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STRENGTH AND RELATED PROPERTIES OF WOODS GROWN IN THE UNITED STATES
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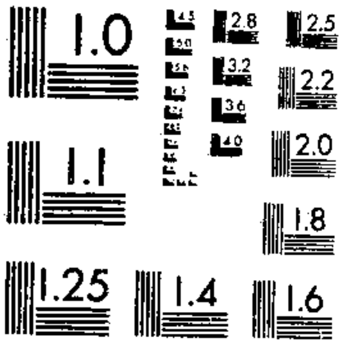


MICROCOPY RESOLUTION TEST CHART
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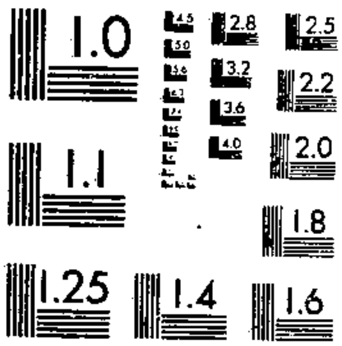


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NATIONAL BUREAU OF STANDARDS-1963-A

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# STRENGTH AND RELATED PROPERTIES OF WOODS GROWN IN THE UNITED STATES

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[1] Acknowledgment is made to J. A. Newlin of the Forest Products Laboratory, who was instrumental in conceiving the study and planning the tests on which this bulletin is based, and under whose supervision the work has been carried out.

[2] Maintained by the U. S. Department of Agriculture at Madison, Wis., in cooperation with the University of Wisconsin.

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## PURPOSE AND RELATION TO OTHER PUBLICATIONS

A knowledge of the properties of any material is essential to its proper use. In recognition of this fact the Forest Products Labora tory in 1910 began a comprehensive series of tests to determine the mechanical, and some of the related physical properties of native woods. Several hundred thousand tests have been made yielding data in varying quantity on 164 species. This bulletin presents data from this study, together with related information on factors that affect strength properties.

The tests reported here were made on clear wood, free from defects that affect the strength. Inasmuch as the strength of wooden members in structural and industrial use is affected by numerous variables, such as species of wood, variation in quality of the clear wood and in defects among pieces of the same species, character and distribution of load and duration of stress, temperature and moisture conditions, and size and shape of the piece, it may be asked, "why make tests on clear wood?"

Information for application to such uses may obviously be obtained by testing actual structural members or finished manufactured articles under such conditions as obtain in service and with defects as found in such pieces. Some earlier investigations by the Forest Service included tests of this character. However, the results of such tests accurately represent only the combination of variables existing in each instance, are difficult to interpret with respect to the separate effects of each variable, and cannot be applied to instances in which a different combination exists. Furthermore, the combinations are so numerous that it is impossible to evaluate them all by such tests, consequently, the limited usefulness of the data was soon evident. The plan that has been largely followed by the Forest Service has been to obtain data that are more generally applicable by testing small clear specimens taken from a specific part of the tree and of a standard size and form according to standardized methods and supplementing the resulting basic data on each species by investigations in which the effects of the more important variables are as far as possible separately studied and evaluated. The supplementary investigations have related to the effects on strength induced by such variables as locality of growth, position in tree, rate of growth, knots, cross grain, pitch pockets, moisture content, size and shape of piece, duration of stress, preservative treatment, and kiln drying. These and other supplementary investigations are the basis for the discussion of factors affecting the strength of wood as presented in pages 31 to 74.

Some of the results of the tests on small clear specimens were combined into simplified comparative figures and published in 1930 in United States Department of Agriculture Technical Bulletin 158 (*28*).[3] Because of their popularized form, data in Technical Bulletin 158 are not suitable for such engineering uses as calculating the strength or size of members, but are usable mainly for comparing species.

The information given here, on the other hand, is more technical, and may be used not only (1) for comparing species but also (2) for calculating the strength of wood members, (3) for establishing safe working stresses when used in conjunction with other information including results of tests of structural timbers, and (4) for grouping

[3] Italic numbers in parentheses refer to Literature Cited, p. 74.

species into classes of approximately like properties for various purposes. The present bulletin is based on the same series of tests, but supersedes United States Department of Agriculture Bulletin 556 (37), because it covers additional species and additional tests on species previously reported. Another important difference is that the values for air-dry wood as given herein have been adjusted uniformly to a 12-percent moisture content, thus making them directly comparable as presented. In addition to the data from the standard series of tests begun in 1910 there is included herein results of all earlier tests by the Forest Service that were made in such a manner as to afford data of comparable character to that resulting from the standard series.

## MEANING AND IMPORTANCE OF STRENGTH

In a broad sense "strength" implies all those properties that fit a material to resist forces. In a more restricted sense, strength is resistance to stress of a single kind, or to the stresses developed in a particular member. Definiteness requires that the name of the specific property be stated; as for instance, strength in shear, strength in compression parallel to grain, or strength as a short column. If the several strength properties had the same relation to each other in all species, a wood that excels in one property would, of course, be higher in all, and misinterpretation of "strength" would be less likely. Actually, however, a species may rank higher in one strength property than in another. Longleaf pine averages higher than white oak in maximum crushing strength parallel to the grain, but lower in hardness. Hence, it cannot be said that longleaf pine is "stronger" or "weaker" than white oak without specifiying the kind of strength. In comparing species for a particular use the kind of strength properties or combination of properties essential to that use must be considered. Thus, from the comparisons just cited, longleaf pine is superior to oak for use as short posts carrying heavy endwise loads, whereas oak excels in resistance to wear and marring.

In most uses the serviceability of wood depends on one or more strength properties. Airplane-wing beams, floor joists, and wheel spokes typify uses in which strength is a major consideration. Other uses often require strength in combination with other characteristics. Telephone poles, railroad ties, and bridge stringers must not only carry loads, but must also resist decay. In addition, many uses not ordinarily associated with strength depend to some degree on strength properties. For example, finish and trim for buildings should be sufficiently hard to avoid marring; window sash must have screw-holding ability to permit secure attachment of hardware, and adequate stiffness to prevent springing when the window is opened and closed. Even matches must have strength to avoid breaking. Information on strength properties is therefore important not only in the design of airplanes, buildings, and bridges, but also as a guide to the selection of wood for a great variety of uses.

The data reported here refer to some of the properties that are important in many uses. Obviously, any such series of mechanical tests does not answer all questions concerning suitability for a given use because the use may involve strength properties that have not been evaluated and because characteristics other than strength (p. 26) are usually also important.

## TESTING PROCEDURE

The material for test was identified botanically in the woods and was brought to the Forest Products Laboratory at Madison, Wis., in the green condition in log form. The procedure for selection and care of material, method of preparing test specimens, and method of testing are the result of many years of development in studying wood properties in the United States and embody some features of European practice. Methods of Testing Small Clear Specimens of Timber adopted as standard by the American Society for Testing Materials (*4*), and the American Standards Association is essentially the same as the procedure used. A generally similar procedure is also being followed in a number of other countries. Detailed description of the procedure used, and of the methods of computing the results are presented in the appendix, p. 78.

## SCOPE OF TESTS

Many individual pieces of each species were tested in determining the average values of strength properties as presented in table 1. In all over 250,000 tests have been made. Only the average results for each species are, however, presented here. It is difficult to determine how many tests should be made on each species. The larger the number, the nearer may the average values be expected to approach the true average of the species, but also the greater is the cost. A balance must be reached between these desiderata, so that a species usually has been represented by only five trees from any one site or locality. Two or more five-tree units, however, from different localities have been tested for the more important species. The individual tests on a species vary in number from about a hundred to several thousand.

## CONSIDERATIONS CONCERNING USE OF TABLE 1

The values given in table 1 are the best available valuations of the true averages. Those for the less important species, being based on fewer tests, are less reliable than those for the common species. In applying the data, too great emphasis should not be placed on small differences in averages. The importance of such differences depends largely on the use to which the wood is put. A discussion of variability and the significance of differences between averages is presented on page 17.

The results obtained in tests of clear wood depend not only on the inherent characteristics of the wood but also on such extrinsic factors as the size and form of specimens, the rate of loading, and other features of testing procedure, and in seasoned material on the moisture content. Care should accordingly be used in comparing the data with that from tests in which a different procedure may have been used and the moisture content of test material should be taken into consideration.

The values in table 1 are primarily for the comparison of species in the form of clear lumber. For comparing structural timbers in which the defects are limited with reference to their effect on strength, allowable working stresses are preferable (*29*, *61*).

TABLE 1.—*Strength and related properties of woods grown in the United States*

| Species (common and botanical names) | Place of growth of material tested | Moisture condition | Trees tested | Rings per inch | Summer wood | Moisture content | Specific gravity, oven dry, based on volume— At test | Specific gravity, oven dry, based on volume— When oven dry | Weight per cubic foot | Shrinkage from green to oven-dry condition based on dimensions when green: Volumetric | Shrinkage: Radial | Shrinkage: Tangential | Static bending: Stress at proportional limit | Static bending: Modulus of rupture | Static bending: Modulus of elasticity | Static bending: Work: Proportional limit | Static bending: Work: Maximum load | Static bending: Work: Total | Impact bending: Stress at proportional limit | Impact bending: Work to proportional limit | Impact bending: Height of drop causing complete failure (50-pound hammer) | Compression parallel to grain: Stress at proportional limit | Compression parallel to grain: Maximum crushing strength | Compression perpendicular to grain; stress at proportional limit | Hardness; load required to embed a 0.444-inch ball to ½ its diameter: End | Hardness: Side | Shear parallel to grain; maximum shearing strength | Cleavage; load to cause splitting | Tension perpendicular to grain; maximum tensile strength |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 | 28 | 29 | 30 |
| HARDWOODS | | | Number | Number | Percent | Percent | | | Pounds | Percent | Percent | Percent | Lb. per sq. in. | Lb. per sq. in. | 1,000 lb. per sq. in. | In.-lb. per cu. in. | In.-lb. per cu. in. | In.-lb. per cu. in. | Lb. per sq. in. | In.-lb. per cu. in. | Inches | Lb. per sq. in. | Lb. per sq. in. | Lb. per sq. in. | Pounds | Pounds | Lb. per sq. in. | Lb. per in. of width | Lb. per sq. in. |
| Alder, red (*Alnus rubra*) | Washington | Green | 6 | 11 | | 98 | 0.37 | 0.43 | 46 | 12.6 | 4.4 | 7.3 | 3,800 | 6,500 | 1,170 | 0.70 | 8.0 | 15.3 | 8,000 | 2.6 | 22 | 2,620 | 2,960 | 310 | 550 | 440 | 770 | 220 | 390 |
| | | Dry | | | | 12 | .41 | | 28 | | | | 6,900 | 9,800 | 1,380 | 1.85 | 8.4 | 10.7 | 11,600 | 4.8 | 20 | 4,530 | 5,820 | 540 | 650 | 590 | 1,080 | 270 | 420 |
| Apple (*Malus pumila* var.) | Virginia | Green | 10 | 9 | | 46 | .61 | .74 | 55 | 17.0 | 5.6 | 10.1 | 3,000 | 7,400 | 1,050 | .75 | 15.7 | 36.4 | 7,600 | 3.0 | 33 | 1,990 | 3,000 | 850 | 1,040 | 1,000 | 1,040 | 480 | 900 |
| | | Dry | | | | 12 | .67 | | 47 | | | | 6,600 | 12,800 | 1,270 | 2.31 | 23.0 | 43.7 | 15,700 | 7.8 | 43 | 8,120 | 9,080 | 1,300 | 2,150 | 1,730 | 1,740 | | |
| Ash, Biltmore white (*Fraxinus biltmoreana*) | Tennessee | Green | 5 | 17 | 49 | 42 | .51 | .58 | 45 | 12.6 | 4.2 | 6.9 | 5,500 | 9,300 | 1,340 | 1.31 | 11.0 | 27.4 | 11,900 | 4.0 | 30 | 3,530 | 3,980 | 880 | 950 | 850 | 1,230 | 340 | 540 |
| | | Dry | | | | 12 | .55 | | 38 | | | | 9,200 | 13,000 | 1,600 | 2.97 | 11.7 | 20.1 | 16,500 | 7.9 | 40 | 5,670 | 7,280 | 1,510 | 1,590 | 1,140 | 1,680 | 410 | 710 |
| Ash, black (*Fraxinus nigra*) | Michigan, Wisconsin | Green | [1] 6 | 24 | | 65 | .45 | .53 | 52 | 15.2 | 5.0 | 7.8 | 2,600 | 6,000 | 1,040 | .41 | 12.1 | 31.7 | | | 33 | 1,600 | 2,300 | 430 | 590 | 520 | 800 | 280 | 490 |
| | | Dry | | | | 12 | .49 | | 34 | | | | 7,200 | 12,600 | 1,600 | 1.57 | 14.9 | 34.4 | | | 35 | 4,520 | 5,970 | 840 | 1,150 | 850 | 1,570 | 350 | 700 |
| Ash, blue (*Fraxinus quadrangulata*) | Kentucky | Green | 5 | 12 | 49 | 39 | .53 | .60 | 46 | 11.7 | 3.9 | 6.5 | 5,700 | 9,600 | 1,240 | 1.47 | 14.7 | 38.2 | 11,100 | 5.0 | 43 | 3,580 | 4,180 | 990 | 1,140 | 1,030 | 1,540 | 350 | 580 |
| | | Dry | | | | 12 | .57 | | 40 | | | | 8,100 | 13,800 | 1,400 | 2.08 | 14.4 | 31.3 | 18,400 | 9.2 | 42 | 5,450 | 6,980 | 1,700 | 1,720 | 1,290 | 2,030 | 440 | |
| Ash, green (*Fraxinus pennsylvanica lanceolata*) | Louisiana, Missouri | Green | 10 | 17 | 58 | 48 | .53 | .61 | 49 | 12.5 | 4.6 | 7.1 | 5,300 | 9,500 | 1,400 | 1.14 | 11.8 | 27.6 | 11,400 | 5.0 | 35 | 3,600 | 4,200 | 910 | 900 | 870 | 1,200 | 350 | 590 |
| | | Dry | | | | 12 | .56 | | 40 | | | | 8,900 | 14,100 | 1,660 | 2.72 | 13.4 | 23.4 | 16,400 | 7.6 | 32 | 5,120 | 7,050 | 1,620 | 1,630 | 1,290 | 1,910 | 440 | 700 |
| Ash, Oregon (*Fraxinus oregona*) | Oregon | Green | 3 | 12 | 63 | 48 | .50 | .58 | 46 | 13.2 | 4.1 | 8.1 | 4,200 | 7,600 | 1,130 | .92 | 12.2 | 33.3 | 8,900 | 3.0 | 39 | 2,700 | 3,510 | 650 | 850 | 790 | 1,190 | 310 | 590 |
| | | Dry | | | | 12 | .55 | | 38 | | | | 7,000 | 12,700 | 1,360 | 2.08 | 14.4 | 22.3 | 13,300 | 5.2 | 33 | 4,100 | 6,040 | 1,540 | 1,430 | 1,160 | 1,700 | 410 | 720 |
| Ash, pumpkin (*Fraxinus profunda*) | Missouri | Green | 3 | 21 | 46 | 51 | .48 | .55 | 46 | 12.0 | 3.7 | 6.3 | 4,600 | 7,600 | 1,040 | 1.08 | 9.4 | 18.4 | 8,800 | 3.7 | 31 | 2,850 | 3,300 | 900 | 880 | 750 | 1,210 | 380 | 570 |
| | | Dry | | | | 12 | .52 | | 36 | | | | 6,500 | 11,100 | 1,270 | 1.91 | 8.0 | 15.2 | 13,600 | 6.8 | 24 | 3,950 | 5,690 | 1,600 | 1,430 | 990 | 1,720 | 430 | 770 |
| Ash, white (*Fraxinus americana*) | Arkansas, New York, West Virginia, Vermont, Massachusetts. | Green | 23 | 12 | 54 | 42 | .55 | .64 | 48 | 13.3 | 4.9 | 7.9 | 5,100 | 9,600 | 1,460 | 1.04 | 10.6 | 41.6 | 13,900 | 5.9 | 38 | 3,190 | 3,990 | 810 | 1,010 | 960 | 1,380 | 530 | 590 |
| | | Dry | | | | 12 | .60 | | 42 | | | | 8,900 | 15,400 | 1,770 | 2.60 | 17.6 | 34.8 | 17,000 | 8.2 | 43 | 5,790 | 7,410 | 1,410 | 1,720 | 1,320 | 1,950 | 480 | 940 |
| Aspen (*Populus tremuloides*) | Wisconsin, New Mexico | Green | 11 | 8 | | 94 | .35 | .40 | 43 | 11.5 | 3.5 | 6.7 | 3,200 | 5,100 | 860 | .69 | 6.4 | 13.4 | 7,000 | 2.7 | 22 | 1,670 | 2,140 | 220 | 280 | 300 | 660 | 140 | 230 |
| | | Dry | | | | 12 | .38 | | 26 | | | | 5,600 | 8,400 | 1,180 | 1.53 | 7.6 | 15.4 | 9,000 | 3.4 | 21 | 3,040 | 4,250 | 460 | 510 | 350 | 850 | 210 | 260 |
| Aspen, largetooth (*Populus grandidentata*) | Wisconsin, Vermont | Green | 10 | 8 | | 90 | .35 | .41 | 43 | 11.8 | 3.3 | 7.9 | 2,900 | 5,400 | 1,120 | .44 | 5.6 | 12.0 | 7,400 | 2.5 | 13 | 2,020 | 2,500 | 250 | 400 | 370 | 730 | 190 | 310 |
| | | Dry | | | | 12 | .39 | | 27 | | | | 5,600 | 9,100 | 1,430 | 1.25 | 7.7 | 13.9 | 11,400 | 4.7 | 22 | 4,000 | 5,300 | 560 | 620 | 420 | 1,080 | 220 | 390 |
| Basswood (*Tilia glabra*) | Wisconsin, Pennsylvania | Green | 8 | 10 | | 105 | .32 | .40 | 42 | 15.8 | 6.6 | 9.3 | 2,700 | 5,000 | 1,040 | .40 | 5.3 | 10.3 | 6,300 | 2.1 | 16 | 1,690 | 2,220 | 210 | 290 | 250 | 600 | 150 | 280 |
| | | Dry | | | | 12 | .37 | | 26 | | | | 5,900 | 8,700 | 1,460 | 1.37 | 7.2 | 10.1 | 9,600 | 3.8 | 16 | 3,600 | 4,730 | 450 | 520 | 410 | 990 | 230 | 350 |
| Beech (*Fagus grandifolia*) | Indiana, Pennsylvania, Vermont | Green | 17 | 15 | | 54 | .56 | .67 | 54 | 16.3 | 5.1 | 11.0 | 4,300 | 8,600 | 1,380 | .85 | 11.9 | 30.8 | 11,600 | 4.4 | 43 | 2,550 | 3,550 | 670 | 970 | 850 | 1,290 | 410 | 720 |
| | | Dry | | | | 12 | .64 | | 45 | | | | 8,700 | 14,900 | 1,720 | 2.63 | 15.1 | 30.9 | 16,000 | 7.0 | 41 | 4,880 | 7,300 | 1,250 | 1,590 | 1,300 | 2,010 | 490 | 1,010 |
| Beech, blue (*Carpinus caroliniana*) | Massachusetts | Green | 12 | 15 | | 48 | .58 | .72 | 53 | 19.1 | 6.7 | 11.4 | 3,200 | 6,800 | 990 | .61 | 19.1 | 60.0 | 10,100 | 4.0 | 106 | 1,420 | 2,670 | 730 | 900 | 940 | 1,100 | 260 | 350 |
| | | Dry | | | | 12 | .70 | | 49 | | | | 3,900 | 12,200 | 1,080 | .77 | 37.1 | 76.7 | 10,300 | 4.3 | | 3,330 | 5,680 | 2,000 | 1,620 | 1,780 | 2,410 | 680 | |
| Birch, Alaska white (*Betula neoalaskana*) | Alaska | Green | 10 | 20 | | 58 | .49 | .59 | 48 | 16.7 | 6.5 | 9.9 | 3,600 | 7,100 | 1,350 | .60 | 11.6 | 32.5 | 9,800 | 3.7 | 37 | 2,050 | 3,030 | 430 | 550 | 560 | 920 | 180 | 200 |
| | | Dry | | | | 12 | .55 | | 38 | | | | 7,700 | 13,600 | 1,900 | 1.65 | 13.9 | 28.6 | 13,700 | 4.8 | 40 | 5,290 | 7,450 | 820 | 860 | 830 | 1,400 | 370 | 660 |
| Birch, gray (*Betula populifolia*) | New Hampshire | Green | 5 | | | 63 | .45 | .55 | 46 | 14.7 | 5.2 | | 1,800 | 4,900 | 400 | .47 | 13.0 | 37.8 | 7,400 | 2.6 | 59 | 1,080 | 1,880 | 250 | 430 | 480 | | | |
| | | Dry | | | | 12 | .51 | | 35 | | | | 5,500 | 9,800 | 1,150 | 1.40 | 10.8 | 35.3 | 10,400 | 3.5 | 35 | 2,670 | 4,870 | 520 | 690 | 760 | 1,340 | | |
| Birch, paper (*Betula papyrifera*) | Wisconsin, New Hampshire | Green | 10 | 6 | | 65 | .48 | .60 | 50 | 16.2 | 6.3 | 8.6 | 3,000 | 6,400 | 1,170 | .45 | 16.2 | 42.8 | 8,000 | 2.7 | 49 | 1,040 | 2,360 | 340 | 470 | 560 | 840 | 210 | 380 |
| | | Dry | | | | 12 | .55 | | 38 | | | | 6,900 | 12,300 | 1,590 | 1.60 | 16.0 | 35.9 | 12,400 | 4.8 | 34 | 3,610 | 5,690 | 740 | 850 | 910 | 1,210 | 540 | |
| Birch, sweet (*Betula lenta*) | Pennsylvania, New Hampshire | Green | 10 | 27 | | 53 | .60 | .71 | 57 | 15.6 | 6.5 | 8.5 | 4,800 | 9,400 | 1,650 | .94 | 15.7 | 41.4 | 10,500 | 3.2 | 48 | 2,680 | 3,740 | 580 | 1,070 | 970 | 1,240 | 300 | 430 |
| | | Dry | | | | 12 | .65 | | 46 | | | | 10,100 | 16,900 | 2,170 | 2.72 | 18.0 | 22.4 | 24,600 | 10.6 | 47 | 6,330 | 8,540 | 1,340 | 1,960 | 1,470 | 2,240 | 640 | 950 |
| Birch, yellow (*Betula lutea*) | Pennsylvania, Vermont, Wisconsin | Green | 17 | 16 | | 67 | .55 | .66 | 57 | 16.7 | 7.2 | 9.2 | 4,200 | 8,300 | 1,500 | .70 | 16.1 | 43.5 | 11,500 | 4.4 | 48 | 2,620 | 3,380 | 530 | 810 | 780 | 1,110 | 270 | 430 |
| | | Dry | | | | 12 | .62 | | 43 | | | | 10,100 | 16,600 | 2,010 | 2.89 | 20.8 | 38.0 | 17,200 | 7.3 | 55 | 6,130 | 8,170 | 1,190 | 1,480 | 1,260 | 1,880 | 520 | 770 |
| Blackwood (*Avicennia nitida*) | Florida | Green | 6 | 16 | | 42 | .83 | .96 | 74 | 15.6 | 6.2 | 9.7 | 5,600 | 11,100 | 1,550 | 1.16 | 12.3 | 39.0 | 15,900 | 6.8 | 42 | 3,760 | 4,940 | 1,870 | 1,570 | 1,700 | 1,370 | 280 | 660 |
| | | Dry | | | | 12 | .83 | | 58 | | | | 8,700 | 16,400 | 2,090 | 2.03 | 17.9 | 75.3 | | | | | 8,340 | 2,360 | | | | | |
| Buckeye, yellow (*Aesculus octandra*) | Tennessee | Green | 5 | 15 | | 141 | .33 | .38 | 49 | 12.0 | 3.5 | 7.8 | 2,600 | 4,800 | 980 | .41 | 5.4 | 10.5 | 6,500 | 2.1 | 18 | 1,680 | 2,050 | 210 | 360 | 290 | 660 | 180 | 320 |
| | | Dry | | | | 12 | .36 | | 25 | | | | 5,100 | 7,500 | 1,170 | 1.26 | 5.9 | 7.7 | 10,000 | 4.3 | 16 | 3,010 | 4,170 | 440 | 470 | 350 | 960 | 240 | 520 |
| Bustic (*Dipholis salicifolia*) | Florida | Green | 1 | | | 44 | .80 | | 77 | | | | 5,800 | 12,400 | 1,860 | 1.00 | 17.1 | | | | | 3,750 | 5,330 | 1,700 | | | | | |
| | | Dry | | | | 12 | .88 | | 62 | | | | | | | | | | 18,400 | 6.6 | 26 | 4,950 | 9,540 | | | | | | |
| Butternut (*Juglans cinerea*) | Tennessee, Wisconsin | Green | 10 | 9 | | 104 | .36 | .40 | 46 | 10.2 | 3.3 | 6.1 | 2,900 | 5,400 | 970 | .52 | 8.2 | 21.2 | 7,300 | 2.6 | 24 | 2,020 | 2,420 | 270 | 410 | 300 | 760 | 220 | 430 |
| | | Dry | | | | 12 | .38 | | 27 | | | | 5,700 | 8,150 | 1,180 | 1.39 | 8.2 | 15.8 | 11,200 | 4.6 | 24 | 4,200 | 5,110 | 570 | 570 | 490 | 1,170 | 220 | 440 |
| Buttonwood (*Conocarpus erecta*) | Florida | Green | 7 | | | 47 | .69 | .85 | 64 | 14.6 | 5.4 | 8.5 | 4,000 | 7,400 | 1,190 | 1.00 | 6.2 | 15.0 | 14,100 | 6.8 | 40 | 3,050 | 4,110 | 1,140 | 1,080 | 1,110 | 1,220 | 370 | 470 |
| | | Dry | | | | 12 | .71 | | 50 | | | | 6,800 | 10,200 | 1,580 | 1.70 | 5.9 | | | | | | 7,850 | 1,630 | | | | | |
| Cascara (*Rhamnus purshiana*) | Oregon | Green | 5 | 17 | | 61 | .50 | .55 | 50 | 7.6 | 3.2 | 4.6 | 3,400 | 6,300 | 630 | 1.04 | 13.4 | 49.7 | 8,700 | 3.0 | 58 | 1,890 | 3,270 | 670 | 680 | 730 | 1,150 | 200 | 510 |
| | | Dry | | | | 12 | .52 | | 36 | | | | 6,000 | 8,700 | 980 | 2.14 | 7.8 | | 10,200 | 4.6 | 28 | 3,460 | 6,090 | 1,310 | 1,240 | 1,040 | 1,010 | | |
| Catalpa, hardy (*Catalpa speciosa*) | Indiana | Green | 15 | 8 | 58 | 72 | .38 | .42 | 41 | 7.3 | 2.5 | 4.9 | 2,700 | 5,200 | 840 | .51 | 7.9 | 25.1 | 7,500 | 3.1 | 35 | 1,450 | 2,300 | 320 | 420 | 410 | 680 | 220 | 430 |
| | | Dry | | | | 12 | .41 | | 29 | | | | 4,700 | 9,400 | 1,210 | 1.08 | 8.6 | 20.2 | 11,000 | 4.3 | 27 | 2,740 | 4,970 | 570 | 650 | 550 | 1,130 | 300 | 570 |
| Cherry, black (*Prunus serotina*) | Pennsylvania | Green | 5 | 11 | | 55 | .47 | .53 | 45 | 11.5 | 3.7 | 7.1 | 4,200 | 8,000 | 1,310 | .80 | 12.8 | 31.8 | 10,200 | 4.1 | 33 | 2,940 | 3,540 | 440 | 750 | 660 | 1,130 | 330 | 570 |
| | | Dry | | | | 12 | .50 | | 35 | | | | 9,000 | 12,300 | 1,490 | 3.11 | 11.4 | 14.2 | 13,600 | 5.4 | 23 | 5,960 | 7,110 | 850 | 1,470 | 950 | 1,700 | 250 | 560 |
| Cherry, pin (*Prunus pennsylvanica*) | Tennessee | Green | 5 | 6 | | 46 | .36 | .42 | 33 | 12.8 | 2.8 | 10.3 | 2,900 | 5,000 | 1,040 | .47 | 6.2 | 18.3 | 6,600 | 2.1 | 22 | 1,810 | 2,170 | 200 | 440 | 390 | 680 | 170 | 300 |
| | | Dry | | | | 12 | .39 | | 27 | | | | 5,700 | 8,500 | 1,270 | 1.51 | 8.2 | 25.1 | 10,100 | 4.0 | 21 | 3,900 | 4,620 | 520 | 740 | 510 | 1,030 | 230 | 320 |
| Chestnut (*Castanea dentata*) | Maryland, Tennessee | Green | 10 | 11 | 48 | 122 | .40 | .46 | 55 | 11.6 | 3.4 | 6.7 | 3,100 | 5,000 | 930 | .59 | 7.0 | 17.0 | 7,900 | 2.8 | 24 | 2,080 | 2,470 | 380 | 530 | 420 | 800 | 240 | 440 |
| | | Dry | | | | 12 | .43 | | 30 | | | | 6,100 | 8,600 | 1,230 | 1.78 | 6.5 | 12.5 | 10,700 | 4.0 | 19 | 3,780 | 5,320 | 760 | 720 | 540 | 1,080 | 250 | 400 |
| Chinquapin, golden (*Castanopsis chrysophylla*) | Oregon | Green | 5 | 15 | | 134 | .42 | .48 | 61 | 13.2 | 4.6 | 7.4 | 4,200 | 7,000 | 1,020 | 1.09 | 9.6 | 20.4 | 8,800 | 3.4 | 31 | 2,030 | 3,020 | 490 | 730 | 600 | 1,010 | 230 | 480 |
| | | Dry | | | | 12 | .46 | | 32 | | | | 7,900 | 10,700 | 1,240 | 3.11 | 9.5 | 19.1 | 10,900 | 4.8 | 30 | 4,150 | 5,640 | 680 | 640 | 730 | 1,260 | | |
| Cottonwood, eastern (*Populus deltoides*) | Missouri | Green | 5 | 6 | | 111 | .37 | .43 | 49 | 14.1 | 3.9 | 9.2 | 2,900 | 5,300 | 1,010 | .49 | 7.3 | 16.9 | 7,200 | 2.3 | 21 | 1,740 | 2,280 | 240 | 380 | 340 | 680 | 220 | 410 |
| | | Dry | | | | 12 | .40 | | 28 | | | | 5,700 | 8,500 | 1,370 | 1.39 | 7.4 | 10.4 | 7,300 | 2.4 | 20 | 3,490 | 4,910 | 470 | 580 | 430 | 930 | 270 | 590 |
| Cottonwood, northern black (*Populus trichocarpa hastata*) | Washington | Green | 5 | 6 | | 132 | .32 | .37 | 46 | 12.4 | 3.6 | 8.0 | 2,900 | 4,800 | 1,070 | .44 | 5.0 | 12.7 | 6,800 | 2.2 | 20 | 1,700 | 2,160 | 200 | 280 | 250 | 600 | 170 | 270 |
| | | Dry | | | | 12 | .35 | | 24 | | | | 5,300 | 8,200 | 1,260 | 1.25 | 6.7 | 13.8 | 9,800 | 3.8 | 22 | 3,270 | 4,420 | 370 | 540 | 350 | 1,020 | 220 | 330 |
| Dogwood (*Cornus florida*) | Tennessee | Green | 5 | 24 | | 62 | .64 | .80 | 64 | 19.9 | 7.1 | 11.3 | 4,800 | 8,800 | 1,180 | 1.11 | 21.0 | 49.1 | 7,100 | 3.5 | 58 | | 3,640 | 1,030 | 1,410 | 1,410 | 1,620 | | |
| | | Dry | | | | 12 | .73 | | 51 | | | | 9,200 | 14,900 | 1,530 | 3.10 | 19.5 | 38.9 | 14,600 | 7.5 | 44 | | 7,700 | 1,970 | 2,430 | 2,150 | 2,260 | | |
| Dogwood, Pacific (*Cornus nuttallii*) | Oregon | Green | 5 | 21 | | 52 | .58 | .70 | 55 | 17.2 | 6.4 | 9.6 | 4,200 | 8,200 | 1,090 | .92 | 17.0 | 38.7 | 9,800 | 3.6 | 56 | 2,410 | 3,640 | 870 | 1,140 | 980 | 1,300 | 340 | 740 |
| | | Dry | | | | 12 | .64 | | 45 | | | | 7,200 | 10,500 | 1,470 | 2.02 | 11.0 | 46.8 | 10,500 | 3.7 | 34 | 4,300 | 7,540 | 1,650 | 1,870 | 1,350 | 1,720 | 410 | 1,040 |
| Elder, blueberry (*Sambucus coerulea*) | do | Green | 5 | 6 | | 124 | .46 | .57 | 65 | 15.6 | 4.4 | 9.0 | 3,400 | 6,600 | 900 | .72 | 8.8 | 30.7 | 8,000 | 2.9 | 38 | 2,380 | 3,040 | 520 | 760 | 720 | 1,090 | 320 | 560 |
| | | Dry | | | | 12 | .52 | | 36 | | | | 5,600 | 9,200 | 1,030 | 1.56 | 9.9 | | 10,500 | 5.1 | 33 | 3,800 | 5,090 | 700 | 840 | 840 | | | |

[1] The averages for this species include data from tests representing an unknown number of trees in addition to the number indicated.

