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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 556

Contribution from the Forest Service
HENRY S. GRAVES, Forester

Washington, D. C. PROFESSIONAL PAPER September 15, 1917

MECHANICAL PROPERTIES OF WOODS GROWN IN THE UNITED STATES

By

J. A. NEWLIN, in Charge of Timber Tests
and THOMAS R. C. WILSON, Engineer in
Forest Products

CONTENTS

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CONTENTS.

PURPOSE OF THE STUDY.

This publication on the mechanical properties of wood makes available for general use data which will serve as a basis for (1) the comparison of species, (2) the choice of species for particular uses, and (3) the establishment of correct working stresses.

The increasing scarcity of many species of timber which had become more or less standard in various wood-using industries is opening the field for other species. Through long use the properties which make the standard species valuable for a particular purpose are quite well understood, but it is doubtful if many manufacturers know to what extent other species possess those same qualities and to what extent they might replace the standard species. Present conditions will not permit long, tedious, and expensive experiments with commercial forms to establish new species in the industries; and to avoid this it is necessary to have definite information and data on both the new and the old species. With such test data at hand it is possible to compare the properties of a known species with those of any other. The possibility of substitution generally reduces to the few species which possess qualities approaching those previously in use. If the properties making a particular wood valuable for a certain purpose are known, the comparison is made the easier.

As an example of the foregoing, suppose it is desired to find a wood for flooring for use in the place of maple. For flooring, hardness is the ruling factor, providing, of course, the wood possesses other strength properties to a reasonable degree. Using hardness as a basis for comparison, white oak should be as good or better than maple for flooring, which is true. Using modulus of rupture, which is a very important strength value in structural material but of very little importance in flooring, as a basis for comparison, longleaf pine or Douglas fir would unjustly be given preference to oak.

In addition to their value in expediting the search for substitute woods, the data presented in this bulletin are of use to manufacturers and others in furnishing definite information concerning the properties of all commercial woods. This information is used in many different ways, several of which are briefly discussed in the following paragraph.

In the preparation of specifications and grading rules for structural timber it is essential to know the relation between physical and mechanical properties, and the results of the tests here reported have been used by a number of associations and societies in preparing such rules. They are also used by architects and engineers in determining safe working stresses for wood in structures, in connection with tests upon full-sized members. In the case of new uses for wood, which frequently arise in special constructions, such as airplanes, for instance, these data are of much help in selecting the species which have the specific properties best fitting them for these uses.

In order to cover the ground successfully, this bulletin must furnish information on all mechanical properties of wood; and with that end in view no effort has been spared in making a complete compilation of the information at hand. There are few uses of timber where at least some of the properties given in the table are not of importance.

The Forest Service tests are standardized and the data contained herein on any one species are directly comparable with similar data on any other species listed. These tests obviously eliminate a great amount of duplication which would result from individual investigations. Industries anxious to find new species to supplant waning supplies of present material would doubtless make tests adapted to their own particular purpose which would probably throw no light on other properties valuable for uses not in their line. In many cases the tendency would be to keep secret such findings in order to meet more effectively competition from other firms; and even though the data from all such individual tests were available, an intelligent comparison of species could not be made because of the lack of standardization of methods of test.

SCOPE AND METHOD OF EXPERIMENTS.

ORIGIN OF DATA.

The data in this bulletin are based upon about 130,000 tests, probably the greatest number ever made in one series upon any material. For this reason, and for others explained later, the data are the most thorough and accurate that are available on the mechanical properties of American woods. The tests were begun about six years ago at the Forest Products Laboratory, which is maintained by the United States Forest Service with the cooperation of the University of Wisconsin. One hundred and twenty-six species of wood have been tested, and it is planned to continue the series until all species which are important, or which give promise of becoming so, have been included.

SMALL CLEAR SPECIMENS USED.

Small clear specimens are used in the tests in order that consideration of the influence of defects may be eliminated from calculations to determine the relation between strength and density, moisture, locality of growth, soil conditions, etc. These various relations are referred to in the present bulletin, however, only when it is necessary in order to render the data thoroughly understandable. The specimens are 2 by 2 inches in cross section. Bending specimens are 30 inches long; others shorter, depending on the kind of test.

SELECTION OF MATERIAL.

The material for any given species and locality is cut from typical trees, usually five in number. These are selected by representatives of the Forest Service, careful descriptions being made of each tree and of the conditions under which it has grown. As a rule the test specimens are taken from the top 4 feet of the 16-foot butt log. The number of test specimens from each tree varies from 40 to 120, depending on the size of the tree. Eventually each important species will be represented by tests from at least five typical trees from each of several localities distributed throughout its range of growth.

OTHER DATA INCLUDED.

Data derived from tests previously made by the Forest Service and under practically the same conditions as the present series are included in Tables 1 and 2. The tests were made at Purdue University and at the Universities of Colorado, California, and Washington in cooperation with those institutions.

TESTS ON LARGE TIMBERS.

A large number of tests have also been made by the Forest Service on full-sized timbers, such as bridge stringers, factory-building timbers, and car sills. These tests have demonstrated the influence of defects such as knots, shakes, and checks on strength, and they serve as a guide to the use of data from tests on small specimens in establishing working stresses and grading rules for structural timbers. The results of tests of this kind on a number of species have already been published. (See list of publications, p. 46.)

PRECAUTIONS TO BE OBSERVED IN THE USE OF THE DATA.

Careful attention must be given to the natural variability of timber in order to make correct use of timber-test data. The following suggestions are offered as a guide to the use of the data given herein. Definitions of the various technical terms, with illustrations, are given on pages 7 to 18.

COMPARISON WITH DATA IN OTHER PUBLICATIONS.

In comparing the data in this publication with those in other publications, it must be kept in mind that scarcely any two series of tests have been made under the same conditions and that very frequently so little is specified concerning the character of the material and the methods of test as to make close comparisons impossible. A specific instance is furnished by the results of Sargent's tests[1] and those given in Forest Service Circular 15. These two publications are chosen as illustrations because of the numerous attempts which have been made to compare the figures in them with each other and with those obtained under the present series. Sargent made about 2,700 tests on 300 species of American woods; but he did not take into account what may have been relative large variations in moisture content, and he selected his specimens from the lower end of the butt logs—in most cases the best although most variable portion of the tree. The lack of data upon moisture content is an insurmountable barrier to comparison with the present series, since differences of moisture content between two groups of tests may be sufficient to cause as much as 100 per cent difference in the strength data. Circular 15, "Summary of Mechanical Tests on Thirty-two Species of American Woods," containing the results of about 30,000 tests, takes moisture into consideration, but allows of no comparison with the present series because of the selection of material with defects as found in the tree. Since no record of the extent or position of these defects in the test piece are now available, no estimate can be made as to the strength of the clear wood.

Data from other publications of the Forest Service which are known to be strictly comparable to those obtained from the present series of tests are included in Tables 1 and 2. The reader is cautioned against any attempt at the comparison of the data in this publication with those in any previous one dealing with tests on small clear pieces.

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[1] Made for the Tenth United States Census, and results published in Vol. IX of the Tenth Census Reports.

Also, in making comparisons, it is important that the data should really be representative of the classes of material which it is proposed to compare. For example, it is not just to take the figures derived from Rocky Mountain Douglas fir, which is known to be inferior to the Pacific coast type,[1] as representative of the coast fir. Nor in general can a comparison of species properly be made from results of tests on large timbers alone; for in practically all cases the large timbers tested have not been selected as representative of the species, but have been chosen to determine the effect of defects, the effect of preservative treatment, or for the solution of other and similar problems.

Comparisons should not be made with greater refinement than the data justify. The change which additional tests would probably make in the average values and the probable variation of a given stick or lot of material from these average values should be considered. Numerical measures of these probable variations are given in Table 3.

CAUSES OF VARIATIONS IN STRENGTH.

Variations in strength of timber can be accounted for more accurately than is usually supposed. In some species there is a difference in strength in wood from different positions in the tree, different localities of growth, etc. But such variations have been overestimated, and a knowledge of them is not essential in order to estimate with a fair degree of accuracy the properties of a piece of timber. Differences in strength are usually due to differences in defects, moisture content, or density, or to combinations of these.

Defects are not considered in this publication. Their effects on structural timbers are discussed in Forest Service Bulletin 108; and limitations on their size, character, and location are given in the grading rules for structural timber which have been recommended by the Forest Service.[2]

Differences of moisture content cause considerable variation in the strength values of air-dry or partially air-dry material, but have no effect as long as all material is thoroughly green.

One of the principal factors causing differences in strength is variable density. As might be expected, the greater the density of a given stick or the more wood it has [3] per unit volume, the stronger is the stick.

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[1] See also "Localities Where Grown," p. 8.

[2] See "Discussion of the Proposed Forest Service Rules for Grading the Strength of Southern Pine Structural Timbers," by H. S. Betts, Proceedings of Am. Soc. for Test. Materials, Vol. XV, 1915, p. 368.

[3] Accurate determinations made at the Forest Products Laboratory on seven species of wood, including both hardwood and coniferous species, showed a range of only about 4½ per cent in the density of the wood substance, or material of which the cell walls are composed. Since the density of wood substance is so nearly constant, it may be said that the density or specific gravity of a given piece of wood is a measure of the amount of wood substance contained in it.

MISUSE OF TERMS.

Considerable confusion often arises from the use of general terms in a limited sense, or with different meanings by different persons. For instance, strength, in the broad sense of the word, is the summation of the mechanical properties or the ability of a material to resist stresses or deformations of various sorts. While such properties as hardness, stiffness, and toughness are not always thought of in connection with the term "strength," they are unconsciously included when, in a specific instance, they are important. This may be illustrated by some comparisons of oak and longleaf pine. For floor beams or posts, the pine, because of its strength and stiffness as a beam, has a slight advantage over the oak and is considered "stronger." For handles, vehicle or implement parts, oak, because of its greater toughness, or shock-resisting ability, is decidedly superior to the pine and is considered "stronger." Thus it is seen that the term "strength" may refer to any one of many properties or combinations of properties, and is necessarily indefinite in meaning unless so modified as to indicate one particular thing. To say, then, that one species is stronger than another is a meaningless statement unless it is specified in what particular respect it excels.

The term strength, in its more restricted sense, is the ability to resist stress of a single kind, or the stresses developed in one kind of a constructional member, as strength in shear, strength in compression, strength as a beam, strength as a column. Used in this way, the term is specific and allows no chance of confusion.

RELATION OF PROPERTIES TO USES.

There are many properties of wood, such as taste imparted to foodstuffs, odor, ease of working, ability to take finish and to maintain shape, resistance to decay, etc., which, of course, are not given in the accompanying tables, but which are very important in some uses to which timber is put. In very few instances will strength data of themselves be sufficient to determine the value of a species for a given use.

There are few, if any, cases in which two species have all the various properties to the same degree or in the same relative proportion. This fact accounts for the special uses of the different species and for the difficulty in finding substitutes for certain species in particular uses. Confusion arises from comparing species for a certain use upon the basis of properties or strength values which are not of first importance in that use. The most important strength values are: In large beams, modulus of rupture, modulus of elasticity, and shear; in long columns, modulus of elasticity and crushing strength in compression parallel to grain; in material for spokes, tongues, or poles, ax handles, etc., modulus of rupture, modulus of elasticity, work to maximum load in static bending, and height of drop in impact. In flooring, the desirable properties are hardness and slight shrinkage.

DATA ON GREEN TIMBER.

Table 1 gives the values obtained from tests on green material. It will be noted that there is a large variation in the moisture content of the various species. All, however, were tested at approximately the moisture content of the living tree and are well above the limit below which differences in moisture content produce differences in strength. Table 1 is more reliable than Table 2, because it is based on a much larger number of tests and on tests which are not influenced by variations in moisture content.

DATA ON AIR-DRY TIMBER.

Table 2, which gives the values obtained in tests of air-dry timber, should be considered as supplementary to Table 1. This table is necessary because the properties of all species are not changed in the same proportion by drying and all the properties are not equally affected.

Some of the properties of air-dry wood are subject to rapid change with change in moisture content. For this reason it is necessary in comparing species on the basis of Table 2 to make proper allowance for whatever differences may be shown in the column of moisture content. Table 3 includes figures showing the approximate changes which are made in the various properties of air-dry wood by the addition or subtraction of 1 per cent of moisture.

It will be noted from Tables 1 and 2 that in most properties the dry material excels the green. In structural design, however, no allowance should be made for such increase in strength, because in large timbers it is a very indefinite quantity. The increased strength of the wood fibers is usually offset by checks and other defects resulting from drying. Moreover, many structural timbers are subject to moisture changes, and the outer fibers may at any time become wet enough to reduce the mechanical properties to the level of those of green timber. For these reasons the strength of green material should be made the basis of stresses to be used in structural design.

EXPLANATION OF TABLES 1 AND 2.

(See tables on pp. 27 and 37.)

NAMES OF SPECIES.

Many of the species have numerous common names, and not infrequently one common name is applied to several species. This leads to so much confusion that it is necessary to refer to a standard nomenclature. The common and botanical names used in the tables are those given in Forest Service Bulletin 17, "Check List of the Forest Trees of the United States."

LOCALITIES WHERE GROWN.

In the second column of the tables are listed the States in which the test specimens originated. The locality of growth has in some cases an influence on the strength of timber. This influence is, however, usually overestimated; just as great differences exist ordinarily between stands of different character grown in the same section of the country as between stands grown in widely separated regions. For this reason it is considered better to average the various localities together. Douglas fir, however, has not been averaged in this manner. Silviculturists have recognized that there are two well-marked types [1] and various intergradations of Douglas fir. Strength tests confirm this fact and show that there is actually a difference in strength between the Rocky Mountain and Pacific Coast types of Douglas fir. For this reason averages are given for the Coast and for the Rocky Mountain regions rather than for the species as a whole.

NUMBER OF TREES.

The number of trees from which test specimens were taken is given in the third column of Table 1. As previously mentioned, five is the usual number from a single locality.

NUMBER OF RINGS PER INCH.

Rings per inch is an inverse measure of the rate of growth. It is taken along a radial line on the end section of each specimen. One ring, consisting of a band of springwood and a band of summerwood, is formed by each year's growth; consequently, few rings per inch indicate fast growth, and vice versa.

Rate of growth is extremely variable, and the values given are to be taken as averages of the material tested only. Rate of growth has no definite relation to strength in the sense of strength being in proportion, either directly or inversely, to the rate of growth. Timber of any species which has grown with exceptional slowness is usually below the average of the species in strength values. In the coniferous species material of very rapid growth is also very likely to be below the average in strength. Among many of the hardwood [2] species, however, timber of rapid growth is usually above the average in strength properties.

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[1] See Forest Service Circular 150, "Douglas Fir: A Study of the Pacific Coast and Rocky Mountain Forms."

[2] A broad classification of timber species divides them into two groups: (1) Angiosperms, or trees with broad leaves, usually deciduous, the so-called "hardwoods"; (2) gymnosperms, or trees with needle or scalelike leaves, usually evergreen, most of them cone bearing, the so-called "softwoods." The two groups are popularly spoken of as "hardwoods" and "softwoods," or "hardwoods" and "conifers." The terms "hardwoods" and "softwoods" are therefore indicative of botanical classification and are not descriptive of the quality of the wood with respect to hardness. Such "hardwoods" as basswood and aspen are low in the scale of hardness; while the southern pines, tamarack, larch, and others, although called "softwoods," are quite hard.

SUMMERWOOD.

The amount of summerwood is expressed in per cent of the entire cross section. (See definition of summerwood, p. 23.) It is measured along a representative radial line.

In many species the proportion of summerwood is indicative of the density; and different proportions of summerwood are usually accompanied by different densities and strength values. When the change from springwood to summerwood is not marked or the contrast between them is not sharp, no accurate measurement can be made and the results have no practical value.

In southern yellow pine and Douglas fir, one-third or more summerwood, except when associated with rapid irregular growth, indicates material of a quality suitable for use as structual timber.

MOISTURE CONTENT.

Moisture content is the weight of water contained in the wood, expressed in per cent of the oven-dry weight of the wood. Moisture content is determined by weighing a small section of the test specimen and then drying it at 100° C. in freely circulating air until its weight becomes constant; the loss of weight is then divided by the dry weight to give the proportion of moisture, and this is usually expressed in per cent of the dry weight. Consequently, "moisture" as determined includes any other substances besides water volatile at 100° C. which may be in the wood.

The various species differ widely as to the amount of moisture contained in the wood of the living tree. For example, white ash and black locust are always comparatively dry; black ash and the oaks have about twice, and chestnut and buckeye three times, as much water as white ash. The coniferous species also show wide range in moisture content. White and red cedars are comparatively dry; cypress and white fir contain large amounts of water.

Moisture content sometimes varies with position in the tree. Most coniferous species have a large proportion of moisture in the sapwood and a much smaller proportion in the heartwood. In some the heartwood is very wet at the base of the tree, but comparatively dry higher up. Most hardwoods, or broad-leaved species, show a fairly uniform distribution of moisture throughout the tree.

SPECIFIC GRAVITY.

Specific gravity is the weight of any given substance divided by the weight of an equal volume of pure water at its greatest density.

Obviously, the weight of wood in a given volume changes with the shrinkage and swelling caused by changes in moisture. Consequently, specific gravity is an indefinite quantity unless the circumstances under which it is determined are specified. Each of the columns of specific gravity figures given in this table is based on the weight of the wood when oven dry and on its volume when green or at a specified stage of drying.

