered suitable for bending stock because of cross grain they contain. The index shown in Figure 7 is a measure of the care necessary in selecting and handling the different woods rather than a measure of the waste that would result from their use, because the specimens were bent without end pressure or support on the outside of the bend. Bending operations on carefully selected material, with equipment capable of supplying the proper end pressure and back support, would in all probability result in a much smaller spread between species. The index shown in Figure 7 is an aid in selecting woods suitable for boat building, certain types of furniture, and other uses.

Use of data on machining and behavior properties.--The numerical values shown in Figures 1 to 7, inclusive, should not be used for computing waste because limitations are placed on them by test conditions and method of selection. They will in all probability not hold under conditions differing materially from those under which the tests were made. The relative position of species, however, should remain about as shown. The charts should prove a valuable aid until better values resulting from

continued work are available in comparing species, and in evaluating properties previously arrived at by guess or superficial observation.

Woods Used by Selected Industries

An important aid in the selection of wood for a given use is a knowledge of woods which are and have been used for the purpose. The woods used indicate fairly well the requirements of the use. When maple, for example, is the principal wood used it indicates that strength and uniform texture are more important than decay resistance and ease of working.

There are available data on the woods used by 48 principal wood-consuming industries. These data, given later in this paper, were collected by Forest Survey of the U. S. Forest Service in cooperation with the Bureau of Census for the years 1928 and 1933. Additional data collected by the states between 1909 and 1913 show the woods used in that period. Ten industries have been selected with the aid of the Wood Industries Division of A.S.M.E. to illustrate the character of data available. The decreased consumption shown in 1933 is largely due to economic conditions. In some uses there has also been a loss of the market for wood.

Furniture.--The distribution of woods used in manufacturing furniture is shown in Figure 8. These woods may be roughly divided into two groups: (1) Woods used for exposed parts, and (2) woods used for concealed parts.

Appearance, style, and finishing qualities are the properties dominating the selection of woods for the first group. Ability to stay in place, nonsplitting, good holding power for screws and nails are important requirements of the second. Properties and use data are of little value in the selection of wood for exposed parts of furniture. The shifts from one wood to another are practically unpredictable from year to year.

Red gum, yellow poplar, maple, chestnut, and tupelo hold an important place as furniture woods regardless of shifting styles. These woods are used largely for core stock or framing and are selected on the basis of their properties rather than their appearance. Red gum and maple are also used as finish woods.

Motor vehicles.--Strength, uniform working qualities, and high nail- and screw-holding qualities are desired in wood for automobile body frames. Figure 9 shows oak, red gum, and maple as the principal woods used. Hickory dropped to a minor position with the adoption of wire and disk wheels. The choice between maple, oak, ash, and elm is largely one of availability and cost. The woods are used interchangeably, sometimes all three being used in a single built-up part. Maple is generally preferred because of its uniformity, working qualities, and high strength.

Red gum has the advantages of low weight combined with medium strength and nail-holding power. These combined with price and uniform texture are responsible for its use in low-priced cars.

Railroad-car construction.--The outstanding woods for railroad-car construction and repair are southern yellow pine and Douglas fir as shown in Figure 10. Availability and price are probably a larger factor in the extensive use of these woods than their strength, decay resistance, and ease of fabrication. Oak is still used in frames for its shock-resisting and high nail- and screw-holding qualities. The substitution of steel for oak is largely responsible for the percentage decrease in its use as shown in Figure 10.

Agricultural implements.--The requirements for agricultural implements differ with individual units. Hay rakes, threshing machines, and seed drills not only differ widely in their requirements but the requirements of individual parts also differ. It is difficult to generalize over such a wide range. Figure 11 shows that southern yellow pine and oak are the woods most extensively used. Oak is used because of its toughness and southern yellow pine because of its ease of seasoning, light weight, moderate strength, and price.

Refrigerators.--The wood requirements for refrigerators have been entirely changed by electric refrigeration. The steel cabinet has replaced the wood cabinet, which accounts for the reduction in the use of oak, ash, and elm shown in Figure 12. The predominating woods are now spruce, hemlock, and Douglas fir. These woods are used for frames. The hemlock and spruce differ little in strength. Hemlock is slightly heavier and stronger than spruce but the latter is stronger for its weight. Neither spruce nor hemlock impart any objectionable odor or taste to food. Both woods are low in decay resistance. Douglas fir is stronger and has more decay resistance than spruce or hemlock, but it has a slight resinous odor. The principal woods used are selected because of their availability and price rather than their properties, although woods with a strong odor are banned.