TABLE 1.—*Strength and related properties of woods grown in the United States*—Continued

| Species (common and botanical names) | Place of growth of material tested | Moisture condition | Trees tested | Rings per inch | Summer wood | Moisture content | Specific gravity, oven dry, based on volume— At test | Specific gravity, oven dry, based on volume— When oven-dry | Weight per cubic foot | Shrinkage from green to oven-dry condition based on dimensions when green: Volumetric | Shrinkage: Radial | Shrinkage: Tangential | Static bending: Stress at proportional limit | Static bending: Modulus of rupture | Static bending: Modulus of elasticity | Static bending, Work: Proportional limit | Static bending, Work: Maximum load | Static bending, Work: Total | Impact bending: Stress at proportional limit | Impact bending: Work to proportional limit | Impact bending: Height of drop causing complete failure (50-pound hammer) | Compression parallel to grain: Stress at proportional limit | Compression parallel to grain: Maximum crushing strength | Compression perpendicular to grain; stress at proportional limit | Hardness; load required to embed a 0.444-inch ball to ½ its diameter: End | Hardness: Side | Shear parallel to grain; maximum shearing strength | Cleavage; load to cause splitting | Tension perpendicular to grain; maximum tensile strength |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 | 28 | 29 | 30 |
| | | | *Number* | *Number* | *Percent* | *Percent* | | | *Pounds* | *Percent* | *Percent* | *Percent* | *Lb. per sq. in.* | *Lb. per sq. in.* | *1,000 lb. per sq. in.* | *In.-lb. per cu. in.* | *In.-lb. per cu. in.* | *In.-lb. per cu. in.* | *Lb. per sq. in.* | *In.-lb. per cu. in.* | *Inches* | *Lb. per sq. in.* | *Lb. per sq. in.* | *Lb. per sq. in.* | *Pounds* | *Pounds* | *Lb. per sq. in.* | *Lb. per in. of width* | *Lb. per sq. in.* |
| HARDWOODS—continued | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Elm, American (*Ulmus americana*) | New Hampshire, Pennsylvania, Wisconsin. | Green | 12 | 13 | 54 | 89 | 0.46 | 0.55 | 54 | 14.6 | 4.2 | 9.5 | 3,900 | 7,200 | 1,110 | 0.81 | 11.8 | 29.7 | | | 38 | 1,920 | 2,910 | 440 | 680 | 620 | 1,000 | | 590 |
| | | Dry | | | | 12 | .50 | | 35 | | | | 7,600 | 11,800 | 1,340 | 2.53 | 13.0 | 33.9 | | | 39 | 4,030 | 5,520 | 850 | 1,110 | 830 | 1,510 | | 660 |
| Elm, rock (*Ulmus racemosa*) | Wisconsin | Green | ¹5 | 29 | 50 | 48 | .57 | .66 | 53 | 14.1 | 4.8 | 8.1 | 4,600 | 9,500 | 1,190 | 1.05 | 19.8 | 40.9 | | 4.6 | 54 | 2,970 | 3,780 | 750 | 980 | 940 | 1,270 | | |
| | | Dry | | | | 12 | .63 | | 44 | | | | 8,000 | 14,800 | 1,540 | 2.45 | 19.2 | 43.1 | | 7.9 | 56 | 4,700 | 7,050 | 1,520 | 1,310 | 1,320 | 1,920 | | |
| Elm, slippery (*Ulmus fulva*) | Indiana, Wisconsin | Green | 6 | 16 | 51 | 85 | .48 | .57 | 55 | 13.8 | 4.9 | 8.9 | 4,000 | 8,000 | 1,230 | .82 | 15.4 | 38.2 | 9,200 | 3.4 | 47 | 2,790 | 3,320 | 510 | 750 | 660 | 1,110 | 380 | 640 |
| | | Dry | | | | 12 | .53 | | 37 | | | | 7,700 | 13,000 | 1,490 | 2.35 | 16.9 | 40.2 | 15,300 | 7.5 | 45 | 6,760 | 6,360 | 1,010 | 1,120 | 860 | 1,630 | 340 | 530 |
| Fig, golden (*Ficus aurea*) | Florida | Green | 1 | | | 88 | .44 | | 51 | | | | 3,200 | 5,800 | 600 | .92 | 6.0 | 15.2 | | | | | 2,630 | 650 | 620 | 580 | | | |
| | | Dry | | | | 12 | .44 | | 31 | | | | 3,900 | 7,200 | 800 | 1.03 | 6.8 | 11.1 | | | | | 4,410 | | | | | | |
| Gum, black (*Nyssa sylvatica*) | Tennessee | Green | 5 | 27 | | 55 | .46 | .55 | 45 | 13.9 | 4.4 | 7.7 | 4,000 | 7,000 | 1,030 | .91 | 8.0 | 15.3 | 9,800 | 4.0 | 30 | 2,400 | 3,040 | 600 | 790 | 640 | 1,100 | 330 | 570 |
| | | Dry | | | | 12 | .50 | | 35 | | | | 7,300 | 9,600 | 1,200 | 2.54 | 6.2 | 10.0 | 14,500 | 7.1 | 22 | 3,470 | 5,520 | 1,150 | 1,240 | 810 | 1,340 | 340 | 500 |
| Gum, blue (*Eucalyptus globulus*) | California | Green | 5 | | | 79 | .62 | .80 | 70 | 22.5 | 7.6 | 15.3 | 7,600 | 11,200 | 2,010 | 1.65 | 13.0 | 38.5 | 14,200 | 4.7 | 40 | 4,840 | 5,250 | 1,020 | 1,310 | 1,340 | 1,550 | 360 | 640 |
| | | Dry | | | | 12 | .74 | | 52 | | | | 11,400 | 16,600 | 2,370 | 3.28 | 12.4 | 28.1 | 26,500 | 8.8 | 41 | 8,190 | 9,840 | 1,720 | 1,640 | 1,540 | 1,840 | | |
| Gum, red (*Liquidambar styraciflua*) | Missouri | Green | ¹5 | 16 | | 81 | .44 | .53 | 50 | 15.0 | 5.2 | 9.9 | 3,700 | 6,800 | 1,150 | .81 | 9.4 | 21.7 | 10,000 | 3.9 | 33 | 2,230 | 2,840 | 460 | 630 | 620 | 1,070 | 330 | 510 |
| | | Dry | | | | 12 | .49 | | 34 | | | | 8,100 | 11,900 | 1,490 | 2.57 | 11.8 | 15.7 | 16,800 | 8.5 | 32 | 4,700 | 5,800 | 860 | 950 | 690 | 1,610 | 380 | 890 |
| Gum, tupelo (*Nyssa aquatica*) | Louisiana, Missouri | Green | 6 | 10 | | 97 | .46 | .52 | 56 | 12.5 | 4.2 | 7.6 | 4,200 | 7,300 | 1,050 | .98 | 8.3 | 17.5 | 9,000 | 3.3 | 30 | 2,090 | 3,370 | 590 | 800 | 710 | 1,190 | 240 | 600 |
| | | Dry | | | | 12 | .50 | | 35 | | | | 7,200 | 9,600 | 1,260 | 2.41 | 6.9 | 11.5 | 12,500 | 5.9 | 23 | 4,280 | 5,920 | 1,070 | 1,200 | 880 | 1,590 | 380 | 700 |
| Gumbo limbo (*Bursera simaruba*) | Florida | Green | 5 | | | 99 | .30 | .22 | 38 | 8.6 | 2.3 | 3.6 | 2,000 | 3,300 | 530 | .45 | 3.5 | 4.1 | 5,000 | 2.3 | 13 | 930 | 1,510 | 290 | 290 | 230 | 590 | 170 | 380 |
| | | Dry | | | | 12 | .31 | | 21 | | | | 3,300 | 4,900 | 740 | .85 | 3.6 | 3.2 | 6,300 | 2.3 | 9 | 1,720 | 2,060 | 500 | 370 | 270 | 600 | 200 | 340 |
| Hackberry (*Celtis occidentalis*) | Indiana, Wisconsin | Green | 6 | 13 | 56 | 65 | .49 | .56 | 50 | 13.8 | 4.8 | 8.9 | 2,900 | 6,500 | 950 | .58 | 14.5 | 38.2 | 7,900 | 3.1 | 48 | 2,070 | 2,050 | 490 | 700 | 700 | 1,070 | 350 | 630 |
| | | Dry | | | | 12 | .53 | | 37 | | | | 5,900 | 11,000 | 1,190 | 1.72 | 12.8 | 27.8 | 13,700 | 7.9 | 43 | 3,710 | 5,440 | 1,100 | 1,110 | 880 | 1,590 | 330 | 580 |
| Haw, pear (*Crataegus tomentosa*) | Wisconsin | Green | 2 | 11 | | 63 | .62 | | 64 | | | | 3,900 | 7,600 | 960 | .89 | 22.7 | 52.0 | | | | | 3,110 | 980 | 1,220 | 1,200 | 1,300 | | |
| | | Dry | | | | 12 | .68 | | 47 | | | | 7,500 | 14,600 | 1,270 | 2.50 | 23.6 | 34.0 | | | | | 6,760 | 1,580 | 1,860 | 1,550 | | | |
| Hickory, bigleaf shagbark (*Hicoria laciniosa*) | Ohio, Mississippi | Green | 10 | 19 | 65 | 61 | .62 | | 62 | 19.2 | 7.0 | 12.6 | 5,600 | 10,500 | 1,340 | 1.30 | 29.9 | 88.0 | 14,200 | 7.0 | 104 | 2,740 | 3,920 | 1,000 | | | 1,100 | | |
| | | Dry | | | | 12 | .69 | | 48 | | | | 8,900 | 18,100 | 1,890 | 2.29 | 23.6 | 65.0 | 22,800 | 13.9 | 88 | | 6,000 | 2,220 | | | 2,110 | | |
| Hickory, bitternut (*Hicoria cordiformis*) | Ohio | Green | 11 | 11 | 76 | 66 | .60 | | 63 | | | | 5,600 | 10,300 | 1,400 | 1.22 | 20.0 | 75.5 | 15,900 | 8.5 | 66 | 4,330 | 4,570 | 990 | | | 1,240 | | |
| | | Dry | | | | 12 | .66 | | 46 | | | | 9,300 | 17,100 | 1,790 | 2.73 | 18.2 | 68.7 | 23,600 | 12.5 | 66 | | 9,040 | 2,070 | | | | | |
| Hickory, mockernut (*Hicoria alba*) | Pennsylvania, Mississippi, West Virginia. | Green | 20 | 18 | 63 | 59 | .64 | | 64 | 17.9 | 7.8 | 11.0 | 6,300 | 11,100 | 1,570 | 1.38 | 20.1 | 74.6 | 16,100 | 6.7 | 88 | 3,900 | 4,480 | 1,000 | | | 1,280 | | |
| | | Dry | | | | 12 | .72 | | 51 | | | | 11,900 | 19,200 | 2,220 | 3.41 | 22.6 | 87.5 | 28,200 | 9.7 | 77 | | 8,940 | 2,140 | | | 1,740 | | |
| Hickory, nutmeg (*Hicoria myristicaeformis*) | Mississippi | Green | 5 | 22 | 59 | 74 | .56 | | 60 | | | | 4,900 | 9,100 | 1,290 | 1.06 | 22.8 | 58.2 | 12,800 | 6.1 | 54 | 3,620 | 3,980 | 940 | | | 1,030 | | |
| | | Dry | | | | 12 | .60 | | 42 | | | | 8,100 | 16,600 | 1,700 | 2.04 | 25.1 | | | | | | 6,910 | 1,930 | | | | | |
| Hickory, pignut (*Hicoria glabra*) | West Virginia, Mississippi, Ohio, Pennsylvania. | Green | 60 | 20 | 65 | 54 | .66 | | 63 | 17.9 | 7.2 | 11.5 | 6,200 | 11,700 | 1,650 | 1.34 | 31.7 | 86.1 | 16,900 | 6.8 | 80 | 3,950 | 4,810 | 1,140 | | | 1,370 | | |
| | | Dry | | | | 12 | .75 | | 52 | | | | 11,300 | 20,100 | 2,260 | 3.23 | 30.4 | 83.1 | 25,200 | 13.2 | 74 | | 9,190 | 2,450 | | | 2,150 | | |
| Hickory, shagbark (*Hicoria ovata*) | Mississippi, Ohio, West Virginia, Pennsylvania. | Green | 24 | 19 | 66 | 60 | .64 | | 64 | 16.7 | 7.0 | 10.5 | 5,900 | 11,000 | 1,570 | 1.28 | 23.7 | 76.4 | 14,400 | 8.4 | 74 | 3,430 | 4,580 | 1,040 | | | 1,520 | | |
| | | Dry | | | | 12 | .72 | | 50 | | | | 10,700 | 20,200 | 2,160 | 3.01 | 25.8 | 78.2 | 19,300 | 9.0 | 67 | | 9,210 | 2,170 | | | 2,430 | | |
| Hickory, water (*Hicoria aquatica*) | Mississippi | Green | 2 | 15 | 67 | 80 | .61 | | 68 | | | | 6,000 | 10,700 | 1,560 | 1.29 | 18.8 | 52.9 | 17,700 | 6.1 | 56 | 3,240 | 4,660 | 1,090 | | | 1,440 | | |
| | | Dry | | | | 12 | .62 | | 43 | | | | 10,200 | 17,800 | 2,020 | 2.88 | 19.3 | 42.3 | | | 53 | 5,400 | 8,600 | 1,810 | | | | | |
| Holly (*Ilex opaca*) | Tennessee | Green | 5 | 27 | | 82 | .50 | .61 | 57 | 10.2 | 4.5 | 9.5 | 3,400 | 6,500 | 900 | .72 | 10.8 | 20.7 | 8,900 | 4.4 | 51 | 2,050 | 2,040 | 610 | 860 | 790 | 1,130 | 360 | 610 |
| | | Dry | | | | 12 | .57 | | 40 | | | | 6,100 | 10,300 | 1,110 | 1.88 | 10.7 | 12.8 | 12,500 | 6.9 | 33 | 3,260 | 5,540 | 1,130 | 1,400 | 1,020 | 1,710 | | 680 |
| Honeylocust (*Gleditsia triacanthos*) | Indiana, Missouri | Green | 6 | 9 | 45 | 63 | .60 | .67 | 61 | 10.8 | 4.2 | 6.6 | 5,600 | 10,200 | 1,290 | 1.40 | 12.6 | 34.4 | 11,800 | 4.6 | 47 | 3,320 | 4,420 | 1,420 | 1,440 | 1,390 | 1,600 | 490 | 930 |
| | | Dry | | | | 12 | | | | | | | 8,800 | 14,700 | 1,630 | 2.74 | 13.3 | 42.3 | 15,400 | 7.4 | 47 | 5,250 | 7,500 | 2,280 | 1,840 | 1,580 | 2,250 | 420 | 900 |
| Hophornbeam (*Ostrya virginiana*) | Wisconsin | Green | 5 | 20 | | 52 | .63 | .76 | 60 | 18.6 | 8.2 | 9.6 | 4,500 | 8,500 | 1,150 | 1.02 | 13.3 | 39.1 | 10,600 | 3.5 | 73 | 2,570 | 3,570 | 730 | 1,100 | 1,170 | 1,370 | 330 | 450 |
| | | Dry | | | | 12 | .70 | | 49 | | | | 9,300 | 14,100 | 1,700 | 2.96 | 14.8 | 31.3 | 14,200 | 5.8 | 49 | 5,780 | 7,760 | 1,400 | 2,200 | 1,860 | 1,790 | | |
| Inkwood (*Exothea paniculata*) | Florida | Green | 2 | | | 50 | .73 | .92 | 71 | 18.8 | 6.6 | 10.9 | 7,200 | 10,700 | 1,540 | 1.88 | 16.0 | 64.1 | 15,200 | 6.8 | 50 | 3,310 | 4,480 | 1,600 | 1,320 | 1,440 | 1,750 | 460 | |
| | | Dry | | | | 12 | .80 | | 56 | | | | 8,900 | 14,900 | 1,910 | 2.34 | 10.3 | 22.4 | | | 28 | 4,520 | 8,430 | 2,530 | 3,120 | 2,220 | 2,260 | | |
| Ironwood, black (*Krugiodendron ferreum*) | do | Green | 4 | | | 32 | 1.04 | 1.08 | 86 | 11.0 | 6.2 | 8.0 | 10,100 | 10,400 | 2,200 | 2.64 | 12.6 | 37.2 | 18,500 | 7.7 | 35 | 5,600 | 7,570 | 3,460 | | | | | |
| | | Dry | | | | 12 | 1.15 | | 81 | | | | 7,200 | 15,200 | 2,050 | 1.02 | 8.8 | 15.7 | 16,500 | 5.2 | 14 | 3,400 | 9,040 | 2,860 | | | | | |
| Laurel, California (*Umbellularia californica*) | Oregon | Green | 5 | 6 | | 70 | .51 | .59 | 54 | 11.9 | 2.8 | 8.1 | 3,900 | 6,600 | 720 | 1.23 | 16.8 | 45.6 | 8,300 | 4.1 | 57 | 1,980 | 3,020 | 800 | 1,020 | 1,000 | 1,270 | 430 | 780 |
| | | Dry | | | | 12 | .55 | | 39 | | | | 5,400 | 8,900 | 940 | 1.85 | 8.2 | 12.8 | 10,700 | 5.3 | 31 | 3,520 | 5,640 | 1,400 | 1,540 | 1,270 | 1,860 | 420 | 870 |
| Laurel, mountain (*Kalmia latifolia*) | Tennessee | Green | 5 | 24 | | 62 | .62 | .74 | 62 | 14.4 | 5.6 | 8. | 5,800 | 8,400 | 920 | 2.03 | 12.5 | 28.0 | 10,200 | 5.2 | 32 | | 4,310 | 1,110 | 1,400 | 1,300 | 1,670 | | |
| | | Dry | | | | 12 | .68 | | 48 | | | | 8,500 | 11,100 | 1,290 | 3.44 | 10.3 | 18.3 | 14,300 | 7.5 | 40 | | 5,920 | 1,830 | 2,000 | 1,790 | | | |
| Locust, black (*Robinia pseudoacacia*) | do | Green | 3 | 11 | 51 | 40 | .66 | .71 | 58 | 9.8 | 4.4 | 6.9 | 6,800 | 13,800 | 1,850 | 2.36 | 15.4 | 39.9 | 18,300 | 7.9 | 44 | 6,120 | 6,800 | 1,430 | 1,540 | 1,570 | 1,760 | 400 | 770 |
| | | Dry | | | | 12 | .69 | | 48 | | | | 12,800 | 19,400 | 2,050 | 4.62 | 18.4 | 49.4 | 21,100 | 9.8 | 57 | 6,800 | 10,180 | 2,280 | 1,580 | 1,700 | 2,480 | 330 | 640 |
| Madrono, Pacific (*Arbutus menziesii*) | California, Oregon | Green | 6 | 10 | | 68 | .58 | .69 | 60 | 17.4 | 5.4 | 11.9 | 4,700 | 7,600 | 880 | 1.43 | 11.2 | 22.0 | 10,200 | 4.7 | 40 | 2,430 | 3,320 | 780 | 1,120 | 940 | 1,420 | 430 | 770 |
| | | Dry | | | | 12 | .65 | | 45 | | | | 7,200 | 10,400 | 1,230 | 2.63 | 8.8 | 12.4 | 16,400 | 4.3 | 23 | 4,040 | 6,880 | 1,620 | 1,800 | 1,460 | 1,810 | 490 | |
| Magnolia, cucumber (*Magnolia acuminata*) | Tennessee | Green | 5 | 14 | | 80 | .44 | .52 | 49 | 13.6 | 5.2 | 8.8 | 4,200 | 7,400 | 1,560 | .66 | 10.0 | 21.8 | 9,300 | 2.9 | 30 | 2,810 | 3,140 | 410 | 600 | 520 | 990 | 260 | 440 |
| | | Dry | | | | 12 | .48 | | 33 | | | | 6,900 | 12,300 | 1,820 | 1.89 | 12.2 | 22.4 | 14,700 | 5.7 | 35 | 4,840 | 6,310 | 710 | 850 | 700 | 1,240 | 290 | 600 |
| Magnolia, evergreen (*Magnolia grandiflora*) | Louisiana | Green | 2 | 15 | | 105 | .46 | .53 | 59 | 12.3 | 5.4 | 6.6 | 2,600 | 6,800 | 1,110 | .67 | 15.4 | 34.8 | 8,800 | 3.2 | 54 | 2,100 | 2,700 | 570 | 780 | 740 | 1,040 | 340 | 610 |
| | | Dry | | | | 12 | .50 | | 35 | | | | 6,800 | 11,200 | 1,400 | 1.90 | 12.8 | 16.8 | 13,000 | 6.4 | 29 | 3,420 | 5,460 | 1,000 | 1,280 | 1,020 | 1,520 | 420 | 760 |
| Magnolia, mountain (*Magnolia fraseri*) | Tennessee | Green | 6 | 16 | | 89 | .40 | .48 | 47 | 13.0 | 4.4 | 7.5 | 3,400 | 6,100 | 1,190 | .55 | 8.3 | 16.5 | 8,600 | 2.9 | 23 | 2,270 | 2,610 | 230 | 570 | 500 | 830 | 260 | 450 |
| | | Dry | | | | 12 | .44 | | 31 | | | | 6,900 | 10,100 | 1,400 | 1.88 | 10.0 | 15.8 | 13,800 | 5.8 | 27 | 4,180 | 6,360 | 620 | 830 | 620 | 1,150 | 290 | 600 |
| Mangrove (*Rhizophora mangle*) | Florida | Green | 4 | | | 39 | .89 | 1.06 | 77 | 15.8 | 5.4 | | 9,700 | 15,200 | 2,300 | 2.30 | 14.0 | 38.7 | 20,500 | 8.2 | 52 | 5,200 | 6,490 | 2,460 | 2,010 | 2,240 | 1,800 | | |
| | | Dry | | | | 12 | .96 | | 67 | | | | 14,900 | 21,700 | 2,950 | 2.80 | 17.9 | 33.2 | | | 32 | 6,170 | 10,750 | 3,300 | | 2,760 | 2,940 | | |
| Maple, bigleaf (*Acer macrophyllum*) | Washington | Green | 5 | 12 | | 72 | .44 | .51 | 47 | 11.6 | 3.7 | 7.1 | 4,400 | 7,400 | 1,100 | 1.02 | 8.7 | 14.2 | 8,500 | 2.8 | 23 | 2,510 | 3,240 | 550 | 760 | 620 | 1,110 | 320 | 600 |
| | | Dry | | | | 12 | .48 | | 34 | | | | 6,600 | 10,700 | 1,450 | 1.86 | 7.8 | 11.8 | | | 28 | 4,790 | 5,950 | 930 | 1,330 | 850 | 1,730 | 400 | 540 |
| Maple, black (*Acer nigrum*) | Indiana | Green | 1 | 17 | | 65 | .52 | .62 | 54 | 14.0 | 4.8 | 9.3 | 4,100 | 7,900 | 1,330 | .70 | 12.8 | 29.8 | 10,200 | 3.8 | 48 | 2,800 | 3,270 | 740 | 940 | 840 | 1,130 | 430 | 720 |
| | | Dry | | | | 12 | .57 | | 40 | | | | 8,300 | 13,300 | 1,620 | 2.39 | 12.5 | 21.5 | 13,500 | 5.6 | 40 | 4,600 | 6,680 | 1,250 | 1,700 | 1,180 | 1,820 | 470 | 670 |
| Maple, red (*Acer rubrum*) | New Hampshire, Pennsylvania, Wisconsin. | Green | 14 | 13 | | 63 | .49 | .55 | 50 | 13.1 | 4.0 | 8.2 | 3,800 | 7,700 | 1,390 | .71 | 11.4 | 24.7 | | | 32 | 2,300 | 3,280 | 500 | 780 | 700 | 1,150 | 290 | |
| | | Dry | | | | 12 | .54 | | 38 | | | | 8,700 | 13,400 | 1,640 | 2.84 | 12.5 | 27.4 | | | 32 | 4,650 | 6,540 | 1,240 | 1,430 | 950 | 1,850 | 500 | |
| Maple, silver (*Acer saccharinum*) | Wisconsin | Green | 5 | 7 | | 66 | .44 | .51 | 45 | 12.0 | 3.0 | 7.2 | 3,100 | 5,800 | 940 | .61 | 11.0 | 22.3 | 6,800 | 2.6 | 29 | 1,930 | 2,490 | 460 | 670 | 590 | 1,050 | 300 | 560 |
| | | Dry | | | | 12 | .47 | | 33 | | | | 6,200 | 8,900 | 1,140 | 1.90 | 8.3 | 13.1 | 12,400 | 6.0 | 25 | 4,360 | 5,220 | 910 | 1,140 | 700 | 1,480 | 340 | 500 |

[1] The averages for this species include data from tests representing an unknown number of trees in addition to the number indicated.

TABLE 1.—*Strength and related properties of woods grown in the United States*—Continued

| Species (common and botanical names) | Place of growth of material tested | Moisture condition | Trees tested | Rings per inch | Summer wood | Moisture content | Specific gravity, oven dry, based on volume—At test | Specific gravity—When oven-dry | Weight per cubic foot | Shrinkage from green to oven-dry condition based on dimensions when green—Volumetric | Shrinkage—Radial | Shrinkage—Tangential | Static bending—Stress at proportional limit | Static bending—Modulus of rupture | Static bending—Modulus of elasticity | Static bending—Work—Proportional limit | Static bending—Work—Maximum load | Static bending—Work—Total | Impact bending—Stress at proportional limit | Impact bending—Work to proportional limit | Impact bending—Height of drop causing complete failure (50-pound hammer) | Compression parallel to grain—Stress at proportional limit | Compression parallel to grain—Maximum crushing strength | Compression perpendicular to grain; stress at proportional limit | Hardness; load required to embed a 0.444-inch ball to ½ its diameter—End | Hardness—Side | Shear parallel to grain; maximum shearing strength | Cleavage; load to cause splitting | Tension perpendicular to grain; maximum tensile strength |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 | 28 | 29 | 30 |
| HARDWOODS—continued | | | *Number* | *Number* | *Per cent* | *Per cent* | | | *Pounds* | *Per cent* | *Per cent* | *Per cent* | *Lb. per sq. in.* | *Lb. per sq. in.* | *1,000 lb. per sq. in.* | *In.-lb. per cu. in.* | *In.-lb. per cu. in.* | *In.-lb. per cu. in.* | *Lb. per sq. in.* | *In.-lb. per cu. in.* | *Inches* | *Lb. per sq. in.* | *Lb. per sq. in.* | *Lb. per sq. in.* | *Pounds* | *Pounds* | *Lb. per sq. in.* | *Lb. per in. of width* | *Lb. per sq. in.* |
| Maple, striped (*Acer pennsylvanicum*) | Vermont | Green | 4 | 12 | | 35 | 0.44 | | 37 | 12.3 | 3.2 | 8.6 | 3,600 | 7,200 | 1,080 | 0.68 | 10.9 | 13.4 | 8,700 | 2.3 | 36 | 1,790 | 2,920 | 500 | 500 | | 1,150 | | |
| | | Dry | | | | 12 | .46 | | 32 | | | | 5,200 | 10,900 | 1,360 | 1.08 | 11.3 | 16.8 | 11,400 | 5.2 | 27 | | 5,540 | 600 | 900 | 700 | 1,320 | | |
| Maple, sugar (*Acer saccharum*) | Indiana, Pennsylvania, Vermont, Wisconsin | Green | [1] 17 | 18 | | 58 | .56 | 0.68 | 56 | 14.9 | 4.9 | 9.5 | 5,100 | 9,400 | 1,550 | 1.03 | 13.3 | 33.0 | 12,200 | 4.8 | 40 | 2,850 | 4,020 | 800 | 1,070 | 970 | 1,460 | | |
| | | Dry | | | | 12 | .63 | | 44 | | | | 9,500 | 15,800 | 1,830 | 2.76 | 16.5 | 27.9 | 20,600 | 9.3 | 39 | 5,390 | 7,830 | 1,610 | 1,840 | 1,450 | 2,330 | | |
| Mastic (*Sideroxylon foetidissimum*) | Florida | Green | 5 | | | 39 | .89 | 1.03 | 77 | 11.7 | 6.1 | 7.5 | 7,100 | 10,400 | 1,580 | 1.79 | 8.1 | 19.8 | 16,000 | 8.7 | 52 | 4,050 | 5,880 | 2,680 | 1,670 | 1,770 | 1,670 | 430 | 1,030 |
| | | Dry | | | | 12 | .93 | | 65 | | | | 8,600 | 10,200 | 1,780 | 1.33 | 6.2 | 6.6 | 14,100 | 5.1 | 24 | 3,940 | 6,980 | 2,830 | 2,000 | 1,790 | 1,470 | 370 | 710 |
| Oak, black (*Quercus velutina*) | Arkansas, Wisconsin | Green | 8 | 15 | 71 | 80 | .56 | .67 | 62 | 14.2 | 4.5 | 9.7 | 4,600 | 8,200 | 1,180 | 1.02 | 12.2 | 30.1 | 11,400 | 4.9 | 40 | 2,720 | 3,470 | 670 | 1,000 | 1,000 | 1,220 | | |
| | | Dry | | | | 12 | .61 | | 43 | | | | 7,900 | 13,900 | 1,640 | 2.15 | 13.7 | 24.0 | 14,400 | 6.4 | 41 | 4,750 | 6,520 | 1,150 | 1,280 | 1,210 | 1,910 | | |
| Oak, bur (*Quercus macrocarpa*) | Wisconsin | Green | 5 | 12 | 59 | 70 | .58 | .67 | 62 | 12.7 | 4.4 | 8.8 | 3,600 | 7,200 | 880 | .89 | 10.7 | 26.1 | 10,000 | 4.7 | 44 | 2,380 | 3,290 | 840 | 1,100 | 1,110 | 1,350 | 430 | 800 |
| | | Dry | | | | 12 | .64 | | 45 | | | | 6,400 | 10,300 | 1,030 | 2.37 | 9.8 | 17.4 | 14,400 | 6.0 | 29 | 3,580 | 6,060 | 1,450 | 1,410 | 1,370 | 1,820 | 320 | 680 |
| Oak, California black (*Quercus kelloggii*) | Oregon, California | Green | 10 | 16 | 52 | 100 | .51 | .58 | 66 | 12.1 | 3.6 | 6.6 | 3,400 | 6,200 | 740 | 1.03 | 8.8 | 16.0 | 8,200 | 3.4 | 30 | 1,880 | 2,800 | 890 | 910 | 850 | 1,140 | 350 | 700 |
| | | Dry | | | | 12 | .57 | | 40 | | | | 6,100 | 8,700 | 990 | 2.28 | 6.5 | 10.8 | 8,800 | 4.0 | 16 | 3,300 | 5,640 | 1,440 | 1,180 | 1,100 | 1,470 | 390 | 770 |
| Oak, canyon live (*Quercus chrysolepis*) | California | Green | 3 | 13 | | 62 | .70 | .84 | 71 | 16.2 | 5.4 | 9.5 | 6,300 | 10,600 | 1,340 | 1.70 | 14.4 | 30.9 | 11,200 | 3.9 | 47 | 3,940 | 4,090 | 1,480 | 1,590 | 1,570 | 1,700 | 520 | 970 |
| | | Dry | | | | 12 | .77 | | 54 | | | | 9,300 | 12,900 | 1,610 | 3.15 | 9.9 | 21.5 | 13,600 | 5.5 | 37 | 6,110 | 9,060 | 2,200 | 2,330 | 2,420 | 2,290 | 640 | |
| Oak, chestnut (*Quercus montana*) | Tennessee | Green | 5 | 23 | 60 | 72 | .57 | .67 | 61 | 16.7 | 5.5 | 9.7 | 4,600 | 8,000 | 1,370 | .90 | 9.4 | 22.4 | 12,000 | 4.6 | 35 | 2,890 | 3,520 | 690 | 970 | 890 | 1,210 | 380 | 690 |
| | | Dry | | | | 12 | .66 | | 46 | | | | 9,000 | 13,300 | 1,590 | 2.88 | 11.0 | 19.4 | 18,600 | 7.7 | 40 | 4,420 | 6,830 | 1,040 | 1,250 | 1,130 | 1,490 | 380 | |
| Oak, laurel (*Quercus laurifolia*) | Louisiana | Green | 5 | 11 | 61 | 84 | .56 | .70 | 65 | 19.0 | 4.0 | 9.9 | 4,500 | 7,900 | 1,390 | .86 | 11.2 | 28.3 | 10,400 | 3.4 | 39 | 2,650 | 3,170 | 710 | 1,020 | 1,000 | 1,180 | 380 | 770 |
| | | Dry | | | | 12 | .63 | | 44 | | | | 7,700 | 12,600 | 1,690 | 2.02 | 11.8 | 28.5 | 14,700 | 5.6 | 39 | 4,440 | 6,980 | 1,310 | 1,230 | 1,210 | 1,830 | 360 | 790 |
| Oak, live (*Quercus virginiana*) | Florida | Green | 5 | 8 | | 50 | .81 | .98 | 76 | 14.7 | 6.6 | 9.5 | 8,400 | 11,900 | 1,580 | 2.54 | 12.3 | 26.0 | 17,200 | 8.5 | 57 | 4,170 | 5,430 | 2,520 | 1,670 | 1,880 | 2,210 | 550 | 1,040 |
| | | Dry | | | | 12 | .88 | | 62 | | | | 8,700 | 18,400 | 1,990 | 2.19 | 16.0 | 20.1 | 21,300 | 11.2 | 32 | 5,120 | 8,900 | 3,510 | 3,150 | 2,680 | 2,660 | 570 | 1,010 |
| Oak, Oregon white (*Quercus garryana*) | Oregon | Green | 10 | 16 | 49 | 72 | .64 | .75 | 69 | 13.4 | 4.2 | 9.0 | 4,600 | 7,700 | 790 | 1.51 | 13.7 | 29.8 | 10,300 | 4.8 | 49 | 2,480 | 3,570 | 1,380 | 1,430 | 1,390 | 1,630 | 450 | 940 |
| | | Dry | | | | 12 | .72 | | 50 | | | | 6,630 | 10,300 | 1,100 | 2.28 | 9.8 | 18.2 | 11,900 | 6.4 | 29 | 3,960 | 6,530 | [illegible] | 1,680 | 1,640 | 2,020 | 390 | 830 |
| Oak, pin (*Quercus palustris*) | Massachusetts | Green | 5 | 9 | 58 | 75 | .58 | .68 | 63 | 14.5 | 4.3 | 9.5 | 4,000 | 8,300 | 1,320 | .71 | 14.0 | 35.2 | 11,900 | 4.2 | 48 | | 3,680 | 880 | 1,000 | 1,070 | 1,290 | 470 | 800 |
| | | Dry | | | | 12 | .63 | | 44 | | | | 8,000 | 14,000 | 1,730 | 2.22 | 14.8 | 30.5 | 12,300 | 3.6 | 45 | 4,620 | 6,820 | 1,260 | 1,600 | 1,510 | 2,080 | 530 | 1,050 |
| Oak, post (*Quercus stellata*) | Arkansas, Louisiana | Green | 10 | 26 | 54 | 69 | .60 | .74 | 63 | 16.2 | 5.9 | 9.8 | 5,000 | 8,100 | 1,090 | 1.31 | 11.0 | 25.4 | 10,900 | 4.1 | 44 | 2,840 | 3,480 | 1,060 | 1,160 | 1,130 | 1,280 | 410 | 790 |
| | | Dry | | | | 12 | .67 | | 47 | | | | 7,600 | 13,200 | 1,510 | 2.25 | 13.2 | 40.4 | 17,600 | 8.6 | 46 | 3,700 | 6,600 | 1,700 | 1,350 | 1,360 | 1,840 | 430 | 780 |
| Oak, red (*Quercus borealis*) | Arkansas, Indiana, Louisiana, New Hampshire, Tennessee | Green | 33 | 10 | 63 | 80 | .56 | .66 | 63 | 13.5 | 4.0 | 8.2 | 4,100 | 8,300 | 1,350 | .73 | 13.2 | 34.5 | 10,600 | 3.8 | 44 | 2,360 | 3,440 | 760 | 1,000 | 1,000 | 1,210 | 430 | 750 |
| | | Dry | | | | 12 | .63 | | 44 | | | | 8,500 | 14,300 | 1,820 | 2.33 | 14.5 | 33.4 | 17,600 | 8.5 | 43 | 4,580 | 6,760 | 1,250 | 1,560 | 1,290 | 1,780 | 410 | 800 |
| Oak, Rocky Mountain white (*Quercus utahensis*) | Arizona | Green | 3 | 24 | | 61 | .62 | .70 | 62 | 12.5 | 4.1 | 7.2 | 3,200 | 5,900 | 480 | 1.23 | 11.3 | 27.2 | 8,100 | 4.3 | 80 | 1,330 | 2,940 | 1,110 | 1,210 | 1,260 | 1,530 | 370 | 750 |
| | | Dry | | | | 12 | .73 | | 51 | | | | 5,700 | 8,500 | 650 | 2.38 | 9.0 | 13.3 | 14,100 | 5.2 | 23 | | 5,200 | 2,070 | 2,030 | 1,440 | | | |
| Oak, scarlet (*Quercus coccinea*) | Massachusetts | Green | 5 | 14 | 52 | 65 | .60 | .71 | 62 | 13.8 | 4.6 | 9.7 | 4,500 | 10,400 | 1,460 | .81 | 15.0 | 41.9 | 11,900 | 4.0 | 54 | 2,840 | 4,090 | 1,030 | 1,170 | 1,200 | 1,410 | 420 | 700 |
| | | Dry | | | | 12 | .67 | | 47 | | | | 9,700 | 17,400 | 1,910 | 2.92 | 20.5 | 43.9 | 18,100 | 6.1 | 53 | 5,550 | 8,330 | 1,350 | 1,890 | 1,400 | 1,890 | 450 | 870 |
| Oak, southern red (*Quercus rubra*) | Louisiana | Green | 4 | 20 | 46 | 90 | .52 | .62 | 62 | 16.3 | 4.5 | 8.7 | 4,200 | 6,900 | 1,140 | .93 | 8.0 | 16.5 | 9,100 | 3.1 | 29 | 2,220 | 3,030 | 680 | 910 | 860 | 930 | 280 | 480 |
| | | Dry | | | | 12 | .59 | | 41 | | | | 6,900 | 10,900 | 1,490 | 1.44 | 9.4 | 15.9 | 13,200 | 7.3 | 26 | 2,910 | 6,090 | 1,050 | 1,920 | 1,060 | 1,390 | 350 | 510 |
| Oak, swamp red (*Quercus rubra pagodaefolia*) | do | Green | 3 | 7 | 63 | 78 | .61 | .71 | 68 | 16.4 | 5.2 | 10.8 | 6,500 | 10,800 | 1,790 | 1.32 | 14.7 | 38.0 | 12,300 | 3.8 | 54 | 3,820 | 4,620 | 940 | 1,270 | 1,240 | 1,320 | 460 | 800 |
| | | Dry | | | | 12 | .68 | | 47 | | | | 11,200 | 18,100 | 2,280 | 3.09 | 18.3 | 34.6 | 23,900 | 12.0 | 49 | 6,350 | 8,740 | 1,540 | 1,570 | 1,480 | 2,000 | 410 | 840 |
| Oak, swamp chestnut (*Quercus prinus*) | do | Green | 4 | 12 | 58 | 76 | .60 | .76 | 65 | 19.4 | 5.9 | 9.2 | 4,800 | 8,500 | 1,350 | 1.00 | 12.8 | 32.2 | 10,400 | 3.2 | 45 | 3,000 | 3,540 | 710 | 1,100 | 1,110 | 1,260 | 400 | 670 |
| | | Dry | | | | 12 | .67 | | 47 | | | | 7,300 | 13,900 | 1,770 | 1.58 | 12.0 | 21.0 | 19,000 | 7.9 | 41 | 4,400 | 7,270 | 1,370 | 1,280 | 1,240 | 1,990 | 350 | 690 |
| Oak, swamp white (*Quercus bicolor*) | Indiana | Green | 1 | 16 | 71 | 74 | .64 | .79 | 69 | 17.7 | 5.5 | 10.6 | 5,400 | 9,900 | 1,590 | 1.05 | 14.5 | 34.7 | 13,300 | 4.8 | 50 | 3,580 | 4,360 | 940 | 1,200 | 1,160 | 1,300 | 480 | 860 |
| | | Dry | | | | 12 | .72 | | 50 | | | | 10,200 | 17,700 | 2,050 | 2.88 | 19.2 | 48.7 | 22,300 | 11.2 | 49 | 5,830 | 8,600 | 1,470 | 1,650 | 1,620 | 2,000 | 460 | 830 |
| Oak, water (*Quercus nigra*) | Louisiana | Green | 5 | 10 | 61 | 81 | .56 | .68 | 63 | 16.4 | 4.2 | 9.3 | 5,600 | 8,900 | 1,550 | 1.14 | 11.1 | 32.5 | 11,600 | 3.8 | 39 | 3,260 | 3,740 | 770 | 1,050 | 1,010 | 1,240 | 450 | 820 |
| | | Dry | | | | 12 | .63 | | 44 | | | | 9,900 | 15,400 | 2,020 | 2.24 | 21.5 | 33.4 | 16,800 | 8.1 | 44 | 3,960 | 6,770 | 1,260 | 1,400 | 1,190 | 2,020 | 470 | 920 |
| Oak, white (*Quercus alba*) | Arkansas, Indiana, Louisiana | Green | 20 | 17 | 60 | 68 | .60 | .71 | 62 | 15.8 | 5.3 | 9.0 | 4,700 | 8,300 | 1,250 | 1.08 | 11.6 | 28.2 | 10,700 | 4.2 | 42 | 3,090 | 3,560 | 830 | 1,120 | 1,060 | 1,250 | 420 | 770 |
| | | Dry | | | | 12 | .68 | | 48 | | | | 8,200 | 15,200 | 1,780 | 2.27 | 14.8 | 29.1 | 17,100 | 7.5 | 37 | 4,760 | 7,440 | 1,320 | 1,520 | 1,360 | 2,000 | 450 | 800 |
| Oak, willow (*Quercus phellos*) | Louisiana | Green | 2 | 14 | 56 | 94 | .56 | .69 | 67 | 18.9 | 5.0 | 9.6 | 4,400 | 7,400 | 1,290 | .88 | 8.8 | 21.3 | 9,200 | 2.9 | 35 | 2,340 | 3,000 | 750 | 1,020 | 980 | 1,180 | 400 | 760 |
| | | Dry | | | | 12 | .69 | | 48 | | | | 9,300 | 14,500 | 1,900 | 2.01 | 14.6 | 37.3 | 15,600 | 7.6 | 42 | 4,360 | 7,040 | 1,400 | 1,420 | 1,460 | 1,650 | | |
| Osage-orange (*Toxylon pomiferum*) | Indiana | Green | 1 | 6 | 82 | 31 | .76 | .84 | 62 | 8.9 | | | 7,800 | 13,700 | 1,330 | 2.53 | 37.9 | 101.7 | 15,500 | 8.9 | 120 | 3,980 | 5,810 | 2,260 | 1,840 | 2,040 | | | |
| | | Dry | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Palmetto, cabbage (*Sabal palmetto*) | Florida | Green | 5 | | | 134 | .37 | .45 | 54 | 25.0 | | | 1,900 | 3,800 | 480 | .45 | 4.0 | 15.8 | 5,000 | 2.7 | 15 | 1,410 | 1,750 | 190 | 330 | 280 | 570 | 110 | 220 |
| | | Dry | | | | 12 | .39 | | 27 | | | | 3,000 | 4,700 | 560 | .91 | 4.5 | 19.6 | 6,200 | 2.9 | 16 | 1,450 | 2,220 | 180 | 300 | 350 | 410 | 80 | 130 |
| Paradise tree (*Simarouba glauca*) | do | Green | 4 | | | 81 | .33 | .36 | 38 | 8.6 | 2.2 | 5.2 | 1,900 | 3,500 | 700 | .40 | 1.8 | 2.4 | 5,400 | 1.9 | 7 | 1,260 | 1,810 | 260 | 350 | 240 | 710 | 150 | 310 |
| | | Dry | | | | 12 | .34 | | 24 | | | | 3,900 | 5,300 | 850 | .68 | 3.1 | 4.0 | 5,500 | 1.5 | 7 | 2,160 | 3,000 | 400 | 600 | 350 | 620 | | 330 |
| Pecan (*Hicoria pecan*) | Missouri | Green | 5 | 12 | 63 | 63 | .60 | .69 | 61 | 13.0 | 4.9 | 8.9 | 5,200 | 9,800 | 1,370 | 1.18 | 14.6 | 43.4 | 12,300 | 5.0 | 53 | 3,100 | 3,990 | 960 | 1,270 | 1,310 | 1,480 | 420 | 680 |
| | | Dry | | | | 12 | .66 | | 46 | | | | 9,100 | 13,700 | 1,730 | 2.81 | 13.8 | 25.5 | 17,400 | 8.2 | 44 | 5,180 | 7,850 | 2,130 | 1,830 | 1,820 | 2,050 | 440 | |
| Persimmon (*Diospyros virginiana*) | do | Green | 5 | 14 | | 58 | .64 | .78 | 63 | 18.3 | 7.5 | 10.8 | 5,600 | 10,000 | 1,370 | 1.35 | 13.0 | 31.2 | 12,100 | 4.5 | 41 | 3,160 | 4,170 | 1,110 | 1,240 | 1,280 | 1,470 | 410 | 770 |
| | | Dry | | | | 12 | .74 | | 52 | | | | 10,900 | 17,700 | 2,010 | 3.49 | 15.4 | 35.2 | 18,400 | 8.6 | 37 | 6,390 | 9,170 | 2,400 | 2,520 | 2,300 | 2,160 | 600 | 1,200 |
| Pigeon-plum (*Coccolobis laurifolia*) | Florida | Green | 5 | | | 52 | .77 | .85 | 73 | 15.7 | 4.4 | 7.8 | 5,000 | 9,800 | 1,300 | 1.17 | 11.6 | 24.7 | 16,000 | 6.8 | 40 | 4,260 | 4,940 | 1,500 | 1,730 | 1,720 | 1,510 | 400 | 850 |
| | | Dry | | | | 12 | .78 | | 55 | | | | 7,800 | 13,900 | 1,790 | 2.67 | 10.8 | | | | | 4,640 | 7,020 | 2,020 | | 2,030 | | | |
| Poisonwood (*Metopium toxiferum*) | do | Green | 4 | | | 71 | .51 | .55 | 54 | 11.6 | 4.2 | 7.2 | 3,200 | 5,100 | 410 | 1.30 | 5.6 | 7.2 | 8,100 | 3.3 | 15 | 1,220 | 2,160 | 900 | 400 | 300 | 910 | 180 | 350 |
| | | Dry | | | | 12 | .53 | | 37 | | | | 5,400 | 10,500 | 1,290 | 1.25 | 6.4 | 6.5 | | | | | 4,780 | 800 | | | | | |
| Poplar, balsam (*Populus balsamifera*) | Alaska, Vermont | Green | 10 | 7 | | 112 | .30 | .35 | 40 | 10.5 | 3.0 | 7.1 | 2,100 | 3,900 | 750 | .35 | 4.2 | 7.2 | 6,000 | 2.2 | 16 | 1,220 | 1,690 | 170 | 240 | 230 | 500 | 130 | 160 |
| | | Dry | | | | 12 | .33 | | 23 | | | | 4,200 | 6,800 | 1,100 | .98 | 5.0 | 6.9 | 8,900 | 2.7 | 14 | 2,920 | 4,020 | 370 | 390 | 300 | 790 | 200 | 350 |
| Poplar, yellow (*Liriodendron tulipifera*) | Kentucky, Tennessee | Green | 11 | 14 | | 64 | .38 | .43 | 38 | 12.3 | 4.0 | 7.1 | 3,400 | 5,400 | 1,090 | .62 | 5.4 | 8.9 | 8,600 | 3.3 | 18 | 1,930 | 2,420 | 330 | 390 | 340 | 740 | 220 | 450 |
| | | Dry | | | | 12 | .40 | | 28 | | | | 6,100 | 9,200 | 1,500 | 1.43 | 6.8 | 11.2 | 13,500 | 5.6 | 20 | 3,550 | 5,290 | 590 | 500 | 450 | 1,100 | 290 | 530 |
| Rhododendron, great (*Rhododendron maximum*) | Tennessee | Green | 5 | 28 | | 99 | .50 | .60 | 62 | 16.2 | 6.3 | 8.7 | 4,600 | 6,900 | 870 | 1.38 | 12.1 | 32.4 | | | 26 | | 3,470 | 800 | 1,000 | 860 | 1,240 | | |
| | | Dry | | | | 12 | .57 | | 40 | | | | 6,800 | 11,000 | 1,110 | 2.30 | 12.4 | 23.0 | | | 19 | | 6,420 | 1,440 | | | | | |
| Sassafras (*Sassafras variifolium*) | do | Green | 5 | 19 | 48 | 67 | .42 | .47 | 44 | 10.3 | 4.0 | 6.2 | 3,600 | 6,000 | 910 | .80 | 7.1 | 22.2 | 8,500 | 3.5 | 37 | 2,400 | 2,730 | 460 | 610 | 520 | 950 | 300 | 520 |
| | | Dry | | | | 12 | .45 | | 31 | | | | 6,200 | 9,000 | 1,120 | 1.91 | 8.7 | 24.6 | 10,800 | 5.2 | 33 | 3,260 | 4,700 | 1,050 | 450 | 630 | 1,240 | 300 | 500 |
| Serviceberry (*Amelanchier canadensis*) | do | Green | 5 | 19 | | 48 | .66 | .79 | 61 | 18.7 | 6.7 | 10.8 | 5,600 | 9,600 | 1,640 | 1.08 | 16.2 | 37.9 | 12,200 | 4.1 | 63 | 3,250 | 4,080 | 780 | 1,250 | 1,240 | 1,260 | 400 | 730 |
| | | Dry | | | | 12 | .74 | | 52 | | | | 11,000 | 16,900 | 1,880 | 2.44 | 15.9 | 49.1 | 21,000 | 9.6 | 59 | 6,240 | 6,770 | 1,790 | 2,000 | 1,800 | 1,500 | | |