SPECIFIC GRAVITY BASED ON VOLUME WHEN GREEN.

In the determination of the figures for specific gravity based on volume when green the test specimens are weighed and measured when green. Their oven-dry weight is then computed by dividing the weight when green by 1 plus the proportion of moisture, moisture being determined as described in previous paragraphs. The specific-gravity data based on green volume are more reliable than the data based on air-dry or oven-dry volume because they are based on the largest number of determinations, and these determinations are unaffected by the shrinkage of the wood. Specific gravity so determined is, aside from actual strength data, the best criterion of the strength of clear wood of any species.

It has been found that in oak, more than in any other species or group of closely related species, pieces of the same density may vary widely in mechanical properties. Occasional very dense pieces of oak are for some unknown reason low in strength; but in all species specimens of low density are invariably weak.

SPECIFIC GRAVITY BASED ON AIR-DRY VOLUME.

Specific gravity based on air-dry volume is obtained in the same manner as that based on volume when green, except that the volume measurements are made after the material has been air dried. The data in the tables are less reliable than those for the specific gravity on green volume because they are based on fewer determinations and are affected by variations in the shrinkage which has taken place.

SPECIFIC GRAVITY BASED ON OVEN-DRY VOLUME.

In determining the specific gravity based on oven-dry volume, the volume as well as the weight is taken after the specimens are dried to a practically constant weight in air at 100° C. The difference between specific gravity based on green volume and that on oven-dry volume is due to the shrinkage, and one may be determined from the other if the shrinkage in volume is known. Specific gravity on oven-dry volume = specific gravity based on volume when green ÷ (1 − the shrinkage.)

The specific gravity based on volume when oven dry and the shrinkage in volume (see columns 8 and 10, Table 1) determinations were made on the same specimens, of which there were usually four from each tree. The specific gravity based on green volume was determined from a much larger number of specimens and is consequently somewhat more reliable. Because these two specific gravities were determined from different specimens the equation given at the end of the preceding paragraph does not hold exactly when applied to the data in columns 7, 8, and 10 of Table 1.

WEIGHT PER CUBIC FOOT.

Weight per cubic foot, like specific gravity, is a very indefinite quantity unless the circumstances under which it is determined are specified. The variability is also large, as may be realized from a consideration of the following: The specific gravity of some specimens may be twice that of others of the same species; occasionally a piece may contain nearly as much resin as wood; the moisture content may be as little as 4 or 5 per cent of the dry weight of the wood in the case of kiln-dry lumber, or it may be as great as 200 per cent in green timber, as is occasionally the case in the sapwood of some of the coniferous species.

WEIGHT PER CUBIC FOOT GREEN.

Weight per cubic foot green is the weight per cubic foot of the wood (including moisture) as it comes from the living tree. The various species differ largely as to the wetness of the green wood. The hardwoods as a rule do not exhibit any considerable variation with the position in the tree. The conifers, on the other hand, show a wide variation in moisture content between the heartwood and sapwood and, in some instances, between wood from the upper and lower parts of the tree. Tamarack and cypress, however, have a comparatively uniform moisture content throughout the tree. Sugar pine and western larch are frequently very heavy because of moisture and resin at the butt. Longleaf pine and some other species have a very low moisture content in the heartwood, while the sapwood is very wet. When this is the case, young thrifty trees with a large proportion of sapwood are much heavier than old overmature trees with a small amount of sapwood.

Variations of 4 per cent above or below the averages given are to be expected in any lot of material of a species which has fairly uniform moisture content. If the species is one that does not have a uniform distribution of moisture, about twice as great a variation may be expected. Under exceptional conditions the weight of green timber of some of the conifers may vary as much as 30 per cent from the average.

WEIGHT PER CUBIC FOOT AIR DRY.[1]

The weights given for air-dry wood are for wood with 12 per cent moisture. A variation of 4 per cent in any given lot of material even at this moisture content is to be expected. Large timbers

[1] See definition of air dry (glossary, p. 20).

ordinarily have more than 12 per cent moisture and average from 10 to 15 per cent heavier than the listed weights.

SHRINKAGE FROM GREEN TO OVEN DRY.

When wood is dried below the fiber saturation point (see glossary, p. 21), shrinkage begins and continues until the moisture is all driven off. Shrinkage along the length of timber is very small. Shrinkage in directions at right angles to the grain is very much greater and varies from 2 or 3 per cent to about 20 per cent. Radial shrinkage is about three-fifths as great as tangential shrinkage (see glossary, pp. 22 and 23.) Shrinkage in volume is of course the resultant of shrinkages along the fibers and in the radial and tangential directions. However, shrinkage in volume and radial and tangential shrinkages were independently determined in the present series of tests. The first was determined from four specimens, and each of the others from one specimen from each tree.

All shrinkages given are expressed in percentages of the original or green dimensions, and are total shrinkages to zero moisture Shrinkage to an air dry condition of about 12 per cent moisture is sometimes more and sometimes less than half the total shrinkage. At about 12 per cent moisture the volume changes by about one-half of 1 per cent for each moisture content change of 1 per cent. Shrinkage in volume is important in measuring cordwood.

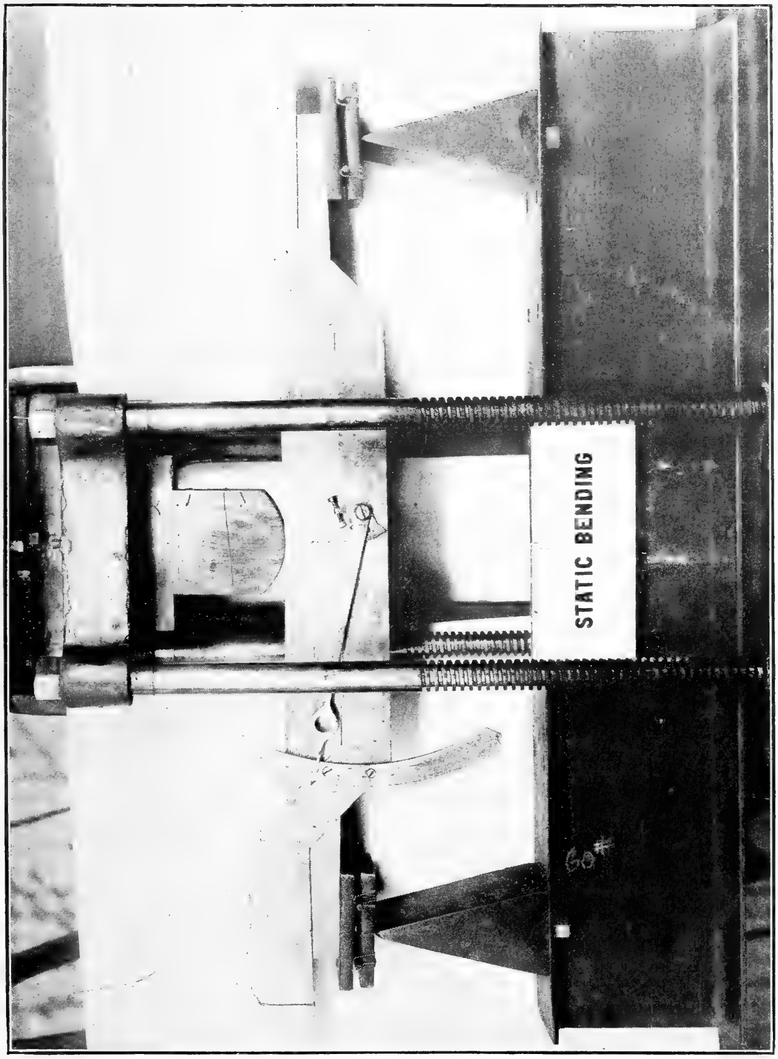
Radial shrinkage is the measure of the change in width of a quarter-sawed or edge-grain board. In most species at about 12 per cent moisture a moisture content change of 1 per cent may be expected to cause a change of about three-sixteenths of 1 per cent in the width of such a board. This is equivalent to three thirty-seconds of an inch change in the width of a 10-inch board for a 5 per cent change in moisture ($5 \times \frac{3}{16}$ per cent of 10 inches $= \frac{3}{32}$ of an inch).

Tangential shrinkage is the measure of the change in width of a flat sawed board. At about 12 per cent moisture a moisture content change of 1 per cent may be expected to cause a change of about five-sixteenths of 1 per cent in the width of such a board, which is equivalent to five thirty-seconds of an inch change in the width of a 10-inch board for 5 per cent change in moisture.

Both radial and tangential shrinkages are important in flooring, fixtures, and any construction which is to remain well joined under changing atmospheric conditions.

STATIC BENDING.

In the static bending test a 2 by 2 by 30 inch beam is supported over a 28-inch span. Loading is applied to its center and at a constant rate of deflection until the beam fails. Readings of load and deflection are taken simultaneously.



STATIC BENDING TEST.

The values derived from this test are applicable to beams of any size by the use of the formulæ given on page 24, except for the defects that occur in the larger sizes.

In all cases it is best to use the results from tests of green material in determining allowable working stresses in large timbers, since defects are usually introduced in drying large timbers with the result that often there is no increase of strength. However, timbers which are always dry may be allowed a slightly higher stress than those exposed to the weather or subject to moisture.

FIBER STRESS AT ELASTIC LIMIT.

Fiber stress at elastic limit (see definition, p. 21) is very important in determining the proper working stresses for a beam. A beam loaded to its elastic limit in static bending for a short time will recover its form immediately upon removal of the load. If the same load is allowed to remain, complete failure will ultimately result. Consequently, the necessity of keeping working stresses below the elastic limit is apparent. It is recommended, however, that working stresses be calculated not from the elastic limit, but from the modulus of rupture, and for the following reasons: There is a personal element in determining the elastic limit; slight inaccuracies in measurements of deflections often cause considerable error in elastic limit values; defects in structural timbers may be such that, in testing, certain portions are stressed to or beyond the elastic limit without discovery; and there is an element of safety in the differential of strength between the elastic limit and modulus of rupture values.

MODULUS OF RUPTURE.

Modulus of rupture is the computed fiber stress in the outermost fibers of a beam at the maximum load and is a measure of the ability of a beam to support a slowly applied load for a very short time. The formula by which modulus of rupture is computed is the same as that for fiber stress at elastic limit, the maximum load being substituted for the elastic limit load. The assumptions on which this formula are based hold only up to the elastic limit, hence modulus of rupture is not a true fiber stress. It is, however, a universally accepted term, and the values are quite comparable for various species and sizes of timber. It is a definite quantity, and the personal factor does not enter to any great extent into obtaining it. It is consequently not so subject to error as the fiber stress at elastic limit, and for that reason is used more than any other value to represent the strength of wood. Modulus of rupture should always be considered in calculating the strength of beams to be used as stringers, floor joists, etc. A green structural timber, if comparatively free from defects, can be expected to have a modulus of rupture about three-fourths as large as that of small clear pieces cut from it.

The modulus of rupture of small clear individual pieces will occasionally vary more than 40 per cent above or below the average modulus of rupture. Pieces giving very low values are almost invariably lacking in density, while very strong pieces are exceptionally dense.

Figures on the variation of modulus of rupture are given in Table 3.

Safe working stresses for carefully selected structural timbers, with all exceptionally light pieces excluded, subjected to bending in dry interior construction and where only small deflections are allowable are about one-fifth the modulus of rupture values given in the table for green material. (Table 1.) In some interior construction where beams may be allowed to sag somewhat without damage, the working stresses may be slightly increased. But for timbers used in bridges or other structures exposed to moisture, the working stress should be slightly lower. However, beams can not be correctly designed on the basis of outer fiber stress in bending alone. Strength in longitudinal shear must also be taken into account. (See p. 17 for allowable shearing stress.)

MODULUS OF ELASTICITY.

The modulus of elasticity is a measure of the stiffness or rigidity of a material. In the case of a beam modulus of elasticity is a measure of its resistance to deflection. The formula (see p. 24) connecting modulus of elasticity, load, and deflection shows that the deflection under a given load varies inversely as the modulus of elasticity; that is, a beam with a high modulus deflects but little. Modulus of elasticity is of value in computing the deflections of joists, beams, stringers, etc., and in computing safe loads for columns. The values given are derived from the static bending test, but are applicable to both beams and columns.

In building construction the means by which the various members are held in place, inequalities in workmanship on the various parts, differences in the quality of the timber in all parts of the structure, and shrinkage due to the adjustment of the moisture content of the various members to that of their surroundings give rise to unequalized local stresses, often very large. When these stresses become equalized through the gradual readjustment of the members, deflections greater than those calculated from the average moduli of elasticity will be found. For this reason it is good practice in the design of structures to use values for moduli of elasticity about one-half those given in Table 1.

WORK TO ELASTIC LIMIT.

Work to elastic limit in static bending is a measure of the work which a beam is able to resist or the shock which it can absorb without being stressed beyond the elastic limit as determined under slowly applied loads.

WORK TO MAXIMUM LOAD.

Work to maximum load in static bending represents the ability of the timber to absorb shock with a slight permanent or semi-permanent deformation and with some injury to the timber. Wood, especially in small sizes, can be bent somewhat beyond its elastic limit with only slight injury if the load is removed at once. Work to maximum load is a measure of the combined strength and toughness of a material under bending stresses. Superiority in this quality is the characteristic which makes hickory better than ash, and oak better than longleaf pine, for such uses as handles and vehicle parts. Many species yield butt cuts that exceed upper cuts in combined strength and toughness, hickory showing this characteristic most markedly. The superiority of butt cuts of hickory to upper cuts for ax handles is well known to experienced woodsmen.

IMPACT BENDING.

The impact bending test is made upon a beam 2 by 2 by 30 inches over a 28-inch span. A 50-pound hammer is dropped upon the stick at the center of the span, first from a height of 1 inch, next 2 inches, etc., up to 10 inches, then increasing 2 inches at a time until complete failure occurs. The deflections of the specimen are recorded on a revolving drum by a pointer attached to the hammer. This pointer also records the position the specimen assumes after the shock. Thus data are obtained for determining the various properties of the wood when subjected to shock.

FIBER STRESS AT ELASTIC LIMIT.

Fiber stress at elastic limit is the greatest stress to which a timber may be subjected under impact loading and recover immediately. Fiber stress at elastic limit in impact is approximately double the fiber stress at elastic limit in static bending. This is an expression of the fact that a small beam, if suddenly strained, bends approximately twice as far to the elastic limit as when loaded slowly. (See also fiber stress at elastic limit, p. 13.)

WORK TO ELASTIC LIMIT.

Work in bending to the elastic limit in impact is a measure of the ability of a timber to absorb shock and recover therefrom immediately and without injury. The values apply only to resistance to falling bodies or to other conditions in which the stress is applied and relieved in one-twenty-fifth of a second or less. It represents a quality important in tool handles and in athletic goods, such as baseball bats.

HEIGHT OF DROP.

Height of drop is the maximum or last drop of the hammer. It represents a quality important in articles which are occasionally stressed under a shock beyond their elastic limit, such as handles and vehicle and implement parts.

COMPRESSION PARALLEL TO GRAIN.

In the compression parallel to grain test a 2 by 2 by 8 inch block is compressed in the direction of its length. Deformation is measured between two collars attached 6 inches apart to the specimen.

FIBER STRESS AT ELASTIC LIMIT.

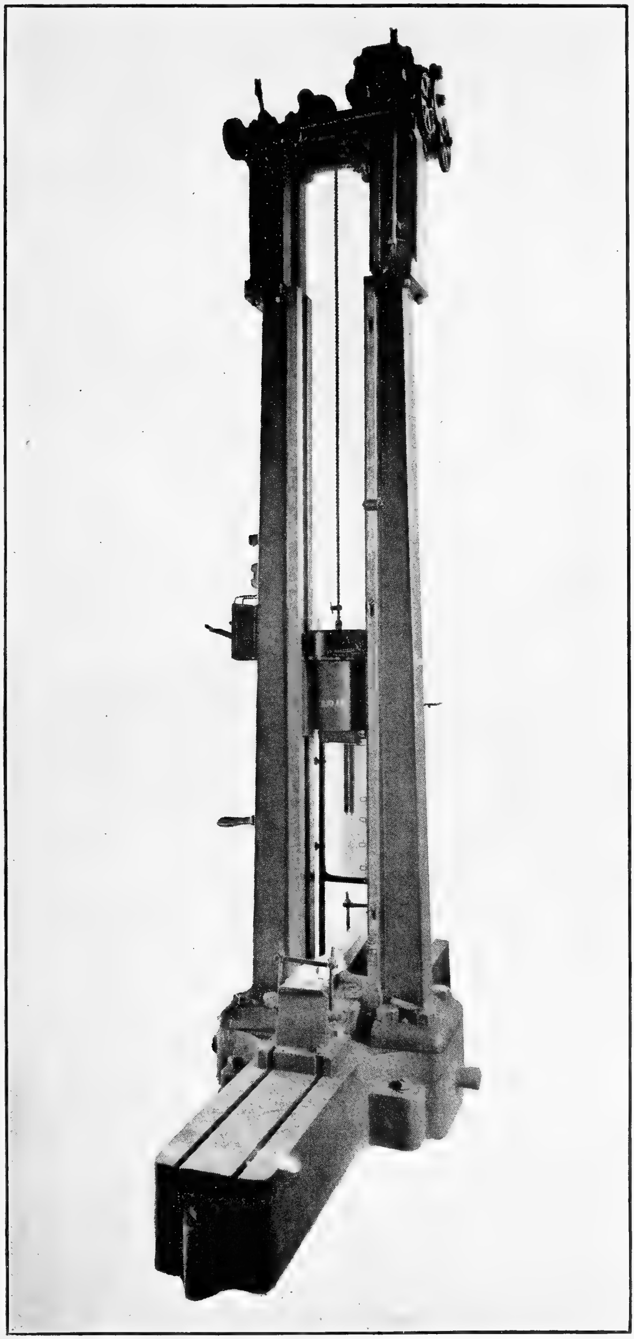
Fiber stress at elastic limit in compression parallel to the grain is not much used because in most cases it is more convenient to use maximum crushing strength, which is less variable and easier to obtain. The value is important in the derivation of safe working stresses for structural timber. (See also fiber stress at elastic limit, glossary, p. 21.)