Caskets and coffins.--Decay resistance is considered the most important requirement for caskets and coffins. It is responsible for the extensive use of chestnut and cypress, as shown in Figure 13. Observations made on caskets and coffins removed from a burial ground after 20 years indicate the failures that had occurred were principally mechanical. Where decay was responsible for failure, it was found that all heart grades had not been used. The mechanical failures do not indicate the necessity of selecting other species, but rather the necessity of improved bracing and design.

The trend toward uncovered hardwood caskets introduces a new requirement. Appearance is important in uncovered wood caskets and will result in an increased use of woods with high or moderate decay resistance, as black walnut, chestnut, white oak.

Firearms.--Black walnut, as shown in Figure 14, is the outstanding wood used in firearms. It meets the requirements for beauty, stability, and hardness. Birch and red gum are used in lower-priced guns. Birch has the hardness but lacks the stability of walnut. Red gum has neither the hardness nor the stability of walnut, but is used as a substitute because it can be finished to closely resemble walnut.

Handles.--Hickory and ash stand out from other woods in their ability to meet exacting requirements of handles as shown in Figure 15. Hickory is outstanding because of its combination of toughness, stiffness, and breaking strength, all of which are required in axe, maul, and similar handles. In addition, hickory turns well and wears smooth. Ash is outstanding because of its high toughness and breaking strength, for its weight, and its low warping, all of which are the requirements for pitch forks, rakes, hoes, and other long handles subjected to heavy use. Beech, birch, and maple are extensively used for hammers, small tools, and other short handles where smoothness in turning is more important than weight or toughness.

Pencils and pen holders.--The requirements for good pencil wood, as stated by manufacturers, are even texture, straight grain, softness, slight brittleness, dark red in color, slightly aromatic, and light weight. The requirements that wood be dark red in color and slightly aromatic are interesting in that they have nothing to do with the serviceability of a pencil.

Eastern red cedar was and is still considered the outstanding pencil wood of the world. Incense cedar has supplanted eastern red cedar as shown in Figure 16, not because it is considered better, but because of an inadequate supply of eastern red cedar. Brittleness is also a questionable requirement because the preferred eastern red cedar is more than twice as tough as incense cedar. Eastern red cedar is also the hardest of the cedars, indicating, that within limits, hardness is not so important as it is rated. The search for a substitute for eastern red cedar has been complicated by an erroneous conception of the actual property requirements. Any of the cedars, a number of junipers, redwood, and white pine all have properties favorable to their use as pencil woods. Prejudice prevents their serious consideration.

Ladders.--The properties that contribute to satisfactory service have been used to classify woods for use in ladder construction. The classification groups woods for side rails on the bases of the required percentage increase or permissible decrease of requirement for spruce for each cross-sectional dimension.³

³"Safety Code for the Construction, Care and Use of Ladders," Bulletin No. 351, October 1923. Department of Labor, Bureau of Labor Statistics, Washington, D. C.

Spruce is not only the standard but is also the principal wood used in the construction of ladders, as shown in Figure 16. Its high ratio of strength to weight is largely responsible for its high rating as a ladder wood. Its light color is responsible for the demand for light-colored wood for ladders, although color has no service value and appearance is of minor or no importance in ladders. Western hemlock, which ranks next to spruce in the use of wood for ladders, makes an excellent substitute for spruce. While the properties of western hemlock do not meet ladder requirements as well as spruce, some manufacturers have found it easier to obtain satisfactory hemlock than spruce, principally because the best quality of spruce is selected for airplanes and other more exacting uses. Southern yellow pine and Douglas fir are used in ladders where the strength-weight ratio is not so important. They make stronger but heavier ladders.

Rungs and cleats of ladders are of hardwoods, white ash being used as a standard. Figure 16 shows that hickory is the principal wood used for this purpose. Hickory is superior to ash in strength and wearing qualities. It is, however, heavier and does not have as favorable a strength-weight ratio.