[1] The averages for this species include data from tests representing an unknown number of trees in addition to the number indicated.

TABLE 1.—*Strength and related properties of woods grown in the United States*—Continued

| Species (common and botanical names) | Place of growth of material tested | Moisture condition | Trees tested | Rings per inch | Summer wood | Moisture content | Specific gravity, oven dry, based on volume—At test | Specific gravity, oven dry, based on volume—When oven-dry | Weight per cubic foot | Shrinkage from green to oven-dry condition based on dimensions when green: Volumetric | Shrinkage: Radial | Shrinkage: Tangential | Static bending: Stress at proportional limit | Static bending: Modulus of rupture | Static bending: Modulus of elasticity | Static bending: Work: Proportional limit | Static bending: Work: Maximum load | Static bending: Work: Total | Impact bending: Stress at proportional limit | Impact bending: Work to proportional limit | Impact bending: Height of drop causing complete failure (50-pound hammer) | Compression parallel to grain: Stress at proportional limit | Compression parallel to grain: Maximum crushing strength | Compression perpendicular to grain; stress at proportional limit | Hardness; load required to embed a 0.444-inch ball to ½ its diameter: End | Hardness: Side | Shear parallel to grain; maximum shearing strength | Cleavage; load to cause splitting | Tension perpendicular to grain; maximum tensile strength |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 | 28 | 29 | 30 |
| HARDWOODS—continued | | | *Number* | *Number* | *Percent* | *Percent* | | | *Pounds* | *Percent* | *Percent* | *Percent* | *Lb. per sq. in.* | *Lb. per sq. in.* | *1,000 lb. per sq. in.* | *In.-lb. per cu. in.* | *In.-lb. per cu. in.* | *In.-lb. per cu. in.* | *Lb. per sq. in.* | *In.-lb. per cu. in.* | *Inches* | *Lb. per sq. in.* | *Lb. per sq. in.* | *Lb. per sq. in.* | *Pounds* | *Pounds* | *Lb. per sq. in.* | *Lb. per in. of width* | *Lb. per sq. in.* |
| Silverbell (*Halesia carolina*) | Tennessee | Green | 5 | 20 | | 70 | 0.42 | 0.48 | 44 | 12.6 | 3.8 | 7.6 | 3,500 | 6,500 | 1,160 | 0.62 | 8.8 | 16.1 | 9,100 | 3.3 | 27 | 2,140 | 2,830 | 430 | 550 | 470 | 930 | 280 | 460 |
| | | Dry | | | | 12 | .45 | | 32 | | | | 5,700 | 8,400 | 1,320 | 1.46 | 6.9 | 18.0 | 13,300 | 6.0 | 24 | 3,580 | 5,120 | 680 | 680 | 590 | 1,180 | 320 | 489 |
| Sourwood (*Oxydendrum arboreum*) | do | Green | 5 | 24 | | 69 | .50 | .59 | 53 | 15.2 | 6.3 | 8.9 | 4,400 | 7,700 | 1,320 | .82 | 9.8 | 20.0 | 10,800 | 4.1 | 38 | 2,700 | 3,250 | 630 | 860 | 730 | 1,160 | 400 | 710 |
| | | Dry | | | | 12 | .55 | | 38 | | | | 8,300 | 11,500 | 1,540 | 2.44 | 10.9 | 21.7 | 17,200 | 6.8 | 33 | 4,400 | 6,100 | 1,080 | 1,350 | 940 | 1,500 | 380 | 520 |
| Stopper, red (*Eugenia confusa*) | Florida | Green | 3 | | | 41 | .81 | .92 | 72 | 13.3 | 6.2 | 9.1 | | 15,000 | 1,940 | | 21.6 | 48.3 | | | 54 | | 6,140 | 2,450 | | | 1,820 | | 920 |
| | | Dry | | | | 12 | .87 | | 61 | | | | | 16,200 | 2,040 | | 10.6 | 19.3 | | | 34 | | 9,790 | 2,700 | | 2,600 | 1,850 | | |
| Sugarberry (*Celtis laevigata*) | Missouri | Green | 5 | 17 | 38 | 62 | .47 | .54 | 48 | 12.7 | 5.0 | 7.3 | 3,200 | 6,600 | 810 | .78 | 12.0 | 30.7 | 8,200 | 3.2 | 33 | 1,990 | 2,800 | 580 | 840 | 740 | 1,050 | 380 | 660 |
| | | Dry | | | | 12 | .51 | | 36 | | | | 6,200 | 9,900 | 1,140 | 2.18 | 11.2 | 26.3 | 11,600 | 5.4 | 25 | 3,970 | 5,620 | 1,240 | 1,230 | 960 | 1,280 | 280 | |
| Sumach, staghorn (*Rhus hirta*) | Wisconsin | Green | 5 | 9 | 61 | 45 | .45 | | 41 | | | | 3,000 | 5,800 | 810 | .67 | 10.8 | 42.4 | | | | | 2,680 | 480 | 670 | 590 | | | |
| | | Dry | | | | 12 | .47 | | 33 | | | | 7,800 | 10,200 | 1,190 | 2.84 | 8.4 | 19.8 | | | | | 5,840 | 1,010 | 880 | 690 | | | |
| Sycamore (*Platanus occidentalis*) | Indiana, Tennessee | Green | 10 | 17 | | 83 | .46 | .54 | 52 | 14.2 | 5.1 | 7.6 | 3,300 | 6,500 | 1,060 | .60 | 7.5 | 15.9 | 8,800 | 3.3 | 26 | 2,400 | 2,920 | 450 | 700 | 610 | 1,000 | 330 | 630 |
| | | Dry | | | | 12 | .49 | | 34 | | | | 6,400 | 10,000 | 1,420 | 1.66 | 8.5 | 14.3 | 10,500 | 3.9 | 26 | 3,710 | 5,380 | 860 | 920 | 770 | 1,470 | 400 | 729 |
| Walnut, black (*Juglans nigra*) | Kentucky | Green | 5 | 12 | | 81 | .51 | .56 | 58 | 11.3 | 5.2 | 7.1 | 5,400 | 9,500 | 1,420 | 1.16 | 14.6 | 35.9 | 11,900 | 4.5 | 37 | 3,520 | 4,300 | 600 | 960 | 900 | 1,220 | 360 | 670 |
| | | Dry | | | | 12 | .55 | | 38 | | | | 10,500 | 14,600 | 1,680 | 3.70 | 10.7 | 17.9 | 16,400 | 6.2 | 34 | 5,750 | 7,580 | 1,250 | 1,050 | 1,010 | 1,370 | 330 | 690 |
| Walnut, little (*Juglans rupestris*) | Arizona | Green | 1 | | | 67 | .53 | .61 | 55 | 10.7 | 4.4 | 4.6 | 3,400 | 8,000 | 910 | .74 | 12.8 | 46.4 | 9,900 | 4.5 | 40 | | 3,020 | 700 | | | | | |
| | | Dry | | | | 12 | .57 | | 40 | | | | 8,200 | 14,200 | 1,480 | 2.60 | 11.7 | 14.3 | 11,100 | 4.3 | 21 | | 4,760 | | | | | | |
| Willow, black (*Salix nigra*) | Missouri, Wisconsin | Green | 10 | 5 | | 139 | .34 | .41 | 50 | 13.8 | 2.5 | 7.8 | 1,800 | 3,800 | 560 | .36 | 10.8 | 19.8 | 5,100 | 2.0 | 30 | 960 | 1,520 | 220 | 350 | 360 | 620 | 230 | 430 |
| | | Dry | | | | 12 | .37 | | 26 | | | | 3,900 | 5,200 | 720 | 1.94 | 7.9 | 11.1 | 7,700 | 3.6 | 20 | 2,020 | 3,420 | 480 | 550 | 450 | 1,250 | 290 | 460 |
| Willow, western black (*Salix lasiandra*) | Oregon | Green | 5 | 5 | | 105 | .39 | .47 | 50 | 13.8 | 2.9 | 9.0 | 3,100 | 5,000 | 1,020 | .58 | 10.8 | 27.6 | 7,000 | 2.5 | 33 | 1,810 | 2,340 | 330 | 490 | 500 | 870 | 210 | 360 |
| | | Dry | | | | 12 | .44 | | 31 | | | | 6,500 | 8,500 | 1,310 | 1.37 | 9.2 | 23.4 | 11,000 | 4.7 | 31 | 3,120 | 4,560 | 680 | 850 | 630 | 1,160 | 290 | 530 |
| Witchhazel (*Hamamelis virginiana*) | Tennessee | Green | 5 | 14 | | 70 | .56 | .71 | 50 | 18.8 | | | 5,000 | 8,300 | 1,110 | 1.29 | 19.5 | 56.8 | 12,400 | 6.3 | 40 | | 3,400 | 620 | 1,010 | 980 | 1,120 | | |
| | | Dry | | | | 12 | .61 | | 43 | | | | 9,100 | 15,200 | 1,460 | 3.17 | 21.0 | | | | | | 6,740 | 1,370 | 1,660 | 1,530 | | | |
| SOFTWOODS | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Cedar, Alaska (*Chamaecyparis nootkatensis*) | Alaska, Oregon | Green | 8 | 28 | | 38 | .42 | .46 | 30 | 9.2 | 2.8 | 6.0 | 3,800 | 6,400 | 1,140 | .77 | 9.2 | 26.2 | 9,100 | 3.2 | 27 | 2,500 | 3,050 | 430 | 540 | 440 | 840 | 170 | 330 |
| | | Dry | | | | 12 | .44 | | 31 | | | | 7,100 | 11,100 | 1,420 | 2.06 | 10.4 | 15.8 | 12,200 | 5.0 | 26 | 5,210 | 6,310 | 770 | 790 | 580 | 1,130 | 180 | 360 |
| Cedar, incense (*Libocedrus decurrens*) | Oregon, California | Green | [1] 4 | 17 | 30 | 108 | .35 | .37 | 45 | 7.6 | 3.3 | 5.2 | 3,900 | 6,200 | 840 | .94 | 6.4 | 8.8 | 7,300 | 2.4 | 17 | 2,940 | 3,150 | 460 | 570 | 390 | 830 | 160 | 280 |
| | | Dry | | | | 12 | .37 | | | | | | 5,900 | 8,000 | 1,040 | 1.47 | 5.4 | 8.2 | 9,600 | 3.9 | 17 | 4,760 | 5,200 | 730 | 880 | 470 | 880 | | 270 |
| Cedar, Port Orford (*Chamaecyparis lawsoniana*) | Oregon | Green | 14 | 23 | 34 | 43 | .40 | .44 | 30 | 10.1 | 4.6 | 6.9 | 4,000 | 6,200 | 1,420 | .65 | 7.4 | 22.8 | 9,200 | 3.0 | 22 | 2,770 | 3,130 | 350 | 460 | 400 | 830 | 100 | 180 |
| | | Dry | | | | 12 | .42 | | 29 | | | | 7,700 | 11,300 | 1,730 | 1.97 | 9.1 | 19.5 | 13,500 | 5.0 | 22 | 5,890 | 6,470 | 700 | 730 | [illegible] | 1,080 | 220 | 400 |
| Cedar, eastern red (*Juniperus virginiana*) | Vermont | Green | 5 | 12 | | 35 | .44 | .49 | 37 | 7.8 | 3.1 | 4.7 | 3,400 | 7,000 | 650 | 1.08 | 15.0 | 34.7 | 7,600 | 2.7 | 35 | 2,540 | 3,570 | 860 | 760 | 650 | 1,010 | 180 | 330 |
| | | Dry | | | | 12 | .47 | | 33 | | | | 3,800 | 8,800 | 880 | 1.01 | 8.3 | | 8,500 | 4.6 | 22 | | 6,020 | 1,140 | 900 | 790 | | 200 | |
| Cedar, southern red (*Juniperus* sp.) | Florida | Green | 5 | 13 | | 26 | .42 | .45 | 33 | 7.0 | 2.2 | 4.0 | 5,000 | 8,400 | 930 | 1.57 | 8.8 | 10.7 | 10,500 | 5.4 | 18 | 3,910 | 4,300 | 910 | 810 | 580 | 1,100 | 210 | 400 |
| | | Dry | | | | 12 | .44 | | 31 | | | | 7,300 | 9,400 | 1,170 | 1.88 | 6.4 | 6.6 | 10,200 | 4.3 | 17 | 5,190 | 6,570 | 1,000 | 1,010 | 610 | 750 | | |
| Cedar, western red (*Thuja plicata*) | Montana, Alaska, Washington | Green | 16 | 19 | 36 | 37 | .31 | .34 | 27 | 7.7 | 2.4 | 5.0 | 3,200 | 5,100 | 920 | .63 | 5.0 | 10.1 | 6,900 | 2.5 | 17 | 2,470 | 2,750 | 340 | 430 | 270 | 710 | 140 | 230 |
| | | Dry | | | | 12 | .33 | | 23 | | | | 5,300 | 7,700 | 1,120 | 1.44 | 5.8 | 10.5 | 8,600 | 3.2 | 17 | 4,300 | 5,020 | 610 | 680 | 350 | 860 | 130 | 220 |
| Cedar, northern white (*Thuja occidentalis*) | Wisconsin | Green | 5 | 23 | 30 | 55 | .29 | .32 | 28 | 7.0 | 2.1 | 4.7 | 2,600 | 4,200 | 640 | .60 | 5.7 | 8.9 | 5,300 | 2.0 | 15 | 1,400 | 1,990 | 290 | 320 | 230 | 620 | 140 | 240 |
| | | Dry | | | | 12 | .31 | | 22 | | | | 4,900 | 6,500 | 800 | 1.72 | 4.8 | 6.0 | 7,100 | 2.8 | 12 | 2,630 | 3,960 | 380 | 450 | 320 | 850 | 150 | 240 |
| Cedar, southern white (*Chamaecyparis thyoides*) | New Hampshire, North Carolina | Green | 10 | 16 | | 35 | .31 | .35 | 26 | 8.4 | 2.8 | 5.2 | 2,500 | 4,700 | 750 | .51 | 5.9 | 13.5 | 6,000 | 2.2 | 18 | 1,060 | 2,390 | 300 | 400 | 290 | 690 | 120 | 180 |
| | | Dry | | | | 12 | .32 | | 23 | | | | 4,600 | 6,800 | 920 | 1.46 | 4.1 | 5.2 | 7,600 | 3.0 | 13 | 2,740 | 4,700 | 500 | 570 | 350 | 800 | 130 | 270 |
| Cypress, southern (*Taxodium distichum*) | Louisiana, Missouri | Green | [1] 10 | 20 | 38 | 91 | .42 | .48 | 51 | 10.5 | 3.8 | 6.2 | 4,200 | 6,600 | 1,180 | .91 | 6.6 | 13.0 | 8,800 | 3.9 | 25 | 3,100 | 3,580 | 500 | 440 | 390 | 810 | 180 | 390 |
| | | Dry | | | | 12 | .46 | | 32 | | | | 7,200 | 10,600 | 1,440 | 2.15 | 8.2 | 11.9 | 10,400 | 3.9 | 24 | 4,470 | 6,360 | 900 | 680 | 510 | 1,000 | 170 | 270 |
| Douglas fir (coast type) (*Pseudotsuga taxifolia*) | Washington, Oregon, California | Green | [1] 30 | 14 | 36 | 36 | .45 | .51 | 38 | 11.8 | 5.0 | 7.8 | 4,800 | 7,600 | 1,550 | .85 | 6.8 | 19.2 | 9,800 | 3.2 | 24 | 3,410 | 3,890 | 510 | 510 | 480 | 930 | 160 | 240 |
| | | Dry | | | | 12 | .48 | | 34 | | | | 8,100 | 11,700 | 1,920 | 1.90 | 8.6 | 22.9 | 12,700 | 4.5 | 20 | 6,450 | 7,420 | 910 | 700 | 670 | 1,140 | 180 | 290 |
| Douglas fir (intermediate type) (*Pseudotsuga taxifolia*) | Montana, Idaho, California | Green | 15 | 16 | 34 | 48 | .41 | .47 | 38 | 11.2 | 4.2 | 7.4 | 3,860 | 6,800 | 1,350 | .63 | 6.6 | 13.1 | 8,700 | 2.7 | 22 | 2,570 | 3,300 | 480 | 510 | 450 | 840 | 190 | 300 |
| | | Dry | | | | 12 | .44 | | 31 | | | | 7,400 | 11,200 | 1,640 | 1.87 | 8.8 | 16.4 | 11,600 | 4.4 | 27 | 5,540 | 6,720 | 970 | 710 | 600 | 1,130 | 190 | 340 |
| Douglas fir (Rocky Mountain type) (*Pseudotsuga taxifolia*) | Wyoming, Montana | Green | 10 | 22 | 27 | 38 | .40 | .45 | 35 | 10.6 | 3.6 | 6.2 | 3,600 | 6,400 | 1,180 | .65 | 6.8 | 13.7 | 9,100 | 3.0 | 20 | 2,540 | 3,000 | 450 | 450 | 400 | 880 | 160 | 350 |
| | | Dry | | | | 12 | .43 | | 30 | | | | 6,300 | 9,600 | 1,460 | 1.49 | 6.4 | 11.3 | 12,100 | 4.9 | 26 | 4,560 | 6,060 | 870 | 740 | 630 | 1,070 | 160 | 330 |
| Fir, alpine (*Abies lasiocarpa*) | Colorado | Green | 5 | 15 | | 47 | .31 | .32 | 28 | 9.0 | 2.5 | 7.1 | 2,400 | 4,400 | 860 | .39 | 4.4 | 5.2 | 5,300 | 1.6 | 9 | 1,690 | 2,060 | 310 | 280 | 220 | 610 | 130 | |
| | | Dry | | | | 12 | .33 | | 23 | | | | | 7,100 | 900 | | 2.8 | 3.5 | 7,000 | 2.3 | 18 | 3,740 | 4,330 | 600 | 470 | 400 | 1,020 | 140 | |
| Fir, balsam (*Abies balsamea*) | Wisconsin | Green | 5 | 12 | 26 | 117 | .34 | .41 | 45 | 10.8 | 2.8 | 6.6 | 3,000 | 4,900 | 960 | .52 | 4.7 | 6.9 | 6,900 | 2.3 | 10 | 2,080 | 2,400 | 210 | 290 | 290 | 610 | 130 | 180 |
| | | Dry | | | | 12 | .36 | | 25 | | | | 5,200 | 7,000 | 1,230 | 1.29 | 5.1 | 10.6 | 7,600 | 2.6 | 20 | 3,870 | 4,530 | 380 | 510 | 400 | 710 | | 180 |
| Fir, corkbark (*Abies arizonica*) | New Mexico | Green | 10 | 14 | | 62 | .28 | .32 | 29 | 9.0 | 2.6 | 6.0 | 2,500 | 4,200 | 850 | .43 | 4.2 | 5.1 | 5,600 | 2.0 | 12 | 1,030 | 2,010 | 190 | 280 | 210 | 600 | 160 | 300 |
| | | Dry | | | | 12 | .30 | | 21 | | | | 4,500 | [illegible] | 1,030 | 1.00 | 4.5 | 5.3 | [illegible] | 2.7 | 13 | 3,820 | 4,110 | 470 | 470 | 290 | 840 | 170 | 250 |
| Fir, lowland white (*Abies grandis*) | Montana, Oregon | Green | 10 | 18 | 30 | 94 | .37 | .42 | 45 | 10.6 | 3.2 | 7.2 | 3,600 | 6,100 | 1,300 | .58 | 5.6 | 14.8 | [illegible] | 2.6 | 22 | 2,640 | 3,020 | 340 | 420 | 300 | 760 | 150 | 240 |
| | | Dry | | | | 12 | .40 | | 28 | | | | 5,800 | 9,300 | 1,630 | 1.22 | 7.5 | 24.9 | 12,000 | 4.6 | 28 | 4,420 | 5,430 | 630 | 660 | 410 | 930 | 190 | 240 |
| Fir, noble (*Abies nobilis*) | Oregon | Green | 9 | 16 | 28 | 36 | .35 | .40 | 30 | 12.5 | 4.5 | 8.3 | 3,600 | 5,800 | 1,270 | .61 | 6.0 | 14.3 | 8,600 | 2.9 | 19 | 2,420 | 2,740 | 340 | 330 | 290 | 750 | 160 | 230 |
| | | Dry | | | | 12 | .39 | | 28 | | | | 6,000 | 10,100 | 1,580 | 1.59 | 8.8 | 16.0 | 11,200 | 3.8 | 23 | 4,900 | 5,550 | 640 | 600 | 410 | 930 | 150 | 290 |
| Fir, California red (*Abies magnifica*) | California | Green | 5 | 11 | 39 | 108 | .37 | .42 | 48 | 11.8 | 3.8 | 6.9 | 4,100 | 6,000 | 1,060 | .95 | 6.7 | 12.0 | 8,600 | 2.8 | 22 | | 2,830 | 440 | 390 | 380 | 920 | 190 | 310 |
| | | Dry | | | | 12 | .39 | | 27 | | | | 7,900 | 11,200 | 1,590 | 1.99 | 9.5 | 14.3 | 13,000 | 4.3 | 23 | | 5,290 | 850 | 1,000 | 500 | 1,050 | 150 | 350 |
| Fir, silver (*Abies amabilis*) | Washington | Green | 6 | 12 | 26 | 66 | .35 | .42 | 36 | 14.1 | 4.5 | 10.0 | 3,500 | 5,700 | 1,260 | .60 | 6.0 | 12.6 | 7,800 | 2.2 | 21 | 2,380 | 2,670 | 290 | 360 | 310 | 670 | 160 | 240 |
| | | Dry | | | | 12 | .38 | | 30 | | | | 6,200 | 9,400 | 1,530 | 1.49 | 9.3 | 21.0 | 11,400 | 4.8 | 24 | 4,660 | 5,550 | 400 | 820 | 430 | 1,050 | 200 | |
| Fir, white (*Abies concolor*) | California, New Mexico | Green | 20 | 11 | 31 | 115 | .35 | .40 | 47 | 9.4 | 3.2 | 7.0 | 3,800 | 5,700 | 1,030 | .84 | 5.1 | 11.5 | 8,500 | 2.9 | 22 | 2,390 | 2,710 | 370 | 380 | 330 | 750 | 170 | 290 |
| | | Dry | | | | 12 | .37 | | 26 | | | | 6,500 | 9,300 | 1,380 | 1.72 | 6.7 | 11.4 | 10,800 | 4.1 | 17 | 3,590 | 5,350 | 600 | 720 | 440 | 930 | 190 | 290 |
| Hemlock, eastern (*Tsuga canadensis*) | Wisconsin, Tennessee, New Hampshire, Vermont | Green | 20 | 17 | 34 | 111 | .38 | .43 | 50 | 9.7 | 3.0 | 6.8 | 3,800 | 6,400 | 1,070 | .76 | 6.7 | 16.8 | 7,900 | 2.9 | 21 | 2,600 | 3,080 | 440 | 500 | 400 | 850 | 150 | 230 |
| | | Dry | | | | 13 | .40 | | 28 | | | | 6,100 | 8,900 | 1,200 | 1.79 | 6.8 | 11.5 | 10,700 | 4.6 | 21 | 4,020 | 5,410 | 850 | 810 | 500 | 1,000 | 150 | |
| Hemlock, mountain (*Tsuga mertensiana*) | Montana, Alaska | Green | 10 | 26 | 45 | 62 | .43 | .51 | 44 | 11.4 | 4.4 | 7.4 | 3,800 | 6,600 | 1,080 | .79 | 9.0 | 29.2 | 9,100 | 3.5 | 32 | 2,540 | 3,150 | 470 | 600 | 500 | 910 | 200 | 530 |
| | | Dry | | | | 12 | .47 | | 33 | | | | 7,400 | 11,300 | 1,320 | 2.36 | 8.6 | 14.0 | 13,300 | 5.8 | 33 | 4,020 | 6,840 | 1,030 | 1,170 | 740 | 1,230 | 170 | 320 |
| Hemlock, western (*Tsuga heterophylla*) | Washington, Alaska, Oregon | Green | 18 | 17 | 31 | 74 | .38 | .44 | 41 | 11.9 | 4.3 | 7.9 | 3,400 | 6,100 | 1,220 | .57 | 6.8 | 17.3 | 8,100 | 2.8 | 22 | 2,480 | 2,990 | 390 | 520 | 430 | 810 | 190 | 310 |
| | | Dry | | | | 12 | .42 | | 29 | | | | 6,800 | 10,100 | 1,490 | 1.82 | 7.5 | 15.3 | 12,400 | 5.4 | 26 | 5,340 | 6,210 | 680 | 840 | 580 | 1,170 | 200 | 310 |

[1] The averages for this species include data from tests representing an unknown number of trees in addition to the number indicated.