MAXIMUM CRUSHING STRENGTH.

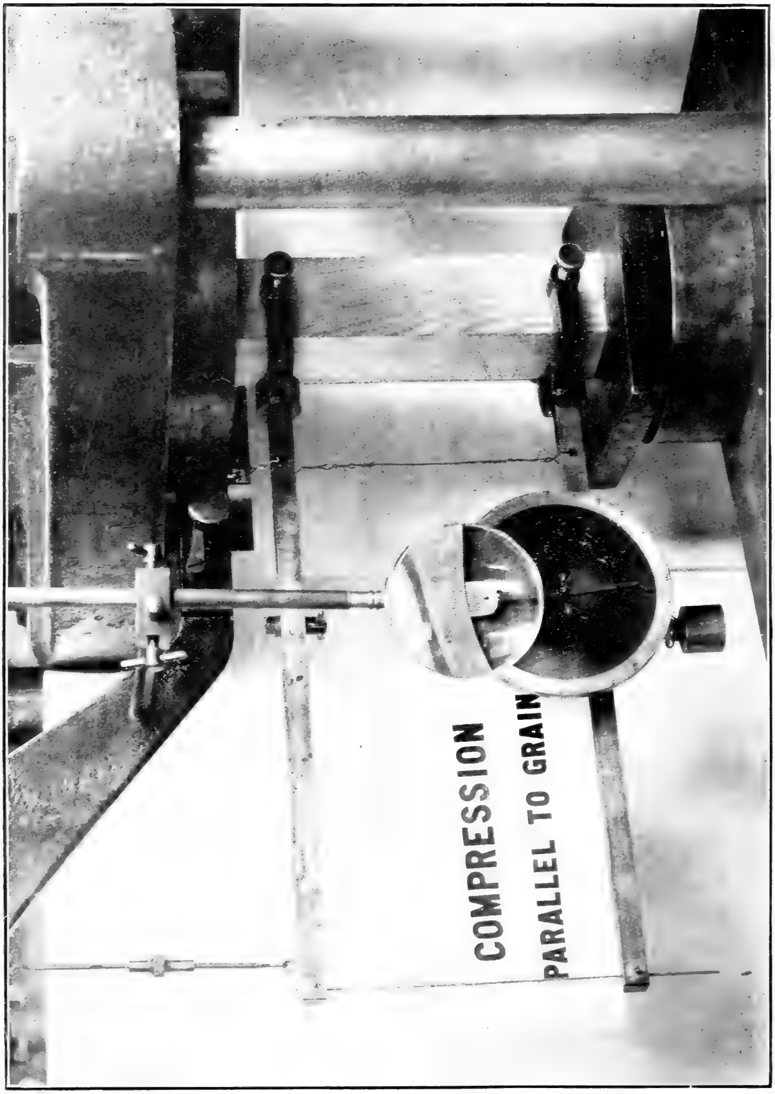
The maximum crushing strength is the maximum ability of a short block to sustain a slowly applied load. It is obtained by dividing the maximum load obtained in the test by the area of cross section of the block. This property is important in estimating the strength of columns.

Tests of the crushing strength, because of their simplicity, are frequently the only tests used in studying the effect of various influences or processes on strength. Crushing strength is not necessarily representative of the other strength properties; consequently, when used alone, it will occasionally lead to erroneous conclusions. For instance, it was found that the crushing strength of some timbers was increased 10 per cent by a certain heat treatment. Other tests, however, revealed the fact that their resistance to shock had been reduced about 50 per cent.

A safe working stress for carefully selected structural timbers used as columns and in dry interior construction, all exceptionally light pieces excluded, is about one-third the crushing strength as given in the table for tests on green materials (Table 1). If the column is longer than about 10 times its least diameter, some formula should be used which will take care of the increased stress which would be caused by eccentric loading or by the bending of the column. (Such



IMPACT TESTING MACHINE.



COMPRESSION PARALLEL TO GRAIN TEST.

formulæ are discussed in the various textbooks on mechanics and strength of materials.)

COMPRESSION PERPENDICULAR TO GRAIN.

In the compression perpendicular to grain test, a block 2 by 2 inches in cross section and 6 inches long is laid upon its side and pressure applied to it through a cast-iron plate 2 inches wide laid across the center of the piece and at right angles to its length. Hence but one-third of the surface is directly subjected to compression.

The only strength value obtained in this test is the fiber stress at elastic limit. It represents the maximum stress which can be applied to the timber without injury. It is important in computing the bearing area for beams, stringers, joists, etc., and in comparing species for railroad ties.

Two-thirds of the fiber stress at elastic limit, as given in the table for tests on green material, may be used as a safe stress in dry interior construction.

HARDNESS.

Hardness is tested by measuring the load required to embed a 0.444-inch ball to one-half its diameter in the wood. This test is a modification of one originated by Janka.[1]

The hardness test is applied to end, radial, and tangential surfaces of the timber. There is no consistent difference between radial and tangential hardnesses and they are averaged and tabulated as "side hardness." End hardness is usually greater than side hardness. The quality represented by these figures is important in woods for paving blocks, railroad ties, furniture, flooring, etc.

SHEARING STRENGTH PARALLEL TO GRAIN.

The shearing test is made by applying force to a 2 by 2 inch lip projecting from the side of a block. The shearing stress is the maximum force required to shear off the projection divided by the area of the plane of failure.

Shearing strength parallel to the grain is a measure of the ability of timber to resist slipping of one part upon another along the grain. Shearing stress is produced to a greater or less degree in most uses of timber. It is most important in beams, where it is known as horizontal shear—the stress tending to cause the upper half of the beam to slide upon the lower. It is also important in the design of various kinds of timber joints.

Only about one-eighth of the values given in the table for green material (Table 1) should be used as allowable stress in horizontal

[1] "Die Härte des Holzes," by Gabriel Janka, k. k. Forst- und Domänenverwalter: Mitteilung der k. k. forstlichen Versuchsanstalt in Mariabrunn, Wien, 1906.

shear in beams. For small details, in timbers unaffected by shakes or checks, the allowable stress may be taken as one-fourth the value listed for green timber.

TENSION PERPENDICULAR TO GRAIN.

The tension perpendicular to grain tests are made on specimens 2 inches square and $2\frac{1}{2}$ inches long, the tension area being 1 by 2 inches. The tension force is applied perpendicular to the grain. The values are of use in estimating the resistance of timber to the splitting actions of bolts and other fastenings. A factor of 5 should be applied to the values in Table 1 to get the allowable stress for design; i. e., one-fifth the values given in the tables.

EXPLANATION OF TABLE 3.

(See table on p. 45.)

The figures in Table 3 are presented as an aid to the interpretation of data given in Tables 1 and 2 and are explained as follows:

COLUMN 2.

The figures given in column 2 are to be applied to the data in Table 2. They are, of course, only approximate, as the exact variation of any property with change in moisture content is different for each species.[1] They will assist in rendering more nearly comparable data which are noncomparable because of differences of moisture.

Example: It is desired to compare the modulus of rupture of air-dry locust with that of air-dry bitternut hickory. The hickory has a modulus of rupture of 18,850 at 9.2 per cent moisture and the locust a modulus of rupture of 20,700 at 10 per cent moisture (see Table 2). According to Table 3, a 1 per cent change of moisture causes a 4 per cent change of modulus of rupture. Changing the hickory from 9.2 to 10 per cent moisture will decrease the strength by $(10 - 9.2) \times 4$ per cent = 3.2 per cent; 3.2 per cent of 18,850 = 600. Then the moduli or rupture of black locust and bitternut hickory, when placed on a comparable basis, each being at 10 per cent moisture, are 20,700 and 18,250 pounds per square inch, respectively. The accuracy of this moisture reduction is greatest across small intervals. As the interval or difference of moisture increases the accuracy becomes less.

COLUMN 3.

Study of the data presented in this bulletin has shown that each of the shrinkage and strength properties of a given species can be estimated with fair accuracy from the average specific gravity, since each varies according to some power of the specific gravity.

[1] See Forest Service Bulletin 70 and Circular 108.

This power is given in column 3. Suppose, for example, it is desired to estimate the comparative strength in modulus of rupture and work to maximum load of a stick of timber whose specific gravity is known to be 25 per cent above the average. Since modulus of rupture varies as the first and work to maximum load as the second power of the specific gravity (see Table 3), it is probable that the modulus of rupture and work to maximum load are, respectively, about 125 and 156 per cent ($1.56 = 1.25^2$) of the average values for the species.

COLUMNS 4 AND 5.

The figures in columns 4 and 5 are derived from the original data on which the averages given in Table 1 are based, by the use of the processes usually employed to determine the accuracy of experimental data. They are not to be taken as too rigidly applicable to these averages (Table 1), but are a convenient approximate measure of the reliability of the averages and of the probability that an individual tree of a given species will be of average quality in any given property.

COLUMN 4.

The probable error of the species average as given in this column is a measure of the reliability of the present averages and of the probable change in these averages by future tests. For example: The probable error in modulus of rupture is given as 4 per cent; this means that there is one chance in four that the present average modulus of rupture for a given species (if based on tests from five trees) is below 96 per cent ($=100-4$) of the true average, two chances in four that it is between 96 and 104 per cent of the true average. It follows that the two possibilities: (1) That the present average will be changed more than 4 per cent by future tests, and (2) that it will not be so changed, are equally probable. There is about one chance in 100 that the average will be changed by four times the probable error, or in this case 16 per cent.

The figures given apply to cases where five trees have been tested. When the number tested is other than five the probable variation can be obtained from the rule that the probable variation varies inversely as the square root of the number of trees tested. For instance, if 20 trees have been tested, the probable variation of the average modulus of rupture is $\sqrt{\frac{5}{20}} \times 4$ per cent, or 2 per cent.

COLUMN 5.

Column 5 gives the probable variation from the species average of the average of tests from an individual tree taken at random. For instance, the figure given for modulus of rupture is 9 per cent, which means that there is one chance in four that the modulus of rupture of a tree taken at random will be below 91 per cent of the species average, one chance in four that it will be above 109 per cent, and two chances in four, or one chance in two, that it will be between 91 and 109 per cent of this average. There is also about one chance in 100 that the random tree will vary from the average an amount equal to four times the probable variation, or in this case 36 per cent.

GLOSSARY.

AIR DRY.

(See p. 7.)

Air-dry condition is the normal condition, with respect to moisture, of wood exposed to the air, although this condition may have been obtained by artificial means. The term "air dried" means dried by exposure to the air, while "kiln dried" indicates artificial drying.

Air dry is a very general term and may mean any degree of dryness from about 6 per cent moisture, as in furniture stock, to over 30 per cent moisture, as in timber dried to reduce its shipping weight. The degree of dryness in timber depends upon species, size, and the conditions under which the material is dried, especially such as humidity, method of piling, shelter, time of drying, etc. For instance, the wood of the conifers dries much more rapidly, on the average, than that of the hardwoods. Douglas fir bridge timbers will fall to about 30 per cent moisture in 2 years. Inch lumber of the same species, under the same conditions, will dry to 15 per cent moisture in considerably less time, and small-sized timber dried in a heated room will in some cases reach 6 per cent moisture. The same species, in the same sizes, piled in the same manner under shelter out of doors, will scarcely ever fall below 12 per cent moisture.

DENSE.

Dense, as applied to wood, means compact, heavy (when dry), containing much wood substance in small space (see footnote, p. 5). For example, hickory is a very dense wood.

The oven-dry specific gravity is a measure of the density of wood. This figure is based on the weight, exclusive of moisture, but including rosin and other substances not volatile at 100° C.

ELASTIC LIMIT.

(See pp. 13, 14, and 15.)

The elastic limit (sometimes called proportional limit) is that point where the distortion ceases to be in proportion to the load. For example, if a beam deflects one-sixteenth of an inch with a 50-pound load it will deflect one-eighth of an inch with 100 pounds, and so on, each additional load of 50 pounds causing an additional deflection of one-sixteenth of an inch until the "elastic limit" is reached, after which the deflections increase more rapidly than the increase in load.

A timber stressed beyond the elastic limit will not resume its original form immediately upon the removal of the load.

ELASTICITY.

Elasticity is the property (possessed by most materials) of changing form with the application of force and recovering at once upon release from the force.

In any elastic material the amount of compression or deformation is proportional to the force applied.

Air and other gases under compression are elastic. The most commonly recognized elastic material is rubber. Timber is elastic within comparatively narrow limits.

The term "very elastic" as applied to wood is indefinite, because it may mean that the force required to produce a given deformation is great and the recovery sudden as in an ivory ball (see "Modulus of elasticity"); or that the amount of distortion to the elastic limit is great, as in a rubber ball, or that the wood possesses high elastic resilience, a combination of the two properties. (See "Elastic resilience" or "Work to the elastic limit.")

FIBER SATURATION POINT.

(See p. 11.)

Green wood usually contains water within the cell walls and "free" water in the pores. In drying, the water in the pores is the first to be evaporated. The fiber saturation point is that point at which no water exists in the pores of the timber but at which the cell walls are still saturated with moisture. The fiber saturation point varies with the species. The ordinary proportion of moisture—based on the dry weight of the wood—at the fiber saturation point is from 20 to 30 per cent.

FIBER STRESS AT ELASTIC LIMIT.

(See pp. 13, 15, and 16.)

Fiber stress at elastic limit is the stress obtained in a timber by loading it to its elastic limit. It is the greatest stress the timber will take under a given loading and immediately return to its former position.

FLEXIBILITY.

Flexibility is that quality which renders a material capable of being bent without breaking. Thus, green timber is more flexible than dry.

GREEN.

Green is the condition of timber as taken from the living tree.

Immediately upon being sawed from the tree lumber begins to lose moisture and otherwise change its condition. The rapidity of these changes is determined by the species, humidity, and circulation of air, heat, etc.

MECHANICAL PROPERTIES.

Mechanical properties are the properties of wood which enable it to resist deformations, loads, shocks, or forces. Thus the ability to resist shearing forces is a mechanical property of timber. (See "Strength.")

MODULUS OF ELASTICITY.

(See p. 14.)

Modulus of elasticity is the ratio of stress per unit area to corresponding strain per unit length, the distortion or strain being within the elastic limit.

Numerically, the modulus of elasticity of a material is the force in pounds required to stretch a sample of that material with a cross-sectional area of 1 square inch to double its length, on the assumption that the fibers would not be stressed beyond their elastic limit. India rubber has a very low modulus of elasticity, while that of steel is very high. It is, then, the measure of the stiffness or rigidity of a substance.

MODULUS OF RUPTURE.

(See p. 13.)

PHYSICAL PROPERTIES.

Physical properties, as the term is used in this bulletin, are those properties of wood which have to do with its structure, such as density, cell arrangements, fiber length, etc. In its broad sense the term physical properties includes all those properties listed as mechanical properties as well as those pertaining to its structure.

RADIAL.

Radial means extending outward from a center or an axis. Thus a radial surface in a tree is one extending from the pith of the tree outward, such as the wide faces of a quarter-sawed board.

RINGS.

(See p. 8.)

Rings are those circular markings around the center of a tree section which are produced by the contrast in density, hardness, color, etc., between springwood and summerwood. One ring, known as an annual ring, consists of a layer of springwood and a layer of summerwood.

SHEAR.

(See p. 17.)

Shear is the name of the stress which tends to keep two adjoining planes or surfaces of a body from sliding, one on the other, under the influence of two equal and parallel forces acting in opposite directions. A force which produces shear (or shearing stress) in a material is called a shearing force.

SPRINGWOOD.

The lighter and more porous layer of wood in the annual rings of a tree is known as the springwood or early wood. As the name implies, it is produced in spring growth, or in the earlier part of the growing season.

STRAIN.

The deformation or distortion produced by a stress or force is known as strain.

STRENGTH.

(See p. 6.)

The term "strength" as ordinarily used is a very indefinite one. It is usually thought of in connection with external loads or forces.

Strength in its broad sense is a measure of the mechanical properties, or of the ability of a timber to resist stress or deformation. Thus, strength in shear, strength as a beam, strength as a post, hardness, stiffness, toughness. These last three properties are not always thought of in connection with the term strength, but are unconsciously included whenever they are important in a specific use. See example of this as given on page 6.

Seldom, if ever, do any two species contain all the various properties in the same degree. This accounts for the special uses of the different species.

Much confusion often arises from comparing species for a special use on the basis of properties or strength values not of first importance in the specific instance.

STRESS.

Stress is distributed force.

Fiber stress is the distributed force tending to compress, tear apart, or change the relative position of the wood fibers.