Significance of species used.---The extensive use of wood for a given purpose indicates that it has been found acceptable by the cut-and-try method. It does not necessarily indicate that it is the best wood for the use. The best wood may be too high priced or the cut-and-try system may not have considered all possible woods, or a wood previously not readily available perhaps now is obtainable.

The selection of wood to replace one that has proved satisfactory is fairly simple. The properties of available woods are compared with those of the wood in use. The selection of the best substitute requires good judgment in evaluating the differences in properties, especially the elimination of the nonessential properties. When a wood in use is not satisfactory, the selection of a wood that will give satisfactory service depends on a knowledge of the exact cause of failure. Strange as it may seem, decay-resistant wood of the same or lower strength is often selected to replace a wood that has failed mechanically. Moreover, woods which are non-decay-resisting are often selected to replace woods that are being replaced because of decay.

The Importance of Species

The general tendency is to overemphasize the importance of species. The importance of small differences in species is magnified, the variability of wood of species is ignored, and there is a tendency to assume that all wood of one species is superior to all wood of another. There is always considerable overlapping in strength and other properties

of all competitive species. Well-selected wood of an inferior species is better than poorly selected wood of a superior species.

Design and treatment are great equalizers of species. A well-designed article made of a comparative inferior species will usually give better service than a poorly designed article made of a superior species. Differences in strength can be compensated for by differences in size. Differences in decay resistance can be compensated for by treatment and better protection from moisture. Differences in working qualities can be compensated for by the control of the speed of machinery, angles of knives, and moisture content of stock. Warping and shrinkage tendencies can be partly controlled by selection. With the exception of a few uses with exacting requirements any one of a number of woods can be used if proper design and treatment are applied.