TABLE 1.—*Strength and related properties of woods grown in the United States*—Continued

| Species (common and botanical names) | Place of growth of material tested | Moisture condition | Trees tested | Rings per inch | Summer wood | Moisture content | Specific gravity, oven dry, based on volume—At test | Specific gravity, oven dry, based on volume—When oven-dry | Weight per cubic foot | Shrinkage from green to oven-dry condition based on dimensions when green—Volumetric | Shrinkage—Radial | Shrinkage—Tangential | Static bending—Stress at proportional limit | Static bending—Modulus of rupture | Static bending—Modulus of elasticity | Static bending—Work—Proportional limit | Static bending—Work—Maximum load | Static bending—Work—Total | Impact bending—Stress at proportional limit | Impact bending—Work to proportional limit | Impact bending—Height of drop causing complete failure (50-pound hammer) | Compression parallel to grain—Stress at proportional limit | Compression parallel to grain—Maximum crushing strength | Compression perpendicular to grain; stress at proportional limit | Hardness; load required to embed a 0.444-inch ball to ½ its diameter—End | Hardness—Side | Shear parallel to grain; maximum shearing strength | Cleavage; load to cause splitting | Tension perpendicular to grain; maximum tensile strength |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 | 28 | 29 | 30 |
| SOFTWOODS—continued | | | *Number* | *Number* | *Percent* | *Percent* | | | *Pounds* | *Percent* | *Percent* | *Percent* | *Lb. per sq. in.* | *Lb. per sq. in.* | *1,000 lb. per sq. in.* | *In.-lb. per cu. in.* | *In.-lb. per cu. in.* | *In.-lb. per cu. in.* | *Lb. per sq. in.* | *In.-lb. per cu. in.* | *Inches* | *Lb. per sq. in.* | *Lb. per sq. in.* | *Lb. per sq. in.* | *Pounds* | *Pounds* | *Lb. per sq. in.* | *Lb. per in. of width* | *Lb. per sq. in.* |
| Juniper, alligator (*Juniperus pachyphloea*) | Arizona | Green | 3 | ---- | ---- | 40 | 0.48 | 0.54 | 42 | 7.8 | 2.7 | 3.6 | 3,600 | 6,600 | 450 | 1.67 | 13.4 | 16.4 | 6,800 | 3.9 | 21 | 2,490 | 3,730 | 1,030 | 960 | 820 | 1,280 | ---- | ---- |
| | | Dry | ---- | ---- | ---- | 12 | .51 | ---- | 36 | ---- | ---- | ---- | 5,400 | 8,700 | 480 | 2.74 | 6.5 | ---- | 5,600 | 2.5 | 12 | ---- | 4,120 | 1,700 | 1,290 | 1,180 | ---- | ---- | ---- |
| Larch, western (*Larix occidentalis*) | Montana, Washington | Green | 13 | 32 | 37 | 58 | .48 | .59 | 48 | 13.2 | 4.2 | 8.1 | 4,000 | 7,500 | 1,350 | 1.01 | 7.1 | 18.2 | 9,400 | 3.7 | 24 | 3,250 | 3,800 | 560 | 470 | 450 | 920 | 160 | 230 |
| | | Dry | ---- | ---- | ---- | 12 | .52 | ---- | 36 | ---- | ---- | ---- | 7,940 | 11,900 | 1,710 | 2.46 | 8.0 | 18.5 | 14,100 | 7.3 | 32 | 5,950 | 7,490 | 1,060 | 1,110 | 790 | 1,300 | 180 | 210 |
| Pine, jack (*Pinus banksiana*) | Wisconsin | Green | 5 | 7 | 30 | 105 | .39 | .46 | 50 | 10.4 | 3.4 | 6.5 | 3,000 | 5,400 | 920 | .55 | 5.0 | 21.0 | 7,800 | 3.3 | 30 | 2,180 | 2,580 | 380 | 380 | 370 | 760 | 180 | 310 |
| | | Dry | ---- | ---- | ---- | 12 | .43 | ---- | 30 | ---- | ---- | ---- | 6,900 | 7,900 | 1,220 | 1.20 | 5.4 | 11.8 | 11,100 | 4.7 | 25 | ---- | 5,400 | 620 | 660 | 580 | 1,130 | [illegible] | [illegible] |
| Pine, jeffrey (*Pinus jeffreyi*) | California | Green | 5 | 18 | 23 | 101 | .37 | .42 | 47 | 9.9 | 4.4 | 6.7 | 3,200 | 5,000 | 980 | .60 | 4.7 | 14.7 | 7,200 | 2.6 | 21 | 2,050 | 2,370 | 350 | 320 | 340 | 690 | 160 | 260 |
| | | Dry | ---- | ---- | ---- | 12 | .40 | ---- | 28 | ---- | ---- | ---- | 7,200 | 9,300 | 1,240 | 2.43 | 6.6 | 11.4 | 17,400 | 5.3 | 27 | 4,240 | 5,530 | 720 | 610 | 500 | 1,210 | 210 | [illegible] |
| Pine, limber (*Pinus flexilis*) | New Mexico | Green | 2 | 14 | 24 | 68 | .37 | .42 | 39 | 8.2 | 2.4 | 5.1 | 3,900 | 5,200 | 800 | 1.08 | 5.2 | 8.3 | 7,100 | 2.0 | 18 | 1,850 | 2,410 | 320 | 300 | 310 | 740 | 170 | 270 |
| | | Dry | ---- | ---- | ---- | 12 | .40 | ---- | 28 | ---- | ---- | ---- | 6,600 | 9,100 | 1,170 | 2.12 | 6.8 | 8.7 | 11,400 | 5.2 | 19 | ---- | 5,290 | 730 | 510 | 450 | 800 | [illegible] | [illegible] |
| Pine, loblolly (*Pinus taeda*) | Florida, Maryland, North Carolina, South Carolina, Virginia. | Green | 56 | 9 | 34 | 81 | .47 | .54 | 53 | 12.3 | 4.8 | 7.4 | 4,100 | 7,300 | 1,410 | .68 | 8.2 | 24.2 | 8,900 | 3.0 | 30 | 2,550 | 3,490 | 480 | 420 | 450 | 850 | 180 | 260 |
| | | Dry | ---- | ---- | ---- | 12 | .51 | ---- | 36 | ---- | ---- | ---- | 7,800 | 12,800 | 1,800 | 1.92 | 10.4 | 17.5 | 13,100 | 4.2 | 30 | 4,820 | 7,060 | 960 | 750 | 690 | 1,370 | 270 | 470 |
| Pine, lodgepole (*Pinus contorta*) | Wyoming, Colorado, Montana | Green | 28 | 24 | 22 | 65 | .38 | .43 | 39 | 11.5 | 4.5 | 6.7 | 3,000 | 5,500 | 1,080 | .49 | 5.6 | 11.9 | 7,200 | 2.3 | 20 | 2,110 | 2,610 | 310 | 320 | 330 | 680 | 150 | 250 |
| | | Dry | ---- | ---- | ---- | 12 | .41 | ---- | 29 | ---- | ---- | ---- | 6,700 | 9,400 | 1,340 | 1.97 | 6.8 | 12.1 | 9,400 | 3.8 | 20 | 4,310 | 5,370 | 750 | 530 | 480 | 880 | 190 | 290 |
| Pine, longleaf (*Pinus palustris*) | Louisiana, Mississippi, Florida, South Carolina. | Green | [1] 44 | 14 | 39 | 63 | .54 | .62 | 55 | 12.2 | 5.1 | 7.5 | 5,200 | 8,700 | 1,600 | .95 | 8.9 | 32.4 | 10,100 | 3.2 | 35 | 3,430 | 4,300 | 590 | 550 | 590 | 1,040 | 210 | 330 |
| | | Dry | ---- | ---- | ---- | 12 | .58 | ---- | 41 | ---- | ---- | ---- | 9,300 | 14,700 | 1,990 | 2.44 | 11.8 | 21.0 | 15,400 | 6.1 | 34 | 6,150 | 8,440 | 1,190 | 920 | 870 | 1,500 | 270 | 470 |
| Pine, mountain (*Pinus pungens*) | Tennessee | Green | 5 | 15 | 20 | 75 | .49 | .55 | 54 | 10.9 | 3.4 | 6.8 | 4,500 | 7,500 | 1,270 | .94 | 8.1 | 25.2 | 10,200 | 3.8 | 29 | 2,980 | 3,540 | 560 | 480 | 490 | 900 | 200 | 320 |
| | | Dry | ---- | ---- | ---- | 12 | .52 | ---- | 36 | ---- | ---- | ---- | 7,900 | 11,600 | 1,550 | 2.30 | 8.7 | 15.8 | 14,200 | 6.4 | 29 | 4,200 | 6,830 | 1,210 | 720 | 660 | 1,200 | [illegible] | [illegible] |
| Pine, northern white (*Pinus strobus*) | Wisconsin, Minnesota, New Hampshire. | Green | [1] 15 | 13 | 29 | 68 | .34 | .37 | 36 | 8.2 | 2.3 | 6.0 | 3,100 | 5,000 | 1,020 | .54 | 5.2 | 10.8 | 6,700 | 2.2 | 17 | 2,060 | 2,490 | 290 | 310 | 310 | 660 | 140 | 240 |
| | | Dry | ---- | ---- | ---- | 12 | .36 | ---- | 25 | ---- | ---- | ---- | 6,000 | 8,600 | 1,280 | 1.50 | 6.7 | 10.5 | 9,500 | 2.7 | 19 | 3,680 | 4,840 | 550 | 500 | 400 | 900 | 180 | [illegible] |
| Pine, Norway (*Pinus resinosa*) | Wisconsin | Green | 5 | 22 | 41 | 54 | .44 | .51 | 42 | 11.5 | 4.0 | 7.2 | 3,700 | 6,400 | 1,320 | .59 | 5.8 | 28.4 | 7,500 | 2.2 | 28 | 2,410 | 3,080 | 380 | 360 | 340 | 780 | 160 | 190 |
| | | Dry | ---- | ---- | ---- | 12 | .48 | ---- | 34 | ---- | ---- | ---- | 9,400 | 12,500 | 1,800 | 2.78 | 10.0 | 16.9 | 15,900 | 6.8 | 25 | 5,330 | 7,340 | 630 | 670 | 580 | 1,220 | [illegible] | 400 |
| Pine, pitch (*Pinus rigida*) | Tennessee, Massachusetts | Green | 10 | 12 | 28 | 70 | .45 | .52 | 50 | 10.9 | 4.0 | 7.1 | 3,600 | 6,800 | 1,200 | .68 | 9.2 | 27.9 | 9,000 | 3.2 | 28 | 1,950 | 2,950 | 450 | 420 | 470 | 860 | 190 | 280 |
| | | Dry | ---- | ---- | ---- | 12 | .49 | ---- | 34 | ---- | ---- | ---- | 6,900 | 10,800 | 1,430 | 1.92 | 9.2 | 15.4 | 12,600 | 5.8 | 31 | 3,900 | 5,940 | 1,010 | 700 | 620 | 1,360 | [illegible] | 400 |
| Pine, pond (*Pinus rigida serotina*) | Florida | Green | 5 | 23 | 35 | 50 | .50 | .58 | 49 | 11.2 | 5.1 | 7.1 | 4,500 | 7,400 | 1,280 | .93 | 7.5 | 26.8 | 9,400 | 3.2 | 33 | 2,940 | 3,660 | 540 | 460 | 510 | 940 | 190 | 290 |
| | | Dry | ---- | ---- | ---- | 12 | .54 | ---- | 38 | ---- | ---- | ---- | 8,300 | 11,600 | 1,750 | 2.31 | 8.6 | 18.0 | 13,200 | 5.0 | 28 | 6,300 | 7,540 | 1,120 | 780 | 740 | 1,380 | 240 | 300 |
| Pine, ponderosa (*Pinus ponderosa*) | Colorado, Washington, Arizona, Montana, California. | Green | [1] 26 | 19 | 30 | 91 | .38 | .42 | 45 | 9.6 | 3.9 | 6.3 | 3,100 | 5,000 | 970 | .59 | 5.1 | 12.4 | 6,800 | 2.5 | 20 | 2,070 | 2,400 | 360 | 300 | 310 | 660 | 170 | 290 |
| | | Dry | ---- | ---- | ---- | 12 | .40 | ---- | 28 | ---- | ---- | ---- | 6,300 | 9,200 | 1,260 | 1.85 | 6.6 | 10.8 | 9,500 | 4.0 | 17 | 4,060 | 5,270 | 740 | 550 | 450 | 1,100 | 210 | 400 |
| Pine, sand (*Pinus clausa*) | Florida | Green | 5 | 7 | 30 | 36 | .45 | .51 | 38 | 10.0 | 3.9 | 7.3 | 4,100 | 7,500 | 1,020 | .95 | 9.6 | 20.0 | 9,800 | 4.6 | 25 | 2,670 | 3,440 | 560 | 460 | 480 | 1,140 | ---- | 380 |
| | | Dry | ---- | ---- | ---- | 12 | .48 | ---- | 34 | ---- | ---- | ---- | 6,700 | 11,600 | 1,410 | 1.82 | 9.6 | 17.4 | 12,400 | 5.4 | 18 | 3,900 | 6,920 | 1,030 | 650 | 730 | 1,100 | ---- | 700 |
| Pine, shortleaf (*Pinus echinata*) | Arkansas, Louisiana, North Carolina, New Jersey, Georgia. | Green | [1] 30 | 12 | 31 | 81 | .46 | .51 | 52 | 12.3 | 4.4 | 7.7 | 3,900 | 7,300 | 1,390 | .63 | 8.2 | 20.1 | 8,600 | 2.9 | 30 | 2,500 | 3,430 | 440 | 410 | 440 | 850 | 200 | 320 |
| | | Dry | ---- | ---- | ---- | 12 | .51 | ---- | 36 | ---- | ---- | ---- | 7,700 | 12,800 | 1,760 | 1.93 | 11.0 | 16.6 | 13,600 | 5.2 | 33 | 5,090 | 7,070 | 1,000 | 750 | 600 | 1,310 | 270 | 470 |
| Pine, slash (*Pinus caribaea*) | Florida, Louisiana | Green | 30 | 9 | 44 | 66 | .56 | .66 | 58 | 12.2 | 5.5 | 7.8 | 5,100 | 8,900 | 1,580 | 1.02 | 9.5 | 30.6 | 10,800 | 3.9 | 36 | 3,040 | 4,340 | 680 | 600 | 630 | 1,000 | 230 | 400 |
| | | Dry | ---- | ---- | ---- | 12 | .61 | ---- | 43 | ---- | ---- | ---- | 9,600 | 15,900 | 2,060 | 2.78 | 12.6 | 20.8 | 15,800 | 5.8 | 36 | 6,280 | 8,100 | 1,300 | 1,080 | 1,010 | 1,730 | 300 | 570 |
| Pine, sugar (*Pinus lambertiana*) | California | Green | 9 | 13 | 32 | 137 | .35 | .38 | 52 | 7.9 | 2.9 | 5.6 | 3,400 | 5,100 | 940 | .70 | 5.4 | 12.0 | 7,400 | 2.6 | 17 | 2,330 | 2,530 | 350 | 320 | 310 | 680 | 180 | 270 |
| | | Dry | ---- | ---- | ---- | 12 | .36 | ---- | 25 | ---- | ---- | ---- | 5,700 | 8,000 | 1,200 | 1.53 | 5.5 | 8.0 | 10,700 | 4.4 | 18 | 4,140 | 4,770 | 500 | 530 | 380 | 1,050 | 180 | 350 |
| Pine, western white (*Pinus monticola*) | Montana, Idaho | Green | [1] 5 | 20 | 33 | 54 | .36 | .42 | 35 | 11.8 | 2.6 | 5.3 | 3,400 | 5,200 | 1,170 | .56 | 5.0 | 17.9 | 7,600 | 2.6 | 19 | 2,430 | 2,650 | 290 | 310 | 310 | 640 | 160 | 260 |
| | | Dry | ---- | ---- | ---- | 12 | .38 | ---- | 27 | ---- | ---- | ---- | 6,200 | 9,500 | 1,510 | 1.47 | 8.8 | 14.1 | 11,900 | 4.5 | 23 | 4,450 | 5,620 | 540 | 440 | 370 | 850 | 180 | ---- |
| Piñon (*Pinus edulis*) | Arizona | Green | 3 | 17 | 22 | 63 | .50 | .57 | 51 | 9.9 | 4.6 | 5.2 | 2,600 | 4,800 | 650 | .61 | 7.0 | 23.0 | 8,200 | 4.2 | 21 | 1,810 | 2,590 | 480 | 510 | 600 | 920 | ---- | 460 |
| | | Dry | ---- | ---- | ---- | 12 | .53 | ---- | 37 | ---- | ---- | ---- | 5,500 | 7,800 | 1,140 | 1.84 | 4.7 | 6.1 | 8,500 | 3.0 | 12 | ---- | 5,400 | 1,530 | 930 | 800 | ---- | ---- | ---- |
| Redwood (virgin) (*Sequoia sempervirens*) | California | Green | 16 | 29 | ---- | 112 | .38 | .42 | 50 | 6.8 | 2.6 | 4.4 | 4,800 | 7,500 | 1,180 | 1.18 | 7.4 | 35.2 | 8,900 | 3.2 | 21 | 3,700 | 4,200 | 520 | 570 | 410 | 800 | 170 | 260 |
| | | Dry | ---- | ---- | ---- | 12 | .40 | ---- | 28 | ---- | ---- | ---- | 6,900 | 10,000 | 1,340 | 2.04 | 6.9 | 8.8 | 10,200 | 3.6 | 19 | 4,560 | 6,150 | 860 | 790 | 480 | 940 | 150 | 240 |
| Redwood (second growth, openly grown) (*Sequoia sempervirens*) | do | Green | 6 | 3 | ---- | 146 | .28 | .31 | 43 | 6.3 | 2.0 | 4.4 | 2,800 | 4,600 | 640 | .68 | 5.1 | 6.3 | 5,900 | 2.3 | 14 | 1,810 | 2,320 | 310 | 390 | 280 | 640 | 160 | 260 |
| | | Dry | ---- | ---- | ---- | 12 | .30 | ---- | 21 | ---- | ---- | ---- | 4,200 | 6,400 | 780 | 1.35 | 4.7 | 4.9 | 6,640 | 2.7 | 11 | 2,860 | 3,810 | 550 | 500 | 340 | 582 | 150 | 240 |
| Redwood (second growth, closely grown) (*Sequoia sempervirens*) | do | Green | 8 | 7 | ---- | 112 | .32 | .36 | 42 | 7.4 | 2.4 | 5.0 | 3,600 | 6,100 | 1,000 | .73 | 6.1 | 10.9 | 7,200 | 2.5 | 18 | 2,840 | 3,280 | 350 | 470 | 350 | 730 | 160 | 290 |
| | | Dry | ---- | ---- | ---- | 12 | .34 | ---- | 24 | ---- | ---- | ---- | 5,500 | 8,900 | 1,120 | 1.30 | 5.7 | 7.9 | 9,100 | 3.2 | 16 | 3,750 | 5,240 | 540 | 710 | 400 | 900 | 180 | 300 |
| Spruce, black (*Picea mariana*) | New Hampshire | Green | 5 | 15 | ---- | 33 | .38 | .43 | 32 | 11.3 | 4.1 | 6.8 | 2,900 | 5,400 | 1,060 | .45 | 7.4 | 20.4 | 6,800 | 1.8 | 24 | 1,540 | 2,570 | 180 | 430 | 370 | 630 | 120 | 100 |
| | | Dry | ---- | ---- | ---- | 12 | .40 | ---- | 28 | ---- | ---- | ---- | 5,900 | 10,300 | 1,530 | 1.26 | 10.5 | 21.4 | 12,400 | 6.2 | 23 | 4,520 | 5,320 | 450 | 700 | 520 | 1,000 | 150 | ---- |
| Spruce, Engelmann (*Picea engelmanni*) | Colorado | Green | 10 | 14 | 35 | 100 | .31 | .35 | 39 | 10.4 | 3.4 | 6.6 | 2,500 | 4,200 | 830 | .43 | 4.9 | 6.2 | 5,800 | 1.9 | 14 | 1,680 | 1,980 | 290 | 250 | 240 | 590 | 130 | ---- |
| | | Dry | ---- | ---- | ---- | 12 | .33 | ---- | 23 | ---- | ---- | ---- | 6,000 | 8,500 | 1,160 | 1.84 | 5.6 | 7.5 | 9,000 | 2.5 | 15 | 3,580 | 4,550 | 440 | 450 | 310 | 1,010 | 200 | ---- |
| Spruce, red (*Picea rubra*) | Tennessee, New Hampshire | Green | 11 | 18 | 28 | 43 | .38 | .41 | 34 | 11.8 | 3.8 | 7.8 | 3,400 | 5,800 | 1,190 | .58 | 6.9 | 16.2 | 7,200 | 2.3 | 18 | 2,360 | 2,650 | 340 | 410 | 350 | 760 | 150 | 220 |
| | | Dry | ---- | ---- | ---- | 12 | .41 | ---- | 28 | ---- | ---- | ---- | 6,600 | 10,200 | 1,530 | 1.72 | 8.4 | 12.4 | 11,900 | 4.6 | 18 | 4,610 | 5,890 | 560 | 660 | 490 | 1,060 | 150 | 350 |
| Spruce, Sitka (*Picea sitchensis*) | Washington, Alaska, Oregon | Green | 25 | 15 | 35 | 42 | .37 | .42 | 33 | 11.5 | 4.3 | 7.5 | 3,300 | 5,700 | 1,230 | .53 | 6.3 | 18.3 | 8,400 | 3.0 | 24 | 2,240 | 2,670 | 340 | 430 | 350 | 760 | 150 | 250 |
| | | Dry | ---- | ---- | ---- | 12 | .40 | ---- | 28 | ---- | ---- | ---- | 6,700 | 10,200 | 1,570 | 1.63 | 8.3 | 17.2 | 11,420 | 4.2 | 25 | 4,780 | 5,610 | 710 | 700 | 510 | 1,150 | 210 | 370 |
| Spruce, white (*Picea glauca*) | New Hampshire, Alaska, Wisconsin. | Green | [1] 10 | 17 | 26 | 50 | .37 | .45 | 35 | 13.7 | 4.7 | 8.2 | 3,300 | 5,600 | 1,070 | .60 | 6.0 | 16.8 | 7,100 | 2.3 | 22 | 2,130 | 2,570 | 290 | 350 | 320 | 690 | 140 | 220 |
| | | Dry | ---- | ---- | ---- | 12 | .40 | ---- | 28 | ---- | ---- | ---- | 6,600 | 9,800 | 1,340 | 1.76 | 7.7 | 14.8 | 10,200 | 3.5 | 20 | 3,700 | 5,470 | 510 | 570 | 480 | 1,000 | 200 | 300 |
| Tamarack (*Larix laricina*) | Wisconsin | Green | 5 | 20 | 38 | 52 | .49 | .56 | 47 | 13.6 | 3.7 | 7.4 | 4,200 | 7,200 | 1,240 | .84 | 7.2 | 28.8 | 7,600 | 2.7 | 28 | 2,930 | 3,480 | 460 | 400 | 380 | 860 | 160 | 260 |
| | | Dry | ---- | ---- | ---- | 12 | .53 | ---- | 37 | ---- | ---- | ---- | 8,000 | 11,600 | 1,640 | 2.19 | 7.1 | 15.1 | 12,500 | 5.4 | 23 | 4,780 | 7,160 | 990 | 670 | 590 | 1,280 | 230 | 400 |
| Yew, Pacific (*Taxus brevifolia*) | Washington | Green | 5 | 27 | ---- | 44 | .60 | .67 | 54 | 9.7 | 4.0 | 5.4 | 6,500 | 10,100 | 990 | 2.46 | 20.2 | 54.3 | 13,100 | 6.2 | 37 | 3,440 | 4,650 | 1,040 | 1,340 | 1,150 | 1,620 | 250 | 450 |
| | | Dry | ---- | ---- | ---- | 12 | .62 | ---- | 44 | ---- | ---- | ---- | 9,800 | 15,200 | 1,350 | 3.59 | 19.7 | 31.1 | 12,100 | 5.5 | 31 | 4,750 | 8,100 | 2,110 | 2,020 | 1,600 | 2,230 | 300 | ---- |

[1] The averages for this species include data from tests representing an unknown number of trees in addition to the number indicated.

## COMMON AND BOTANICAL NAMES OF SPECIES (COLUMN 1)

For convenience, the species listed in table 1 are grouped in two major classifications:

(1) Hardwoods, or trees with broad leaves, usually deciduous; (2) softwoods, or trees with needle or scalelike leaves, usually evergreen and most of them cone-bearing. The two groups are also known as hardwoods and conifers. The terms "hardwoods" and "softwoods" are thus indicative of botanical classification. They are not correlated with the actual hardness or softness of the wood. For example, basswood, poplar, aspen, and cottonwood are classified as hardwoods but are in reality among the softest of native woods, whereas longleaf pine, classed as a softwood, is quite hard.

Avoidance of confusion requires a standard nomenclature for species of wood many of which are known by several common names and to several of which a single common name is often applied. The United States Forest Service has adopted such a nomenclature, designating each species by a single common name, in addition to a botanical name about which confusion rarely exists. The official names are used herein and are those given in Check List of the Forest Trees of the United States, their Names and Ranges, except for a few subsequent changes. Page 92 shows the relation between this nomenclature and commercial lumber names (*46*, *54*).

## PLACE OF GROWTH OF MATERIAL TESTED (COLUMN 2)

In the second column are listed the States from which the trees furnishing the test specimens were obtained. The locality of growth has in some instances an influence on the strength of timber (p. 43). That this influence is, however, frequently overestimated is indicated by the fact that fully as great differences have been found between stands of different character grown in the same section of the country as between stands grown in widely separated regions within the normal range of growth. For this reason it is considered better to average together the test data on material from the various localities. However, there is a distinct difference in the properties of Douglas fir from the more arid Rocky Mountain region and those of the Douglas fir from the Pacific Northwest. Further, Douglas fir from the so-called "Inland Empire"[4] region is found to be intermediate in its characteristics between that from the arid Rocky Mountain region and that from the Pacific Northwest. For these reasons separate averages are given for Douglas fir from the Pacific coast, intermediate type, and the Rocky Mountain regions.

## MOISTURE CONDITION (COLUMN 3)

Both green and dry material were tested. The resulting data are entered in lines designated "green" and "dry", respectively, in column 3.

Values in the first of each pair of lines beginning with column 3 of table 1 are from tests on green material. Although the moisture content varies among the different species, all tests on green wood were made at approximately the moisture content of the living tree,

[4] Northwestern Montana, Idaho north of the Salmon River, Washington east of the Cascade Mountains, and the northeastern tip of Oregon.

which is above the limit [5] below which differences in moisture content affect the strength properties.

The strength of dry or partially dry wood depends greatly on the particular stage of dryness and on the distribution of the moisture. Values pertaining to a uniformly distributed moisture content of 12 percent are listed in the second of each pair of lines beginning with column 3. These values were obtained by adjusting values obtained from tests made at various moisture contents. The moisture basis adopted (12 percent) represents an average air-dry condition attained without artificial heat by thoroughly seasoned wood over a considerable portion of the United States, including the Lake States region.

Table 1 shows that in most strength properties the dry material in the form of small, clear specimens excels the green. In large timbers, however, the increased strength of the wood fibers is usually offset by checks and other defects resulting from drying, so that as large increases in strength values as in small specimens cannot be expected.

Except where data on dry material are specifically required, or where significant differences in increase with seasoning is involved, the data on green material are preferable for comparing species, because they are based on a larger number of tests.

### NUMBER OF TREES TESTED (COLUMN 4)

The number of trees from which specimens were obtained is stated in the fourth column of table 1. The average values for the more important species represent groups of trees from different localities. Five trees of a species were selected, as a rule, from a single locality.

### NUMBER OF RINGS PER INCH (COLUMN 5)

The number of rings per inch measures the rate of growth in diameter or radius of the trees from which the test specimens were cut. Rings per inch were counted along a radial line on the end section of each specimen. One ring, consisting of a band of spring wood and a band of summer wood, is formed during each year. Few rings per inch indicate fast growth, and conversely.

Rate of growth of many species is quite variable, and the values listed are to be regarded mainly as averages of the material tested. Rate of growth does not have a definite relation to strength in the sense of strength being proportional, either directly in inversely, to the rate of growth (p. 44).

### SUMMER WOOD (COLUMN 6)

Column 6 shows the proportion of summer wood in the material tested, as measured along a representative radial line. Summer wood is usually much denser than spring wood [6] of the same species so that within a species the proportion of summer wood is indicative

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[5] Green wood contains "absorbed", or "imbibed", water within the cell walls and "free" water in the cell cavities. The free water from the cell cavities is the first to be evaporated in drying. The fiber-saturation point is that point at which no water exists in the cell cavities of the timber but at which the cell walls are still saturated with moisture. The fiber-saturation point varies with the species (*15*). The ordinary proportion of moisture—based on the weight of the dry wood—at the fiber-saturation point is about 30 percent. Most strength properties of wood begin to increase, and shrinkage begins to occur, when the fiber-saturation point is reached in seasoning.

[6] Numerous determinations have shown that in the southern pines specific gravity of the summer wood is usually from 2 to 3 times as great as that of the spring wood.

of the specific gravity, and hence, of strength. It is difficult to measure the proportion of summer wood accurately and when the change from spring wood to summer wood is not marked or the contrast between them is not sharp, as in many species, the difficulty is even greater. For this reason the proportion of summer wood is given for only part of the species tested.

Summer wood is unusually well differentiated from spring wood in the southern yellow pines and Douglas fir. Some of the structural grading rules for these species involve, among other features, the selection of pieces showing one-third or more summer wood, such material being awarded as a premium higher working stresses (*54, 61*).

## MOISTURE CONTENT (COLUMN 7)

Moisture content is the weight of water contained in the wood, expressed as a percentage of the weight of the oven-dry wood. Since it is thus expressed it is useful to remember that with a given moisture content in percent a block of wood of a given size contains more weight or volume of water if the wood is heavy than if it is light. Moisture content is commonly determined by weighing a sample and then drying it at 212° F. (100° C.) until the weight becomes constant. The loss of weight divided by the weight of the oven-dry wood is the proportion of moisture in the piece. "Moisture" as thus determined is subject to some inaccuracy, because the loss in weight includes that of any substances other than moisture that evaporate at 100° C. Also some constituents other than actual wood substance are not evaporated. Errors from these sources are not sufficient to affect the practical application of the data given in column 7.

The moisture content listed in table 1 for green material is the average for specimens taken from the pith to the circumference of the log. Hence it represents a combination of the moisture as found in the heartwood and in the sapwood, although not in proportion to the amount of wood represented by each. In each instance 12 percent is entered as the moisture content of "dry" material, because the data have all been adjusted to this basis.

As shown by table 1, the average moisture content of the green wood varies widely among species. Also moisture content often differs between heartwood and sapwood of the same species and in some instances varies with height in the tree. Many coniferous species have a large proportion of moisture in the sapwood and much less in the heartwood. Most hardwoods on the other hand show much more nearly the same moisture content in heartwood and sapwood (p. 29). Extreme limits observed in the moisture content of green wood range from as low as 30 to 40 percent in the heartwood of such species as black locust, white ash, Douglas fir, southern pines, and various cedars to about 200 percent in the sapwood of some coniferous species. In the heartwood of some species the moisture content is high at the base of the tree and becomes less toward the top. For example, in green redwood trees examined at the Forest Products Laboratory, the heartwood decreased in average moisture content from 160 percent at stump height to 60 percent at heights above 100 feet. In this instance the sapwood increased slightly in percentage moisture with height in tree.

## SPECIFIC GRAVITY (COLUMNS 8 AND 9)

Specific gravity is the relation of the weight of a substance to that of an equal volume of water.

The volume occupied by a specified weight of wood substance changes with the shrinking and swelling caused by changes in moisture content. In table 1, three values of specific gravity are given for each species. They correspond to volumes when green, at 12-percent moisture, and oven-dry, and each is based on the weight of the wood when oven-dry. The number of pounds of wood (exclusive of moisture) in a cubic foot at either of the three moisture conditions may be found by multiplying the specific gravity figure by 62.4. To get the weight per cubic foot of the wood plus that of the associated water, multiply by the factor:

$$1+\frac{\text{percentage moisture content}}{100}$$

Additional data on the specific gravity of a number of species are presented on page 30. For some species these data are more extensive than those of table 1.

### SPECIFIC GRAVITY BASED ON VOLUME WHEN GREEN (COLUMN 8)

Values of specific gravity, based on weight when oven-dry and volume when green, are determined from weights and measurements of specimens tested when green. The weight when oven-dry is computed by dividing the weight when green by 1 plus the proportion of moisture, as found from a moisture determination on the same specimen.

The specific-gravity values based on volume when green, as listed in column 8, are averages of determinations made on each green test specimen. The number of determinations is much larger in most instances than those of specific gravity based on volume when air-dry or when oven-dry.

### SPECIFIC GRAVITY BASED ON VOLUME WHEN AIR-DRY (COLUMN 8)

Specific gravity based on volume when air-dry is found in the same manner as that based on volume when green, except that the volume measurements are made on air-dry material. The values for air-dry wood listed in column 8 are adjusted to a volume basis corresponding to 12-percent moisture content.

### SPECIFIC GRAVITY BASED ON VOLUME WHEN OVEN-DRY (COLUMN 9)

In determining the specific gravity based on volume when oven-dry, the volume as well as the weight is taken after the specimens are oven-dried to practically constant weight at 100° C.

Specific gravity, as listed in column 9, and shrinkage in volume, as listed in column 11, were determined on the same specimens of which there were usually 4 to 6 from a tree.

The difference between specific gravity based on volume when green and that on volume when air-dry or oven-dry, is due to shrinkage, and either specific gravity may be determined from the other if the corresponding shrinkage in volume is known. For example, specific gravity based on weight and volume when oven-dry equals specific gravity based on weight when oven-dry and volume when green divided by

$$\left(1-\frac{\text{percent volumetric shrinkage}}{100}\right)$$

As the determinations of specific gravity, based on volume when oven-dry, and of volumetric shrinkage were made on only a few specimens from each bolt, they are not related to specific gravity based on weight when oven-dry and volume when green in exact accordance with this equation.

### WEIGHT PER CUBIC FOOT (COLUMN 10)

Changes in moisture content affect the weight of a piece of wood. When the moisture content is below the value at the fiber-saturation point (p. 48), changes in the moisture content also affect the volume of the piece. Consequently, in order to be specific in stating weight per cubic foot, various degrees of dryness must be recognized.

Green or freshly cut wood, contains, as shown in column 7, a considerable proportion of water. After being dried by exposure to the air until the weight is practically constant, wood is said to be "air-dry." If dried in an oven at 212° F. (100° C.) until all moisture is driven off, wood is "oven-dry."

The weights per cubic foot presented in table 1 are based on weights and volumes of small, clear specimens taken usually from the top 4 feet of 16-foot butt logs of typical trees. Because the wood from such portions is often heavier than that from higher in the tree, material thus selected averages slightly heavier than the wood in ordinary timbers, poles, posts, or railway ties.

#### WEIGHT PER CUBIC FOOT WHEN GREEN

The value for green wood as given in column 10 includes the moisture in the wood as received at the laboratory, and because protection from seasoning was afforded during transit and pending test, it represents closely the weight of the wood as it comes from the living tree. The weight when green is based on the average of heartwood and sapwood pieces as represented by test specimens taken from pith to circumference. In those species which have a higher moisture content in the sapwood, variations in the proportion of sapwood are accompanied by comparatively large variations in weight per cubic foot of green material.

The weights per cubic foot in column 10 correspond to the average moisture-content values listed in column 7. When in specific instances there are large differences in moisture content between heartwood and sapwood and the proportion of sapwood in logs or other products is known, better estimates of the weight per cubic foot when green may be obtained by correcting the value given in column 7 to a suitable moisture content. For example, the weight and moisture content of ponderosa pine are given in table 1 as 45 pounds per cubic foot and 91 percent, respectively. The average moisture content of ponderosa pine logs having 75 percent sapwood by volume is computed on page 30 as 121 percent. The estimated weight of such logs is then

$$45\left(\frac{100+121}{100+91}\right)=51\tfrac{3}{4}\text{ pounds per cubic foot.}$$

### WEIGHT PER CUBIC FOOT WHEN AIR-DRY

Weight per cubic foot depends upon the amount of moisture in the wood which in turn depends on the species, the size and form of the pieces, the length of the seasoning period, and on the rapidity of seasoning as governed by the climate. The average air-dry condition reached in the northern Central States by wood that is sheltered from rain and snow and not artificially heated, is a moisture content of about 12 percent. The values for dry wood in column 10 apply to this moisture content. The moisture content of thoroughly air-dry wood may be 3 to 5 percent higher in humid regions, and in very dry climates, as much lower. It also varies slightly from day to day because of changes in temperature and atmospheric humidity. Large timbers will have a slightly higher average moisture content when thoroughly air-dry than small pieces. Species vary in the rate at which they give off moisture in drying, and also in the rate at which they take up moisture during periods of wet or damp weather.

Changes of several percent in the moisture content of dry wood cause only small changes in the weight per cubic foot, because of two actions which tend to counteract one another. The weight decreases as drying takes place because of the loss of moisture. At the same time shrinkage reduces the volume. Conversely, both weight and volume increase as moisture is absorbed.

Weight per cubic foot at a moisture content near 12 percent may be estimated from that at 12 percent by assuming that one-half percent increase or decrease in weight accompanies an increase or decrease of 1 percent in moisture content. Thus, raising the moisture content from 12 to 14 percent increases the weight per cubic foot about 1 percent and in drying from 12- down to 8-percent moisture content the weight per cubic foot is reduced about 2 percent.