Stress is measured by the force per unit area. Thus a short column 2 inches square (4 square inches) and supporting a load of 2,000 pounds will be under a stress or fiber stress of 500 pounds per square inch.

SUMMERWOOD.

(See p. 9.)

Summerwood is that denser layer of wood in the annual rings of a tree which is put on in summer or the latter part of the growing season.

TANGENTIAL.

Tangential, as applied in this publication, means tangent to or parallel to the curves of the annual rings in a cross section. Thus a tangential surface is a surface perpendicular to the radius of a tree.

WORK.

(See p. 15.)

Work is the product of force and distance, or force acting through distance.

Work is essential in stopping bodies in motion, or in causing motion or change of motion of bodies.

Work is measured in inch-pounds, foot-pounds, etc.

An inch-pound is the work required to raise one pound 1 inch or to move a body 1 inch against a resistance of 1 pound.

FORMULÆ USED IN COMPUTING.

LEGEND.

A = Area of cross section; square inches.
B = Area under plate in compression-perpendicular-to-grain tests, square inches.
CS = Crushing strength, pounds per square inch.
E = Modulus of elasticity, pounds per square inch.
EL = Fiber stress at elastic limit, pounds per square inch.
J = Greatest calculated longitudinal shear, pounds per square inch.
K = Constant = 27.7 when weight is in pounds; 0.061 when weight is in grams.
MR = Modulus of rupture, pounds per square inch.
P = Maximum load, pounds.
P′ = Load at elastic limit, pounds.
S = Dry specific gravity.
Δ = Total deflection or compression at elastic limit, inches.
b = Width, inches
d = Distance between centers of collars, inches.
h = Height, inches.
l = Span, inches (in compression parallel to grain l = length).

BENDING.

Load applied at center:

$$J = \frac{0.75 \times P}{b \times h}$$

$$MR = \frac{1.5 \times P \times l}{b \times h^2}$$

$$EL = \frac{1.5 \times P' \times l}{b \times h^2}$$

$$E = \frac{P' \times l^3}{4 \times b \times h^3 \times \Delta}$$

Uniformly distributed load:

$$J=\frac{0.75\times P}{b\times h}$$

$$MR=\frac{0.75\times P\times l}{b\times h^2}$$

$$EL=\frac{0.75\times P'\times l}{b\times h^2}$$

$$E=\frac{P'\times l^3}{6.4\times b\times h^3\times \Delta}$$

Any loading:

$$M=1/6\ F\times b\times h^2.$$

Where M = moment in inch-pounds either external or internal.
F = fiber stress for moment M.

$J=3/2\times \frac{V}{b\times h}$ where J = unit horizontal shear at any point and V = total vertical shear at that point.

COMPRESSION PARALLEL TO GRAIN.

$$CS=\frac{P}{A}$$

$$EL=\frac{P'}{A}$$

$$E=\frac{P'\times d}{A\times \Delta}$$

COMPRESSION PERPENDICULAR TO GRAIN.

$$EL=\frac{P'}{B}$$

SHEAR PARALLEL TO GRAIN.

$$\text{Shear}=\frac{P}{A}$$

SPECIFIC GRAVITY.

$$S=\frac{\text{weight}\times K}{\left(1+\%\ \frac{\text{moisture}}{100}\right)\times \text{volume of piece in cubic inches.}}$$

TABLE 1.

The data in Table 1 are derived from a considerably larger number of tests and are therefore somewhat more reliable than those of Table 2. Before an attempt is made to use these data, it is recommended that the entire text of this bulletin be read carefully, particularly "Misuse of terms," page 6. Attention should be given to "Precautions to be observed in the use of data," page 4, to the explanation of the column heads, pages 7 to 18, and to the discussion and illustrations of the use of the variability figures given in Table 3.

Where an apparent discrepancy is found between figures in this table and those in previous publications of the Forest Service, the data herein given may be considered as the most accurate (see p. 4).

Safe working stresses for the design of structural timbers should be based on the data in Table 1 rather than on those given in Table 2 for reasons presented elsewhere in this bulletin, particularly under "Data on air-dry timber," page 7, and "Static bending," page 12.

Safe working stresses will of necessity vary with the conditions under which the timber is used. Factors for obtaining working stresses for timber used in dry interior construction are given elsewhere in this bulletin as follows:

Columns—Under "Maximum crushing strength," page 16.

Details of joints—Under "Shearing strength parallel to grain," page 17, and under "Tension perpendicular to grain," page 18.

TABLE 1.—*Results of tests on 126 species of wood tested in a green condition in the form of small clear pieces.*

[Test specimens are 2 by 2 inches in section. Bending specimens are cut 30 inches long; others are shorter, depending on kind of test.]

Common and botanical name.	Locality where grown.	Number of trees.	Number of rings per inch.	Summerwood (per cent).	Moisture content (per cent).	Specific gravity, oven dry, based on—		Weight per cubic foot (green) (pounds).	Shrinkage from green to oven-dry condition.			Static bending.					Impact bending.			Compression parallel to grain.		Compression perpendicular to grain—fiber stress at elastic limit (pounds per square inch).	Shearing strength parallel to grain (pounds per square inch).	Tension perpendicular to grain (pounds per square inch).	Hardness, load required to imbed a 0.444-inch ball to one-half its diameter.	
						Volume when green.	Volume when oven-dry.		In volume (per cent of dimensions when green).	Radial (per cent of dimensions when green).	Tangential (per cent of dimensions when green).	Fiber stress at elastic limit (pounds per square inch).	Modulus of rupture (pounds per square inch).	Modulus of elasticity (1,000 pounds per square inch).	Work in bending—To elastic limit (inch-pounds per cubic inch).	Work in bending—To maximum load (inch-pounds per cubic inch).	Fiber stress at elastic limit (pounds per square inch).	Work in bending to elastic limit (inch-pounds per cubic inch).	Height of drop causing complete failure, 50-pound hammer (inches).	Fiber stress at elastic limit (pounds per square inch).	Maximum crushing strength (pounds per square inch).				End (pounds).	Side (pounds).
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
HARDWOODS.																										
Alder, red (Alnus oregona).	Washington	6	11	....	98	0.37	0.43	46	12.6	4.4	7.3	3,800	6,500	1,170	0.70	8.0	8,000	2.6	22	2,650	2,960	310	770	390	550	440
Ash, biltmoren (Fraxinus biltmoreana).	Tennessee	5	17	49	42	.51	.58	45	12.6	4.2	6.9	5,500	9,300	1,340	1.31	11.6	11,900	4.9	30	3,560	3,980	880	1,230	540	950	850
Ash, black (Fraxinus nigra).	Michigan, Wisconsin.	15	24	53	83	.46	.53	53	15.2	5.0	7.8	2,600	6,000	1,020	.42	12.4	7,200	2.5	32	1,620	2,290	430	870	490	580	550
Ash, blue (Fraxinus quadrangulata).	Kentucky	5	12	49	39	.53	.60	46	11.7	3.9	6.5	5,700	9,600	1,240	1.47	14.7	11,100	5.0	43	3,540	4,180	990	1,540	580	1,140	1,030
Ash, green (Fraxinus lanceolata).	Missouri, Louisiana.	10	18	58	48	.52	.61	48	12.5	4.6	7.1	5,300	9,500	1,400	1.14	11.8	11,400	5.0	34	3,560	4,200	910	1,260	590	960	870
Ash, Oregon (Fraxinus oregona).	Oregon	3	12	63	48	.50	.58	46	13.2	4.1	8.1	4,200	7,600	1,130	.92	12.2	8,900	3.0	39	2,740	3,510	650	1,190	490	850	790

TABLE 1.—*Results of tests on 126 species of wood tested in a green condition in the form of small clear pieces*—Continued.

Common and botanical name.	Locality where grown.	Number of trees.	Number of rings per inch.	Summerwood (per cent).	Moisture content (per cent).	Specific gravity oven dry, based on— Volume when green.	Specific gravity oven dry, based on— Volume when oven-dry.	Weight per cubic foot (green) (pounds).	Shrinkage from green to oven-dry condition. In volume (per cent of dimensions when green).	Shrinkage: Radial (per cent of dimensions when green).	Shrinkage: Tangential (per cent of dimensions when green).	Static bending. Fiber stress at elastic limit (pounds per square inch).	Static bending: Modulus of rupture (pounds per square inch).	Static bending: Modulus of elasticity (1,000 pounds per square inch).	Static bending: Work in bending— To elastic limit (inch-pounds per cubic inch).	Static bending: Work in bending— To maximum load (inch-pounds per cubic inch).	Impact bending. Fiber stress at elastic limit (pounds per square inch).	Impact bending: Work in bending to elastic limit (inch-pounds per cubic inch).	Impact bending: Height of drop causing complete failure, 50-pound hammer (inches).	Compression parallel to grain. Fiber stress at elastic limit (pounds per square inch).	Compression parallel to grain: Maximum crushing strength (pounds per square inch).	Compression perpendicular to grain—fiber stress at elastic limit (pounds per square inch).	Shearing strength parallel to grain (pounds per square inch).	Tension perpendicular to grain (pounds per square inch).	Hardness, load required to imbed a 0.444-inch ball to one-half its diameter. End (pounds).	Hardness: Side (pounds).
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
HARDWOODS—contd.																										
Ash, pumpkin (Fraxinus profunda).	Missouri	3	21	46	51	0.48	0.55	46	12.0	3.7	6.3	4,500	7,600	1,040	1.08	9.4	8,800	3.7	31	2,830	3,360	990	1,210	570	880	750
Ash, white (forest grown) (Fraxinus americana).	Arkansas, West Virginia.	10	16	50	43	.52	.60	46	12.6	4.2	6.5	4,900	9,100	1,350	1.03	13.4	11,700	5.0	36	3,230	3,800	800	1,260	620	1,000	900
Ash, white (second growth) (Fraxinus americana).	New York	5	9	63	40	.58	.71	51	14.0	5.3	8.7	6,100	10,800	1,640	1.30	16.3	13,800	5.9	47	3,820	4,610	790	1,600	790	1,140	1,080
Aspen (Populus tremuloides).	Wisconsin	5	8	....	107	.36	.42	47	11.1	3.3	6.9	2,900	5,300	840	.65	6.9	6,900	2.5	28	1,620	2,160	200	620	180	270	320
Aspen, largetooth (Populus grandidentata).	.....do	5	8	....	96	.35	.41	43	11.6	3.1	7.9	3,200	5,800	1,180	.50	6.1	7,600	2.7	18	2,130	2,720	270	810	390	440	370
Basswood (Tilia americana).	Pennsylvania, Wisconsin.	8	19	29	103	.33	.40	41	15.8	6.6	9.3	2,700	5,000	1,030	.42	5.2	6,200	2.0	17	1,710	2,210	210	610	280	280	250
Beech (Fagus atropunicea).	Indiana, Pennsylvania.	10	19	30	62	.54	.66	55	16.2	4.8	10.6	4,500	8,200	1,240	.99	12.5	10,400	4.2	40	2,550	3,280	610	1,210	760	950	820
Birch, paper (Betula papyrifera).	Wisconsin	5	6	36	72	.47	.60	51	16.3	6.6	8.8	2,900	5,800	1,010	.49	15.0	7,800	2.7	45	1,650	2,210	300	790	380	400	490

Birch, sweet (Betula lenta).	Pennsylvania	5	27	....	61	.59	.70	59	15.0	6.3	7.6	4,500	8,600	1,490	.81	15.6	9,500	3.1	44	2,650	3,560	520	1,220	550	1,020	890
Birch, yellow (Betula lutea).	Pennsylvania, Wisconsin.	10	19	26	68	.54	.66	58	16.8	7.4	9.0	4,600	8,600	1,540	.80	16.6	11,700	4.5	40	2,760	3,460	450	1,110	480	820	740
Buckeye, yellow (Æsculus octandra).	Tennessee	5	15	....	141	.33	.38	49	12.0	3.5	7.8	2,600	4,800	980	.41	5.4	6,500	2.1	18	1,640	2,050	210	660	320	360	290
Buckthorn, cascara (Rhamnus purshiana).	Oregon	5	17	....	61	.50	.55	50	7.6	3.2	4.6	3,400	6,300	630	1.04	13.4	8,700	3.6	58	1,880	3,270	670	1,150	510	680	730
Butternut (Juglans cinerea).	Tennessee, Wisconsin.	10	9	....	104	.36	.40	46	10.2	3.3	6.1	2,900	5,400	970	.52	8.2	7,300	2.5	24	1,960	2,420	270	760	430	410	390
Cherry, black (Prunus serotina).	Pennsylvania	5	11	....	55	.47	.53	46	11.5	3.7	7.1	4,200	8,000	1,310	.80	12.8	10,200	4.1	33	2,940	3,540	440	1,130	570	750	660
Cherry, wild red (Prunus pennsylvanica).	Tennessee	5	6	....	46	.36	.42	33	12.8	2.8	10.3	2,900	5,000	1,040	.47	6.2	6,600	2.1	22	1,830	2,170	260	680	300	440	390
Chestnut (Castanea dentata).	Maryland, Tennessee.	10	10	48	122	.40	.46	55	11.6	3.4	6.7	3,100	5,600	930	.59	7.0	7,900	2.8	24	2,040	2,470	380	800	430	530	420
Chinquapin, western (Castanopsis chrysophylla).	Oregon	5	15	....	134	.42	.48	61	13.2	4.6	7.4	4,200	7,000	1,020	1.09	9.5	8,800	3.4	31	1,920	3,020	490	1,010	480	730	600
Cottonwood (Populus deltoides).	Missouri	5	6	....	111	.37	.43	49	14.1	3.9	9.2	2,900	5,300	1,010	.49	7.3	7,200	2.3	21	1,770	2,280	240	680	410	380	340
Cottonwood, black (Populus trichocarpa).	Washington	5	6	....	132	.32	.37	46	12.4	3.6	8.6	2,900	4,800	1,070	.44	5.0	6,800	2.2	20	1,770	2,160	200	600	270	280	250
Cucumber tree (Magnolia acuminata).	Tennessee	5	14	....	80	.44	.52	50	13.6	5.2	8.8	4,200	7,400	1,560	.66	10.0	9,300	2.9	30	2,760	3,140	410	990	440	600	520
Dogwood (flowering) (Cornus florida).	....do	5	24	....	62	.64	.80	65	19.9	7.1	11.3	4,800	8,800	1,180	1.11	21.0	7,100	3.5	58	......	3,640	1,030	1,520	....	1,410	1,410
Dogwood, western (Cornus nuttallii).	Oregon	5	21	....	52	.58	.70	55	17.2	6.4	9.6	4,200	8,200	1,090	.92	17.0	9,800	3.6	56	2,280	3,640	870	1,300	740	1,140	980
Elder, pale (Sambucus glauca).	....do	5	6	....	124	.46	.57	65	15.6	4.4	9.0	3,400	6,600	900	.72	8.8	8,000	2.9	38	2,450	3,040	520	1,090	560	760	720
Elm, cork (Ulmus racemosa).	Wisconsin	10	28	50	50	.58	.66	54	14.1	4.8	8.1	4,600	9,500	1,190	1.20	19.8	11,000	4.1	50	2,870	3,780	750	1,270	660	980	990
Elm, slippery (Ulmus pubescens).	Indiana, Wisconsin.	6	16	54	85	.48	.56	56	13.8	4.9	8.9	4,000	8,000	1,230	.82	15.4	9,200	3.4	47	2,840	3,320	510	1,110	650	750	660
Elm, white (Ulmus americana).	Wisconsin, Pennsylvania.	6	18	31	88	.44	.54	52	14.4	4.2	9.5	3,600	6,900	1,030	.83	11.0	8,100	2.9	34	2,290	2,880	390	920	560	610	550
Gum, black (Nyssa sylvatica).	Tennessee	5	27	....	55	.46	.55	45	13.9	4.4	7.7	4,000	7,000	1,030	.91	8.0	9,800	4.0	30	2,440	3,040	600	1,100	570	790	640
Gum, blue (Eucalyptus globulus).	California	5	....	....	79	.62	.80	70	22.5	7.6	15.3	7,600	11,200	2,010	1.65	13.9	14,200	4.7	40	4,870	5,250	1,020	1,550	640	1,310	1,340
Gum, cotton (Nyssa aquatica).	Louisiana	6	10	26	97	.46	.52	56	12.5	4.2	7.6	4,200	7,300	1,050	.98	8.3	9,000	3.3	30	2,760	3,370	590	1,190	600	800	710
Gum, red (Liquidambar styraciflua).	Missouri	10	16	....	81	.44	.53	50	15.0	5.2	9.9	3,700	6,800	1,150	.81	9.4	10,000	3.9	33	2,360	2,840	460	1,070	510	630	520
Hackberry (Celtis occidentalis).	Indiana, Wisconsin.	6	12	56	65	.48	.56	50	13.8	4.8	8.9	2,900	6,500	950	.58	14.5	7,900	3.1	48	2,060	2,650	490	1,070	630	760	690
Haw, pear (Cratægus tomentosa).	Wisconsin	2	11	....	63	.62	....	63	....	....	....	3,900	7,600	960	.89	22.7	......	....	....	......	3,110	980	1,360	....	1,220	1,200
Hickory, big shellbark (Hicoria laciniosa).	Mississippi, Ohio	19	19	65	61	.62	....	63	19.2	7.6	12.6	5,600	10,500	1,340	1.36	29.9	14,200	7.0	104	2,740	43,920	1,000	1,190	....	......	.....