Quality Indices of Southern and Appalachian Hardwoods

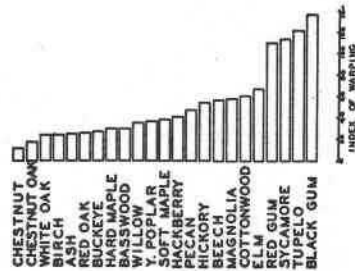


Fig. 1.--Unstrained warping

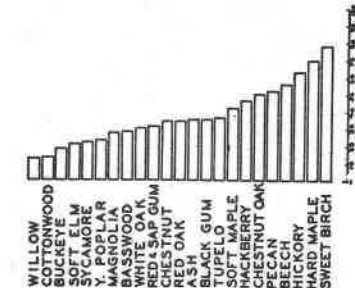


Fig. 2.--End splitting, seven-penny nails driven in 3/8-inch stock

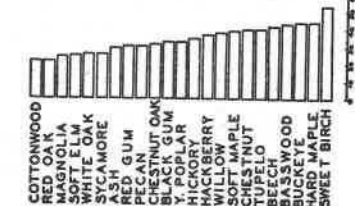


Fig. 3.--End splitting, screws driven in 3/8-inch stock

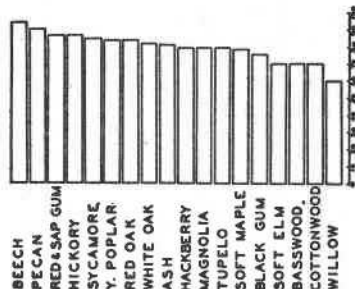


Fig. 4.--Turning quality with modified back knife

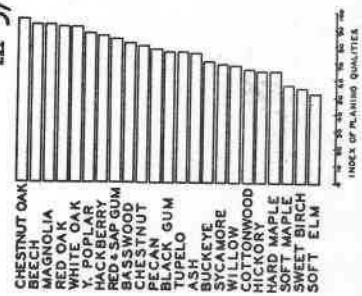


Fig. 5.--Cabinet planer, knives set at 30 degrees

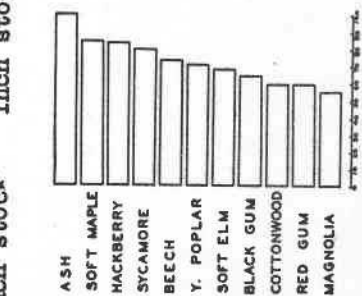


Fig. 6.--Tendency to impart odor or taste, butter-taint tests

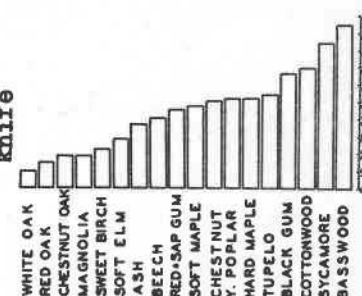


Fig. 7.--Bending quality, unsupported specimens selected at random

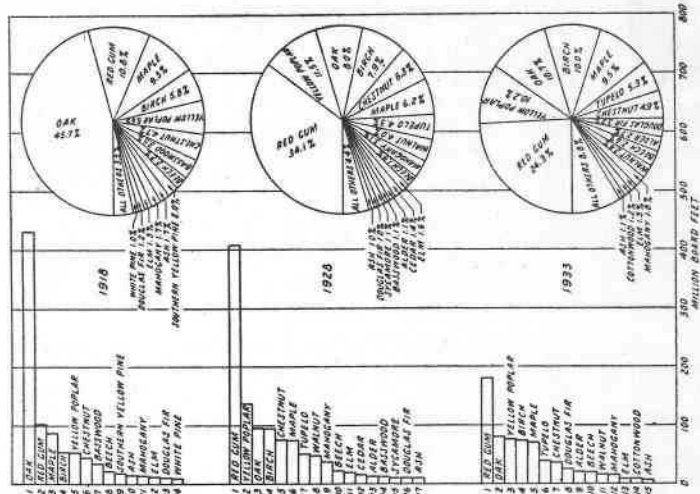
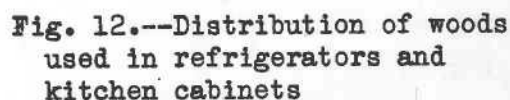
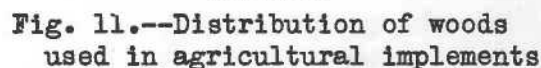
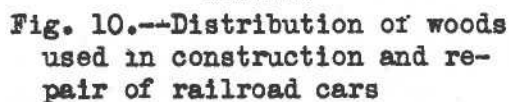
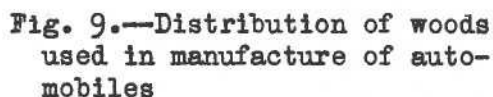