### SHRINKAGE (COLUMNS 11, 12, AND 13)

Shrinkage across the grain (in width and thickness) results when wood loses some of the absorbed moisture (pp. 6, 48). Conversely, swelling occurs when dry or partially dry wood is soaked or when it takes moisture from the air or other source. Shrinkage and swelling in the direction of the grain (length) of normal wood is only a small fraction of 1 percent and is too small to be of practical importance in most uses of wood.[7] All shrinkages are expressed as percentages of the original or green dimensions.

Column 11 lists for the various species the shrinkage in volume from the green to the oven-dry condition. The values are averages from actual volume determinations on small specimens.

In columns 12 and 13 are average values of the measured radial and tangential shrinkages in drying standard specimens from the green to the oven-dry condition. Radial shrinkage is that across the annual growth rings as in the width of a quarter-sawed board. Tangential shrinkage is that approximately parallel to the annual-growth rings as in the width of a flat-sawed board.

The shrinkage of any piece of wood depends on numerous factors, some of which have not been thoroughly studied. In all species listed in table 1 the radial shrinkage is less than the tangential. Hence,

[7] Appreciable longitudinal shrinkage is associated with "compression wood", and other abnormal wood structure (p. 72).

quarter-sawed (edge-grained) boards shrink less in width but more in thickness than flat-sawed boards. The smaller the ratio of radial to tangential shrinkage for a species, the greater is the advantage to be gained through minimizing shrinkage in width by using quarter-sawed wood. Also, the less the difference between radial and tangential shrinkage, the less ordinarily is the tendency of the wood to check in drying and to cup when its moisture content changes.

Air-dry wood takes on or gives off moisture with each change in weather or heating conditions. The fact that time is required for these moisture changes, causes a lag between atmospheric changes and their full effect on the moisture condition of the wood. The lag is greater in some species than in others, greater in heartwood than in sapwood, and is much less in small than in large pieces. It is increased by protective coatings such as paint, enamel, or varnish. Some species whose shrinkage from the green to the oven-dry condition is large cause less inconvenience in use than woods with lower total shrinkage, because their moisture content does not respond to atmospheric changes so closely. The shrinkage figures given do not take into account the readiness with which the species take on and give off moisture, and therefore should be considered as the relative shrinkage between woods after long exposure to fairly uniform atmospheric conditions or with the same change in moisture content.

The values listed in columns 11, 12, and 13 are shrinkages from the green to the oven-dry condition and thus are much greater than ordinarily occur in the seasoning of wood or with changes in moisture content subsequent to seasoning. About half the listed value represents the shrinkage from green to the average air-dry condition of 12 to 15 percent moisture. A change in moisture content of dry material by 1 percent may be expected to produce a percentage shrinkage or swelling of about one twenty-fifth of the value listed in columns 11, 12, or 13.

## MECHANICAL PROPERTIES (COLUMNS 14 TO 30)

Columns 14 to 30 inclusive list the average values obtained from tests made according to the standardized procedure (pp. 4, 78). For convenience and ease of reference, each of the column headings is discussed independently in the order in which it appears in the table. The reliability of the averages and the significance of differences between species is discussed in a later section on variability. Appreciation of the significance of the values and of how they should be modified to apply to conditions of use differing from those under which the tests were made will be enhanced by study of later discussions, particularly those on form factors and effect of duration of stress. Modifications to make them applicable to material affected by various types of defects are indicated by the discussion of factors affecting strength.

## STRESS AT PROPORTIONAL LIMIT, STATIC BENDING (COLUMN 14)

The proportional limit in any test is the limit of proportionality between load (or stress) and deformation (or strain). When load is increased by a given percentage without passing this limit, deformation increases by the same percentage. With an increase in load beyond the proportional-limit value, deformation increases by a greater percentage than the load. Both these facts are illustrated by the load-deflection graph shown on page 80.

In accordance with current practice (*3*) in the field of testing materials this bulletin uses "proportional limit", instead of "elastic limit", as used in previous Forest Service publications, to designate the limit of proportionality between stress and strain or between load and deformation.

The determination of the proportional limit in any test is subject to uncertainty because it is somewhat dependent on the increments of load and deflection used in testing and on personal judgment in locating the point of departure from the straight-line relation in such a diagram as shown on page 80. Values of load and deformation at proportional limit for wooden members depend on the rate at which the load is increased and on the length of time it acts on the member. This is illustrated by the fact that stress and deformation at proportional limit are much greater in impact bending, in which the specimen is subjected to instantaneous shocks, than in static bending in which the load increases at a moderate rate.

Because a piece stressed within the proportional limit recovers from its deformation on removal of the load and release of the piece from stress, the proportional limit is sometimes called the elastic limit.

Tests have demonstrated that loads in bending or in compression parallel to grain that exceed the proportional-limit values as found from tests made at the standard speeds (*4*) will ultimately cause failure if they continue to act on a wooden member. Thus, these proportional-limit values of stress are upper limits to the stresses that can be used in the design of permanent structures. In determining safe working stresses, factors of safety must be applied to average values of stress at proportional limit in order to allow for variations below the average and to provide for the contingency that the member will be loaded more heavily than was assumed in its design. The effects of duration and repetition of stress are discussed on page 59.

Stress at proportional limit in static bending (column 14) is the stress that exists in the top and bottom fibers of a beam at the proportional limit load. It is in general applicable to clear beams of rectangular cross section, although a slight adjustment is necessary to adapt values from the standard 2- by 2-inch specimen to pieces of other sizes. In estimating the strength of beams of special forms, such as **I**, circular, box, or diamond-shaped cross sections, on the basis of the data derived from square specimens as presented herein, the effect of the shape and proportions of the section (p. 63) must be considered.

## MODULUS OF RUPTURE, STATIC BENDING (COLUMN 15)

Modulus of rupture is the computed stress in the top and bottom 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 short time. The formula by which it is computed is based on assumptions that are valid only to the proportional limit, hence modulus of rupture is not a true stress. It is, however, a widely accepted term and values for various species are quite comparable.

Since the modulus of rupture is based on the maximum load, which is directly determinable, it is less influenced by personal and other factors than proportional limit values.

The modulus-of-rupture values are used to compare the bending strengths of different species, and in conjunction with the results of tests on timbers containing defects to determine safe working stresses for structural timbers.

Like stress at proportional limit, modulus of rupture as found from the standard 2- by 2-inch specimens requires some modification to adapt it to square or rectangular beams of other sizes or to make it applicable to beams of I, circular, box, or diamond-shaped cross section (p. 63).

## MODULUS OF ELASTICITY, STATIC BENDING (COLUMN 16)

Modulus of elasticity is a measure of the stiffness or rigidity of a material. The deflection of a beam under load varies inversely as the modulus of elasticity; that is, the higher the modulus the less the deflection. Modulus of elasticity is useful for computing the deflections of joists, beams, and stringers under loads that do not cause stress beyond the proportional limit. It is also used in computing the load that can be carried by a long column, because for such columns the load depends on the stiffness, and not on the crushing strength of the wood parallel to the grain.

Some of the deflection that occurs in the bending of a wooden beam is due to shear distortion, the amount varying with the proportions of the piece and the placement of the load. About one-tenth of the deformation measured in tests of the standard bending specimen is due to shearing distortion. The true moduli of elasticity are consequently about 10 percent higher than the values in column 16.

## WORK TO PROPORTIONAL LIMIT, STATIC BENDING (COLUMN 17)

Work to proportional limit in static bending, as the name implies, is a measure of the energy that the beam absorbs in being stressed to the proportional limit. Since work is the product of average force times the distance moved, work to proportional limit involves both the load and the deflection at the proportional limit.

Values of work to proportional limit may be used to compare the ability of different species to withstand a combination of high load and high deflection without appreciable injury. Hence, they measure the toughness of a piece to the elastic limit. It is a comparative property only and cannot be used directly like modulus of rupture in strength calculations.

## WORK TO MAXIMUM LOAD, STATIC BENDING (COLUMN 18)

Work to maximum load in static bending represents the capacity of the timber to absorb shocks that cause stress beyond the proportional limit and are great enough to cause some permanent deformation and more or less injury to the timber. It is a measure of the combined strength and toughness of a material under bending stresses. Superiority in this quality makes hickory better than ash, and oak better than longleaf pine for such uses as handles and vehicle parts subjected to shock. Work to maximum load is closely related to height of drop in impact bending as a measure of shock resistance.

Work-to-maximum-load values cannot be used directly in design, but, like many others, their usefulness is limited to comparisons.

## TOTAL WORK, STATIC BENDING (COLUMN 19)

Total work in static bending is a measure of the toughness under bending stresses that cause complete failure. Like work to maximum load, it is a measure of that quality which makes hickory a superior wood for handles, and other uses involving shock resistance. It is also indicative of the same quality as is measured by height of drop in impact bending.

## STRESS AT PROPORTIONAL LIMIT, IMPACT BENDING (COLUMN 20)

The stress at proportional limit is the computed stress in the top and bottom fibers of the beam at the proportional limit (pp. 11, 84). The stress at proportional limit averages approximately twice as great in impact as in static bending. It is mainly of use in comparing species with respect to their elastic behavior under impact loads. Stress at proportional limit is the only stress computed from the standard-impact-bending test.

It is impossible from the measurements made in this test to find the maximum force between the hammer and the specimen or to compute a maximum stress value analogous to modulus of rupture in static bending. That such a value would, if determined, be considerably higher than modulus of rupture is demonstrated by the fact that stress at proportional limit in impact averages somewhat higher than modulus of rupture. In a few tests in which specimens were broken by a single impact and the maximum force acting on the specimen found from records of the deceleration of the hammer, the computed maximum stress was approximately 75 percent higher than modulus of rupture of similar specimens tested in static bending (*58*).

## WORK TO PROPORTIONAL LIMIT, IMPACT BENDING (COLUMN 21)

The work to proportional limit in impact bending is a measure of the energy that the beam absorbs in being stressed to the proportional limit. It involves both the deflection and the stress at proportional limit. Work to proportional limit is used to compare the ability of a timber to absorb shock and recover promptly without injury. It represents a quality important in such products as tool handles or tennis rackets. The values apply only to the resistance to falling bodies or like conditions in which the stress is applied and removed in a fraction of a second.

## HEIGHT OF DROP OF HAMMER, IMPACT BENDING (COLUMN 22)

The height of drop of the hammer in impact bending is the height from which the 50-pound hammer is finally dropped to cause complete failure of the standard test specimen. It is a comparative figure expressing the ability of wood to absorb shock that causes stresses beyond the proportional limit. It represents a quality important in such articles as handles, and picker sticks, which are stressed in service beyond the proportional limit. Wood requiring a large height of drop to produce failure usually exhibits a splintering fracture when broken, whereas a small height of drop is associated with a brittle fracture.

### STRESS AT PROPORTIONAL LIMIT, COMPRESSION PARALLEL TO GRAIN (COLUMN 23)

Stress at proportional limit is the greatest stress at which the compressive load remains proportional to the shortening of the specimen (pp. 11, 86).

The stress at proportional limit is applicable to clear compression members for which the ratio of length to least dimension does not exceed 11 to 1. It is the limiting stress in compression parallel to grain which should not be exceeded in determining safe loads. The stress at proportional limit in compression parallel to grain is taken into account in arriving at safe working stresses for short columns and other compression members, determining design values for bolted joints and the like. The stress at proportional limit averages about 80 percent of the maximum crushing strength for coniferous woods, and 75 percent for hardwoods.

### MAXIMUM CRUSHING STRENGTH, COMPRESSION PARALLEL TO GRAIN (COLUMN 24)

Maximum crushing strength is the maximum ability of a short piece to sustain a slowly applied end load over a short period. It is applicable to clear compression members whose ratio of length to least dimension does not exceed 11. This property is important in estimating endwise crushing strength of wood, and in developing safe working stresses for structural timbers, design of bolted joints, and the like.

Maximum crushing strength is one of the simplest properties to determine. It is usually less adversely affected by various treatments or processes applied to wood than other strength properties, and hence should not be regarded as representative of other strength properties in appraising the effect of such treatments.

### STRESS AT PROPORTIONAL LIMIT, COMPRESSION PERPENDICULAR TO GRAIN (COLUMN 25)

Stress at proportional limit is the maximum across-the-grain stress of a few minutes duration that can be applied without injury through a plate 2 inches wide and covering but a portion of the timber surface. It is useful in deriving safe working stresses in compression perpendicular to grain, for computing the bearing area for beams, stringers, and joists, and in comparing species for railroad ties and other uses in which this property is important.

In compression perpendicular to grain, particularly if the load is applied to only part of the surface area as in this test, wood does not exhibit a true ultimate or maximum strength as in compression parallel to grain and static bending; but the load continues to increase until the block is badly crushed and flattened out. Hence, no ultimate or maximum strength value is obtained.

In the standard test procedure, the specimen is placed with the direction of the annual growth rings parallel to the direction of the load except when this is impossible, such as with specimens from near the pith of the tree. Thus the load is applied to the radial face, but it should be pointed out that the fiber stress at proportional limit in compression perpendicular to grain like other across-the-grain properties of wood are very appreciably affected by ring placement.

Although there appears to be no consistent difference in fiber stress at proportional limit when the rings are parallel and perpendicular respectively to the direction of the applied load, appreciably lower values obtain when the rings are at an angle of 45°. This fact is of practical importance in timber design and use.

The fiber stress at proportional limit in compression perpendicular to grain depends also on the size of plate with respect to the length of the test specimen. With the surface of the specimen but partly covered, there is a component of tension parallel to grain at the edge of the plate, in addition to the compressive stress proper. Values of proportional limit lower than those obtained with the standard test are found when the plate covers the entire surface of the test specimen, and higher values result when the width of plate is decreased. The method of test employing a plate covering but part of the surface is somewhat analogous to the bearing conditions in service where a joist or beam rests on its supports.

## HARDNESS (COLUMNS 26 AND 27)

Hardness is the load required to embed a 0.444-inch ball to one-half its diameter in the wood. It represents a property important in wood subjected to wear and marring, such as flooring, furniture, railroad ties, and paving blocks. The hardness test provides data for comparing different pieces or different species of wood, but the results cannot be used for calculating the size of members, as can such properties as modulus of rupture.

Hardness tests are made on end, radial, and tangential surfaces. End hardness values are given in column 26. There is no significant difference between radial and tangential hardness, and they are averaged together as "side hardness" in column 27.

In determining side hardness the principal stress is perpendicular to the grain, but because of the depth of penetration of the ball, a considerable component of end-grain hardness is introduced in the load. Likewise the end-hardness values reflect a component of side-grain hardness. Although end hardness is usually higher than side hardness, it is evident that the two are closely related.

Although hardness is the best available index of the ability of wood to resist wear, it is not so good a criterion of suitability as would be actual comparisons from some kind of abrasion tests that would more nearly simulate service conditions. However, no abrasion test for wood has yet been standardized and systematic results are not available.

## MAXIMUM SHEARING STRENGTH, SHEAR PARALLEL TO GRAIN (COLUMN 28)

Maximum shearing strength is the average stress required to shear off from the test specimen a projecting lip having a length in the direction of the grain of 2 inches. 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 in most uses of timber. It is 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—and in the design of various kinds of joints.

It is difficult to devise a test that involves only shearing stress. A tensile component perpendicular to the grain of the wood influences the results of tests made by the standard method, but in general, the same effect in varying degree obtains in other methods in use or proposed. In obtaining the average shear values presented, a uniform distribution of stress throughout the shearing area is assumed, although it is not certain that uniformity obtains. The maximum shearing strength also varies with the amount of offset between the shearing force and the line of support of the specimen. Comparable values are obtained by standardizing the test procedure as in this series of tests.

### LOAD TO CAUSE SPLITTING, CLEAVAGE (COLUMN 29)

Cleavage is the maximum load required to cause splitting of the standard specimen. It is expressed in pounds per inch of width.

It is evident that the maximum load in cleavage depends on the width and length of the specimen. In order to insure comparable results, the standard length of 3 inches is always maintained. The cleavage strength, like some of the other properties cannot be used directly for calculating required sizes of wood members or in similar design problems, but is useful mainly for comparisons. This test differs from the action of nails in splitting wood when driven, and should not be taken as a criterion of the relative resistance of the different species to such splitting.

### MAXIMUM TENSILE STRENGTH, TENSION PERPENDICULAR TO GRAIN (COLUMN 30)

The maximum tensile strength perpendicular to the grain is the average maximum stress sustained across the grain by the wood.

The tabulated values are obtained by dividing the maximum load by the tension area. It is recognized that the tensile stress is not uniformly distributed over the area. Consequently, the values probably do not represent a true tensile strength. They are, nevertheless, useful for comparing species and for estimating the resistance of timber to forces acting across the grain.

## VARIABILITY

Variability is common to all materials. If one tests pieces of wire from a roll, the loads necessary to pull the wire apart will vary. Likewise, the breaking strengths of different pieces of the same kind of string or rope are not the same. Materials, however, differ considerably in the amount of variation or the spread of values.

The growing tree is subject to numerous constantly changing influences that affect the wood produced, and it is not surprising that even the clear wood is variable in strength and other properties. The factors affecting tree growth include, soil, moisture, temperature, growing space, and heredity.

Everyone who has handled and used lumber has encountered variability and observed that different pieces even of the same species, are not exactly alike. The differences most commonly recognized are in the appearance, but even greater differences in weight and in strength properties occur and may be of greater importance.

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The variability of wood can be illustrated by considering as an example the data on specific gravity of Douglas fir presented in table 2.

These data show that the specific gravity of the heaviest piece included in the series was nearly twice that of the lightest, and that the number of very heavy and very light pieces is small. Most of the values are grouped closely about the average.

TABLE 2.—*Results of specific gravity determinations on 1,240 samples of Douglas fir (coast type)*

| Specific gravity [1] group limits | Pieces in group | | Specific gravity [1] group limits | Pieces in group | |
|---|---|---|---|---|---|
| | *Number* | *Percent* | | *Number* | *Percent* |
| 0.300 to 0.309 | 2 | 0.16 | 0.460 to 0.469 | 96 | 7.74 |
| 0.310 to 0.319 | 7 | .56 | 0.470 to 0.479 | 74 | 5.97 |
| 0.320 to 0.329 | 6 | .48 | 0.480 to 0.489 | 70 | 5.65 |
| 0.330 to 0.339 | 15 | 1.21 | 0.490 to 0.499 | 56 | 4.52 |
| 0.340 to 0.349 | 13 | 1.05 | 0.500 to 0.509 | 46 | 3.71 |
| 0.350 to 0.359 | 23 | 1.85 | 0.510 to 0.519 | 41 | 3.31 |
| 0.360 to 0.369 | 25 | 2.02 | 0.520 to 0.529 | 30 | 2.42 |
| 0.370 to 0.379 | 38 | 3.06 | 0.530 to 0.539 | 23 | 1.85 |
| 0.380 to 0.389 | 47 | 3.79 | 0.540 to 0.549 | 12 | .97 |
| 0.390 to 0.399 | 64 | 5.16 | 0.550 to 0.559 | 9 | .73 |
| 0.400 to 0.409 | 75 | 6.05 | 0.560 to 0.569 | 10 | .81 |
| 0.410 to 0.419 | 85 | 6.86 | 0.570 to 0.579 | 4 | .32 |
| 0.420 to 0.429 | 76 | 6.13 | 0.580 to 0.589 | 1 | .08 |
| 0.430 to 0.439 | 99 | 7.98 | 0.590 to 0.599 | 3 | .24 |
| 0.440 to 0.449 | 100 | 8.06 | | | |
| 0.450 to 0.459 | 90 | 7.26 | Total | 1,240 | 100.00 |

[1] Based on weight when oven-dry and volume when green. Average specific gravity equals 0.445; highest observed specific gravity, 0.640; lowest, 0.308.

The manner in which the values are grouped about an average is called a frequency distribution, from which the chances that a random piece will differ from the average by a given amount can be estimated by computation. Such calculations, for example, assuming that the specific-gravity values conform to a so-called normal distribution, leads to the expectation that one-half of the Douglas fir samples would be within 7.9 percent of the average specific gravity, or within the limits 0.41 and 0.48 inclusive, and that one-fourth would be below 0.41 and one-fourth above 0.48. The figure defining such limits, 7.9 percent in this instance, is called the probable variation. By actual count 654 of the pieces or 52.7 percent of the total number (1,240) have a specific gravity between 0.41 and 0.48, whereas 25.4 percent (315) were below 0.38 and 21.9 percent (271) were above 0.48. Thus, as might be expected, the calculated percentages do not agree exactly with the actual count. Nevertheless, the agreement is sufficiently close to show the value of the theory in estimating the variability.

The range in strength properties can be studied and used as a basis for making estimates in a like manner.

After tests have been made it is, of course, easy to determine from the results the proportion of the test pieces within any given range, but one can only estimate the reliability of the averages and the degree to which this test data applies to other pieces. One would like to know the true average for each species, a quantity which cannot actually be determined. The best that can be done is to assume that the laws of chance are operative and thus estimate the probability of variations of given magnitude from the averages found. Such is the basis of the suggestions for estimating variability by means of data presented herein.

It would be desirable to present a measure of the variability of each property of each species. However, the extensive calculations involving all properties and species have not been made; and if available, their presentation would be involved. Although it is known that all species are not equally variable, existing information indicates that they are enough alike that estimates made on the assumption that the percentage variability in any one property is the same for all species will be sufficiently accurate for approximate calculations.

The questions that most frequently arise in a consideration of the variability of wood, are of two types:

(1) What is the significance of the differences between average values for two species or what is the likelihood that the averages will be changed a specified amount by additional tests?

(2) What is the range that includes a specified proportion of material of a species, or what is the likelihood that a piece selected at random will be within a specified range?

## VARIATION OF AVERAGE VALUES

The probable variations of observed averages from the true averages enables one to appraise the significance of differences between observed averages. The estimated probable variation of the observed average from the true average of a species, when based on different numbers of trees, is given in table 3. The percentage probable variations listed in table 3 being average values for a number of species, an occasional species may be considerably more or less variable than indicated.

TABLE 3.—*Percentages probable variation*[1] *of the observed average from the true average of a species, when based on material from different numbers of trees*

| Trees ........ number | 1 | 2 | 3 | 4 | 5 | 10 | 15 | 20 | 30 | 40 | 50 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Specific gravity based on volume when green | 4.7 | 3.3 | 2.7 | 2.4 | 2.1 | 1.5 | 1.2 | 1.0 | 0.9 | 0.7 | 0.7 |
| Shrinkage: | | | | | | | | | | | |
| Radial | 11.6 | 8.2 | 6.7 | 5.8 | 5.2 | 3.7 | 3.0 | 2.6 | 2.1 | 1.8 | 1.6 |
| Tangential | 9.0 | 6.4 | 5.2 | 4.5 | 4.0 | 2.8 | 2.3 | 2.0 | 1.6 | 1.4 | 1.3 |
| Volumetric | 8.8 | 6.2 | 5.1 | 4.4 | 3.9 | 2.8 | 2.3 | 2.0 | 1.6 | 1.4 | 1.2 |
| Static bending: | | | | | | | | | | | |
| Fiber stress at proportional limit | 11.2 | 7.9 | 6.4 | 5.6 | 5 | 3.5 | 2.9 | 2.5 | 2.0 | 1.8 | 1.6 |
| Modulus of rupture | 8.9 | 6.3 | 5.2 | 4.5 | 4 | 2.8 | 2.3 | 2.0 | 1.6 | 1.4 | 1.3 |
| Modulus of elasticity | 11.2 | 7.9 | 6.4 | 5.6 | 5 | 3.5 | 2.9 | 2.5 | 2.0 | 1.8 | 1.6 |
| Work to proportional limit | 15.6 | 11.1 | 9.0 | 7.8 | 7 | 5.0 | 4.0 | 3.5 | 2.9 | 2.5 | 2.2 |
| Work to maximum load | 13.4 | 9.5 | 7.7 | 6.7 | 6 | 4.2 | 3.5 | 3.0 | 2.4 | 2.1 | 1.9 |
| Impact bending: | | | | | | | | | | | |
| Fiber stress at proportional limit | 8.9 | 6.3 | 5.2 | 4.5 | 4 | 2.8 | 2.3 | 2.0 | 1.6 | 1.4 | 1.3 |
| Work to proportional limit | 11.2 | 7.9 | 6.4 | 5.6 | 5 | 3.5 | 2.9 | 2.5 | 2.0 | 1.8 | 1.6 |
| Height of drop | 15.6 | 11.1 | 9.0 | 7.8 | 7 | 5.0 | 4.0 | 3.5 | 2.9 | 2.5 | 2.2 |
| Compression parallel to grain: | | | | | | | | | | | |
| Fiber stress at proportional limit | 11.2 | 7.9 | 6.4 | 5.6 | 5 | 3.5 | 2.9 | 2.5 | 2.0 | 1.8 | 1.6 |
| Maximum crushing strength | 8.9 | 6.3 | 5.2 | 4.5 | 4 | 2.8 | 2.3 | 2.0 | 1.6 | 1.4 | 1.3 |
| Compression perpendicular to grain: | | | | | | | | | | | |
| Fiber stress at proportional limit | 13.4 | 9.5 | 7.7 | 6.7 | 6 | 4.2 | 3.5 | 3.0 | 2.4 | 2.1 | 1.9 |
| Hardness, end | 8.9 | 6.3 | 5.2 | 4.5 | 4 | 2.8 | 2.3 | 2.0 | 1.6 | 1.4 | 1.3 |
| Hardness, side | 11.2 | 7.9 | 6.4 | 5.6 | 5 | 3.5 | 2.9 | 2.5 | 2.0 | 1.8 | 1.6 |
| Shearing strength parallel to grain | 6.7 | 4.7 | 3.9 | 3.4 | 3 | 2.1 | 1.7 | 1.5 | 1.2 | 1.1 | .9 |
| Tension perpendicular to grain | 11.2 | 7.9 | 6.4 | 5.6 | 5 | 3.5 | 2.9 | 2.5 | 2.0 | 1.8 | 1.6 |

[1] The percentage probable variation of the average of a species is a figure such that there is an even chance that the true average is within this percentage of the observed average in table 1.

The observed average is always the most probable value of the true average. The importance of the differences between species with respect to averages depends on the magnitude of this difference in relation to the probable variation of the averages, as well as on how exacting the strength requirements are for the particular use under consideration.

If the averages of any property of two species of table 1 differ by an amount equal to the probable variation of the difference,[8] there is 1 chance in 4 that the true average for the species which is lower in that property on the basis of present data equals or exceeds the true average of the other. There is also 1 chance in 4 that the true average for the higher species exceeds that of the lower one by as much as twice the observed difference. When the averages differ by amounts that are ½, 1, 2, 3, 4, or 5 times the probable variation of their difference the chances of the true average of the lower species equaling or exceeding the true average of the higher, or of the observed difference being at least doubled are given in the following tabulation:

| *Multiples* | *Chance* |
|---|---|
| ½ | 1 in 2¾. |
| 1 | 1 in 4. |
| 2 | 1 in 11. |
| 3 | 1 in 46. |
| 4 | 1 in 285. |
| 5 | 1 in 2,850. |

As an example, consider the average values for modulus of rupture of 9,300 and 9,600 pounds per square inch for Biltmore white ash and blue ash, respectively, in the green condition (table 1). These averages being based on five trees of each species the probable variation according to table 3 is 4 percent. Then 4 percent of 9,300 equals 372, and 4 percent of 9,600 equals 384, the probable variations of these averages. The probable variation of the difference between the averages is then $\sqrt{(372)^2+(384)^2}$ or 535; the observed difference in the averages for modulus of rupture (9,600–9,300) is 300. The ratio of the observed difference to the estimated probable variation being less than 1, it may be estimated from the tabulation that the chance that the true average modulus of rupture for Biltmore white ash equals or exceeds that for blue ash is somewhat greater than 1 in 4. There is the same chance that the true average of blue ash exceeds that for Biltmore white ash by as much as 600 or twice the difference in present average figures as shown in table 1. Therefore, the difference in modulus of rupture between blue ash and Biltmore white ash is not to be regarded as significant.

As a second example, consider the figures for modulus of rupture of 9,400 and 8,300 for sweet birch and yellow birch, respectively (table 1). The figures for sweet birch are based on 10 trees, those for yellow birch on 17. From table 3 the probable variation of the species average for modulus of rupture when based on 10 trees is 2.8 percent and when based on 17 trees it is 2.2 percent. (The figure for 17 trees is taken as between that given for 15 trees and 20 trees). Following the method of the preceding example, the probable variation of the difference between the averages is found to be 320. The difference between the observed averages is 1,100, which is about three and one-half times its probable variation of 320. The tabula-

[8] The probable variation of the difference of two average figures is the square root of the sum of the squares of the probable variations of the averages. The probable variation of the average of any property may be estimated from the figures in table 3.

tion indicates that the chance that the true average for modulus of rupture of yellow birch would equal or excel that for sweet birch is less than 1 in 46. The importance of such differences will depend on the use to be made of the wood.

## VARIATION OF AN INDIVIDUAL PIECE FROM THE AVERAGE

The upper and lower limits for any property within which one-half of the material of a species would be expected to fall may be estimated from the following tabulation.

*Estimated probable variation of an individual piece from average for species*

| *Property:* | *Percent* |
|---|---|
| Specific gravity based on volume when green | 8 |
| Shrinkage: | |
| Radial | 11 |
| Tangential | 10 |
| Volumetric | 12 |
| Static bending: | |
| Fiber stress at proportional limit | 16 |
| Modulus of rupture | 12 |
| Modulus of elasticity | 16 |
| Work to maximum load | 23 |
| Impact bending: | |
| Fiber stress at proportional limit | 13 |
| Height of drop | 18 |
| Compression parallel to grain: | |
| Fiber stress at proportional limit | 18 |
| Maximum crushing strength | 13 |
| Compression perpendicular to grain: Fiber stress at proportional limit | 21 |
| Hardness, end | 13 |
| Hardness, side | 15 |

As an example, consider the modulus of rupture of red alder, when green, which is found from table 1 to be 6,500 pounds per square inch. The tabulation lists the probable variation for modulus of rupture as 12 percent. Twelve percent of 6,500 is 780; which when subtracted from and added to the average gives limits of 5,720 and 7,280 pounds per square inch. The probable variation is a value associated with the range within which one-half of the material of a species will fall. Consequently, it may be estimated that in red alder approximately one-half of the material would be between 5,720 and 7,280 pounds per square inch in modulus of rupture.

Considered in another way, there is 1 chance in 4 that the modulus of rupture of an individual specimen taken at random will be below 5,720 pounds per square inch, 1 chance in 4 that it will be above 7,280 pounds per square inch, and there are 2 chances in 4 that it will be between 5,720 and 7,280 pounds per square inch. The greater the probable variation, the greater the difference that may be expected in values, and the less the certainty with which the average values can be applied to individual pieces.

It is possible by means of mathematical tables, which are available in numerous texts on the theory of probability or statistical methods, to calculate the proportion of material associated with other ranges or that may be expected to be below or above any specified limit.

## SELECTION FOR PROPERTIES

The fact that a piece of wood differs in properties from another of the same species often makes one more suitable than the other for a specific use. This suggests the possibility of selecting material of a quality best suited to meet specific use requirements. Fortunately, strength is frequently correlated with weight and to a lesser degree with other physical characteristics, and these relationships sometimes afford a basis for grading and selecting for strength.

Aside from weight, the other physical characteristics most usable for selecting on the basis of the strength of the clear wood are proportion of summer wood, rate of growth, hardness, and stiffness. Either visual or mechanical methods, or both, may be employed in appraising the properties. For example, selection may be made at the sawmill so that the heavier, and consequently stronger and harder, pieces go into structural timbers, flooring, or other uses for which the higher measure of these properties particularly adapt them, while the lighter pieces may preferably be used for such purposes as trim or heat insulation; or selection may be made at the lumber yard when material of high weight or that of low weight is desired. By means of selective methods the variability of wood, usually regarded as a liability, can within certain limits be made an asset. Selection on the basis of grades that limit defects is a common practice. Selection on the basis of quality of clear wood is less common, but is frequently very desirable, and offers possibility in the improvement of marketing practice. In any instance defects must of course be considered.

## OTHER MECHANICAL PROPERTIES NOT INCLUDED IN TABLE 1

In addition to the data from the tests presented in table 1, information on certain other mechanical properties, principally tension parallel to grain and torsional properties is sometimes needed. A brief discussion of these properties, and of a special toughness test that may be used as an acceptance method follows.

### TENSION PARALLEL TO GRAIN

In order to get reliable data on tension along the grain, special care must be exercised in preparing test specimens, and for this and other reasons little information on this property is available. Furthermore, the true tensile strength of wood along the grain is less important in design than other properties because it is practically impossible to devise attachments that permit the tensile strength of the full cross section of a wooden member to be developed.

Available results of tension tests show that generally the ultimate tensile strength considerably exceeds the modulus of rupture. Hence the modulus of rupture may be used as an estimate of the ultimate tensile strength parallel to grain for conditions where a uniform distribution of tensile stress obtains over the net cross section of a member. Uniform stress distribution, however, does not occur in the net tension area of a bolted joint, where it has been found that for softwoods the net tension area must be 80 percent, and for hardwoods 100 percent of the total bearing area under all the bolts (*50*) in the joint.

Table 4 presents the average results of tests in tension parallel to the grain on several species.

**TABLE 4.**—*Results of tests to determine the ultimate tensile strength parallel to the grain*

| Species | Green | | | | Air-dry | | | |
|---|---|---|---|---|---|---|---|---|
| | Moisture content | Tests | Specific gravity[1] | Ultimate tensile strength | Moisture content | Tests | Specific gravity[1] | Ultimate tensile strength |
| | *Percent* | *Number* | | *Lb. per sq. in.* | *Percent* | *Number* | | *Lb. per sq. in.* |
| Ash, white | | 1 | 0.535 | 16,150 | | | | |
| Beech | 53 | 1 | .569 | 12,530 | | | | |
| Cedar: | | | | | | | | |
| Port Orford | 34 | 34 | .393 | 11,380 | | | | |
| Western red | 40 | 10 | .300 | 6,200 | 8.8 | 7 | 0.323 | 7,180 |
| Cypress, southern | 78 | 15 | .424 | 8,720 | | | | |
| Douglas fir: | | | | | | | | |
| Coast | 24 | 48 | .425 | 12,960 | 11.1 | 8 | .444 | 13,830 |
| "Inland Empire" | 30 | 9 | .409 | 9,380 | 10.2 | 1 | .474 | 14,880 |
| Fir: | | | | | | | | |
| Noble | 29 | 11 | .353 | 14,750 | 10.2 | 9 | .370 | 13,020 |
| California red | 108 | 14 | .373 | 9,040 | 10.1 | 10 | .385 | 10,760 |
| White | 48 | 9 | .307 | 8,030 | 10.7 | 6 | .382 | 10,450 |
| Hemlock, western | 67 | 20 | .380 | 9,860 | 10.9 | 14 | .400 | 9,820 |
| Maple, sugar | 48 | 5 | .577 | 15,660 | | | | |
| Oak, pin | 80 | 3 | .578 | 16,200 | | | | |
| Pine: | | | | | | | | |
| Loblolly | 47 | 2 | .446 | 11,570 | 11.6 | 1 | .484 | 15,050 |
| Ponderosa | 69 | 11 | .364 | 8,320 | | | | |
| Poplar, balsam | 100 | 3 | .298 | 7,940 | 10.4 | 2 | .351 | 12,160 |
| Redwood | 104 | 29 | .377 | 9,780 | 10.7 | 33 | .401 | 10,920 |
| Spruce: | | | | | | | | |
| Eastern[2] | 34 | 14 | .366 | 13,650 | 11.7 | 13 | .391 | 13,070 |
| Sitka | 40 | 17 | .385 | 8,110 | 9.5 | 10 | .400 | 11,150 |

[1] Based on weight when oven-dry and volume at test.
[2] Exact species not known.

Figure 1 illustrates the form of specimen on which table 4 is based. Despite the reduced cross section in the central portion of the length the specimens sometimes fail by shear instead of in tension. Specimens that failed other than in tension are not included in the average values of table 4.

## TORSIONAL PROPERTIES

The torsional strength of wood is little needed in design and, except for Sitka spruce, has not been studied extensively. Available results, however, indicate that the shearing stress at maximum torsional load, as calculated by the usual formulas, are approximately one-third greater than the values in table 1 for shearing strength parallel to the grain (*51*).