TABLE 1.—*Results of tests on 126 species of wood tested in a green condition in the form of small clear pieces*—Continued.

Common and botanical name.	Locality where grown.	Number of trees.	Number of rings per inch.	Summerwood (per cent).	Moisture content (per cent).	Specific gravity oven dry, based on—Volume when green.	Specific gravity oven dry, based on—Volume when oven-dry.	Weight per cubic foot (green) (pounds).	Shrinkage from green to oven-dry condition. In volume (per cent of dimensions when green).	Shrinkage: Radial (per cent of dimensions when green).	Shrinkage: Tangential (per cent of dimensions when green).	Static bending. Fiber stress at elastic limit (pounds per square inch).	Static bending: Modulus of rupture (pounds per square inch).	Static bending: Modulus of elasticity (1,000 pounds per square inch).	Static bending: Work in bending—To elastic limit (inch-pounds per cubic inch).	Static bending: Work in bending—To maximum load (inch-pounds per cubic inch).	Impact bending. Fiber stress at elastic limit (pounds per square inch).	Impact bending: Work in bending to elastic limit (inch-pounds per cubic inch).	Impact bending: Height of drop causing complete failure, 50-pound hammer (inches).	Compression parallel to grain. Fiber stress at elastic limit (pounds per square inch).	Compression parallel to grain: Maximum crushing strength (pounds per square inch).	Compression perpendicular to grain—fiber stress at elastic limit (pounds per square inch).	Shearing strength parallel to grain (pounds per square inch).	Tension perpendicular to grain (pounds per square inch).	Hardness, load required to imbed a 0.444-inch ball to one-half its diameter. End (pounds).	Hardness: Side (pounds).
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
HARDWOODS—contd.																										
Hickory, bitternut (Hicoria minima).	Ohio	11	11	70	66	0.60	....	63	....	....	....	5,500	10,300	1,400	1.22	20.0	15,900	8.5	66	4,330	4,570	990	1,240	....	....	....
Hickory, mockernut (Hicoria alba).	West Virginia, Mississippi, Pennsylvania.	20	18	63	59	.64	....	64	17.9	7.8	11.0	6,300	11,100	1,570	1.38	26.1	15,100	6.7	88	3,900	4,480	1,000	1,280	....	....	....
Hickory, nutmeg (Hicoria myristicaeformis).	Mississippi	5	22	59	74	.56	....	61	....	....	....	4,900	9,100	1,290	1.06	22.8	12,800	6.1	54	3,620	3,980	940	1,030	....	....	....
Hickory pecan (Hicoria pecan).	Missouri	5	12	63	63	.60	0.69	61	13.6	4.9	8.9	5,200	9,800	1,370	1.18	14.6	12,300	5.0	53	3,040	3,990	960	1,480	680	1,270	1,310
Hickory, pignut (Hicoria glabra).	Ohio, Mississippi, Pennsylvania, West Virginia.	60	20	65	54	.66	....	64	17.9	7.2	11.5	6,200	11,700	1,650	1.34	31.7	16,900	8.8	89	3,950	4,810	1,140	1,370	....	....	....
Hickory, shagbark (Hicoria ovata).	....do	24	19	66	60	.64	....	64	16.7	7.0	10.5	5,900	11,000	1,570	1.28	23.7	14,400	6.4	74	3,430	4,580	1,000	1,320	....	....	....
Hickory, water (Hicoria aquatica).	Mississippi	2	15	67	80	.61	....	69	....	....	....	6,000	10,700	1,560	1.29	18.8	13,700	6.1	56	3,240	4,660	1,090	1,440	....	....	....

Holly, American (Ilex opaca).	Tennessee	5	27	....	82	.50	.61	57	16.2	4.5	9.5	3,400	6,500	900	.72	10.8	8,900	4.4	51	1,970	2,640	610	1,130	610	860	790
Hornbeam (Ostrya virginiana).	Wisconsin	5	29	....	52	.63	.76	60	18.6	8.2	9.6	4,500	8,500	1,150	1.02	13.3	10,600	3.5	73	2,620	3,570	730	1,370	450	1,160	1,170
Laurel, California (Umbellularia californica).	Oregon	5	6	....	70	.51	.59	55	11.9	2.8	8.1	3,900	6,600	720	1.23	16.8	8,300	4.1	57	1,960	3,020	800	1,270	780	1,020	1,000
Laurel, mountain (Kalmia latifolia).	Tennessee	5	24	....	62	.62	74	62	14.4	5.6	8.8	5,800	8,400	920	2.03	12.5	10,200	5.2	32	......	4,310	1,110	1,670	....	1,400	1,300
Locust, black (Robinia pseudacacia).	.....do	3	11	51	40	.66	.71	58	9.8	4.4	6.9	8,800	13,800	1,850	2.36	15.4	18,300	7.9	44	6,280	6,800	1,430	1,760	770	1,640	1,570
Locust, honey (Gleditsia triacanthos).	Missouri, Indiana	6	9	45	63	.60	.67	61	10.8	4.2	6.6	5,600	10,200	1,290	1.40	12.6	11,800	4.6	47	3.320	4,420	1,420	1,660	930	1,440	1,390
Madrona (Arbutus menziesii).	California, Oregon	6	10	....	68	.57	.69	60	17.4	5.4	11.9	4,700	7,600	880	1.43	11.2	10,200	4.7	40	2,340	3,320	780	1,420	770	1,120	940
Magnolia (evergreen) (Magnolia foetida).	Louisiana	2	15	....	117	.46	.53	62	12.3	5.4	6.6	3,600	6,800	1,110	.67	15.4	8,800	3.2	54	2,200	2,700	570	1,040	610	780	740
Maple, Oregon (Acer macrophyllum).	Washington	5	12	....	72	.44	.51	47	11.6	3.7	7.1	4,400	7,400	1,100	1.02	8.7	8,500	2.8	23	2,380	3,240	550	1,110	600	760	620
Maple, red (Acer rubrum).	Pennsylvania, Wisconsin.	9	16	24	70	.48	.54	51	12.5	3.8	8.1	4,100	7,800	1,420	.60	10.6	9,900	3.7	30	2,500	3,350	520	1,080	580	740	600
Maple, silver (Acer saccharinum).	Wisconsin	5	7	...	66	.44	.51	46	12.0	3.0	7.2	3,100	5,800	940	.61	11.0	6,800	2.6	29	1,950	2,490	460	1,050	560	670	590
Maple, sugar (Acer saccharum).	Indiana, Pennsylvania, Wisconsin.	17	21	49	60	.56	.66	56	14.5	4.8	9.2	5,000	9,100	1,480	1.08	11.9	12,100	5.0	36	3,120	3,860	750	1,380	770	1,000	910
Oak, bur (Quercus macrocarpa).	Wisconsin	5	12	59	70	.58	.67	61	12.7	4.4	8.8	3,600	7,200	880	.89	10.7	10,000	4.7	44	2,310	3,290	840	1,350	800	1,160	1,110
Oak, California black (Quercus californica).	California, Oregon	10	16	52	106	.51	.58	66	12.1	3.6	6.6	3,400	6,200	740	1.03	8.8	8,200	3.4	30	1,880	2,800	890	1,140	700	910	850
Oak, canyon live (Quercus chrysolepsis).	California	3	13	....	62	.70	.84	71	16.2	8.0	14.3	6,300	10,600	1,340	1.70	14.4	11,200	3.9	47	4,050	4,690	1,480	1,700	970	1,590	1,570
Oak, chestnut (Quercus prinus).	Tennessee	5	23	50	72	.57	.67	62	16.7	5.5	9.7	4,600	8,000	1,370	.90	9.4	12,000	4.6	35	2,890	3,520	660	1,210	690	970	890
Oak, cow (Quercus michauxii).	Louisiana	4	12	58	76	.60	.76	65	19.4	5.9	9.2	4,800	8,500	1,350	1.00	12.8	10,400	3.2	45	3,060	3,540	710	1,260	670	1,100	1,110
Oak, laurel (Quercus laurifolia).	.....do	5	11	61	84	.56	.70	64	19.0	3.9	9.5	4,500	7,900	1,390	.86	11.2	10,400	3.4	39	2,730	3,170	710	1,180	770	1,020	1,000
Oak, Pacific post (Quercus garryana).	Oregon	10	16	49	72	.64	.75	69	13.4	4.2	9.0	4,600	7,700	790	1.51	13.7	10,300	4.8	49	2,510	3,570	1,380	1,630	940	1,430	1,390
Oak, post (Quercus minor).	Arkansas, Louisiana.	10	26	54	69	.60	.74	63	16.2	5.4	9.8	5,000	8,100	1,090	1.31	11.0	10,900	4.1	44	2,840	3,480	1,060	1,280	790	1,160	1,130
Oak, red (Quercus rubra)	Arkansas, Louisiana, Indiana, Tennessee.	21	11	62	84	.56	.65	64	14.2	3.9	8.3	3,700	7,700	1,290	.65	11.5	10,400	3.9	41	2,330	3,200	730	1,120	740	1,020	950
Oak, Spanish (highland) (Quercus digitata).	Louisiana	4	20	46	90	.52	.62	62	16.3	4.5	8.7	4,200	6,900	1,140	.93	8.0	9,100	3.1	29	2,180	3,030	680	930	480	910	860
Oak, Spanish (lowland) (Quercus pagodæfolia).	.....do	3	7	63	78	.61	.71	67	16.4	5.2	10.8	6,500	10,800	1,790	1.32	14.7	12,300	3.8	54	3,760	4,620	940	1,320	800	1,270	1,240
Oak, water (Quercus minor).	.....do	5	10	61	81	.56	.68	63	16.4	4.2	9.3	5,600	8,900	1,550	1.14	11.1	11,600	3.8	39	3,200	3,740	770	1,240	820	1,050	1,010
Oak, white (Quercus alba).	Arkansas, Louisiana, Indiana.	20	17	60	68	.60	.71	62	15.8	5.3	9.0	4,700	8,300	1,250	1.08	11.5	10,700	4.2	42	2,990	3,560	830	1,250	770	1,120	1,060

TABLE 1.—*Results of tests on 126 species of wood tested in a green condition in the form of small clear pieces*—Continued.

Common and botanical name.	Locality where grown.	Number of trees.	Number of rings per inch.	Summerwood (per cent).	Moisture content (per cent).	Specific gravity oven dry, based on—: Volume when green.	Specific gravity oven dry, based on—: Volume when oven-dry.	Weight per cubic foot (green) (pounds).	Shrinkage from green to oven-dry condition: In volume (per cent of dimensions when green).	Shrinkage from green to oven-dry condition: Radial (per cent of dimensions when green).	Shrinkage from green to oven-dry condition: Tangential (per cent of dimensions when green).	Static bending: Fiber stress at elastic limit (pounds per square inch).	Static bending: Modulus of rupture (pounds per square inch).	Static bending: Modulus of elasticity (1,000 pounds per square inch).	Static bending: Work in bending—To elastic limit (inch-pounds per cubic inch).	Static bending: Work in bending—To maximum load (inch-pounds per cubic inch).	Impact bending: Fiber stress at elastic limit (pounds per square inch).	Impact bending: Work in bending to elastic limit (inch-pounds per cubic inch).	Impact bending: Height of drop causing complete failure, 50-pound hammer (inches).	Compression parallel to grain: Fiber stress at elastic limit (pounds per square inch).	Compression parallel to grain: Maximum crushing strength (pounds per square inch).	Compression perpendicular to grain—fiber stress at elastic limit (pounds per square inch).	Shearing strength parallel to grain (pounds per square inch).	Tension perpendicular to grain (pounds per square inch).	Hardness load required to imbed a 0.444-inch ball to one-half its diameter: End (pounds).	Hardness load required to imbed a 0.444-inch ball to one-half its diameter: Side (pounds).
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
HARDWOODS—contd.																										
Oak, willow (Quercus phellos).	Louisiana	2	14	56	94	0.56	0.69	67	18.9	5.0	9.6	4,400	7,400	1,290	0.88	8.8	9,200	2.9	35	2,480	3,000	750	1,180	760	1,020	980
Oak, yellow (Quercus velutina).	Arkansas, Wisconsin.	8	15	71	78	.56	.67	63	14.2	4.5	9.7	4,600	8,200	1,180	1.20	12.3	10,800	4.4	40	2,870	3,460	870	1,180	830	1,000	1,060
Persimmon (Diospyros virginiana).	Missouri	5	14	....	58	.64	.78	63	18.3	7.5	10.8	5,600	10,000	1,370	1.35	13.0	12,100	4.5	41	3,030	4,170	1,110	1,470	770	1,240	1,280
Poplar, yellow (Liriodendron tulipifera).	Tennessee	5	14	....	64	.37	.42	38	11.4	4.1	6.9	3,200	5,600	1,210	.48	5.6	8,000	2.6	17	2,000	2,550	310	790	460	420	340
Rhododendron, great (Rhododendron maximum).	....do	5	28	....	99	.50	.60	62	16.2	6.3	8.7	4,600	6,900	870	1.38	12.1	......	....	26	......	3,470	890	1,240	....	1,000	860
Sassafras (Sassafras sassafras).	....do	5	19	48	67	.42	.47	44	10.3	4.0	6.2	3,600	6,000	910	.80	7.1	8,500	3.5	37	2,410	2,730	460	950	520	610	520
Serviceberry (Amelanchier canadensis).	....do	5	19	....	48	.66	.79	61	18.7	6.7	10.8	5,600	9,600	1,640	1.08	16.2	12,200	4.1	63	3,200	4,080	780	1,260	730	1,250	1,240
Silverbell-tree (Mohrodendrum carolinum).	....do	5	20	....	70	.42	.48	44	12.6	3.8	7.6	3,500	6,500	1,160	.62	8.8	9,100	3.3	27	2,110	2,830	430	930	460	550	470

Sourwood (Oxydendrum arboreum).	.....do...........	5	24	....	69	.50	.59	53	15.2	6.3	8.9	4,400	7,700	1,320	.82	9.8	10,800	4.1	38	2,720	3,250	680	1,160	710	860	730
Sumac, staghorn (Rhus hirta).	Wisconsin.........	5	9	61	45	.45	....	41	....	....	....	3,000	5,800	810	.67	10.8	......	....	....	......	2,680	480	......	....	670	590
Sugarberry (Celtis mississippiensis).	Missouri..........	5	17	38	62	.47	.54	48	12.7	5.0	7.3	3,200	6,600	810	.78	12.0	8,200	3.2	33	1,950	2,800	580	1,050	660	840	740
Sycamore (Platanus occidentalis).	Indiana, Tennessee.	10	16	77	83	.46	.54	52	14.2	5.1	7.6	3,300	6,500	1,060	.60	7.5	8,800	3.3	26	2,390	2,920	450	1,000	630	700	610
Umbrella, Fraser (Magnolia fraseri).	Tennessee.........	5	15	....	89	.40	.48	47	13.0	4.4	7.5	3,400	6,100	1,190	.55	8.3	8,600	2.9	23	2,250	2,610	330	830	450	570	500
Walnut, black (Juglans nigra).	Kentucky.........	5	12	....	81	.51	.56	58	11.3	5.2	7.1	5,400	9,500	1,420	1.16	14.6	11,900	4.5	37	3,600	4,300	600	1,220	570	960	900
Willow, black (Salix nigra).	Wisconsin, Missouri.	10	5	....	138	.34	.41	50	13.8	2.6	7.8	1,800	3,800	560	.36	10.8	5,100	2.0	36	970	1,510	210	620	430	350	360
Willow, western black (Salix lasiandra).	Oregon............	5	5	....	105	.39	.47	50	13.8	2.9	9.0	3,100	5,600	1,020	.58	10.8	7,600	2.5	33	1,810	2,340	330	870	360	490	500
Witch hazel (Hamamelis virginiana).	Tennessee.........	5	14	....	70	.56	.71	59	18.8	....	....	5,000	8,300	1,110	1.29	19.5	12,400	6.3	40	......	3,400	620	1,120	....	1,010	980
CONIFERS.																										
Cedar, incense (Libocedrus decurrens).	California, Oregon.	8	16	30	108	.35	.36	45	7.6	3.3	5.7	3,900	6,200	840	.94	6.4	7,300	2.4	17	2,870	3,150	460	830	280	570	390
Cedar, Port Orford (Chamæcyparis lawsoniana).	Oregon...........	5	24	25	52	.41	.47	39	10.7	5.2	8.1	3,900	6,800	1,500	.59	7.8	9,300	2.7	25	2,970	3,280	380	880	240	560	480
Cedar, western red (Thuja plicata).	Washington, Montana.	10	20	36	39	.31	.34	27	8.1	2.5	5.1	3,300	5,200	950	.64	5.0	7,100	2.4	17	2,500	2,840	310	720	210	430	260
Cedar, white (Thuja occidentalis).	Wisconsin.........	5	23	36	55	.29	.32	28	7.0	2.1	4.9	2,600	4,200	640	.60	5.7	5,300	2.0	15	1,420	1,990	290	620	240	320	230
Cypress, bald (Taxodium distichum).	Louisiana, Missouri.	10	16	31	87	.41	.47	48	10.7	3.8	6.0	4,000	6,800	1,190	.86	6.4	8,000	2.6	24	3,100	3,490	470	820	280	470	380
Cypress, yellow (Chamæscyparis nootkaten is).	Oregon...........	5	31	....	40	.40	.44	35	7.9	1.9	5.0	3,600	6,200	960	.77	9.5	8,600	3.2	27	2,390	2,880	410	820	260	520	410
Douglas fir (Pseudotsuga taxifolia).	Washington, Oregon.	18	13	35	36	.45	.52	38	12.6	5.0	7.9	5,000	7,800	1,580	.86	6.7	9,400	2.9	25	3,400	3,940	530	910	200	510	470
Do................	Montana, Wyoming.	10	22	27	38	.40	.44	34	10.6	3.6	6.2	3,600	6,400	1,180	.65	6.8	9,100	3.0	20	2,520	3,000	450	880	350	450	400
Fir, Alpine (Abies lasiocarpa).	Colorado..........	5	15	14	47	.31	.32	28	9.0	2.5	7.1	2,400	4,400	860	.39	4.4	5,300	1.6	9	1,660	2,060	310	610	....	280	220
Fir, amabilis (Abies amabilis).	Oregon, Washington.	20	8	26	102	.37	.42	47	14.1	4.5	10.0	3,900	6,300	1,300	.60	6.0	7,800	2.2	21	2,380	2,930	320	670	240	360	310
Fir, balsam (Abies balsamea).	Wisconsin.........	5	12	26	117	.34	.41	45	10.8	2.8	6.6	3,000	4,900	960	.52	4.7	6,900	2.3	16	2,220	2,400	210	610	180	290	290
Fir, grand (Abies grandis).	Montana, Oregon..	10	18	30	94	.37	.42	44	10.6	3.2	7.2	3,600	6,100	1,300	.58	5.6	8,100	2.6	22	2,680	3,010	340	760	230	420	360
Fir, noble (Abies nobilis)	Oregon...........	5	23	17	41	.35	.41	31	13.6	4.9	9.1	3,400	5,700	1,280	.53	6.2	7,900	2.6	20	2,370	2,700	310	700	180	300	250
Fir, white (Abies concolor).	California.........	5	10	30	156	.35	.44	56	10.2	3.4	7.0	3,900	6,000	1,130	.77	5.2	7,200	2.2	18	2,610	2,800	440	730	260	380	330
Hemlock black (Tsuga mertensiana).	Montana..........	5	23	45	70	.42	.48	45	10.8	4.4	7.1	3,500	6,000	940	.78	9.4	8,800	3.6	36	2,590	2,890	400	880	360	580	460

TABLE 1.—*Results of tests on 126 species of wood tested in a green condition in the form of small clear pieces*—Continued.