Fig. 8.--Distribution of woods used in manufacture of furniture



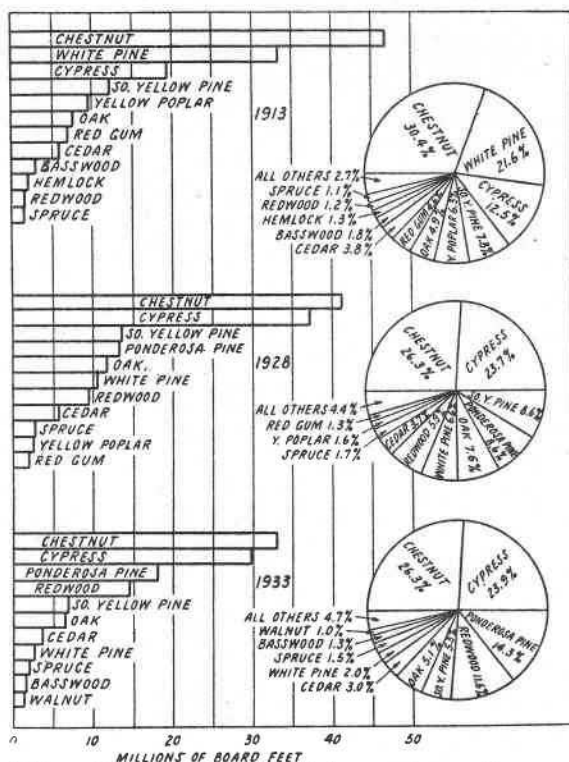


Fig. 13.—Distribution of woods used in caskets and coffins

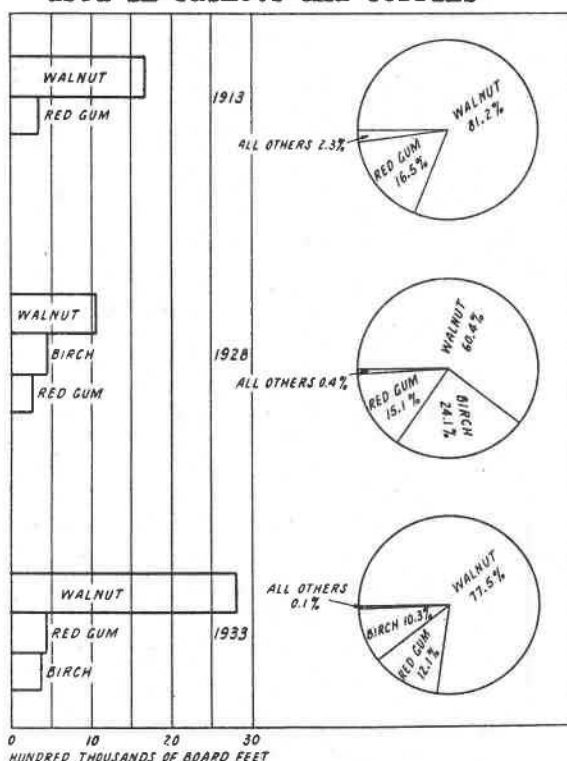


Fig. 14.—Distribution of woods used in firearms

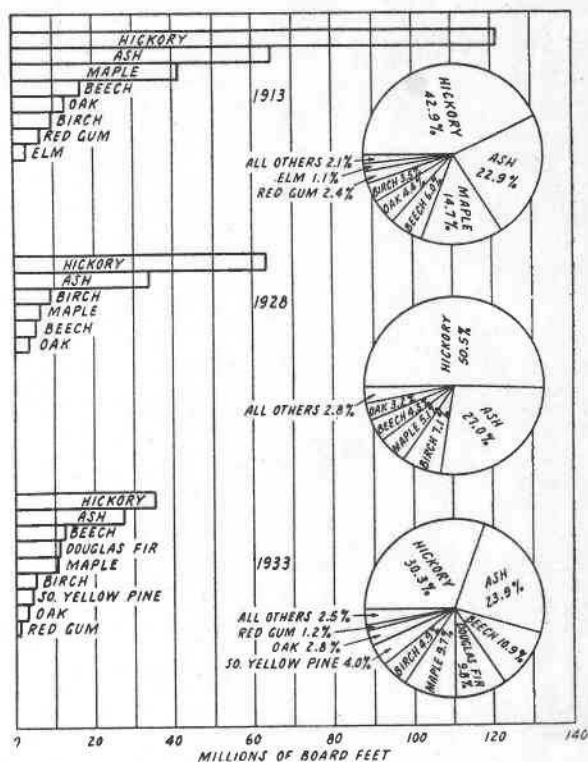


Fig. 15.—Distribution of woods used for handles

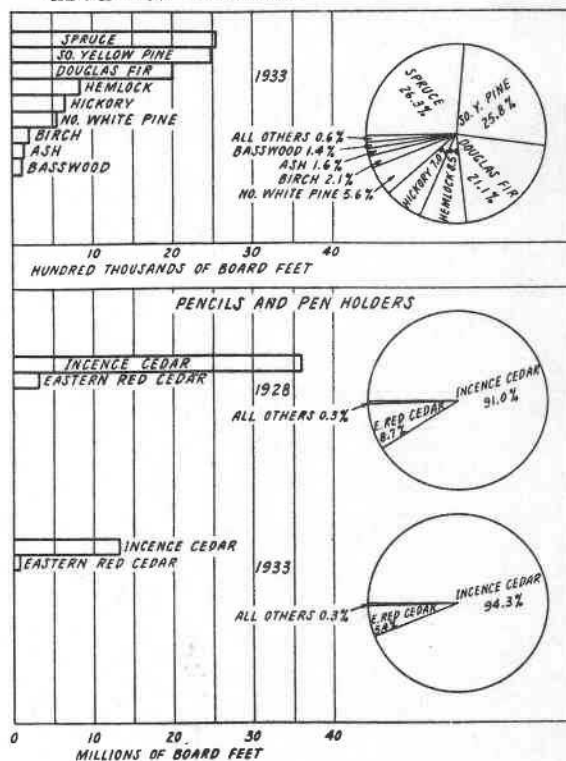


Fig. 16.—Distribution of woods used in ladders, pencils