The effect of duration of stress on torsional strength is pronounced, being greater on the proportional limit than on the maximum torsional strength. With slowly applied loads the proportional limit may be less than 50 percent of the maximum, whereas with quickly applied loads the proportional limit may be 75 percent of the maximum load.

The modulus of rigidity or the modulus of elasticity of wood in shear is a combination of the component moduli along radial and tangential surfaces, and is influenced among other things by the position of the growth rings. The combined moduli are known as the mean modulus of rigidity, which for Sitka spruce is about one-fifteenth the modulus of elasticity along the grain. Scattered tests on other species show a range in values of the mean modulus of rigidity between one-fourteenth and one-eighteenth the modulus of elasticity along the grain. Until definite values are available for other species, a ratio of one-seventeenth appears conservative.

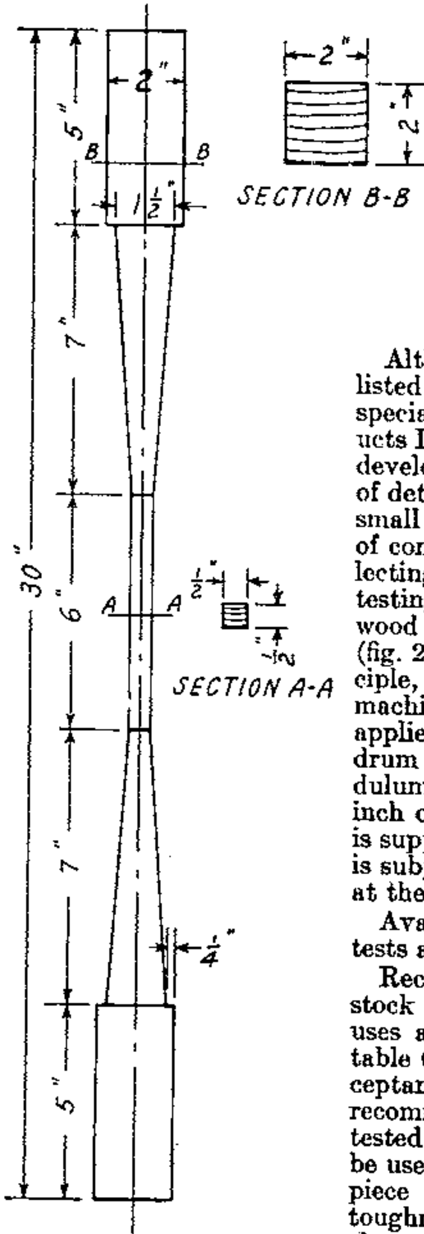


FIGURE 1.—Details of tension-parallel-to-grain test specimen.

A third shear modulus that does not come in play in torsion about an axis parallel to the grain is associated with stresses that tend to roll the wood fibers by each other in a direction at right angles to the grain. This shearing modulus is extremely low but is of little importance in most design.

## TOUGHNESS

Although a number of the properties listed in table 1 measure toughness, a special device known as the Forest Products Laboratory toughness machine was developed to provide a simple method of determining toughness from relatively small samples. The test affords a means of comparing species, and a basis for selecting stock of known properties by testing small specimens from pieces of wood intended for use. The machine (fig. 2) operates on the pendulum principle, but it differs from other pendulum machines in that the striking force is applied through a cable attached to a drum mounted on the axis of the pendulum. The specimen, which is ⅝ by ⅝ inch or ¾ by ¾ inch in cross section and is supported over an 8- or 10-inch span, is subjected to an impact bending force at the middle of its length (*26*).

Available average results of toughness tests are presented in table 5.

Recommended acceptance values for stock for aircraft and other high-class uses are presented for a few woods in table 6. In applying the test as an acceptance requirement for wood, it is recommended that four specimens be tested from the same piece as the part to be used is taken. To be acceptable, the piece (1) must either meet a minimum toughness requirement established for the species under consideration, or if within a certain tolerance below this minimum must pass in addition a minimum specific-gravity requirement; (2) must show a limited range in toughness values for specimens from the same piece, and (3) must pass careful visual inspection.

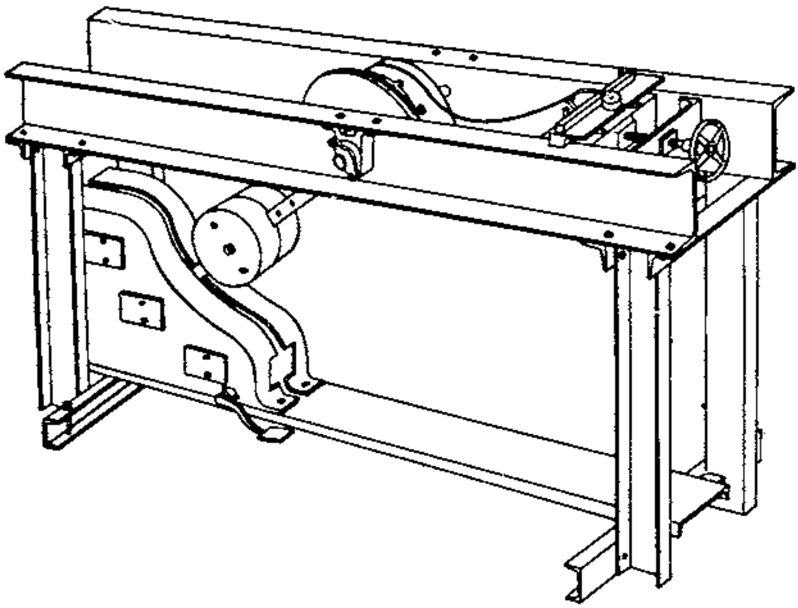

FIGURE 2.—Forest Products Laboratory toughness-testing machine.

TABLE 5.—*Results of toughness tests*

[Specimens ⅝ by ⅝ by 10 inches tested on an 8-inch span]

| Species | Moisture content | Specific gravity (oven-dry based on volume at test) | Face to which load is applied: Radial — Tests | Radial — Toughness | Tangential — Tests | Tangential — Toughness |
|---|---|---|---|---|---|---|
| | *Percent* | | *Number* | *In.-lb. per specimen* | *Number* | *In.-lb. per specimen* |
| Birch: | | | | | | |
| Alaska white | 9.8 | 0.50 | 14 | 184 | 16 | 180 |
| Yellow | 11.9 | .65 | 10 | 202 | 11 | 330 |
| Catalpa, hardy | 66 | .40 | 13 | 180 | 19 | 181 |
| | 11.8 | .41 | 18 | 104 | 17 | 124 |
| Cedar: | | | | | | |
| Alaska | 10.4 | .48 | 10 | 109 | 10 | 122 |
| Western red | 9.2 | .33 | 21 | 45 | 21 | 70 |
| Douglas fir | 36 | .43 | 51 | 82 | 59 | 112 |
| | 10 | .46 | 36 | 86 | 36 | 151 |
| Fir, corkbark | 55 | .31 | 44 | 36 | 44 | 52 |
| | 9.9 | .31 | 28 | 36 | 30 | 51 |
| Hemlock, eastern | 12.3 | .41 | 13 | 56 | 13 | 80 |
| Hemlock, western | 11.1 | .38 | 31 | 60 | 34 | 86 |
| Maple, sugar | 13.8 | .64 | 11 | 194 | 11 | 192 |
| Oak, pin | 11.5 | .64 | 15 | 226 | 18 | 225 |
| Pine, loblolly | 86 | .47 | 99 | 139 | 206 | 176 |
| | 11.9 | .51 | 174 | 93 | 168 | 149 |
| Pine, longleaf | 90 | .54 | 39 | 183 | 38 | 232 |
| | 13.3 | .57 | 39 | 94 | 43 | 143 |
| Pine, shortleaf | 88 | .48 | 106 | 140 | 71 | 191 |
| | 12.9 | .50 | 75 | 77 | 71 | 120 |
| Pine, slash | 78 | .55 | 72 | 185 | 73 | 238 |
| | 11.6 | .59 | 67 | 109 | 63 | 107 |
| Redwood | 103 | .39 | 101 | 58 | 96 | 106 |
| | 11.4 | .39 | 104 | 49 | 90 | 75 |
| Spruce, Sitka | 9.8 | .44 | 33 | 83 | 37 | 121 |

TABLE 6.—*Minimum acceptance requirements for aircraft woods based on tests*[1] *in the Forest Products Laboratory toughness machine*

| Species of wood | Size of specimen | Span | Minimum average acceptable toughness | | |
|---|---|---|---|---|---|
| | | | With specific gravity limitation | | Without specific gravity limitation; minimum average toughness[3] |
| | | | Minimum specific gravity[2] | Minimum average toughness[3] | |
| | *Inches* | *Inches* | | *In.-lb. per specimen* | *In.-lb. per specimen* |
| White ash | 5/8 by 5/8 by 10 | 8 | 0.56 | 150 | 175 |
| Yellow birch | 3/4 by 3/4 by 12 | 10 | .58 | 225 | 260 |
| Douglas fir | 5/8 by 5/8 by 10 | 8 | .45 | 95 | 115 |
| White oak | 3/4 by 3/4 by 12 | 10 | .62 | 175 | 200 |
| Sitka spruce | 5/8 by 5/8 by 10 | 8 | .36 | 75 | 90 |
| Black walnut | 3/4 by 3/4 by 12 | 10 | .52 | 150 | 175 |

[1] Load applied to the tangential face of the specimen.
[2] Based on weight and volume of oven-dry wood.
[3] These values are to be applied to the average of 4 or more test specimens, and the range in individual test values used in arriving at the average should not exceed 1 to 2½ among 4 specimens.

The procedure is simple and tests are made very rapidly. No calculation is necessary as the readings of the machine are readily converted into toughness values by the use of available tables. The procedure is further simplified by the fact that when testing dry wood the moisture condition of the specimen may be ignored, as tests have shown that toughness is affected but little by such moisture differences as may be commonly encountered.

The one essential in the application of the toughness test as an acceptance method, in addition to the necessary machine for making the tests, is a knowledge of the species with respect to minimum toughness requirements. The recommended values presented in table 6 have been established from tests made at the Forest Products Laboratory.

## PROPERTIES OTHER THAN STRENGTH

### RATING OF SPECIES IN SEVEN PROPERTIES

It has been mentioned that consideration of properties other than strength, weight, and shrinkage may be necessary in appraising the suitability of a wood for various uses (p. 3). Table 7 compares a number of species with respect to ease of kiln drying, ability to stay in place, workability, nail-holding ability, ease of gluing, resistance to decay, and ability to hold paint. The classifications are approximate, and only in some instances are they based on technical research. In others they are based on observation, experience, and general information. The ratings vary from 1 to 4 or 1 to 5, the lowest number indicating the best rating. For some other properties, such as acid resistance, sufficient information is not available to prepare even such a general classification of species. Information on properties other than those presented in this bulletin, insofar as available, may be obtained by writing the Forest Products Laboratory, Madison, Wis.

TABLE 7.—*Approximate comparison of 7 properties of commercial species of wood*

[Key to classification of woods: Columns 2 and 4 represent a gradation of properties in the various woods from those which can be dried and worked with comparative ease (class 1) to those which present some difficulty in those respects (class 4). Column 3 represents a gradation from those woods which possess the greatest ability to stay in place under conditions of actual use (class 1) to those species which do not possess that ability to the same extent (classes 2, 3, 4, in the order named). Column 5 represents a gradation from those which possess the greatest nail-holding power but have the greatest tendency to split (which necessitates the use of smaller nails) to those having the least nail-holding ability but which are less likely to split. In column 6 the woods in class 1 are known to be used commercially in glued construction. Class 2 includes species about which little is known but which are not believed to be difficult to glue. Class 3 includes species which are known to require a little more attention in gluing than class 1 woods in order to get best results. Class 4 includes woods which are known to present real difficulties in gluing, and class 5 those species about which little is known but which it is believed would present some difficulties in view of their similarity to species of known properties. Column 7 presents comparative values for resistance to decay of heartwood when used under conditions that favor decay, class 1 being most decay-resistant. Column 8 represents a classification of softwood species with respect to ability to hold paint when used outside, class 1 species holding paint the most satisfactorily. Ability to hold paint is more important for outside than for inside use. The hardwood species are not commonly used for exterior work requiring painting and have not yet been classified]

| Species | Ease of kiln drying [1] | Ability to stay in place | Work-ability | Nail-holding ability | Ease of gluing | Resistance to decay (heart-wood) | Ability to hold paint |
|---|---|---|---|---|---|---|---|
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| HARDWOODS | | | | | | | |
| Alder, red | 2 | 3 | 2 | | 1 | | |
| Ash: | | | | | | | |
| Black | 3 | 4 | 3 | | | | |
| White | 2 | 3 | 4 | 2 | 3 | 4 | |
| Aspen | 2 | 3 | 2 | 5 | 2 | 5 | |
| Basswood | 2 | 3 | 2 | 5 | 1 | 5 | |
| Beech | 4 | 4 | 4 | 1 | 5 | 4 | |
| Birch: | | | | | | | |
| Paper | 2 | 4 | 3 | | 5 | | |
| Sweet and yellow | 2 | 4 | 4 | 1 | 3 | 4 | |
| Buckeye, yellow | | | 2 | | 2 | | |
| Butternut | 2 | 2 | 2 | | 2 | | |
| Cascara | | | 4 | | | | |
| Cherry: | | | | | | | |
| Black | 4 | 3 | 3 | | | | |
| Pin | 3 | 3 | 2 | | 2 | | |
| Chestnut | 2 | 2 | 2 | 4 | 1 | 1 | |
| Chinquapin, golden | | | 3 | | | | |
| Cottonwood: | | | | | | | |
| Black | 3 | 4 | 2 | 5 | 1 | 5 | |
| Eastern | 2 | 4 | 2 | 5 | 1 | 5 | |
| Dogwood | 2 | 5 | 5 | 1 | 5 | | |
| Elm: | | | | | | | |
| American | 3 | 5 | 4 | 3 | 1 | | |
| Rock | 3 | 5 | 4 | | | | |
| Gum: | | | | | | | |
| Black | 3 | 5 | 4 | | 2 | 5 | |
| Red | [2] 2, 4 | 4 | 4 | 3 | 1 | 3 | |
| Hackberry | 2 | 4 | 3 | | 2 | | |
| Hickory, shagbark | 4 | 5 | 5 | 1 | 4 | | |
| Honey locust | 4 | 2 | 4 | 1 | 5 | 2 | |
| Hophornbeam | 3 | 5 | 5 | 1 | 5 | | |
| Laurel, California | 5 | 3 | 4 | | 5 | | |
| Madrone, Pacific | 4 | 5 | 4 | | 5 | | |
| Magnolia, cucumber | 3 | 4 | 3 | 3 | 1 | | |
| Maple: | | | | | | | |
| Bigleaf | 3 | 3 | 3 | | 5 | | |
| Red | 3 | 3 | 4 | | 5 | | |
| Sugar | 3 | 4 | 4 | 1 | 3 | 4 | |
| Oak: | | | | | | | |
| California black | 4 | 3 | 4 | | 5 | | |
| Red | [3] 4, 5 | 4 | 4 | 1 | 3 | 4 | |
| White | [3] 4, 5 | 4 | 4 | 1 | 1 | 2 | |
| Persimmon | 4 | 4 | 5 | 1 | 4 | | |
| Poplar, yellow | 2 | 2 | 2 | 4 | 1 | | |
| Sycamore | 4 | 4 | 4 | 2 | 2 | | |
| Walnut, black | 4 | 2 | 3 | | 1 | 1 | |
| Willow, black | 2 | 3 | 2 | | 2 | 5 | |

[1] Softwoods are in general easier to dry than hardwoods. A softwood given the same numerical rating a a hardwood is, therefore, regarded as slightly easier to dry. These ratings are based on ease of removal of moisture without visible degrade but do not take into account susceptibility to reduction in strength in drying under high temperatures (*67*).

[2] 2 refers to sapwood and 4 to heartwood, known commercially as sap gum and red gum, respectively.

[3] 4 refers to the upland type of oak and 5 to the lowland type of oak.

TABLE 7.—*Approximate comparison of 7 properties of commerical species of wood*—Continued

| Species | Ease of kiln drying | Ability to stay in place | Work-ability | Nail-holding ability | Ease of gluing | Resistance to decay (heart-wood) | Ability to hold paint |
|---|---|---|---|---|---|---|---|
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| SOFTWOODS | | | | | | | |
| Cedar: | | | | | | | |
| Alaska | 1 | 1 | 3 | ----- | 2 | 1 | 1 |
| Incense | 1 | 1 | 2 | ----- | 2 | 1 | 1 |
| Northern white | 2 | 1 | 2 | 5 | 2 | 1 | 1 |
| Port Orford | 2 | 2 | 3 | ----- | 2 | 1 | 1 |
| Western red | [4] 2, 3 | 1 | 2 | 5 | 2 | 1 | 1 |
| Cypress, southern | 3 | 2 | 3 | 3 | 2 | 1 | 1 |
| Douglas fir | 1 | 3 | 4 | 3 | 1 | [5] 2, 3 | 4 |
| Fir: | | | | | | | |
| Alpine and balsam | 1 | ----- | 2 | 5 | 2 | 5 | 3 |
| Grand, noble and white | 1 | 3 | 2 | 5 | 2 | 5 | 3 |
| Hemlock: | | | | | | | |
| Eastern | 2 | 3 | 3 | 4 | 2 | 4 | 3 |
| Western | 2 | 3 | 3 | 3 | 1 | 4 | 3 |
| Larch, western | 3 | 3 | 4 | 3 | 2 | 3 | 4 |
| Pine: | | | | | | | |
| Jack | 1 | 3 | 3 | 4 | 2 | ----- | 3 |
| Lodgepole | 1 | 2 | 2 | 5 | 2 | ----- | 3 |
| Northern white | 2 | 1 | 1 | 4 | 1 | ----- | 2 |
| Norway | 1 | 3 | 2 | 3 | 2 | ----- | 3 |
| Pitch | 1 | 3 | 4 | 3 | 2 | 3 | 4 |
| Ponderosa | 1 | 2 | 2 | 4 | 1 | ----- | 3 |
| Southern yellow | 1 | 3 | 4 | 2 | 1 | [5] 2, 3 | 4 |
| Sugar | 2 | 1 | 1 | ----- | 1 | ----- | 2 |
| Western white | 3 | 2 | 2 | 4 | 1 | ----- | 2 |
| Redwood | [6] 3, 4 | 2 | 3 | 4 | 1 | 1 | 1 |
| Spruce: | | | | | | | |
| Engelmann | 2 | 2 | 2 | 5 | 2 | 4 | 3 |
| Red and white | 1 | 2 | 2 | 4 | 1 | 4 | 3 |
| Sitka | 1 | 2 | 2 | 4 | 1 | 4 | 3 |
| Tamarack | 2 | 3 | 4 | ----- | 2 | 3 | 3 |

[4] 2 refers to material from upper logs and 3 to material from butt logs which are generally susceptible to collapse.
[5] 2 refers to dense Douglas fir and dense southern yellow pine.
[6] 3 refers to material from upper logs and 4 to sinker stock from butt logs.

## REQUIREMENTS FOR MOISTURE CONTENT OF WOOD IN BUILDINGS

The satisfactory use of lumber frequently depends upon the characteristics of the stock in its entirety, such as the size, kind, and number of defects as well as upon the properties of the clear wood, and may be further influenced by sizes available, degree of seasoning, and marketing practices. For most purposes seasoned is to be preferred to unseasoned stock, and for some uses, such as flooring, a definite degree of seasoning is essential for satisfactory results.

As an example of seasoning requirements, table 8 gives recommendations for desirable initial moisture content of lumber for various parts of dwellings (*40*).

While it is desirable that the average moisture content be near the value given in table 8, it is far more important that the moisture content of individual pieces of a lot be within the specified range.

TABLE 8.—*Recommended moisture-content values for various wood items at time of installation*

| Use of lumber | Moisture content (percentage of weight of oven-dry wood) for— | | | | | |
|---|---|---|---|---|---|---|
| | Dry southwestern States | | Damp southern coastal States | | Remainder of the United States | |
| | Average | Range for individual pieces | Average | Range for individual pieces | Average | Range for individual pieces |
| Interior finishing woodwork and softwood flooring | 6 | 4–9 | 11 | 8–13 | 8 | 5–10 |
| Hardwood flooring | 6 | 5–8 | 10 | 9–12 | 7 | 6–9 |
| Sheathing, framing, siding, and exterior trim | 9 | 7–12 | 12 | 9–14 | 12 | 9–14 |

## MOISTURE CONTENT OF HEARTWOOD AND SAPWOOD

Average moisture-content values from green specimens consisting entirely of sapwood, or entirely of heartwood, are listed in table 9, for a number of species. These values show the variation in moisture content among species, the relative equality in moisture content of heartwood and sapwood in several hardwoods, and the large differences commonly existing in softwoods.

TABLE 9—*Average moisture content for green heartwood and sapwood of 19 species*

| Species | Trees | Average moisture content | | Species | Trees | Average moisture content | |
|---|---|---|---|---|---|---|---|
| | | Heartwood | Sapwood | | | Heartwood | Sapwood |
| HARDWOODS | | | | SOFTWOODS—contd. | | | |
| | *Number* | *Percent* | *Percent* | | *Number* | *Percent* | *Percent* |
| Ash, white | 12 | 38 | 40 | Hemlock: | | | |
| Beech | 6 | 53 | 78 | Eastern | 5 | 58 | 119 |
| Birch, yellow | 9 | 68 | 71 | Western | 13 | 42 | 170 |
| Elm, American | 3 | 95 | 92 | Pine: | | | |
| Gum, black | 4 | 50 | 61 | Loblolly | 8 | 34 | 94 |
| Maple: | | | | Lodgepole | 5 | 30 | 113 |
| Silver | 4 | 60 | 88 | Longleaf | 18 | 34 | 99 |
| Sugar | 6 | 58 | 67 | Norway | 4 | 31 | 135 |
| | 5 | 30 | 117 | Ponderosa | 4 | 40 | 148 |
| SOFTWOODS | 3 | 91 | 136 | Shortleaf | 8 | 34 | 108 |
| | | | | Spruce: | | | |
| Douglas fir | 5 | 30 | 117 | Engelmann | 2 | 54 | 107 |
| Fir, lowland white | 3 | 91 | 136 | Sitka | 2 | 33 | 140 |

The moisture content of green heartwood and sapwood varies greatly among trees, and varies within the tree at different heights. The sapwood of the softwood species was consistently higher in moisture content than the heartwood, but some hardwood trees were found in which the heartwood was slightly higher than the sapwood. Because of the variation in moisture content of green wood, the values presented should not be taken as rigid averages for the species, but rather as indications of what may be expected.

The values in table 9 may be used in specific instances to estimate the average moisture content of logs. For example, if ponderosa pine logs in a shipment are observed to have 75 percent of sapwood by volume, the average moisture content would be estimated as $(0.75\times148)+(0.25\times40)=121$ percent. Average moisture-content values computed in this way are likely to be more accurate in such instances and a better basis for computing weights than the average values listed for green material in column 7 of table 1 as these latter values may represent a quite different proportion of sapwood. The proportion of sapwood and heartwood in trees varies with the age of the stand and with growth conditions.

## OTHER DATA ON SPECIFIC GRAVITY

In addition to the data on the specific gravity of the wood subjected to strength tests as presented in table 1, the Forest Products Laboratory has obtained for 14 common softwood species information based on sections of boards collected at sawmills in various parts of the United States (*41*). For a number of species the sampling from sawmills was more extensive than that used in obtaining specimens for strength tests, and the data are of interest on that account. In addition, data on heartwood and sapwood were segregated, whereas this has not been done with the data from the standard series of strength tests.

The principal data from the study of samples collected at sawmills are shown in table 10.

TABLE 10.—*Comparison of specific gravity (oven-dry, based on volume when green) of mill-run samples with that of specimens used for mechanical tests*

| Species | Mill-run samples [1] | | | | | Specimens for mechanical tests | | |
|---|---|---|---|---|---|---|---|---|
| | Specimens | Specific gravity heartwood and sapwood combined | Probable variation | Specific gravity heartwood | Specific gravity sapwood | Trees | Specimens | Specific gravity |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
| | *Number* | | *Percent* | | | *Number* | *Number* | |
| Cypress, southern | 377 | 0.38 | 10.0 | 0.39 | 0.36 | 20 | 479 | 0.42 |
| Douglas fir: | | | | | | | | |
| Washington and Oregon | 2,764 | .44 | 8.1 | .44 | .43 | 34 | 1,029 | .45 |
| "Inland Empire" | 176 | .44 | 6.6 | | | 10 | 113 | .41 |
| Fir: White | [1] 1,187 | [1] .33 | [1] 7.1 | [1] .33 | [1] .33 | 45 | 278 | .35 |
| Hemlock, western | 1,359 | .39 | 6.8 | .39 | .39 | 18 | 689 | .38 |
| Larch, western | 820 | .46 | 7.5 | .45 | .43 | 13 | 214 | .48 |
| Pine: | | | | | | | | |
| Longleaf | [1] 5,396 | [1] .52 | [1] 10.3 | [1] .57 | [1] .48 | 34 | 806 | .55 |
| Northern white | 386 | .34 | 5.7 | .35 | .34 | 18 | 299 | .34 |
| Norway | 121 | .39 | 6.6 | .39 | .38 | 5 | 120 | .44 |
| Ponderosa | 1,876 | .37 | 8.7 | .38 | .36 | 31 | 579 | .38 |
| Shortleaf | [1] 4,357 | [1] .47 | [1] 8.5 | [1] .51 | [1] .46 | [2] 22 | [2] 1,190 | [2] .49 |
| Sugar | 965 | .33 | 6.7 | .33 | .32 | 9 | 191 | .35 |
| Western white | 1,178 | .36 | 5.9 | .36 | .36 | 14 | 211 | .36 |
| Redwood | 585 | .36 | 9.7 | .36 | | 16 | 564 | .39 |
| Spruce, Sitka | 658 | .36 | 6.9 | .36 | .33 | 25 | 1,392 | .37 |

[1] The mill-run specimens were classified according to commercial species designations of the lumber and not according to botanical classification, although in most instances the two are approximately the same. The southern pines are the principal exception as there is no known method of distinguishing the several species botanically from the wood alone, and hence species are mixed in the commercial designations. The samples used for mechanical tests were taken from trees identified botanically in the woods.

[2] Values for shortleaf and loblolly pine combined.

It was not possible in all cases to identify these samples as to species. Consequently, the data are classified according to commercial designation of the lumber and not according to exact species. However, except for those names to which footnote 1 is appended, the designations are probably the correct species names.

Table 10 shows for comparison values of specific gravity taken from column 8 of table 1. In general, the values in columns 3 and 9 of table 10 are in reasonable agreement although with but two exceptions (western hemlock and Douglas fir from the "Inland Empire" region) those of column 9 are the same or higher. Other studies have disclosed considerable variation in Douglas fir in the "Inland Empire" region and in this instance the operation of chance in sampling might readily lead to the difference between the values in columns 3 and 9. Further reasons for differences include the effect of position of material in the tree, and the fact that the methods of determining specific gravity were not quite identical.

The specimens used for standard strength tests (column 9) were taken mainly from the top 4 feet of 16-foot butt logs, whereas the samples collected at the mill (column 3) represent mixed material in which wood from all parts of the tree may be included. Because in many species the wood near the butt of the tree is heavier than that from the upper portions of the trunk, the specific-gravity values in column 9 would in general be expected to be slightly higher than those representing mixed material. An example of this kind is afforded by western larch. The butt portions of western larch trees contain large quantities of extractives which increase the weight considerably and as much as 12 feet of the portion immediately above the stump is often discarded because the extra weight makes handling of the logs difficult. On the other hand, Sitka spruce is an example of a species whose specific gravity varied but little with height in tree.

In general, the differences between the values listed in columns 3 and 9 are not greater than are to be expected from the causes just discussed combined with the effects of chance in sampling.

Table 10 also lists some data on the specific gravity of heartwood and sapwood, and the probable variation in specific gravity of the mill samples. It may be noted that the specific gravity of heartwood is in general slightly higher than that of sapwood. One reason for this higher value is the greater quantity of extractives (p. 47) in the heartwood.

## FACTORS AFFECTING THE STRENGTH OF WOOD

The numerical data presented in table 1 were, as has been shown, derived from tests of small clear specimens taken from a specific part of the tree and tested under a standardized procedure.

Most uses of wood involve pieces differing in size and shape from those tested; clear material may not be available or may be more expensive than a contemplated use justifies; conditions of use may differ radically from standard test conditions; time limitations may require kiln drying; need for permanence may point to preservative treatment; the user may have erroneous concepts of the rate of growth as a criterion of suitability or of the comparative strength of heartwood or sapwood; he may hesitate to accept material from dead trees, or from turpentined trees. These and many other questions that may arise require consideration in order to properly interpret the numerical data and adapt it to specific uses of wood. A knowledge of factors affecting strength is thus essential to the interpretation of test data and is of value in the purchase of lumber, in the preparation of specifications covering the use of timber in engineering structures, and in the selection, classification, and use of wood for manufactured products. A brief discussion of various factors affecting the strength of wood is accordingly presented.

## RELATION OF PROPERTIES TO STRUCTURE

Wood is a heterogeneous material consisting essentially of fibers of cellulose cemented together by lignin. The fibers, which taper toward the ends, are about one-eighth of an inch long in softwoods, one twenty-fourth of an inch in hardwoods, with a central diameter about one hundredth of the length. They are hollow, their longer dimension running lengthwise of the tree. In the softwoods the fibers act as water conductors. In the hardwoods a limited number of fibers act similarly and there are also relatively large pores or vessels which serve the same function. Besides these vertical fibers which comprise the principal part of the wood, all woods except palms and yuccas contain horizontal strips of cells known as rays or wood rays which are oriented radially and are an important part of the tree's food transfer and storage system. Among different species the rays differ widely in their size and prevalence.

The shape, size, and arrangement of the fibers, the presence of the wood rays, and the layer effect of spring and summer wood make wood a nonisotropic material with large differences in the properties along and across the grain (*19, 43*). Certain of the properties across the grain may be but a small fraction of the like properties along the grain. In air-dry Sitka spruce, for instance, the modulus of elasticity across the grain, may be only one one-hundred-and-fiftieth as great as when the load is parallel to the grain (10,200 pounds per square inch for 45° angle (p. 35) as compared to 1,570,000 pounds per square inch in column 16, table 1). There is an increasing need for information which will permit a closer correlation of structure and properties. Such information is of value in accounting for and remedying and preventing certain difficulties in the use of wood, and for giving a more precise basis for timber design through a better knowledge of properties and stress distribution.

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TABLE 11.—*Average results of tests showing influence of position of growth rings on the mechanical properties of Sitka spruce, Douglas fir, and loblolly pine*

| Properties | Sitka spruce | | | | Douglas fir | | | | Loblolly pine, green | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Green | | Air-dried | | Green | | Kiln-dried | | | |
| | Position A[1] | Position B[1] | Position A[1] | Position B[1] | Position A[1] | Position B[1] | Position A[1] | Position B[1] | Position A[1] | Position B[1] |
| **Static bending:** | | | | | | | | | | |
| Moisture ... percent[2] | 45.2 | 45.3 | 12.2 | 12.2 | 30.6 | 29.4 | 11.9 | 11.9 | 26.0 | 25.8 |
| Specific gravity[3] | .341 | .343 | .370 | .372 | .427 | .431 | .455 | .459 | .599 | .599 |
| Fiber stress at proportional limit ... pounds per square inch | 3,160 | 3,150 | 5,800 | 5,900 | 4,510 | 4,700 | 7,800 | 8,120 | 4,820 | 4,540 |
| Fiber stress at maximum load ... pounds per square inch | 4,890 | 4,960 | 8,470 | 8,450 | 7,280 | 7,470 | 10,630 | 10,860 | 9,750 | 9,740 |
| Modulus of elasticity ... 1,000 pounds per square inch | 1,104 | 1,124 | 1,370 | 1,374 | 1,475 | 1,480 | 1,723 | 1,713 | 1,398 | 1,398 |
| Work to proportional limit ... inch-pounds per cubic inch | .52 | .52 | 1.46 | 1.49 | .81 | .86 | 2.03 | 2.22 | 1.00 | .90 |
| Work to maximum load ... inch-pounds per cubic inch | 5.2 | 5.6 | 7.5 | 7.5 | 6.3 | 7.6 | 7.4 | 7.5 | ------ | ------ |
| Work, total ... inch-pounds per cubic inch | 15.8 | 14.4 | ------ | ------ | 15.0 | 11.9 | ------ | ------ | ------ | ------ |
| **Impact bending, 50-pound hammer:** | | | | | | | | | | |
| Moisture ... percent[2] | 45.8 | 44.4 | 12.7 | 12.5 | 30.4 | 30.3 | 10.7 | 11.0 | ------ | ------ |
| Specific gravity[3] | .343 | .350 | .372 | .378 | .422 | .431 | .457 | .460 | ------ | ------ |
| Fiber stress at proportional limit ... pounds per square inch | 7,870 | 7,860 | 10,150 | 9,900 | 8,870 | 9,450 | 12,550 | 12,370 | ------ | ------ |
| Modulus of elasticity ... 1,000 pounds per square inch | 1,277 | 1,274 | 1,618 | 1,662 | 1,480 | 1,729 | 2,140 | 2,110 | ------ | ------ |
| Work to proportional limit ... inch-pounds per cubic inch | 2.7 | 2.7 | 3.7 | 3.4 | 3.0 | 2.9 | 4.2 | 4.1 | ------ | ------ |
| Height of drop causing complete failure ... inches | 20 | 20 | 21.0 | 20.9 | 20.4 | 18.8 | [4] 23.4 | [4] 23.1 | ------ | ------ |
| **Compression parallel to grain:** | | | | | | | | | | |
| Moisture ... percent[2] | 45.2 | 46.4 | 12.7 | 12.7 | 29.6 | 29.2 | 10.2 | 10.4 | ------ | ------ |
| Specific gravity[3] | .339 | .341 | .363 | .370 | .428 | .419 | .451 | .459 | ------ | ------ |
| Rings per inch | 14.5 | 15.7 | 6.5 | 7.6 | 16.3 | 15.9 | 20.4 | 23.0 | 7.0 | 7.5 |
| Fiber stress at maximum load ... pounds per square inch | 2,220 | 2,210 | 4,490 | 4,670 | 3,810 | 3.730 | 7,230 | 7,250 | 4,680 | 4,650 |
| **Hardness[5]:** | | | | | | | | | | |
| End ... pounds | 357 | 357 | 682 | 701 | 440 | 440 | 713 | 713 | ------ | ------ |
| Side ... pounds | 289 | 283 | 436 | 462 | 452 | 446 | 700 | 657 | ------ | ------ |
| Compression perpendicular to grain: Fiber stress at proportional limit ... pounds per square inch | 227 | 227 | 548 | 582 | 455 | 496 | 609 | 667 | ------ | ------ |
| Shear parallel to grain: Shearing strength ... pounds per square inch | 713 | 668 | 184 | 1,202 | 883 | 833 | 1,209 | 1,266 | ------ | ------ |
| Cleavage: Cleavage strength ... pounds per square inch | 122 | 94 | 242 | 189 | 133 | 136 | 163 | 163 | ------ | ------ |
| Tension at right angles to grain: Tensile strength ... pounds per square inch | 208 | 130 | 466 | 357 | 179 | 165 | 255 | 307 | ------ | ------ |

[1] Position A and B refer to placement of growth rings with respect to directions of application of load, as illustrated in fig. 3.
[2] Percent moisture based on weight of oven-dry wood.
[3] Specific gravity based on weight when oven-dry and volume at test.
[4] Adjusted to drop for 2- by 2-inch cross section.
[5] Load required to imbed a 0.444-inch ball to ½ its diameter.

### POSITION OF GROWTH RINGS

In the sawing of lumber and timber the position of the growth rings may be made to assume different directions with respect to the surfaces of the piece. Any effect of position of growth rings on the properties thus assumes practical significance.