Common and botanical name.	Locality where grown.	Number of trees.	Number of rings per inch.	Summerwood (per cent).	Moisture content (per cent).	Specific gravity oven dry, based on— Volume when green.	Specific gravity oven dry, based on— Volume when oven-dry.	Weight per cubic foot (green) (pounds).	Shrinkage from green to oven-dry condition. In volume (per cent of dimensions when green).	Shrinkage: Radial (per cent of dimensions when green).	Shrinkage: Tangential (per cent of dimensions when green).	Static bending. Fiber stress at elastic limit (pounds per square inch).	Static bending: Modulus of rupture (pounds per square inch).	Static bending: Modulus of elasticity (1,000 pounds per square inch).	Static bending: Work in bending— To elastic limit (inch-pounds per cubic inch).	Static bending: Work in bending— To maximum load (inch-pounds per cubic inch).	Impact bending. Fiber stress at elastic limit (pounds per square inch).	Impact bending: Work in bending to elastic limit (inch-pounds per cubic inch).	Impact bending: Height of drop causing complete failure, 50-pound hammer (inches).	Compression parallel to grain. Fiber stress at elastic limit (pounds per square inch).	Compression parallel to grain: Maximum crushing strength (pounds per square inch).	Compression perpendicular to grain—fiber stress at elastic limit (pounds per square inch).	Shearing strength parallel to grain (pounds per square inch).	Tension perpendicular to grain (pounds per square inch).	Hardness, load required to imbed a 0.444-inch ball to one-half its diameter. End (pounds).	Hardness: Side (pounds).
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
CONIFERS—continued.																										
Hemlock (eastern) (Tsuga canadensis).	Tennessee, Wisconsin.	10	20	34	105	0.38	0.44	48	10.4	3.0	6.4	4,200	6,700	1,120	0.88	6.8	7,900	2.8	20	2,710	3,270	500	880	260	510	410
Hemlock (western) (Tsuga heterophylla).	Washington	5	10	27	71	.38	.43	41	11.6	4.5	7.9	3,400	6,100	1,190	.58	6.0	7,800	2.4	20	2,290	2,890	350	810	260	540	430
Larch, western (Larix occidentalis).	Montana, Washington.	13	32	37	58	.48	.59	48	13.2	4.2	8.1	4,600	7,500	1,350	1.01	7.1	9,400	3.7	24	3,250	3,800	560	920	230	470	450
Pine, Cuban (Pinus heterophylla).	Florida	5	17	44	47	.58	.68	53	12.7	5.9	7.5	5,600	8,800	1,630	1.10	7.9	11,300	3.9	37	3,950	4,470	590	1,030	290	570	630
Pine, jack (Pinus divaricata).	Wisconsin	5	7	30	105	.39	.46	50	10.4	3.4	6.5	3,000	5,400	920	.55	5.9	7,800	3.3	30	2,250	2,580	380	760	310	380	370
Pine, Jeffrey (Pinus jeffreyi).	California	5	18	23	101	.37	.42	47	9.9	4.4	6.7	3,200	5,000	980	.60	4.7	7,200	2.6	21	2,030	2,370	350	690	260	320	340
Pine, loblolly (Pinus tæda).	Florida, North Carolina, South Carolina.	15	8	42	70	.50	.59	54	12.6	5.5	7.5	4,400	7,500	1,380	.81	8.0	9,500	3.1	32	2,870	3,580	550	900	280	400	450
Pine, lodgepole (Pinus contorta).	Colorado, Montana, Wyoming.	28	24	22	65	.38	.44	39	11.5	4.5	6.7	3,000	5,500	1,080	.49	5.6	7,200	2.3	20	2,100	2,610	310	690	220	320	330

Pine, longleaf (Pinus palustris).	Florida, Louisiana, Mississippi.	34	18	39	47	.55	.64	50	12.3	5.3	7.5	5,400	8,700	1,630	1.00	8.0	10,800	3.5	34	3,840	4,390	600	1,070	290	550	590
Pine, Norway (Pinus resinosa).	Wisconsin........	5	22	41	54	.44	.51	42	11.5	4.6	7.2	3,700	6,400	1,380	.59	5.8	7,500	2.2	28	2,470	3,080	360	780	190	360	340
Pine, pitch (Pinus rigida).	Tennessee........	5	12	30	85	.47	.54	54	11.7	4.8	7.4	3,700	6,700	1,120	.75	8.5	9,100	3.4	29	2,100	3,040	510	950	350	460	480
Pine, pond (Pinus serotina).	Florida..........	5	13	35	56	.50	.58	49	11.2	5.1	7.1	4,500	7,400	1,280	.93	7.5	9,400	3.2	33	2,990	3,660	540	940	280	460	510
Pine, shortleaf (Pinus echinata).	Arkansas, Louisiana.	12	12	40	64	.50	.58	50	12.6	5.1	8.2	4,500	8,000	1,450	.79	8.7	11,200	4.0	39	3,650	3,810	480	890	330	490	560
Pine, sugar (Pinus lambertiana).	California........	5	12	34	123	.36	.39	50	8.4	2.9	5.6	3,300	5,300	970	.66	5.0	6,700	2.3	17	2,340	2,600	350	710	270	330	320
Pine, table-mountain (Pinus pungens).	Tennessee........	5	15	29	75	.49	.55	54	10.9	3.4	6.8	4,500	7,500	1,270	.94	8.1	10,200	3.8	29	2,980	3,540	560	960	320	480	490
Pine, western white (Pinus monticola).	Montana..........	5	28	33	58	.39	.45	39	11.5	4.1	7.4	3,500	5,700	1,330	.54	5.1	7,600	2.3	23	2,770	3,070	300	710	250	330	330
Pine, western yellow (Pinus ponderosa).	Colorado, Montana, Arizona, Washington, California.	25	20	22	95	.38	.42	46	10.0	3.9	6.4	3,100	5,200	1,010	.54	5.1	6,700	2.3	19	2,080	2,460	340	680	280	310	320
Pine, white (Pinus strobus).	Wisconsin........	5	16	31	74	.36	.39	39	7.8	2.2	5.9	3,400	5,300	1,070	.62	5.9	6,500	2.1	18	2,370	2,720	310	640	260	300	300
Spruce, Engelmann (Picea engelmanni).	Colorado..........	10	14	14	100	.31	.35	38	10.4	3.4	6.6	2,500	4,200	830	.43	4.9	5,800	1.9	14	1,740	1,980	290	590	....	250	240
Spruce, red (Picea rubens).	New Hampshire, Tennessee.	9	17	27	43	.38	.41	34	11.8	3.8	7.8	3,400	5,700	1,180	.56	6.1	7,200	2.3	18	2,360	2,740	350	770	220	420	350
Spruce, Sitka (Picea sitchensis).	Washington.......	5	9	24	53	.34	.37	33	11.2	4.5	7.4	3,000	5,500	1,180	.44	6.4	7,900	2.5	29	2,280	2,600	330	780	230	430	370
Spruce, white (Picea canadensis).	New Hampshire, Wisconsin.	7	14	27	46	.36	.43	33	14.8	3.7	7.3	3,300	5,400	980	.66	5.7	6,800	2.0	20	2,280	2,380	270	670	200	300	280
Tamarack (Larix laricina).	Wisconsin........	5	20	38	52	.49	.56	47	13.6	3.7	7.4	4,200	7,200	1,240	.84	7.2	7,800	2.7	28	3,010	3,480	480	860	260	400	380
Yew, western (Taxus brevifolia).	Washington.......	5	27	....	44	.60	.67	54	9.7	4.0	5.4	6,500	10,100	990	2.46	20.2	13,100	6.2	38	3,400	4,600	1,040	1,620	450	1,340	1,150

TABLE 2.

Table 2 is to be considered supplementary to Table 1. In using this table attention should be given to the comments on "Data on air-dry timber," page 7, to the explanation of column heads, pages 7 to 18, to the figures on change of properties with changes of moisture as given under "Shrinkage from green to oven dry," page 12, and in column 2 of Table 3; also to the explanation of column 2 of Table 3. (See p. 18.)

TABLE 2.—*Results of tests on 126 species of wood tested in an air-dry condition in the form of small clear pieces.*

[Test specimens are 2 by 2 inches in section. Bending specimens are cut 30 inches long; others are shorter, depending on kind of test.]

Common and botanical name.	Locality where grown.	Number of rings per inch.	Summerwood (per cent.)	Moisture content (per cent).	Specific gravity, oven dry, based on volume when air dry.	Weight per cubic foot (air dry) (pounds).	Static bending.			Work in bending—		Impact bending.			Compression parallel to grain.		Compression perpendicular to grain—fiber stress at elastic limit (pounds per square inch).	Shearing strength parallel to the grain (pounds per square inch).	Tension perpendicular to grain (pounds per square inch).	Hardness, load required to imbed a 0.444-inch ball to one-half its diameter.	
							Fiber stress at elastic limit (pounds per square inch).	Modulus of rupture (pounds per square inch).	Modulus of elasticity (1,000 pounds per square inch).	To elastic limit (inch-pounds per cubic inch).	To maximum load (inch-pounds per cubic inch).	Fiber stress at elastic limit (pounds per square inch).	Work to elastic limit (inch-pounds per cubic inch).	Height of drop causing complete failure, 50-pound hammer (inches).	Fiber stress at elastic limit (pounds per square inch).	Maximum crushing strength (pounds per square inch).				End (pounds).	Side (pounds).
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
HARDWOODS.																					
Alder, red (Alnus oregona).	Washington	11	......	8.6	0.42	29	8,100	10,800	1,440	2.37	8.5	13,000	5.9	20	5,350	7,050	650	1,210	430	1,170	650
Ash, biltmore (Fraxinus biltmoreana).	Tennessee	17	49	5.3	.57	38	12,100	15,600	1,760	4.60	11.7	19,800	10.4	46	7,140	10,370	2,020	1,970	810	2,060	1,330
Ash, black (Fraxinus nigra).	Michigan, Wisconsin	24	52	10.4	.50	34	8,300	13,900	1,680	1.84	15.5	12,200	5.3	36	5,070	6,890	1,080	1,730	730	1,250	890
Ash, blue (Fraxinus quadrangulata).	Kentucky	12	49	9.6	.58	40	8,700	14,800	1,430	3.00	14.3	20,600	10.5	42	6,120	7,740	1,910	2,150	440	1,890	1,360
Ash, green (Fraxinus lanceolata).	Missouri, Louisiana	18	58	10.4	.57	39	9,460	14,900	1,690	3.00	13.6	17,400	8.2	31	5,330	7,580	1,760	2,080	710	1,770	1,260
Ash, Oregon (Fraxinus oregona).	Oregon	12	63	8.4	.57	39	8,000	14,500	1,430	2.58	15.1	15,000	6.2	31	4,710	7,100	2,000	2,090	780	1,670	1,300
Ash, pumpkin (Fraxinus profunda).	Missouri	21	46	9.6	.53	36	7,000	11,800	1,310	2.11	7.8	15,200	7.9	22	4,040	6,300	2,000	1,890	830	1,540	1,030
Ash, white (forest grown) (Fraxinus americana).	Arkansas, West Virginia.	16	50	8.7	.58	40	10,200	16,800	1,810	3.29	15.1	17,000	8.8	36	5,600	8,190	1,540	2,110	880	1,950	1,320
Ash, white (second growth) (Fraxinus americana).	New York	9	63	9.5	.64	44	13,000	18,600	1,980	4.80	17.0	23,800	12.8	46	8,500	9,420	2,090	2,520	1,130	2,240	1,680

TABLE 2.—*Results of tests on 126 species of wood tested in an air-dry condition in the form of small clear pieces*—Continued.

Common and botanical name.	Locality where grown.	Number of rings per inch.	Summerwood (per cent).	Moisture content (per cent).	Specific gravity, oven dry, based on volume when air dry.	Weight per cubic foot (air dry) (pounds).	Static bending. Fiber stress at elastic limit (pounds per square inch).	Static bending. Modulus of rupture (pounds per square inch).	Static bending. Modulus of elasticity (1,000 pounds per square inch).	Static bending. Work in bending—To elastic limit (inch-pounds per cubic inch).	Static bending. Work in bending—To maximum load (inch-pounds per cubic inch).	Impact bending. Fiber stress at elastic limit (pounds per square inch).	Impact bending. Work to elastic limit (inch-pounds per cubic inch).	Impact bending. Height of drop causing complete failure, 50-pound hammer (inches).	Compression parallel to grain. Fiber stress at elastic limit (pounds per square inch).	Compression parallel to grain. Maximum crushing strength (pounds per square inch).	Compression perpendicular to grain—fiber stress at elastic limit (pounds per square inch).	Shearing strength parallel to the grain (pounds per square inch).	Tension perpendicular to grain (pounds per square inch).	Hardness, load required to imbed a 0.444-inch ball to one-half its diameter. End (pounds).	Hardness, load required to imbed a 0.444-inch ball to one-half its diameter. Side (pounds).
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
HARDWOODS—contd.																					
Aspen (Populus tremuloides).	Wisconsin	8	......	5.2	0.42	28	7,600	10,800	1,290	2.43	7.3	10,500	4.0	24	4,490	6,400	550	890	380	850	420
Aspen, largetooth (Populus grandidentata).	do	8	......	8.0	.40	27	7,100	10,900	1,640	1.83	6.7	15,100	7.0	27	5,060	7,080	650	1,300	380	710	460
Basswood (Tilia americana).	Pennsylvania, Wisconsin.	19	29	8.4	.38	26	7,300	10,200	1,580	1.99	8.1	11,200	4.6	16	4,430	5,980	580	1,240	370	590	450
Beech (Fagus atropunicea).	Indiana, Pennsylvania	19	30	11.2	.63	44	9,000	15,000	1,680	2.91	13.7	19,700	9.2	35	4,870	7,400	1,340	1,970	890	1,400	1,190
Birch, paper (Betula papyrifera).	Wisconsin	6	36	4.2	58	38	11,400	16,000	1,810	4.32	13.2	13,800	6.6	24	6,780	9,470	910	1,630	......	1,490	1,280
Birch, sweet (Betula lenta).	Pennsylvania	27	......	9.0	.66	45	13,300	19,600	2,140	4.56	17.0	26,700	13.2	48	7,220	10,680	1,750	2,680	610	2,090	1,490
Birch, yellow (Betula lutea).	Pennsylvania, Wisconsin.	19	26	9.6	.63	44	12,300	18,900	2,200	3.93	20.2	21,200	9.9	58	7,720	9,760	1,410	1,880	890	1,590	1,320
Buckeye, yellow (Æsculus octandra).	Tennessee	15	......	6.2	.38	25	7,000	9,300	1,280	2.20	6.2	12,700	6.4	14	4,220	5,870	640	1,140	660	550	400
Buckthorn, cascara (Rhamnus purshiana).	Oregon	17	......	4.0	.53	34	8,500	10,500	1,240	3.28	5.7	11,200	5.4	16	5,510	9,190	2,000	1,990	......	1,790	1,280
Butternut (Juglans cinerea).	Tennessee, Wisconsin.	9	......	7.6	.39	26	7,300	9,300	1,260	2.32	8.2	12,900	5.7	24	4,490	6,680	760	1,360	440	650	530
Cherry, black (Prunus serotina).	Pennsylvania	11	......	9.2	.51	35	11,000	13,800	1,540	4.48	11.0	14,800	5.9	28	7,330	8,370	1,020	1,930	560	1,690	1,030