Table 11 presents, for three species, data on clear specimens 2 by 2 inches in cross-section tested to determine the effect of two positions of growth rings on the strength properties (fig. 3). It may be noted

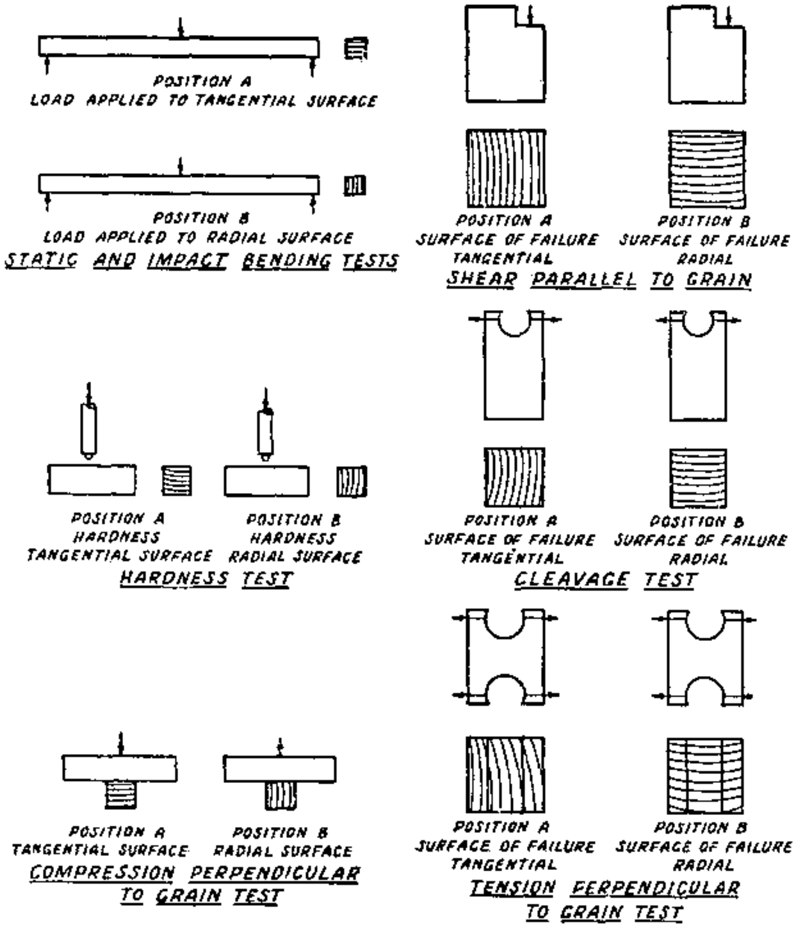



FIGURE 3.—Sketch of standard mechanical tests which afford choice in placement of growth rings with respect to direction of application of load.

that the bending tests, which were on specimens 30 inches long, show little difference in the properties listed, whether the rings as viewed on the end of a piece are vertical or horizontal. Some of the other properties listed, however, show significant differences between the two placements of rings resulting not only from the difference in structure due to the rings themselves, but also the difference orientation of the other minute structural elements of the wood with respect to the direction of stress.

The values from the tests in compression parallel to grain, which were unaffected by the placement of growth rings because the specimens were square, together with the data on specific gravity and rings per inch, show that the wood representing position A was practically identical in quality with that representing position B.

There are many further effects of stratified structure on properties, as evidenced by the growth-ring position, not brought out by results of standard tests. An outstanding example is in compression perpendicular to grain. The results of some preliminary determinations of modulus of elasticity in compression perpendicular to grain are presented in table 12.

TABLE 12.—*Modulus of elasticity in compression perpendicular to grain as influenced by direction of growth rings*

[Specimens 1½ by 1½ by 6 inches loaded on the 1½ by 1½-inch face]

| Species | Specific gravity | Moisture content | Modulus of elasticity when the growth rings with respect to the applied load are at an angle of— | | | | |
|---|---|---|---|---|---|---|---|
| | | | 0° | 22½° | 45° | 67½° | 90° |
| | | *Percent* | *Lb. per sq. in.* | *Lb. per sq. in.* | *Lb. per sq. in.* | *Lb. per sq. in.* | *Lb. per sq. in.* |
| Redwood | 0.34 | 11 | 78,400 | 28,600 | 17,100 | 27,900 | 106,600 |
| Douglas fir | .45 | 37 | 58,200 | 21,400 | 12,200 | 20,800 | 85,400 |
| Spruce, Sitka | .42 | 13 | 62,400 | 18,100 | 10,200 | 22,400 | 110,300 |
| Hemlock, western | .44 | 88 | 45,400 | 11,600 | 8,300 | 14,100 | 71,500 |
| Birch, yellow | .68 | 63 | 48,030 | 39,900 | 34,000 | 55,900 | 81,200 |
| Do | .67 | 13 | 106,400 | 82,300 | 80,800 | 113,200 | 158,000 |
| Oak, red | .56 | 119 | 60,200 | 57,800 | 59,700 | 77,400 | 110,300 |

It may be noted that there is a large difference in the modulus of elasticity in compression perpendicular to grain with position of rings, amounting to as much as 11 to 1 in Sitka spruce between material with the rings at 90° to the direction of the load and that with rings at 45°. Proportional limit and maximum crushing strength perpendicular to grain are also affected by ring position, although the indications are that the differences are considerably less than for modulus of elasticity.

In the Forest Products Laboratory toughness test, in which specimens one-half to three-fourths inch square and 10 to 12 inches long are used, some marked differences have been found, depending on whether the load is applied to the radial or tangential face. In some species avarage differences of as much as 50 percent of the lesser values were noted (table 5), the higher values resulting when the load was applied to the tangential face. These results as compared with those of table 11, indicate that size of specimen may be an important factor in the influence of position of rings.

### SPRING WOOD AND SUMMER WOOD PLACEMENT EFFECT

Significant differences with ring placement may become evident in properties not appreciably affected in 2- by 2-inch pieces when specimens of smaller size are tested. This was demonstrated by static-bending tests on 1- by 1- by 16-inch specimens of southern yellow pine and Douglas fir containing large amounts of summer wood, modulus of elasticity being determined (without stressing the specimen beyond the proportional limit) by placing the specimen with the rings horizontal and then vertical. The modulus of elasticity of specimens with summer wood layers on the two faces averaged 12 percent higher for southern yellow pine, and 16 percent higher for Douglas fir with the rings horizontal (load applied to tangential face) than with the rings vertical (load applied to radial face). On the other hand, with specimens having spring wood layers on two faces, the modulus of elasticity when the rings were horizontal (load applied to the tangential face) averaged 9 percent lower than when the rings were vertical (load applied to radial face) for southern yellow pine and 13 percent lower for Douglas fir. These differences, it should be observed, represent a spring wood and summer wood placement effect rather than a pure growth-ring placement effect. Theoretical calculations based on the assumption of widely different properties in spring wood and summer wood check these observed values closely.

## SPECIES OF WOOD

Some species of wood differ greatly from others in their average specific gravity, strength, and other properties. Certain species, such as hickory and ash, excel in toughness and shock-resisting ability. Others, such as southern yellow pine and Douglas fir, are high in bending strength and stiffness for their weight. Still other species are soft, uniform in texture, and easy to work. Such differences permit a choice of species to meet the requirements of diverse and exacting uses. Comparative data on important properties are presented for 164 species of wood in table 1.

The average differences in strength properties between species ordinarily competing for the same use are often quite small. Nevertheless, there may be decided differences in structure and in behavior with respect to moisture relations, drying, and manufacturing characteristics which make it necessary to vary the handling procedure or manufacturing practice to best suit the wood under consideration. In this way as satisfactory service may be obtained from species not generally regarded so suitable for a use as from species that give a good account of themselves regardless of care or of lack of care in their handling.

## SPECIFIC GRAVITY (OR DENSITY) AS RELATED TO STRENGTH

The substance of which wood is composed is actually heavier than water, its specific gravity being about 1.5 regardless of the species of wood. In spite of the fact that the actual wood substance is heavier than water, the dry wood of most species floats in water, and it is thus evident that a considerable portion of the volume of a piece of wood is occupied by cell cavities and pores. The specific gravity of a piece of dry wood is thus an excellent index of the amount of wood substance it contains and hence is an index of the strength properties.

The relations between specific gravity and other properties of wood may be considered on the basis of (1) different species and (2) different pieces of the same species.

### SPECIFIC GRAVITY-STRENGTH RELATIONSHIP AMONG SPECIES

The general relation of specific gravity to strength is illustrated by two widely different woods, mastic, a very heavy species growing in Florida, and balsa, a very light species from Central America. Compression-parallel-to-grain tests on green material gave the results in table 13, and show that mastic with average specific gravity 9 times as great as that of balsa was 9 times as high in crushing strength along the grain. Weight for weight, the crushing strength parallel to grain of these diverse species are substantially equal.

TABLE 13.—*Comparison of the specific gravity and the maximum crushing strength of mastic and balsa*

| Species | Specific gravity, based on weight and volume of wood when oven dry | Maximum crushing strength parallel to grain | Specific strength (column 3 ÷ column 2) |
|---|---|---|---|
| (1) | (2) | (3) | (4) |
| | | *Lb. per sq. in.* | |
| Mastic | 1.03 | 5,880 | 5,710 |
| Balsa | .11 | 644 | 5,850 |

The average specific gravity-strength relations based on 163 species of hardwoods and softwoods show that some properties, such as maximum crushing strength parallel to grain, increase approximately in proportion to the increase in specific gravity, whereas others increase more rapidly. Modulus of rupture, for instance, varies from one species to another as the 1¼ power of specific gravity. Other properties are related to specific gravity by equations of still higher powers; for example, the exponent of specific gravity for relation to hardness is 2¼. It is evident, therefore, that small differences in specific gravity may result in large differences in certain strength properties. For example, one species twice as high in specific gravity as another has 4¾ times the hardness.

Approximate average relations of specific gravity to strength properties among different species are given in table 14 (*38*).

TABLE 14.—*Specific gravity-strength relations among different species* [1]

| Property | Unit | Moisture condition | |
|---|---|---|---|
| | | Green | Air-dry (12-percent moisture content) |
| Static bending: | | | |
| Fiber stress at proportional limit | Pounds per square inch | $10200G^{1.25}$ | $16700G^{1.25}$ |
| Modulus of rupture | do | $17600G^{1.25}$ | $25700G^{1.25}$ |
| Work to maximum load | Inch-pounds per cubic inch | $35.6G^{1.75}$ | $32.4G^{1.75}$ |
| Total work | do | $103G^{2}$ | $72.7G^{2}$ |
| Modulus of elasticity | 1,000 pounds per square inch | $2360G$ | $2800G$ |
| Impact bending: | | | |
| Fiber stress at proportional limit | Pounds per square inch | $23700G^{1.25}$ | $31200G^{1.25}$ |
| Modulus of elasticity | 1,000 pounds per square inch | $2940G$ | $3380G$ |
| Height of drop | Inches | $114G^{1.75}$ | $94.6G^{1.75}$ |
| Compression parallel to grain: | | | |
| Fiber stress at proportional limit | Pounds per square inch | $5250G$ | $8750G$ |
| Maximum crushing strength | do | $6730G$ | $12200G$ |
| Modulus of elasticity | 1,000 pounds per square inch | $2910G$ | $3380G$ |
| Compression perpendicular to grain: Fiber stress at proportional limit. | Pounds per square inch | $3000G^{2.25}$ | $4630G^{2.25}$ |
| Hardness: | | | |
| End | Pounds | $3740G^{2.25}$ | $4800G^{2.25}$ |
| Radial | do | $3380G^{2.25}$ | $3720G^{2.25}$ |
| Tangential | do | $3400G^{2.25}$ | $3820G^{2.25}$ |

[1] The values listed in this table are to be read as equations, for example: Modulus of rupture for green material $= 17600G^{1.25}$, where $G$ represents the specific gravity, oven-dry, based on volume at moisture condition indicated.

Some species of wood contain relatively large amounts of resins, gums, and other extractives, which add to the weight but do not contribute so much to the strength as would a like amount of wood substance (*23*). In addition, species vary in the structural arrangement of their fibers. For these reasons, two species which average the same in specific gravity may exhibit different strength character-

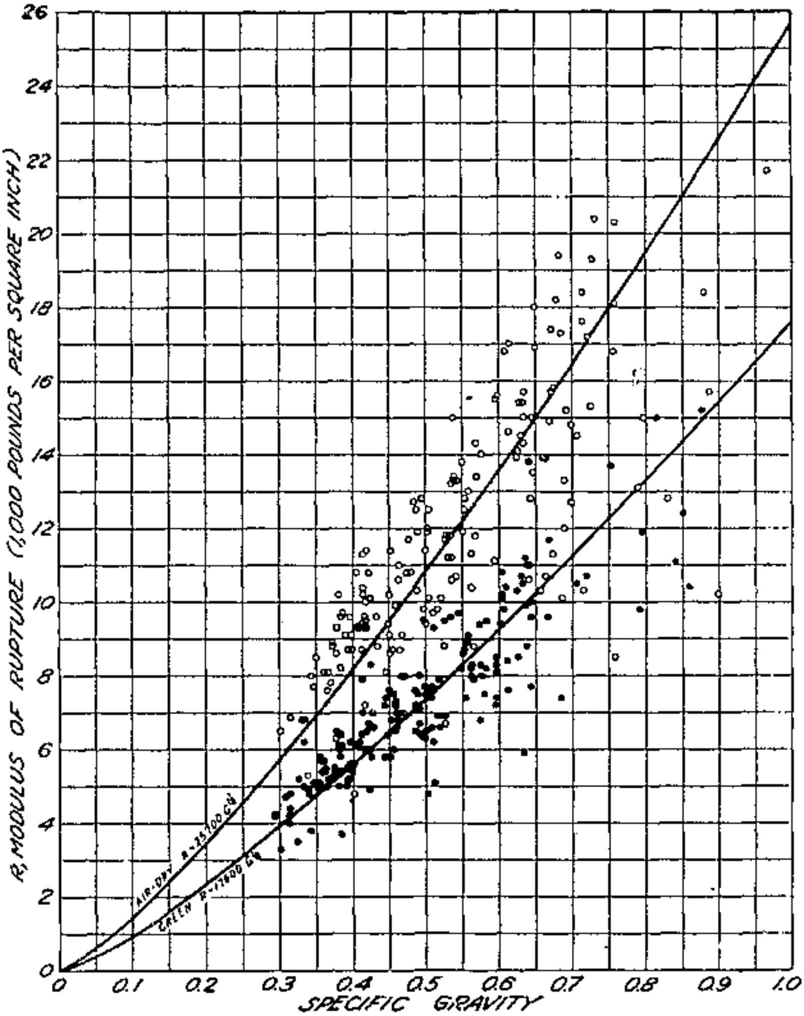



FIGURE 4.—Relation of modulus of rupture to specific gravity for green and air-dry material of various species.

istics. This fact is illustrated by the scattering of the points in figure 4. The values for Douglas fir (coast type) and red gum in table 1 illustrate an extreme example of variations from the average density-strength relations among species. Although these woods are about equal in weight per unit volume when dry, Douglas fir averages 39 percent higher in compressive strength but considerably lower than red gum in shock resistance.

It is true, likewise, that some species of wood are equal in some respects to others of higher density. Douglas fir (coast type), although its density is but three-fourths that of commercial white oak, is about equal to the oak in bending and compressive strengths, and excels it in stiffness. However, the oak averages much higher than Douglas fir in hardness and shock resistance. Hence the specific gravity relationships among species represent general trends and not uniform laws. Departure of a species from the general relationship often indicates some exceptional characteristic which makes this species particularly desirable for certain use requirements.

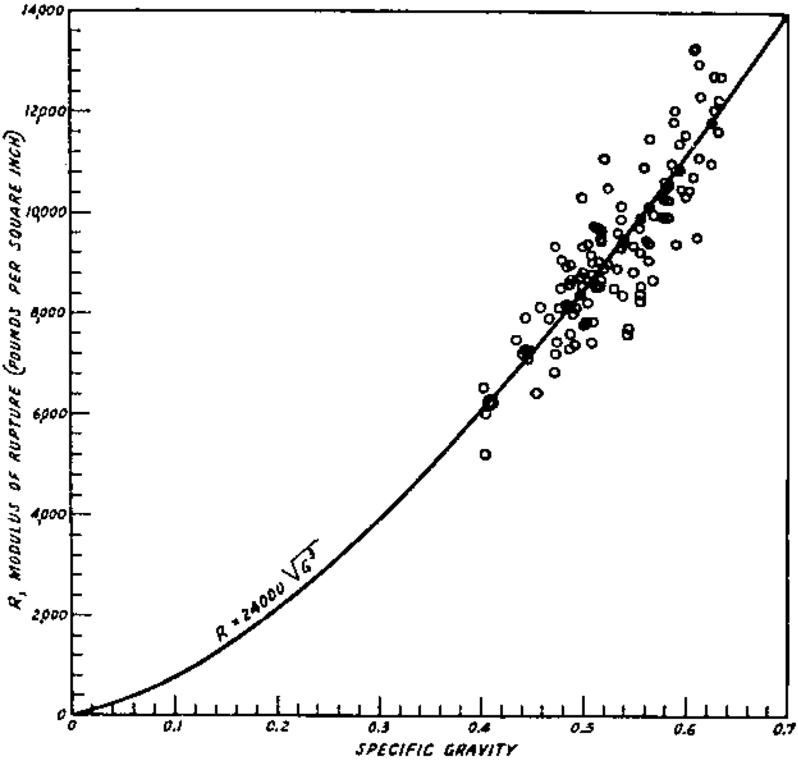



FIGURE 5.—Relation of modulus of rupture of white ash (green) to specific gravity.

### SPECIFIC GRAVITY-STRENGTH RELATIONSHIP AMONG INDIVIDUAL PIECES OF A SPECIES

While a general relationship thus exists between the specific gravities and strength properties among different species, specific gravity affords a still better index of strength within a species. The heaviest pieces of any species of wood are generally 2 to 3 times as high in specific gravity as the lighter ones of the species, and are correspondingly stronger. The relationship of pieces within a species is usually represented by a power of specific gravity slightly higher than that representing average values for different species. Furthermore, departures from the average relationship are less marked. Figure 5 illustrates the relation between the specific gravity and the modulus of rupture for individual pieces of white ash.

## THE TREE IN RELATION TO STRENGTH

### HEIGHT IN TREE

The wood from the butt of the trees of many species is higher in specific gravity than that from higher positions. Since wood of higher specific gravity usually has the better mechanical properties regardless of position in tree, the height in tree ordinarily needs to be taken into account only in connection with other factors (fig. 6). Sometimes, however, notably in hickory and ash, material from the

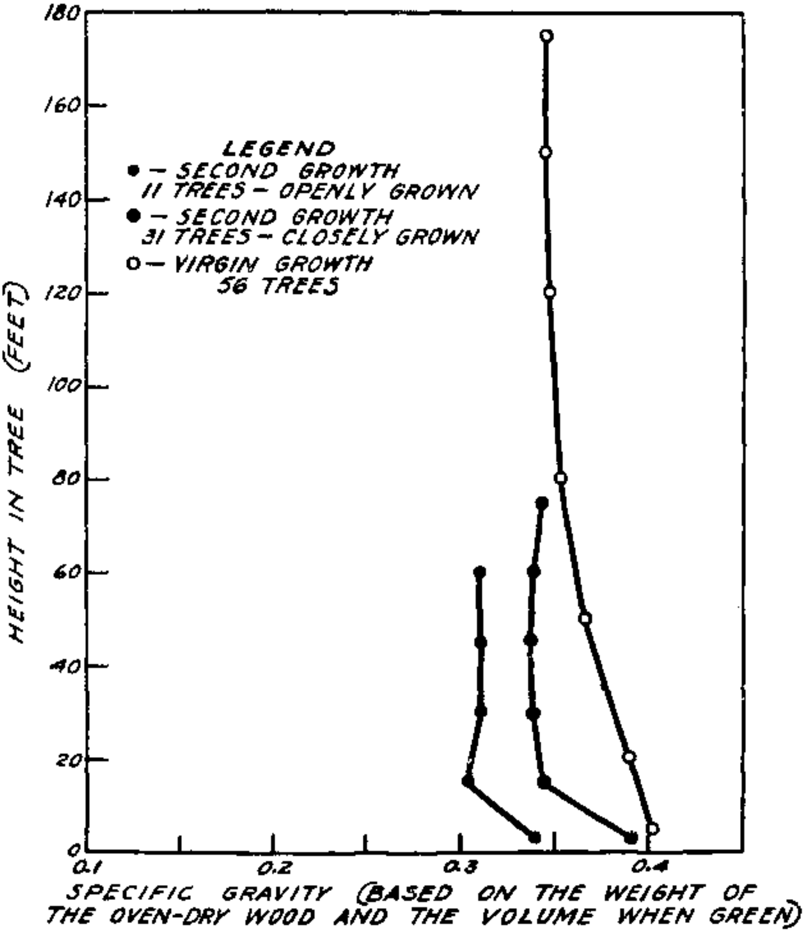



FIGURE 6.—Variation in specific gravity with height for virgin-growth and second-growth redwood.

butt shows superior toughness or shock resistance for its weight. On the other hand, wood from the swelled butts of certain swamp-grown hardwoods is usually low in specific gravity and of inferior strength properties, whereas that above the swelled butt is more nearly normal.

### POSITION IN CROSS SECTION OF TREE

Position in cross section is not in itself a reliable guide to the strength of the wood. As in other instances, the wood of highest specific gravity has the best strength properties.

In coniferous species wood near the pith of the tree is often of very rapid growth and low specific gravity, whereas that in the outer part of overmature trees is of slow growth and likewise of medium to low specific gravity, the wood of highest strength most frequently being that in the intermediate zone. The many factors influencing growth, however, result in wide diversity of wood formation and preclude the drawing of rigid general rules (fig. 7).

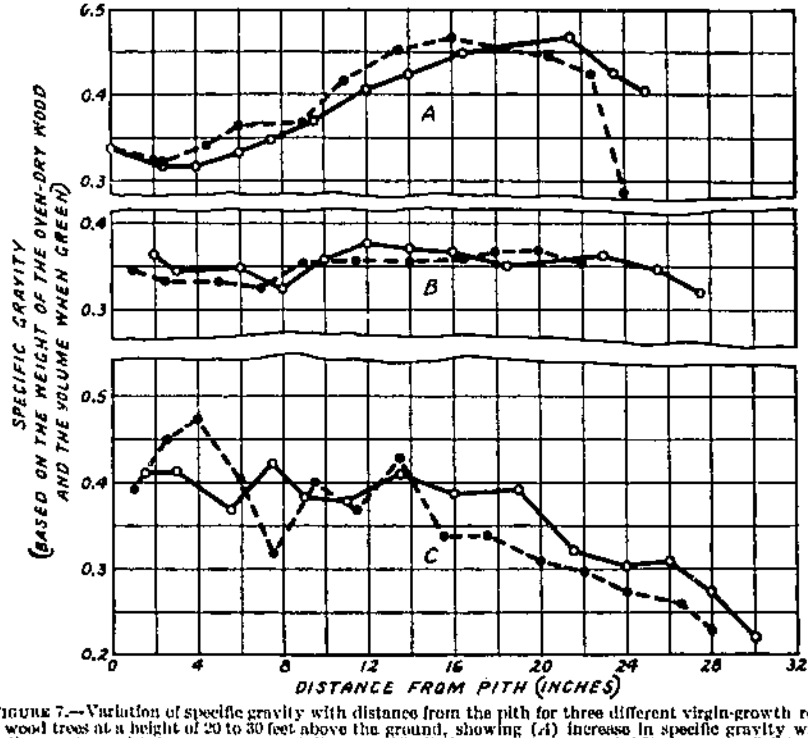



FIGURE 7.—Variation of specific gravity with distance from the pith for three different virgin-growth redwood trees at a height of 20 to 30 feet above the ground, showing (*A*) increase in specific gravity with distance from pith for greater part of diameter (*B*) little or no change, and (*C*) decrease. Solid and dotted lines represent specimens taken from opposite sides of the pith.

In the hardwoods, wood of high density may be produced at any stage in the life of the tree, depending on the growth conditions at the particular time the wood is formed *(39)*. In some hickory trees, for instance, wood of high density is found near the pith, and in others farther out in the cross section.

### HEARTWOOD AND SAPWOOD

The trunk and principal branches of a tree consist of a central portion called heartwood surrounded by a layer of sapwood.

All wood is formed as sapwood and as the growth of the tree proceeds the inner portion becomes heartwood. In most species the transformation is accompanied by an infiltration of various substances that cause a change in color and in some species by the plugging up of the pores with a frothlike growth, known as "tyloses" *(13)*.

In the many tests which have been made on the various species of wood, no effect upon the mechanical properties of most species due to change from sapwood to heartwood has been found. In general the conditions of growth that prevail when wood is first formed determine its strength properties and whether heartwood or sapwood is the stronger depends on those conditions. Consequently, in one tree the heartwood may excel and in another of the same species the sapwood. Thus the heartwood of the southern pines and of Douglas fir is not, as has often been supposed to be the case, intrinsically stronger than the sapwood. The sapwood of hickory or ash may be either superior or inferior to the heartwood for handles (*8*). In some instances, however, as shown in the discussion of extractives, heartwood and sapwood do differ essentially in strength properties.

The heartwood of many species is of much darker color than the sapwood. In numerous species, on the other hand, the color difference is nonexistent or very slight. The sapwood of all species is lacking in resistance to decay and rapidly loses its strength if exposed to conditions favoring the growth of decay-producing organisms. The heartwood of some species is very resistant to decay, while that of other species is readily attacked.

Sapwood is more permeable to liquids than heartwood, and hence is desirable in wood that is to be impregnated or treated to increase its resistance to decay, fire, or insect attack.

### VARIATION AMONG TREES

In addition to the variation of wood from one part to another of the same tree, there are considerable differences among trees of a species including those that grow side by side. The magnitude of these variations is illustrated by data on redwood. Of 57 virgin-growth trees examined in lots of 4 to 6 from each of 12 different localities throughout the range, the greatest observed difference in average specific gravity between individual trees from a single locality was 25 percent, based on the heaviest tree, whereas considering the entire range the greatest difference between individual trees was only 30 percent. The two trees representing the extremes found in the entire range were from the same county. These data indicate that the growth conditions affecting individual trees within a single site, and perhaps inherent differences in strains or types of trees, are of much greater importance in causing variations in specific gravity than geographical location within the normal range of growth of the species.

*Probable variation of random tree from average for species*

| Property | Percent |
|---|---|
| Specific gravity based on volume when green | 4 |
| Static bending: | |
| Fiber stress at proportional limit | 9 |
| Modulus of rupture | 7 |
| Modulus of elasticity | 9 |
| Work to maximum load | 15 |
| Impact bending: | |
| Fiber stress at proportional limit | 8 |
| Work to proportional limit | 12 |
| Height of drop | 13 |
| Compression parallel to grain: | |
| Fiber stress at proportional limit | 12 |
| Crushing strength | 7 |
| Compression perpendicular to grain: Fiber stress at proportional limit | 14 |
| Hardness: | |
| End | 10 |
| Side | 9 |
| Shearing strength parallel to grain | 7 |
| Tension perpendicular to grain | 12 |

The preceding tabulation presents an estimate of the probable variation of a random tree from the average for a species, for a number of physical and mechanical properties. The values are general figures derived from a number of species.

### LOCALITY OF GROWTH

In considering the causes of variations in properties of wood, it may first be noted that many factors affect the growth of trees. Such features of environment as soil, soil moisture, climatic conditions, and competition for light and food, vary widely within small areas, and are subject to further variation from one period to another during the life of the tree. Their effect is seemingly of greater importance than geographical location within the normal range of a species. This is indicated by the finding of significant differences in strength properties between samples from adjacent areas, among trees grown within a few yards of each other and between the inner and outer portions of the same tree and the observation that samples from widely separated regions may be very similar (*29*). This is illustrated by the discussion of redwood on page 42.

A further example is noted in Sitka spruce. Samples from two localities in Oregon show an average difference of 12 percent in specific gravity and 20 percent or more in modulus of rupture. In contrast, samples from near Ketchikan, Alaska, tested in a green condition, average the same in specific gravity as samples from near Portland, Oreg., and the difference in modulus of rupture was only a few percent. These and similar observations lead to the general conclusion that, in the absence of specific data concerning a given lot of material, average data for the species is a more reliable estimate of the strength properties of that lot than data on samples from adjacent localities or from sites that appear to be the same. However, there may be differences apparent in the grade and quality of wood from different stands, especially old-growth and second-growth stands in which prevalence of defects, seasoning characteristics, and the like, are sufficient in importance to justify marketing preferences.

The whole problem of the effect of region, site, and conditions of stand on wood properties is an exceedingly complicated one, and sufficient data are not available nor has sufficient study been made to attempt a final appraisal.

A few instances of significant differences in the properties of a species grown in different regions have been noted. For example, Douglas fir grows to larger size in the moist region of the Pacific Northwest than in the drier Rocky Mountain States, and the wood from the former region averages somewhat higher in specific gravity and strength properties than the latter. On the other hand, weight for weight, the wood from the two regions has the same strength, and pieces of Douglas fir from the Rocky Mountain region may be selected which are higher in properties than unselected Douglas fir from the Pacific Northwest.

Another significant effect of growth conditions on properties is that resulting from inundation. Some of the hardwoods, notably ash and tupelo gum (*44*) grown in the overflow bottom lands of the lower Mississippi basin develop swelled butts, the wood in which although of rapid growth and relatively good appearance, is low in specific gravity and poor in mechanical properties compared to average material of the species. The characteristics of the wood from these swelled butts are so unlike those of the normal wood of the species that it cannot be satisfactorily employed for the same uses. Wood above this butt swell usually is normal in properties. Hence one utilization problem is the proper classification of such stock according to its properties and potential uses.

### RATE OF GROWTH

Rate of growth as indicated by the width of the annual rings is of some assistance in appraising the physical and mechanical properties of wood, but it cannot be regarded as an efficient criterion for selection. Density or specific gravity, as explained on page 36, is a much more reliable criterion of strength. In any species, wood of excellent mechanical properties may vary considerably in rate of growth, but such material will quite consistently be of good density.

Among the ring-porous hardwoods, such as hickory, ash, and the oaks, the production of wood with low specific gravity is caused by some unfavorable condition which interferes with the normal growth of the tree. As a rule, wood of fairly rapid growth put on at any

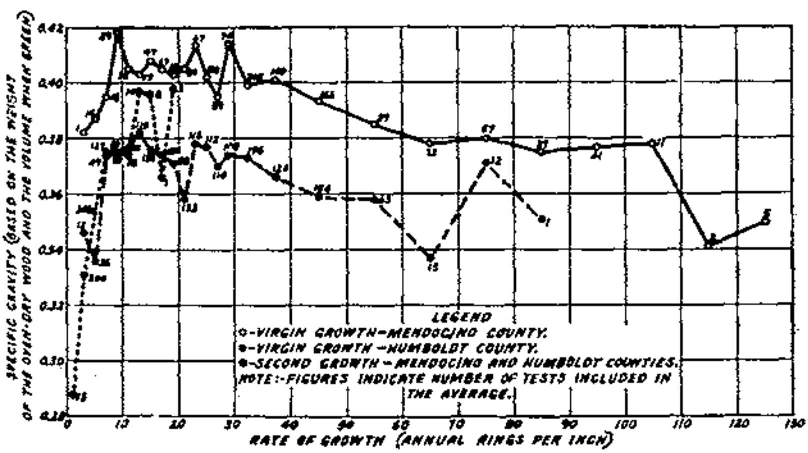



FIGURE 8.—Relation between specific gravity and rate of growth of the heartwood of redwood.

period of the life of the tree, is likely to be excellent in weight and strength. Wood of slow but uniform growth near the center of a tree may also be of high density, but wood of slow growth near the outside of the same tree is sure to be poorer if an interval of faster growth has intervened, or if the outer growth is slower than that about the center (*39*). Hence, in the ring-porous hardwoods fast growth (few rings per inch) is generally indicative of good strength properties, although slow growth does not necessarily indicate weak material. An exception is found in the rapid growth material from swelled butts of swamp-grown trees (p. 40).

Of the diffuse-porous hardwoods studied, sugar maple trees produced dense wood during early age whether their growth was rapid or slow. In some of the yellow poplar trees examined, wood of more rapid growth near the center was lighter in weight than that from the rest of the cross section, while other trees growing on rich alluvial soil did not exhibit this difference. Accelerated growth following a period of slow growth resulted in an increase in the specific gravity of the wood, and hence in strength.

Softwood species show a wide range in density and strength at each rate of growth, but usually the strongest material is associated with a normal growth rate. Exceedingly rapid or exceptionally slow growth is most likely to be attended by low density and low mechanical properties. The lighter weight, slow-growth material shrinks and swells less with moisture changes than the heavier material, and usually stays in place better because of its greater freedom from internal stresses, so that it is to be preferred for many uses not primarily involving strength.

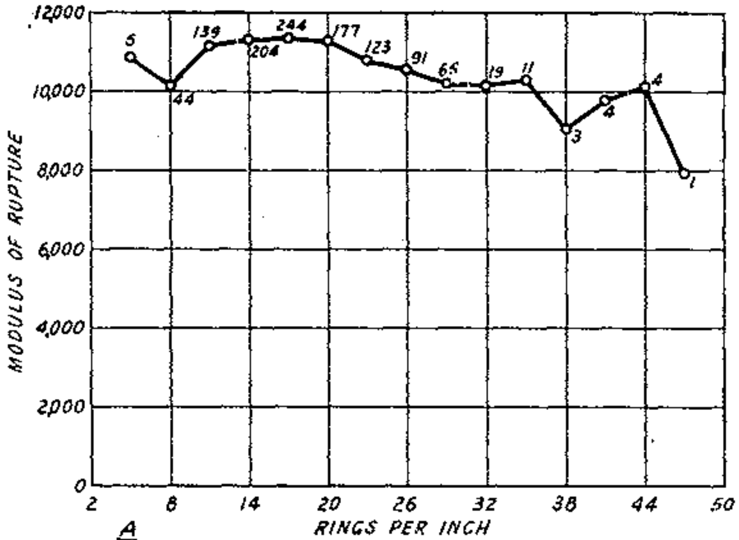
Figure 8 illustrates the relations between rate of growth (rings per inch) and specific gravity for redwood (*24*), and figure 9, the relation between rate of growth and modulus of rupture and work to maximum load for hickory.

#### TIMBER FROM LIVE AND FROM DEAD TREES

Sound wood from trees killed by insects, fungi, wind, or fire is, unless unduly checked, as good for any structural purpose as that from trees that were alive when cut (*20*).

If a tree stands on the stump after its death the sapwood is likely to become decayed or to be severely attacked by wood-boring insects, and in time the heartwood will be similarly affected. Such deterioration occurs also in logs that have not been properly cared for subsequent to being cut from live trees. Because of variations in climatic and local weather conditions and in other factors that affect the rate of deterioration, the length of the period during which timber may stand dead on the stump or may lie in the forest without serious deterioration varies. Tests on wood from trees of one species that had stood as long as 15 years after fire-killing demonstrated that this wood was sound and as strong as wood from live trees. Also logs of some of the more durable species have had thoroughly sound heartwood after lying on the ground in the forest for several decades. On the other hand, decay may cause great loss of strength within a very brief time, both in trees standing dead on the stump and in logs that have been cut from live trees and allowed to lie on the ground. Consequently, the important consideration is not whether the trees from which timber products are cut are alive or dead, but whether the products themselves are free from decay or other defects that would render them unsuitable for use. In considering the utility of timber from a dead tree it is helpful to remember that the heartwood of a living tree is entirely dead, and in the sapwood only a fraction of the cells are alive.

Decay that is not sufficiently advanced to be readily detected may still affect seriously the strength of a piece of wood. For this reason and also because decay is present in timber from dead trees more frequently than in that cut from freshly felled live trees, timber from dead trees needs more careful inspection. Specifications for some timber products, notably poles and piling, often require that only live trees be used. This requirement is difficult to enforce unless inspection is made in the forest, because wood cut from dead trees before weathering, seasoning, discoloration, decay, insect attack, or similar change has occurred cannot ordinarily be distinguished from wood



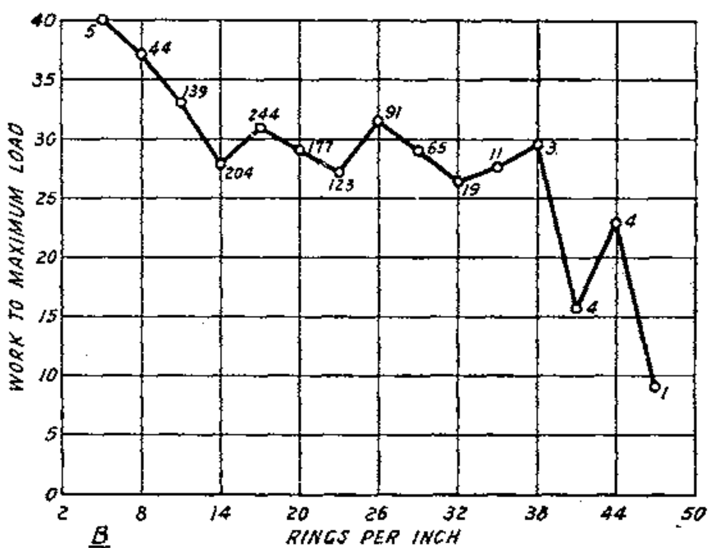




FIGURE 9.—Relation between the rate of growth and modulus of rupture (A) and also work to maximum load for green hickory (B). Figures indicate number of tests included in the average.

taken from live trees. Many specifications omit the live-tree requirement, depending entirely on inspection to determine the suitability of timber for use.