Cherry, wild red (Prunus pennsylvanica).	Tennessee	6	......	6.6	.41	27	7,800	10,700	1,400	2.54	9.3	12,100	5.2	36	5,460	6,490	700	1,240	340	930	580
Chestnut (Castanea dentata).	Maryland, Tennessee	10	48	8.6	.44	30	7,400	9,700	1,330	2.41	6.4	11,500	5.4	18	4,420	6,620	930	1,160	470	780	580
Chinquapin, western (Castanopsis chrysophylla).	Oregon	15	......	4.8	.48	31	11,900	14,100	1,410	6.14	9.5	12,500	6.0	29	5,780	7,970	860	1,450	......	920	830
Cottonwood (Populus deltoides).	Missouri	6	......	4.7	.43	28	8,600	11,400	1,640	2.61	7.4	7,500	2.4	19	5,060	7,830	730	1,120	700	740	480
Cottonwood, black (Populus trichocarpa).	Washington	6	......	8.5	.36	24	6,200	9,600	1,310	1.62	7.2	10,900	4.4	22	4,410	5,440	460	1,160	340	670	390
Cucumber tree (Magnolia acuminata).	Tennessee	14	......	6.8	.50	33	10,700	15,400	1,940	3.22	13.4	17,800	7.6	37	6,020	8,540	860	1,530	815	1,160	790
Dogwood (flowering) (Cornus florida).	....do	24	......	7.5	.77	52	11,800	18,300	1,700	4.63	18.9	19,300	10.1	40	6,030	7,090	2,470	2,740	1,730	2,980	2,530
Dogwood, western (Cornus nuttallii).	Oregon	21	......	5.3	.68	45	10,100	12,200	1,760	3.26	8.5	10,900	3.8	26	5,950	11,310	2,470	2,060	1,400	2,510	1,640
Elder, pale (Sambucus glauca).	....do	6	......	4.6	.55	36	7,600	11,300	1,120	2.51	10.7	12,100	6.9	30	4,140	6,990	980	......	......	920	900
Elm, cork (Ulmus racemosa).	Wisconsin	28	50	8.5	.66	44	9,400	16,500	1,610	3.32	18.7	18,500	9.4	53	5,510	8,420	1,860	2,140	740	1,730	1,470
Elm, slippery (Ulmus pubescens).	Indiana, Wisconsin	16	54	8.3	.54	37	9,400	14,900	1,570	3.28	17.3	17,800	9.4	45	5,370	7,800	1,240	1,810	490	1,220	900
Elm, white (Ulmus americana).	Wisconsin, Pennsylvania.	18	34	8.8	.51	35	9,200	14,600	1,490	3.46	13.7	16,600	9.9	44	5,270	6,850	850	1,740	610	1,240	870
Gum, black (Nyssa sylvatica).	Tennessee	27	......	7.2	.52	35	9,200	10,900	1,270	3.84	5.6	17,200	9.1	19	4,060	7,000	1,500	1,460	470	1,380	850
Gum, blue (Eucalyptus globulus).	California	......	......	5.7	.82	54	14,400	20,600	2,600	4.82	11.6	25,200	12.6	42	11,400	13,900	2,250	2,050	......	1,840	1,650
Gum, cotton (Nyssa aquatica).	Louisiana	10	26	6.1	0.52	34	9,800	11,300	1,370	4.19	6.4	14,700	7.8	20	5,450	7,910	1,530	1,840	940	1,470	990
Gum, red (Liquidambar styraciflua).	Missouri	16	......	11.3	.49	34	8,400	12,300	1,500	3.39	11.8	19,300	10.4	32	4,960	6,020	790	1,750	870	1,010	720
Hackberry (Celtis occidentalis).	Indiana, Wisconsin	12	56	9.2	.54	37	6,900	12,300	1,250	2.18	12.4	15,800	8.7	42	4,200	6,450	1,330	1,790	570	1,210	930
Haw, pear (Cratægus tomentosa).	Wisconsin	11	......	8.6	.70	48	9,000	17,200	1,370	3.30	23.8	13,500	5.5	20	4,750	8,420	1,880	1,920	......	2,270	1,680
Hickory, big shellbark (Hicoria laciniosa).	Mississippi, Ohio	18	77	8.7	.71	48	9,800	20,500	2,040	2.59	22.4	25,100	14.5	84	......	9,710	2,660	2,430	......	......	......
Hickory, bitternut (Hicoria minima).	Ohio	13	77	9.2	.68	46	10,300	18,800	1,880	3.19	17.9	26,500	14.0	66	......	10,600	2,390	2,050	......	......	......
Hickory, mockernut (Hicoria alba).	Mississippi, Pennsylvania.	18	73	8.9	.75	50	13,500	21,600	2,380	4.19	22.0	21,900	10.6	74	......	10,610	2,540	1,900	......	......	......
Hickory, nutmeg (Hicoria myristicaeformis).	Mississippi	......	......	8.9	.62	42	9,200	19,300	1,820	2.40	25.7	......	......	......	......	7,960	2,320	2,100	......	......	......
Hickory, pecan (Hicoria pecan).	Missouri	12	63	6.2	.70	46	12,000	16,200	1,940	4.33	13.4	20,400	10.4	41	6,170	10,890	3,350	2,540	1,310	2,370	2,140
Hickory, pignut (Hicoria glabra).	Ohio, Mississippi, Pennsylvania, West Virginia.	16	74	9.6	.78	53	12,700	22,500	2,410	3.87	30.2	26,200	13.4	70	......	10,640	2,860	2,450	......	......	......
Hickory, shagbark (Hicoria ovata).	....do	22	70	9.4	.74	50	11,900	22,600	2,290	3.55	26.3	22,500	10.7	65	......	10,700	2,470	2,340	......	......	......

TABLE 2.—*Results of tests on 126 species of wood tested in an air-dry condition in the form of small clear pieces*—Continued.

Common and botanical name.	Locality where grown.	Number of rings per inch.	Summerwood (per cent).	Moisture content (per cent).	Specific gravity, oven dry, based on volume when air dry.	Weight per cubic foot (air dry) (pounds).	Static bending.					Impact bending.			Compression parallel to grain.		Compression perpendicular to grain—fiber stress at elastic limit (pounds per square inch).	Shearing strength parallel to the grain (pounds per square inch).	Tension perpendicular to grain (pounds per square inch).	Hardness, load required to imbed a 0.444-inch ball to one-half its diameter.	
							Fiber stress at elastic limit (pounds per square inch).	Modulus of rupture (pounds per square inch).	Modulus of elasticity (1,000 pounds per square inch).	Work in bending—To elastic limit (inch-pounds per cubic inch).	Work in bending—To maximum load (inch-pounds per cubic inch).	Fiber stress at elastic limit (pounds per square inch).	Work to elastic limit (inch-pounds per cubic inch).	Height of drop causing complete failure, 50-pound hammer (inches).	Fiber stress at elastic limit (pounds per square inch).	Maximum crushing strength (pounds per square inch).				End (pounds).	Side (pounds).
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
HARDWOODS—contd.																					
Hickory, water (Hicoria aquatica).	Mississippi	15	70	8.8	0.62	42	11,800	20,200	2,160	3.55	19.4	......	......	52	6,190	10,140	2,210	1,860	......	......	......
Holly, American (Ilex opaca).	Tennessee	27	......	6.4	.60	40	8,000	12,700	1,230	2.95	10.6	14,800	8.5	27	4,450	7,820	1,520	2,060	740	1,770	1,150
Hornbeam (Ostrya virginiana).	Wisconsin	29	......	5.6	.75	49	13,900	18,600	2,110	5.34	14.4	16,600	7.6	40	8,310	11,750	2,300	2,110	......	3,150	2,390
Laurel, California (Umbellularia californica).	Oregon	6	......	4.9	.58	38	6,700	9,000	1,110	2.40	5.2	12,500	6.2	22	5,220	8,140	1,930	2,340	950	1,980	1,460
Laurel, mountain (Kalmia latifolia).	Tennessee	24	......	5.0	.72	47	10,900	13,200	1,410	4.77	9.1	17,400	9.3	46	5,270	7,120	2,420	......	......	2,670	2,180
Locust, black (Robinia pseudacacia).	....do	11	51	10.0	.70	48	13,800	20,700	2,090	5.29	19.1	21,600	10.1	59	7,790	10,880	2,520	2,710	620	1,570	1,730
Locust, honey (Gleditsia triacanthos).	Missouri	10	37	6.0	.63	42	10,700	16,700	1,690	3.76	12.6	17,000	9.3	45	6,520	9,520	2,800	2,580	820	2,030	1,600
Madrona (Arbutus menziessii).	California, Oregon	10	......	4.5	.70	45	9,500	12,700	1,500	3.45	7.6	10,700	4.4	16	5,790	10,800	2,640	2,190	......	2,620	1,930
Magnolia (evergreen) (Magnolia foetida).	Louisiana	15	......	8.8	.51	35	7,800	12,500	1,480	2.39	12.3	15,000	7.5	25	3,940	6,600	1,250	1,700	780	1,480	1,120
Maple, Oregon (Acer macrophyllum).	Washington	12	......	8.3	.50	34	7,600	12,000	1,580	1.93	7.6	......	......	30	6,370	7,180	1,120	2,010	520	1,630	950
Maple, red (Acer rubrum)	Pennsylvania, Wisconsin.	14	24	10.1	.54	37	9,200	14,200	1,740	2.80	12.8	17,000	8.2	31	5,430	7,330	1,280	1,970	660	1,530	990

Maple, silver (Acer saccharinum).	Wisconsin	7	......	8.2	0.48	32	7,700	10,100	1,210	2.67	7.6	15,000	9.4	24	5,600	6,600	1,180	1,710	490	1,380	750
Maple, sugar (Acer saccharum).	Indiana, Pennsylvania, Wisconsin.	21	49	10.5	.62	43	10,400	15,800	1,820	3.52	13.6	19,100	9.3	33	6,060	8,570	1,620	2,450	770	2,000	1,430
Oak, bur (Quercus macrocarpa).	Wisconsin	12	59	10.2	.65	45	7,000	10,900	1,060	2.79	9.6	15,300	8.6	27	3,700	6,640	1,670	1,920	650	1,460	1,420
Oak, California black (Quercus californica).	California, Oregon	16	52	5.2	.60	40	8,400	10,500	1,160	3.72	5.7	9,200	4.2	12	4,440	8,420	1,860	1,710	830	1,360	1,280
Oak, canyon live (Quercus chrysolepsis).	California	13	......	5.0	.82	54	11,900	14,700	1,810	4.67	7.8	14,300	6.7	32	8,100	13,360	2,890	2,740	1,500	3,360	3,150
Oak, chestnut (Quercus prinus).	Tennessee	23	50	9.5	.68	46	10,600	15,000	1,640	3.85	11.5	21,200	9.0	42	5,280	7,840	1,180	1,600	1,510	1,340	1,200
Oak, cow (Quercus michauxii).	Louisiana	12	58	11.3	.68	47	7,500	14,500	1,810	1.75	11.9	19,200	8.1	41	4,420	7,580	1,420	2,190	700	1,310	1,260
Oak, laurel (Quercus laurifolia).	.....do	11	61	9.5	.64	44	8,700	14,000	1,770	2.47	12.0	15,200	5.9	39	5,280	8,230	1,490	2,030	790	1,280	1,260
Oak, Pacific post (Quercus garryana).	Oregon	16	49	6.6	.76	51	7,800	11,700	1,270	2.73	8.5	12,700	5.7	23	5,020	8,570	2,560	2,210	810	2,090	1,780
Oak, post (Quercus minor).	Arkansas, Louisiana	26	54	11.2	.68	47	7,800	13,600	1,540	2.34	13.3	17,800	8.6	46	3,960	6,890	1,900	1,900	780	1,360	1,390
Oak, red (Quercus rubra)	Arkansas, Louisiana, Indiana, Tennessee.	11	62	10.9	.63	44	8,600	14,200	1,870	2.32	13.3	18,500	9.1	39	4,610	7,370	1,210	1,760	780	1,500	1,310
Oak, Spanish (highland) (Quercus digitata).	Louisiana	20	46	10.1	.60	41	6,400	11,800	1,560	1.55	9.7	16,500	8.3	26	3,030	6,800	1,180	1,530	520	1,050	1,100
Oak, Spanish (lowland) (Quercus pagodæfolia).	.....do	7	63	10.0	.69	47	12,000	19,400	2,360	3.45	18.8	25,200	13.2	49	7,010	9,720	1,730	2,170	860	1,640	1,540
Oak, water (Quercus nigra).	.....do	10	61	10.8	.64	44	9,200	16,000	2,060	2.36	22.6	19,400	8.6	44	3,930	7,200	1,320	2,010	940	1,450	1,220
Oak, white (Quercus alba).	Arkansas, Louisiana, Indiana.	17	60	11.5	.69	48	8,300	15,200	1,780	2.31	14.8	17,200	7.6	38	4,350	7,610	1,340	2,090	800	1,540	1,370
Oak, willow (Quercus phellos).	Louisiana	14	56	9.8	.72	49	10,700	16,400	2,040	3.18	16.0	17,500	9.3	44	4,910	8,230	1,640	1,800	1,430	1,530	1,620
Oak, yellow (Quercus velutina).	Arkansas, Wisconsin	14	62	11.6	.61	42	8,000	14,100	1,650	2.18	13.7	14,400	6.4	41	4,780	6,660	1,160	1,970	820	1,400	1,210
Persimmon (Diospyros virginiana).	Missouri	14	......	5.5	.81	53	15,400	23,700	2,460	5.70	16.9	22,400	11.7	35	9,210	14,050	3,910	2,670	1,520	3,730	3,180
Poplar, yellow (Liriodendron tulipifera).	Tennessee	14	......	6.1	.41	27	8,400	11,800	1,610	2.52	7.5	18,600	8.9	22	4,470	7,480	740	1,170	570	590	450
Rhododendron, great (Rhododendron maximum).	.....do	28	......	4.6	.63	41	8,400	14,400	1,270	3.09	12.5	9,200	3.3	16	5,510	9,360	1,920	......	890	......	......
Sassafras (Sassafras sassafras).	.....do	19	48	6.8	.46	31	7,700	10,600	1,220	2.71	9.5	11,700	6.1	31	3,740	6,060	1,470	1,380	620	670	690
Serviceberry (Amelanchier canadensis).	.....do	19	......	8.4	.77	52	13,400	20,000	1,960	4.88	19.8	24,500	12.3	58	8,640	11,020	2,300	1,720	......	2,490	2,030
Silverbell-tree (Mohrodendrum carolinum).	.....do	20	......	6.1	.47	31	7,300	9,800	1,400	2.22	6.2	16,000	8.0	23	4,330	6,890	860	1,310	480	1,060	650
Sourwood (Oxydendrum arboreum).	.....do	24	......	6.8	.57	38	10,900	13,800	1,640	3.87	11.4	20,700	11.5	38	5,600	8,190	1,370	1,680	450	1,680	1,060
Sumac, staghorn (Rhus hirta).	Wisconsin	9	61	8.0	.48	32	10,400	12,100	1,350	4.50	7.8	......	......	......	5,660	7,750	1,370	......	......	960	720

TABLE 2.—*Results of tests on 126 species of wood tested in an air-dry condition in the form of small clear pieces*—Continued.

Common and botanical name.	Locality where grown	Number of rings per inch.	Summerwood (per cent).	Moisture content (per cent).	Specific gravity, oven dry, based on volume when air dry.	Weight per cubic foot (air dry) (pounds).	Static bending.					Impact bending.			Compression parallel to grain.		Compression perpendicular to grain—fiber stress at elastic limit (pounds per square inch).	Shearing strength parallel to the grain (pounds per square inch).	Tension perpendicular to grain (pounds per square inch).	Hardness, load required to imbed a 0.444-inch ball to one-half its diameter.	
							Fiber stress at elastic limit (pounds per square inch).	Modulus of rupture (pounds per square inch).	Modulus of elasticity (1,000 pounds per square inch).	Work in bending—To elastic limit (inch-pounds per cubic inch).	Work in bending—To maximum load (inch-pounds per cubic inch).	Fiber stress at elastic limit (pounds per square inch).	Work to elastic limit (inch-pounds per cubic inch).	Height of drop causing complete failure, 50-pound hammer (inches).	Fiber stress at elastic limit (pounds per square inch).	Maximum crushing strength (pounds per square inch).				End (pounds).	Side (pounds).
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
HARDWOODS—contd.																					
Sugarberry (Celtis mississippiensis).	Missouri	17	38	5.0	0.54	35	9,500	13,000	1,410	4.23	10.7	14,100	7.4	37	5,960	8,450	2,010	1,450	700	1,640	1,110
Sycamore (Platanus occidentalis).	Indiana, Tennessee	16	77	9.2	.50	34	7,600	11,300	1,510	2.20	9.2	10,800	4.0	28	4,260	6,280	1,010	1,460	750	970	810
Umbrella, Fraser (Magnolia fraseri).	Tennessee	15	......	6.4	.47	31	9,300	12,700	1,520	3.27	10.9	16,400	7.4	28	5,220	7,500	840	1,340	790	980	690
Walnut, black (Juglans nigra).	Kentucky	12	......	4.8	.57	37	14,500	17,900	1,820	6.43	9.2	19,400	11.3	33	7,880	10,660	1,960	1,480	780	1,110	1,080
Willow, black (Salix nigra).	Wisconsin, Missouri	5	......	6.4	.38	26	5,600	7,600	830	2.45	6.8	9,200	4.8	16	2,880	5,030	710	1,340	470	680	500
Willow, western black (Salix lasiandra).	Oregon	5	......	4.0	.47	31	8,000	11,100	1,540	2.39	8.4	13,900	7.1	30	5,000	7,120	920	1,410	660	1,230	730
Witch hazel (Hamamelis virginiana).	Tennessee	14	......	5.1	.65	43	12,000	20,300	1,660	4.85	21.8	......	......	......	6,440	8,430	2,170	......	......	2,560	1,940
CONIFERS.																					
Cedar, incense (Libocedrus decurrens).	California, Oregon	17	30	5.1	.36	24	7,400	9,400	1,300	2.31	4.9	11,100	5.2	17	6,400	7,200	840	900	270	1,040	520
Cedar, Port Orford (Chamæcyparis lawsoniana).	Oregon	24	25	9.0	.45	31	8,900	14,500	2,040	2.25	......	17,600	7.2	39	7,700	7,750	1,020	1,500	630	950	700

Cedar, western red (Thuja plicata).	Washington, Montana.	20	36	7.4	0.34	22	6,100	8,800	1,250	1.68	6.4	9,600	3.4	16	5,390	6,320	700	920	180	750	380
Cedar, white (Thuja occidentalis).	Wisconsin	23	36	11.2	.31	22	5,100	6,700	810	1.84	4.7	7,200	2.8	12	2,840	4,140	390	900	240	470	340
Cypress, bald (Taxodium distichum).	Louisiana, Missouri	16	31	9.0	.44	30	8,700	11,300	1,540	3.03	7.3	11,200	4.7	26	5,970	7,690	910	1,080	280	800	550
Cypress, yellow (Chamæcyparis nootkatensis).	Oregon	31	......	5.5	.43	28	9,000	12,800	1,430	3.37	8.5	14,600	7.9	29	7,780	8,080	960	1,120	430	810	580
Douglas fir (Pseudotsuga taxifolia).	Montana, Wyoming	22	27	9.4	.44	30	6,900	10,300	1,460	1.83	6.5	13,300	5.6	28	5,320	7,090	950	1,080	320	750	660
Do	Washington, Oregon	13	35	6.2	.51	34	10,600	14,000	2,210	2.94	8.4	14,300	5.4	33	9,260	10,680	1,220	1,270	330	920	810
Fir, Alpine (Abies lasiocarpa).	Colorado	15	14	15.9	.32	23	4,800	6,000	890	1.73	3.4	6,700	2.1	14	3,270	3,400	500	1,010	......	420	340
Fir, amabilis (Abies amabilis).	Washington	12	26	9.3	.39	27	7,000	10,600	1,600	1.73	10.3	11,900	5.3	24	5,070	6,540	580	1,180	290	720	470
Fir, balsam (Abies balsamea).	Wisconsin	12	26	4.8	.38	25	7,300	9,900	1,440	2.11	5.4	8,500	2.9	23	......	6,640	530	790	180	740	500
Fir, grand (Abies grandis)	Montana, Oregon	18	30	6.8	.41	27	7,100	11,000	1,790	1.66	8.3	14,000	5.8	32	5,970	7,060	850	1,000	190	820	560
Fir, noble (Abies nobilis)	Oregon	23	17	8.4	.39	26	7,700	12,000	1,750	1.92	9.4	12,500	4.6	27	6,140	7,240	850	1,090	130	860	470
Fir, white (Abies concolor).	California	10	30	9.6	.38	26	7,000	9,800	1,490	1.86	5.5	8,400	3.2	14	4,180	6,150	720	1,060	260	780	460
Hemlock, black (Tsuga mertensiana).	Montana	23	45	8.0	.46	31	7,400	11,400	1,180	2.74	9.1	15,600	7.9	36	4,360	7,510	1,420	1,260	340	1,290	690
Hemlock (eastern) (Tsuga canadensis).	Tennessee, Wisconsin	20	34	8.6	.42	28	7,200	9,700	1,300	2.32	5.8	12,500	6.0	24	5,240	7,060	1,060	1,160	190	860	490
Hemlock (western) (Tsuga heterophylla).	Washington	10	27	5.4	.42	28	8,000	10,800	1,520	2.48	6.1	13,000	6.0	26	7,780	7,910	830	1,170	170	1,020	620
Larch, western (Larix occidentalis).	Montana, Washington.	36	37	8.3	.54	36	10,100	13,500	1,830	3.06	8.2	17,000	8.6	34	8,420	9,640	1,280	1,530	340	1,380	870
Pine, Cuban (Pinus heterophylla).	Florida	17	44	8.8	.66	45	12,400	18,300	2,220	3.88	13.1	18,000	7.2	42	9,160	11,890	1,620	1,920	650	1,200	1,160
Pine, jack (Pinus divaricata).	Wisconsin	7	30	6.1	.44	29	6,500	9,700	1,400	1.81	5.1	13,100	5.6	37	......	7,770	1,150	1,330	440	870	740
Pine, Jeffrey (Pinus jeffreyi).	California	18	23	8.7	.41	28	8,800	10,900	1,310	3.42	7.1	14,200	6.2	29	5,200	6,980	1,000	1,450	410	740	550
Pine, loblolly (Pinus tæda).	Florida	9	42	6.5	.57	38	11,700	15,600	2,130	3.70	9.0	14,800	5.9	26	7,980	11,300	1,600	1,720	370	1,030	840
Pine, lodgepole (Pinus contorta).	Colorado, Montana, Wyoming.	24	22	7.1	.43	28	9,000	11,500	1,460	3.24	7.6	10,800	4.7	20	6,270	7,300	1,120	980	380	640	500
Pine, longleaf (Pinus palustris).	Florida, Louisiana, Mississippi.	18	38	9.2	.66	42	11,800	16,700	2,200	3.58	11.3	16,400	6.6	32	9,250	10,880	1,670	1,640	420	1,140	1,020
Pine, Norway (Pinus resinosa).	Wisconsin	22	41	12.5	.48	34	9,200	12,300	1,790	2.68	9.9	15,100	6.3	25	5,660	7,080	830	1,260	470	700	600
Pine, pitch (Pinus rigida)	Tennessee	12	30	7.6	.52	35	7,800	12,400	1,500	2.56	8.7	17,200	10.7	28	4,490	7,600	1,170	1,670	580	820	690
Pine, pond (Pinus serotina).	Florida	13	35	6.2	.56	37	11,300	14,600	2,050	3.43	9.2	15,700	6.3	26	8,220	10,690	1,580	1,720	410	1,020	890
Pine, shortleaf (Pinus echinata).	Arkansas, Louisiana	10	40	11.0	.54	38	9,200	13,900	1,970	2.46	10.1	16,600	6.5	36	7,080	8,660	1,310	1,390	410	940	880
Pine, sugar (Pinus lambertiana).	California	12	34	11.4	.37	26	6,400	8,600	1,210	1.79	5.0	10,100	4.3	17	4,740	5,190	640	1,080	350	650	460
Pine, table-mountain (Pinus pungens).	Tennessee	15	29	8.0	.53	36	9,400	13,400	1,650	3.06	8.9	15,900	7.6	29	4,560	8,500	1,530	1,290	......	830	730

TABLE 2.—*Results of tests on 126 species of wood tested in an air-dry condition in the form of small clear pieces*—Continued.

Common and botanical name.	Locality where grown.	Number of rings per inch.	Summerwood (per cent).	Moisture content (per cent).	Specific gravity, oven dry, based on volume when air dry.	Weight per cubic foot (air dry) (pounds).	Static bending. Fiber stress at elastic limit (pounds per square inch).	Static bending. Modulus of rupture (pounds per square inch.	Static bending. Modulus of elasticity (1,000 pounds per square inch).	Static bending. Work in bending—To elastic limit (inch-pounds per cubic inch.	Static bending. Work in bending—To maximum load (inch-pounds per cubic inch.	Impact bending. Fiber stress at elastic limit (pounds per square inch).	Impact bending. Work to elastic limit (inch-pounds per cubic inch).	Impact bending. Height of drop causing complete failure, 50-pound hammer (inches).	Compression parallel to grain. Fiber stress at elastic limit (pounds per square inch).	Compression parallel to grain. Maximum crushing strength (pounds per square inch).	Compression perpendicular to grain—fiber stress at elastic limit (pounds per square inch.	Shearing strength parallel to the grain (pounds per square inch).	Tension perpendicular to grain (pounds per square inch).	Hardness, load required to imbed a 0.444-inch ball to one-half its diameter. End (pounds).	Hardness, load required to imbed a 0.444-inch ball to one-half its diameter. Side (pounds).
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
CONIFERS—continued.																					
Pine, western white (Pinus monticola).	Montana	28	33	7.9	0.43	29	7,900	11,500	1,690	2.17	10.0	14,900	5.8	29	5,810	7,840	810	590	......	470	420
Pine, western yellow (Pinus ponderosa).	Colorado, Montana, Arizona, Washington, California.	20	22	10.8	.41	28	6,900	9,800	1,340	2.13	6.4	10,000	4.1	16	4,490	5,990	760	1,160	410	570	460
Pine, white (Pinus strobus).	Wisconsin	16	31	9.9	.39	27	7,000	9,600	1,420	2.04	6.4	9,300	3.3	18	5,070	6,360	760	1,070	340	610	470
Spruce, Engelmann (Picea engelmanni).	Colorado	14	14	14.8	.32	24	4,500	6,800	1,030	1.09	5.4	8,300	3.2	15	2,980	3,810	520	910	......	390	290
Spruce, red (Picea rubens).	New Hampshire, Tennessee.	17	32	10.8	.41	28	7,400	10,800	1,550	1.97	8.7	12,100	4.9	28	5,470	6,380	620	1,160	380	670	510
Spruce, Sitka (Picea sitchensis).	Washington	9	24	8.9	.38	26	7,200	11,200	1,610	1.78	10.4	13,900	5.2	25	......	5,770	1,010	1,210	......	780	530
Spruce, white (Picea canadensis).	New Hampshire, Wisconsin.	14	27	9.6	.40	28	5,900	9,200	1,390	1.40	8.2	9,700	3.5	20	4,620	6,020	590	970	350	760	560
Tamarack (Larix laricina).	Wisconsin	20	38	11.0	.53	37	8,400	12,000	1,680	2.35	7.1	13,000	5.7	23	5,150	7,590	1,080	1,370	410	720	640
Yew, western (Taxus brevifolia).	Washington	27	......	9.2	.63	43	10,100	16,800	1,460	3.94	18.4	11,900	5.3	30	4,720	9,220	2,680	2,480	410	2,330	1,800

TABLE 3.—*Approximate figures for change of properties with change of moisture content; variation of properties with specific gravity; reliability of averages, and probable deviations from averages of individual trees and specimens. For use with Tables 1 and 2.*

Property.	Average increase (or decrease) in value effected by raising (or lowering) the moisture content 1 per cent when at about 12 per cent. (See p. 18.)	Approximate power of specific gravity according to which property varies. (See p. 18.)	Probable variation of present average (when from 5 trees) from true species average. (See p. 19.)	Probable variation of random tree from average for species. (See p. 19.)
1	2	3	4	5
	Per cent.		*Per cent.*	*Per cent.*
Specific gravity based on volume when green			1.7	3.8
Weight per cubic foot [1]				
Shrinkage [2]		1		
Static bending:				
Fiber stress at elastic limit	6	1	5	12
Modulus of rupture	4	1	4	9
Modulus of elasticity	2	1	5	11
Work to elastic limit	8	2	7	16
Work to maximum load	[3] −1	2	6	14
Impact bending:				
Fiber stress at elastic limit	4	1	4	8
Work to elastic limit	5	2	5	12
Height of drop	−3	2	7	15
Compression parallel to grain:				
Fiber stress at elastic limit	5	1	5	12
Crushing strength	4	1	4	9
Compression perpendicular to grain—fiber stress at elastic limit	6	2	6	14
Hardness, end	3	2	4	9
Hardness, side	1	2	5	10
Shearing strength parallel to grain	4	1	3	7
Tension perpendicular to grain	1	2	5	12

[1] See explanation, p. 11. [2] See explanation, p. 12. [3] The minus sign indicates decrease.

LIST OF PUBLICATIONS AND PAPERS DEALING WITH THE MECHANICAL PROPERTIES OF TIMBER.

1. GOVERNMENT PUBLICATIONS.

	Date of issue.
Red Gum, with Discussion of Mechanical Properties of Red Gum Wood, Forest Service Bulletin 58. 15 cents	1905
Holding Force of Railroad Spikes in Wooden Ties, Forest Service Circular 46. 5 cents	1906
Effect of Moisture on Strength and Stiffness of Wood, Forest Service Bulletin 70. 15 cents	1906
*Tests of Vehicle and Implements Woods, Forest Service Circular 142. 5 cents.	1908
*Properties and Uses of Southern Pines, Forest Service Circular 164. 5 cents	1909
The Commercial Hickories, Forest Service Bulletin 80. 15 cents	1910
Properties and Uses of Douglas Fir, Forest Service Bulletin 88. 15 cents	1911
Uses of Commercial Woods of United States—Cedars, Cypresses, and Sequoias, Forest Service Bulletin 95. 10 cents	1911
Uses of Commercial Woods of United States—Pines, Forest Service Bulletin 99. 15 cents	1911
Manufacture and Utilization of Hickory, Forest Service Circular 187. 5 cents	1911
Tests of Structural Timbers, Forest Service Bulletin 108. 20 cents	1912
Fire-Killed Douglas Fir: A Study of Its Rate of Deterioration, Usability, and Strength, Forest Service Bulletin 112. 10 cents	1912
Strength Values for Structural Timbers, Forest Service Circular 189. 5 cents	1912
Mechanical Properties of Redwood, Forest Service Circular 193. 5 cents	1912
*Strength Tests of Cross-Arms, Forest Service Circular 204. 5 cents	1912
Mechanical Properties of Western Hemlock, Forest Service Bulletin 115. 15 cents	1913
Mechanical Properties of Western Larch, Forest Service Bulletin 122. 10 cents.	1913
Mechanical Properties of Woods Grown in United States, Forest Service Circular 213. 5 cents	1913
Tests of Packing Boxes, Forest Service Circular 214. 5 cents	1913
Uses of Commercial Woods of United States—Beech, Birches, and Maples, Department Bulletin 12. 10 cents	1913
Tests of Rocky Mountain Woods for Telephone Poles, Department Bulletin 67. 5 cents	1914
Rocky Mountain Mine Timbers, Department Bulletin 77. 5 cents	1914
Tests of Wooden Barrels, Department Bulletin 86. 5 cents	1914
Strength Tests of Structural Timber Treated by Commercial Wood Preserving Processes, Department Bulletin 286. 5 cents	1915

* Indicates supply is exhausted.

Department Bulletin 552.—"The Seasoning of Wood" is also of special interest to those handling timber. It can be obtained from the Superintendent of Documents, Government Printing Office, Washington, D. C.

NOTE.—Publications out of print can be consulted at many public libraries. In a number of cases they have been superseded by more recent publications. Others can be obtained from the Superintendent of Documents, Government Printing Office, Washington. D. C., at the price stated, until the supply is exhausted. Remittances should be made by money order, or in coin (at sender's risk); stamps can not be accepted.

2. PAPERS PREPARED BY FOREST PRODUCTS LABORATORY AND PUBLISHED IN PROCEEDINGS OF SOCIETIES AND TECHNICAL, TRADE, AND OTHER JOURNALS.

Title.	Author.	Where published.	Date.
A Few Deductions from Strength Tests of American Woods.	Newlin, J. A	American Lumberman	Jan. 16, 1915.
Factors Affecting Structural Timbers.	Betts, H. S	Engineering Record	Aug. 29, 1914.
Grading Rules of Yellow Pine Structural Timber Discussed.	do	American Lumberman	Apr. 24, 1915.
Applicability of Yellow Pine Grading Rules to Other Timbers.	Newlin, J. A	Engineering Record	Oct. 3, 1914.
Air Seasoning of Timber	Kempfer, W. H	American Railway Engineering Bulletin 161.	
Effect of Different Methods of Drying on Strength of Wood.	Tiemann, H. D	Lumber World Review	Apr. 10, 1915.
*Fourth Progress Report on Tests of Treated Ties.		American Railway Engineering and Maintenance of Way Association Bulletin 124.	
The Protection of Ties from Mechanical Destruction.	Weiss, H. F	Proceedings American Wood Preservers' Association.	1914.
Greenheart: a Timber with Exceptional Properties.	Armstrong, A. K	Engineering Record	Jan. 29 and Feb. 5, 1916.
Variation in the Weight and Strength of Timber.	Newlin, J. A	St. Louis Lumberman, American Lumberman, Southern Lumberman, Lumber World Review.	
Structural Timber in the United States.	Betts, H. S., and Greeley, W. B.	International Engineering Congress, San Francisco.	Sept. 20-25, 1915.

* Indicates supply is exhausted.

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