### EFFECT OF RESIN AND OF TURPENTINING

Resin is formed in some of the conifers, especially the southern pines. Amounts up to 6 percent of the weight of the dry wood are common, and pieces with a resin content up to 50 percent are sometimes found.

Tests at the Forest Products Laboratory on southern yellow pine indicate that resin will slightly increase some strength properties but the effect is too small to be of any practical significance (*10*). An excessive amount of resin is sometimes associated with an injury such as a compression failure that may have greatly reduced the strength.

Longleaf and slash pine trees are frequently "tapped" for turpentine. The results of a special investigation, involving mechanical tests, and physical and chemical analyses of the wood of turpentined and unturpentined trees from the same locality (*10*), show that (1) turpentined timber is as strong as unturpentined if of the same weight (table 15); (2) the weight and shrinkage of the wood is not affected by turpentining; and (3) except in parts adjacent to the "faces" where there may be a concentration of resin, turpentined trees contain practically neither more nor less resin than unturpentined trees, the exudation of resin occurring only from the sapwood, and therefore the resin content of the heartwood is not affected by the turpentining process.

TABLE 15.—*Effect of turpentining on the strength of longleaf pine*

| Item | Tests | Relative specific gravity of test pieces | Modulus of rupture | Maximum crushing strength (parallel to grain) |
|---|---|---|---|---|
| | *Number* | | *Lb. per sq. in.* | *Lb. per sq. in.* |
| Unboxed (not turpentined) trees | 400 | 1.00 | 12,358 | 7,160 |
| Boxed (turpentined) and recently abandoned | 390 | 1.07 | 12,961 | 7,613 |
| Boxed (turpentined) and abandoned 5 years | 535 | 1.03 | 12,586 | 7,575 |

## EXTRACTIVES AS RELATED TO STRENGTH

Extractives are constituents that dissolve when a piece of wood is placed in a solvent that has little or no effect on the wood substance. They are referred to as cold-water, hot-water, or alcohol-soluble extractives, depending on the solvent used. Extractives are found in the heartwood of many species and are especially abundant in redwood, western red cedar, and black locust. These species are also relatively high in certain strength properties for the amount of wood substance they contain, particularly when unseasoned, and tests have shown that the presence of extractives is probably accountable. The extent to which extractives affect the strength is apparently dependent upon the amount and nature of the extractives, the species of wood, the moisture condition of the piece, and the mechanical property under consideration. Of the properties examined, maximum crushing strength in compression parallel to the grain showed the greatest increase as the result of the infiltration of extractives accompanying the change of sapwood into heartwood, and shock resistance the least, with modulus of rupture intermediate. In fact, under some conditions shock resistance appears to be actually lowered by extractives. That extractives may affect different species differently is indicated by the fact that they appear to affect the strength of western red cedar less than the strength of black locust, although black locust has a smaller percentage of extractives (*23*). Difference in the character of the extractives is probably also a factor in this connection.

## TIME OR SEASON OF CUTTING

The time or season of cutting is sometimes thought to affect the properties and durability of wood, but so far as is known it actually has very little direct effect on the characteristics of the wood itself. The method of handling after cutting, however, may be very important. During the summer, for instance, seasoning proceeds more rapidly and is more apt to produce checking than in the winter. Insects, stains, and decay-producing fungi are more vigorous in the summer and the freshly-cut wood is most subject to attack at this time. Winter cutting, therefore, has the advantage that more favorable seasoning conditions and greater freedom from stains, molds, decay, and insects simplify the problem of caring for the timber before conversion. There is but little difference in the moisture content of green wood in winter and in summer.

## MOISTURE AS RELATED TO STRENGTH

Wood in the green state contains considerable moisture varying from about 30 to 40 percent (based on the weight of the dry wood) in the heartwood of some of the pines to over 200 percent in some other species. Part of this moisture is held absorbed by the cell walls and part is held within the cell cavities as water is held in a container (*15, 47, 60*). As wood dries, the cell walls do not give off moisture until the adjacent cavities are empty. The condition in which the cell walls are fully saturated and the cell cavities empty is known as the "fiber-saturation point." It varies from 25 to 35 percent moisture content.

Increase in strength begins when the cell walls begin to lose moisture; that is, after the wood is dried to below the fiber-saturation point. From this point on most strength properties increase rapidly as drying progresses. This increased strength of dry over green wood of the same dimensions is due to two causes: (1) Actual strengthening and stiffening of the cell walls as they dry out, and (2) increase in the compactness or the amount of wood substance in a given volume because of the shrinkage that accompanies drying below the fiber-saturation point.

Drying wood down to 5-percent moisture may add from about 2½ to 20 percent to its density, while in small pieces its end-crushing strength, and bending strength, may easily be doubled and in some woods tripled. Thus, the first of the two factors mentioned is the one chiefly responsible for the increase in strength.

The increase in strength with seasoning is much greater in small clear specimens of wood than in large timbers containing defects. In the latter the increase in strength is to a large extent offset by the influence of defects that develop in seasoning.

The various strength properties are not equally affected by changes in moisture content. Whereas some properties, such as crushing strength and bending strength increase greatly with decrease in moisture, others, such as stiffness, change only moderately, and still

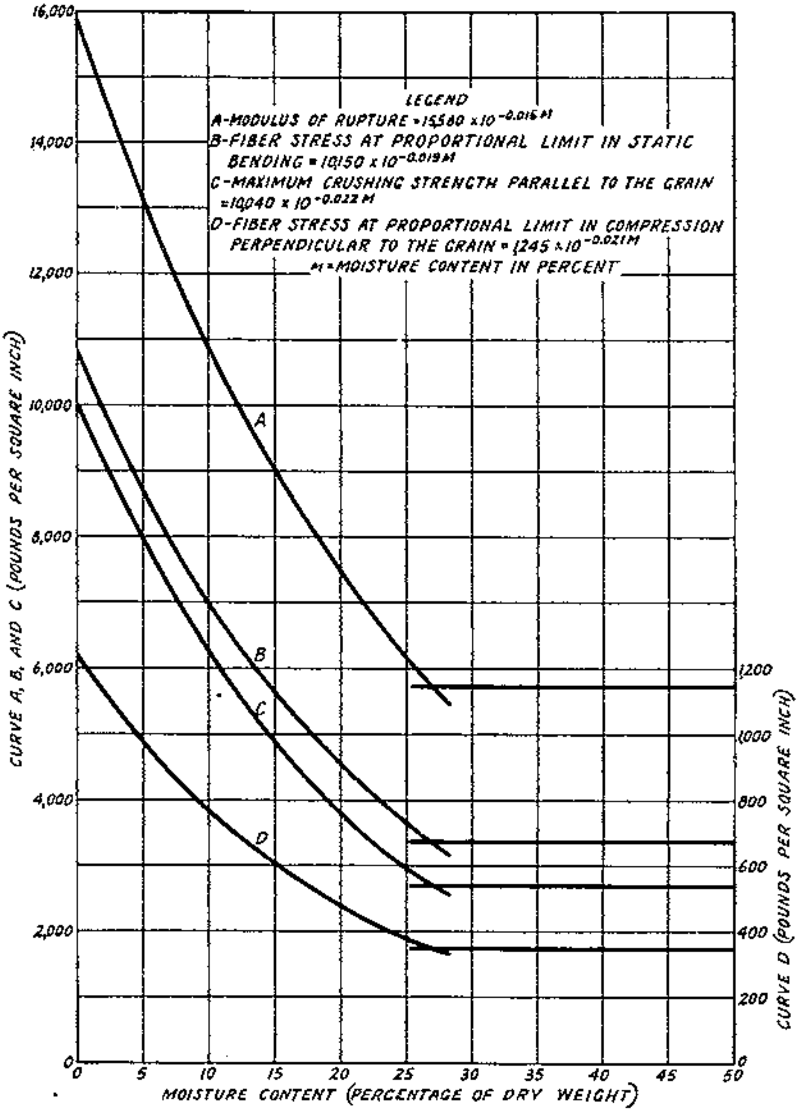



FIGURE 10.—The relation between mechanical properties and the moisture content of small clear specimens of Sitka spruce.

others, such as shock resistance, may even show a slight decrease. This last effect is due to the fact that drier wood does not bend so far as green wood before failure, although it will sustain a greater load, and because shock resistance or toughness is dependent upon both strength and pliability.

120605°—35——4

The following tabulation shows the average variation of the strength properties of wood with change in moisture content, and figure 10 shows graphically the effect of moisture on certain strength properties of Sitka spruce.

*Average increase (or decrease) in value effected by lowering (or raising) the moisture content 1 percent*

| Property: | *Percent* |
|---|---|
| Static bending: | |
| Fiber stress at proportional limit | 5 |
| Modulus of rupture, or cross-breaking strength | 4 |
| Modulus of elasticity or stiffness | 2 |
| Work to proportional limit | 8 |
| Work to maximum load or shock-resisting ability | ½ |
| Impact bending: | |
| Fiber stress at proportional limit | 3 |
| Work to proportional limit | 4 |
| Height of drop of hammer causing complete failure | −½ |
| Compression parallel to grain: | |
| Fiber stress at proportional limit | 5 |
| Maximum crushing strength | 6 |
| Compression perpendicular to grain: | |
| Fiber stress at proportional limit | 5½ |
| Hardness, end grain | 4 |
| Hardness, side grain | 2½ |
| Shearing strength parallel to grain | 3 |
| Tension perpendicular to grain | 1½ |

## METHODS OF MOISTURE-STRENGTH ADJUSTMENT

It is often desirable to adjust strength values for wood at one moisture content to what they would be under some other condition. This can be done quite accurately when the data apply to small clear specimens which are quite uniformly dried so that the moisture content is approximately the same at all points of the cross section.

Three general methods, differing materially in their accuracy, and in simplicity and facility of application, may be used for moisture-strength adjustments. These are referred to as the (1) approximate method, (2) the equation method, and (3) the graphical method.

### APPROXIMATE METHOD

The approximate method of moisture-strength adjustment consists simply in an application of the percentage figures of the tabulation above for the property under consideration, regardless of species. For example, if the maximum crushing strength of Sitka spruce at 12-percent moisture content is 5,610 pounds per square inch, what is the approximate value at 10-percent moisture? From the tabulation it may be noted that the average change in maximum crushing strength for 1-percent change in moisture is 6 percent. For 2-percent change in moisture content (12-percent moisture to 10-percent moisture) the average expected change in maximum crushing strength would consequently be 12 percent. Since this property increases with decrease in moisture content, the approximate increase in strength is 12 percent of 5,610=673, and the approximate maximum crushing strength at 10-percent moisture is 5,610+673=6,283 pounds per square inch.

This is the least accurate of the several methods described, and is useful only for making rough approximations. For comparison it may be noted that application of the equation method to the foregoing example gives a value of 6,194 pounds per square inch.

## EQUATION METHOD

Studies at the Forest Products Laboratory (*60*) have led to the derivation of a formula for strength adjustment, the numerical solution of which affords more accurate estimates than any other method. This formula, known as the exponential formula is based on the fact that for any one species and strength property, moisture-content values within certain limits and the logarithms of corresponding strength values have been found to conform closely to a straight-line relationship.

The formula may be written

$$\text{Log } S_D = \log S_C + (C - D)\,\frac{\log (S_B \div S_A)}{A - B}$$

where $A$, $B$, $C$, and $D$, are values of moisture content and $S_A$, $S_B$, $S_C$, and $S_D$ are corresponding strength values; $S_C$ is the strength value from tests made at moisture content $C$ and $S_D$ is this strength value adjusted to moisture content $D$. The expression

$$\frac{\log (S_B \div S_A)}{A - B}$$

which is equivalent to

$$\frac{\log S_B - \log S_A}{A - B}$$

measures the change in strength property caused by a change of 1 percent in the moisture content. Required for evaluation of this expression are strength values $S_A$ and $S_B$ found from tests made at two different moisture contents $A$ and $B$ on matched specimens; that is, specimens that can be assumed to be alike except for the single factor of moisture content, such as specimens from closely adjacent positions within the same annual growth layers.

When in any instance a strength value is that for green material, the corresponding moisture content to be used for the species under consideration is listed in the following tabulation:

| Species[9]: | *Moisture content* (*Percent*) |
|---|---|
| Ash, white | 24 |
| Birch, yellow | 27 |
| Chestnut | 24 |
| Douglas fir | 24 |
| Hemlock, western | 28 |
| Larch, western | 28 |
| Pine: | |
| Loblolly | 21 |
| Longleaf | 21 |
| Norway | 24 |
| Redwood | 21 |
| Spruce: | |
| Red | 27 |
| Sitka | 27 |
| Tamarack | 24 |

[9] The exact value has been determined only for the species listed here. For other species the value of 24 percent may be assumed to apply.

Three types of moisture-strength adjustment differing with respect to the source of the data for evaluating the expression

$$\frac{\log (S_B \div S_A)}{A-B}$$

are defined and illustrated in the following paragraphs:

TYPE 1. From tests on matched groups of material at two different moisture-content values, a strength value corresponding to a third value of moisture content is computed, the data for evaluating the expression

$$\frac{\log (S_B \div S_A)}{A-B}$$

being supplied by the tests on the material under consideration.

Example: The average maximum crushing strength of Sitka spruce as listed in table 1 is 2,670 pounds per square inch for green material and 5,610 pounds per square inch for material at 12 percent moisture. Compute the maximum crushing strength corresponding to a moisture content of 14 percent.

$S_A$=2,670 from table 1, and $A$ for green material is 27.

$S_B$=5,610, $B$=12. $C$ may be taken either as 27 or 12 with corresponding choice of $S_C$; that is, either the value for green material or that for material at 12-percent moisture may be adjusted to 14-percent moisture content.

D=14.

Taking $C$=12, and $S_C$=5,610.

$$\text{Log } S_{14} = \log 5{,}610 + (12-14)\frac{\log (5{,}610 \div 2{,}670)}{27-12}$$

$$= 3.7490 - 2 \times \frac{0.3224}{15}$$

$$= 3.7490 - 0.0430 = 3.7060$$

Then $S_{14}$=antilog 3.7060=5,082.

or

Taking $C$=27 and $S_C$=2,670

$$\text{Log } S_{14} = \log 2{,}670 + (27-14)\frac{\log (5{,}610 \div 2{,}670)}{27-12}$$

$$= 3.4265 + 13 \times \frac{0.3224}{15}$$

$$= 3.4265 + 0.2794 = 3.7059$$

Then $S_{14}$=antilog 3.7059=5,082 as before, and the maximum crushing strength of Sitka spruce at 14-percent moisture content, as obtained by adjusting to this moisture content the average values given in table 1, is 5,082 pounds per square inch.

TYPE 2. A strength value obtained at one moisture content is adjusted to a second value of moisture content, the data for evaluating the expression

$$\frac{\log (S_B \div S_A)}{A-B}$$

as found in other tests on the same species being assumed to apply.

Example: A specimen of longleaf pine at 9.8-percent moisture content was found from test to have a modulus of rupture of 13,500 pounds per square inch. Estimate the value of modulus of rupture that would have resulted had the test been made at a moisture content of 12 percent.

Values of modulus of rupture on matched specimens of longleaf pine are given in table 1 as 8,700, which is equal to $S_A$, and 14,700, which is equal to $S_B$, pounds per square inch for the green and 12-percent moisture conditions, respectively. $A$, from the tabulation (p. 51) $=21$, $B=12$, $C=9.8$, and $D=12$.

Then substituting in the formula

$$\text{Log } S_{12} = \log 13{,}500 + (9.8-12)\frac{\log (14{,}700 \div 8{,}700)}{21-12}$$

$$=4.1303-2.2\times\frac{0.2278}{9}$$

$$=4.1365-0.0557=4.0746$$

$S_{12}$=antilog 4.0746=11,874

and the modulus of rupture at 12-percent moisture as estimated from the value determined at 9.8-percent moisture is 11,874 pounds per square inch.

TYPE 3. As in type 2. except that the data for evaluating the expression

$$\frac{\log (S_B \div S_A)}{A-B}$$

for the same species not being known an average value as computed from tests of other species is assumed to apply.

Example: The modulus of rupture of a sample of a hardwood species tested at 9-percent moisture content was 11,700 pounds per square inch. Estimate the value at 12-percent moisture. Here $S_C=11{,}700$, $C=9$, and $D=12$. No values of $S_A$ and $S_B$ for the same species being available, it is assumed that the strength-moisture relationship for this hardwood is similar to that for hardwood species in general and 1.59, the value of $\frac{S_{12}}{S_G}$ as given for modulus of rupture of hardwood species in table 16, is used for $\frac{S_A}{S_B}$. $A=12$ and for $B$ the value of 24 from the tabulation on page 51 is taken. Substituting in the formula:

$$\text{Log } S_{12} = \log 11{,}700 + (9-12)\frac{\log 1.59}{24-12}$$

$$=4.0682-3\times\frac{0.2014}{12}$$

$$=4.0682-0.0503=4.0179$$

TABLE 16.—*Average strength ratios* $\left(\frac{S_{12}}{S_g}\right)$ *for species in drying from a green condition to 12-percent moisture content*

| Property | Hardwoods (113 species) | Softwoods (54 species) |
| --- | --- | --- |
| Static bending: | | |
| Fiber stress at proportional limit | 1.80 | 1.81 |
| Modulus of rupture | 1.59 | 1.61 |
| Modulus of elasticity | 1.31 | 1.28 |
| Work to proportional limit | 2.49 | 2.56 |
| Work to maximum load | 1.05 | 1.13 |
| Impact bending: | | |
| Fiber stress at proportional limit | 1.44 | 1.39 |
| Work to proportional limit | 1.68 | 1.59 |
| Height of drop causing complete failure | .80 | 1.03 |
| Compression parallel to grain: | | |
| Fiber stress at proportional limit | 1.74 | 1.86 |
| Maximum crushing strength | 1.95 | 1.97 |
| Compression perpendicular to grain: Fiber stress at proportional limit | 1.84 | 1.96 |
| Hardness: | | |
| End | 1.55 | 1.67 |
| Side | 1.33 | 1.40 |
| Shear parallel to the grain: Maximum shearing strength | 1.43 | 1.37 |
| Tension perpendicular to grain: Maximum tensile strength | 1.20 | 1.23 |

$$S_{12} = \text{antilog } 4.0179 = 10{,}400$$

Obviously, adjustments of type 1 are most and those of type 3 least accurate. The inaccuracy in types 2 and 3 is due to the assumed values of the expression

$$\frac{\log (S_B \div S_A)}{A - B}$$

not being definitely applicable.

In types 2 and 3 the accuracy of the computed or estimated value decreases with increase in moisture difference for which adjustment is made.

### GRAPHICAL METHOD

The graphical method consists of using a chart (fig. 11) for the solution of the formula described under the equation method, thus avoiding the use of logarithms as required in the arithmetical calculation. This method is, therefore, simpler than the equation method, but due to the personal equation in reading the chart and the small scale of the chart, the adjustment is less accurate.

The procedure in the use of the chart is as follows:

1. First determine *K*, the ratio of the strength when dry to the strength when green for the strength property and species under consideration. This ratio should be determined from one of the three following sources, with preference in the order named:

(*a*) From the tests of matched green and dry material for which the adjustment is to be made.

(*b*) From the data for green and dry material of table 1.

(*c*) From the ratios of table 16.

2. Determine the difference in moisture between the value to be used for green material (table 1) and the moisture content of the dry material on which the preceding dry to green strength ratio is based. (For all species listed in table 1 the moisture content of the dry material is 12 percent.

3. Determine the difference between the moisture content of the material at test and the moisture content to which adjustment is to

be made. This difference represents the range in moisture over which the adjustment is to be made.

4. Locate on the chart a point corresponding to the difference in moisture content as determined under 2 and the ratio $K$ as determined under 1. From the line joining this point with the lower

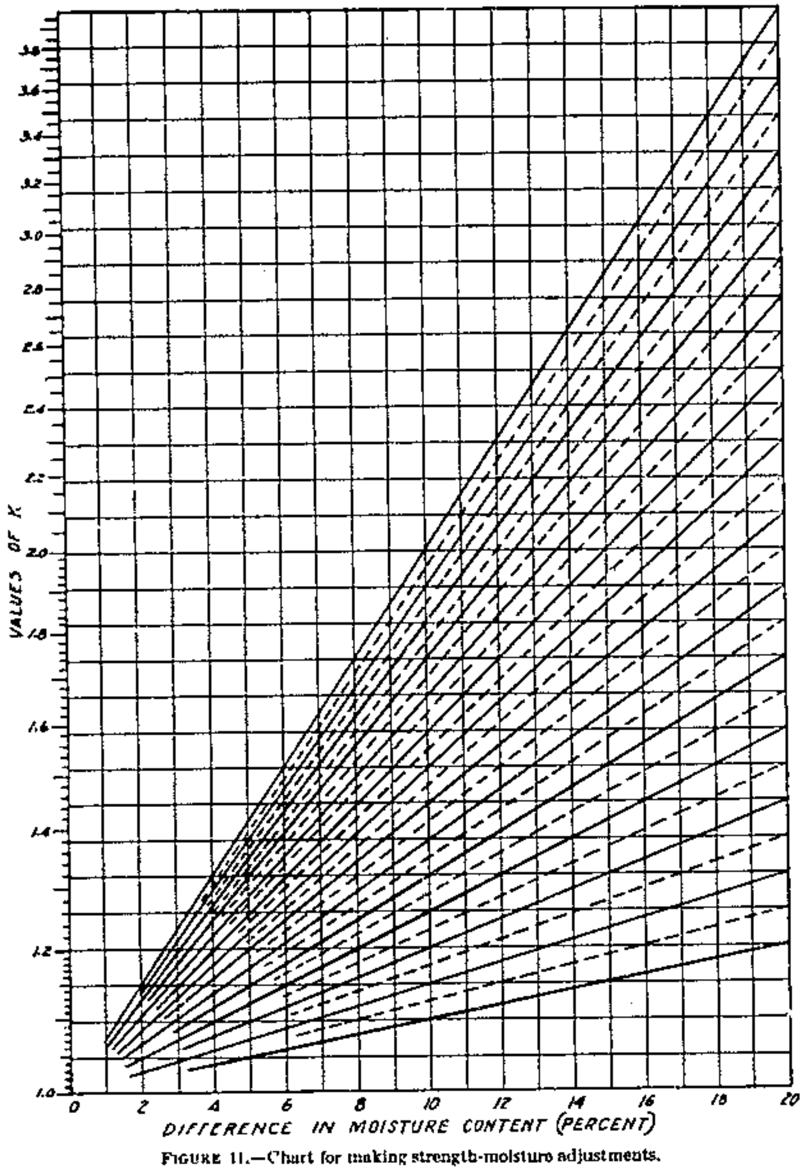



FIGURE 11.—Chart for making strength-moisture adjustments.

left-hand corner of the chart the ratio corresponding to any difference in moisture content can be found.

5. Locate on this line, the point that corresponds to the difference in the moisture content as determined under 3, and read the corresponding new strength ratio $K$ on the left-hand scale.

6. (*a*) If the adjustment is being made to a lower moisture content than that at which the tests were made, multiply the strength at test by the new ratio (as obtained in 5 above) to get the adjusted strength value.

(*b*) If the adjustment is being made to a higher moisture content than that at which the tests were made, divide the strength at test by the new ratio (as obtained in 5 above) to get the adjusted strength value.

Example 1. Tests of matched specimens of Douglas fir gave values of maximum crushing strength of 3,940 and 10,680 pounds per square inch, respectively, for green wood and wood at 6.2-percent moisture content. What is the strength at 12-percent moisture content?

1. The ratio $K=\frac{10{,}680}{3{,}940}=2.71$.

2. The difference between the moisture content to be used for green material (tabulation on p. 51) and that at test is 24−6.2=17.8 which is the difference in moisture content to which the ratio 2.71 applies.

3. The difference between the moisture content of the dry material at test and the moisture content to which adjustment is desired is 12−6.2=5.8.

4. Starting with the ratio 2.71 on the left-hand margin of figure 11, and following horizontally to the vertical representing the 17.8-percent moisture difference, locate a point.

5. Following the converging line on which this point is located to its intersection with a vertical corresponding to the moisture difference of 5.8 (step 3), and thence horizontally to the left-hand margin, a new ratio $K$ of 1.38 is found.

6. The maximum crushing strength at 12 percent moisture is $\frac{10{,}680}{1.38}=7{,}740$ pounds per square inch. The moisture content of 12 percent to which adjustment is made is higher than the moisture content at test. Consequently the strength value at test is divided by the ratio.

Example 2. The modulus of rupture of a sample of hardwood species tested at 13-percent moisture content was 10,030 pounds per square inch. What is the estimated value at 9-percent moisture?

1. Since data on matched green and dry material are not available, the average ratio of strength when dry (12-percent moisture content) to that when green for a hardwood is taken from table 16, and is 1.59.

2. From the tabulation on page 51, the moisture content to be used for green material is assumed to be 24-percent moisture content. The ratio of 1.59 applies to material at 12-percent moisture content. The moisture difference is, therefore, 24−12=12-percent moisture content.

3. The differences between the moisture content of the sample at test and the moisture to which adjustment is desired is 13−9=4 percent.

4. Starting with the ratio 1.59 on the left-hand margin of figure 11, and following horizontally to the vertical representing 12-percent moisture difference, locate a point.

5. Following the converging line through this point to its intersection with the vertical corresponding to the moisture difference of 4

percent (step 3), and thence horizontally to the left-hand margin, the ratio $K$ of 1.165 is found.

6. The modulus of rupture at 9-percent moisture content is $10{,}030 \times 1.165 = 11{,}680$ pounds per square inch. In this instance the moisture content of 9 percent to which adjustment is made is lower than the moisture content at test and the strength value at test is multiplied by the ratio $K$.

#### LIMITATIONS TO MOISTURE-STRENGTH ADJUSTMENTS

When the strength data are from tests on material in which the moisture is not uniformly distributed in the cross section, moisture-strength adjustments on the basis of the methods just outlined cannot be considered as reliable, and no acceptable general method for the adjustment of such data is available.

### COMPARATIVE STRENGTH OF AIR-DRIED AND KILN-DRIED WOOD

Some wood users contend that kiln-dried wood is brash and not equal in strength to wood that is air-dried. Others advance figures purporting to show that kiln-dried wood is much stronger than air-dried. However, comparative strength tests, made by the Forest Products Laboratory on kiln-dried and air-dried specimens of 28 common species of wood, show that good kiln drying and good air drying have the same effect upon the strength of wood but that severe conditions in the kiln will lower most of the strength properties (*56*).

The belief that kiln drying produces stronger wood than air drying is usually the result of failure to consider differences in moisture content. The moisture content of wood on leaving the kiln is generally from 2 to 6 percent lower than that of thoroughly air-dried stock. Since wood rapidly increases in most strength properties with loss of moisture, higher strength values may be obtained from kiln-dried than from air-dried wood. Such a difference in strength is not permanent, since in use a piece of wood will come to practically the same moisture condition whether it is kiln-dried or air-dried.

It must be emphasized that the appearance of wood is not a reliable criterion of the effect the drying process may have upon its strength. The strength properties may be seriously injured without visible damage to the wood. Also, it has been found that the same kiln-drying process cannot be applied with equal success to all species. To insure kiln-dried material of the highest strength, a knowledge of the correct kiln conditions to use with stock of a given species, grade, and thickness, and a record showing that no more severe treatment has been employed, are necessary.

### TEMPERATURE AS RELATED TO STRENGTH

The moisture content of wood determines to a large extent how it is affected by temperature.

Lowering the temperature of wet or green wood decidedly increases its stiffness and its strength in compression parallel to grain. Freezing temperatures have resulted in increases of from 5 to 25 percent as compared to values at normal room temperature, the results varying with the strength property considered, the species, and the moisture condition (*12, 47*). Such effects are much less pronounced in wood whose moisture content is below the fiber-saturation point and become comparatively small at very low moisture content values.

Tests in compression parallel to grain have shown values for green wood at temperatures near the boiling point about one-fifth as great as at normal room temperature. Including both moisture and temperature effects a tenfold difference in maximum crushing strength has been observed between specimens tested immediately after soaking in hot water and other matched specimens that were tested after cooling subsequent to over drying to expel all moisture. This illustrates the importance of establishing comparable conditions of moisture and temperature when making comparisons involving strength.

Aside from the current or immediate effects of temperature as just cited, tests have shown that heating to or above the boiling point for several hours or to more moderate temperatures, such as are used in kiln drying, for longer periods may permanently lower the strength properties as compared to unheated wood at the same moisture content. The effect on the strength at some lower moisture content is somewhat less than on the strength of wood in the green or wet condition. The amount of this lowering apparently depends on a large number of variables including species, size, and moisture content of the material when heated, the temperature, and the duration of the heating period (*22*, *42*, *59*).

Steaming or boiling of wood for brief periods is used to make it pliable and prepare it for bending to curved form. Such preparation makes it possible to bend the wood to curvatures otherwise unattainable. The heating is usually for comparatively brief periods and probably has little permanent effect on the strength.

## EFFECT OF PRESERVATIVE TREATMENT ON STRENGTH

Coal-tar creosote, water-gas tar, wood-tar creosote, creosote-tar mixtures, and creosote-petroleum mixtures are practically inert to wood and have no chemical influence upon it that would affect its strength (*6*). The 2- to 5-percent solutions of zinc chloride commonly used in preservative treatment apparently have no important effect.

Although wood preservatives are not harmful in themselves, the treatment used in injecting them into the wood may result in considerable loss of strength to the wood. Green wood conditioned for the injection of preservatives by steaming or by boiling under vacuum may be seriously reduced in strength if extreme temperatures or heating periods are employed. Consequently, care should be used to keep the temperature as low and the duration of the treatment as short as is consistent with satisfactory absorption and penetration of the preservative (*59*). A gage pressure of 20 pounds (259° F.) is sufficiently high for steam conditioning. No advantage is known to result from higher pressures, and the resulting higher temperatures are much more likely to damage the wood. The maximum temperature employed in the boiling-under-vacuum process is usually less than 210°.

The use of pressures greater than 175 pounds in injecting preservatives into wood that is soft from long heating is likely to cause severe end checking and collapse. Considerably higher pressures can be used if the wood has been heated for a short time only, or not at all. Woods of low density are more subject to injury from high pressures than woods of high density.

## STRENGTH AS AFFECTED BY RATE AND METHOD OF LOADING

### DURATION OF STRESS

The duration of stress or the time during which a load or force acts on a beam or other wooden member has an important bearing on the use of the timber, and on the adaptation of results of tests to the design of different kinds of structures or members. For instance, when an airplane traveling at high speed suddenly changes its course as in flattening out following a dive, wooden members may without damage be subjected for a few seconds to forces which would cause complete failure if applied for a longer time. In impact-bending tests, where the load is suddenly applied and is maintained for but a fraction of a second, a stick will resist a force more than double that required to produce failure in a standard static-bending test. On the other hand, beams under continuous loading for years, as in warehouse floors, will fail at loads one-half to three-fourths as great as would be required to produce failure in the standard static bending test where the maximum load is reached in a few minutes (*5*, *27*, *31*, *49*).

From the foregoing it is clear that tests made under widely different conditions of loading are not comparable, and that the allowable stress in a wooden beam must be determined in accordance with the loading to which it will be subjected in service. The rapidity with which the load is applied and the duration of the stress are material factors in the result.

Figure 12 presents an interpretation of some data on the influence of rate of loading from tests of small clear specimens. A tenfold increase or decrease in the rate of loading produces approximately a 10-percent increase or decrease, respectively, in bending strength.

In timber testing, the allowable tolerance in rate of loading is limited to ±25 percent of the required rate in order to keep the variation in test results from this cause within about 1 percent (*48*).

### FATIGUE

Some tests have been carried on both in the United States and in Europe to determine the effect of repeated stress and vibration although no extended and thorough or complete investigation has been made (*30*).

In tests made at the Forest Products Laboratory on beams of circular cross section, rotated so that the outer fibers were stressed in compression and tension alternately at each revolution, the fatigue limit was found to be about one-third of the modulus of rupture as determined in static tests, on beams having square cross sections. Sometimes the fatigue limit of wooden beams with circular cross section is expressed as a ratio to the static modulus of rupture of beams also of circular cross section. Expressed in this way the ratio is less than one-third, since a beam of circular section has a form factor of 1.18. These tests involved over 300,000 stress cycles (table 17).

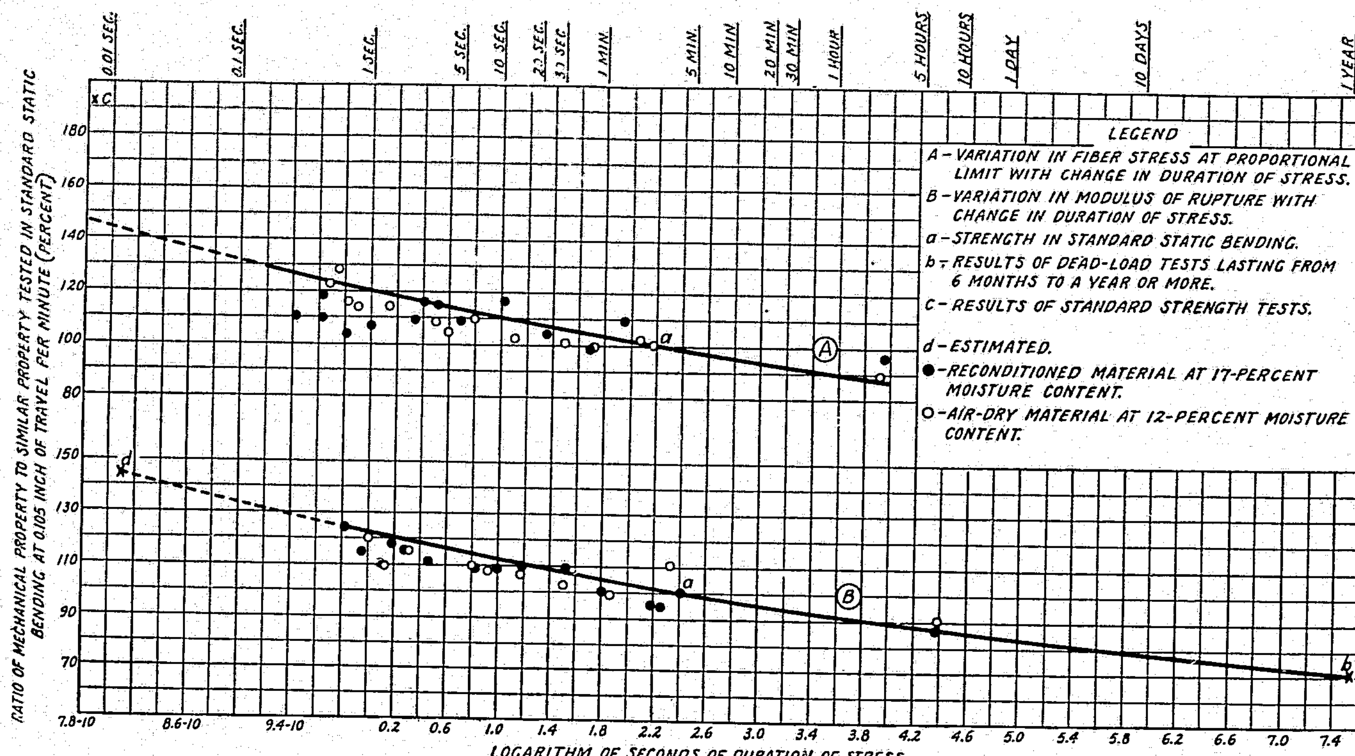



FIGURE 12.—The relation between fiber stress at proportional limit in static bending and modulus of rupture of Sitka spruce, and duration of stress. Each point is the average of the results of from 5 to 10 tests. Duration of stress is the total time between application of load and reaching the proportional limit or the maximum load.

TABLE 17.—*Results of static tests and fatigue rotating beam tests of wood*

| Kind of wood | Moisture content | Specific gravity [1] | Static modulus of rupture for specimens of circular cross section | Estimated endurance limit (rotating beam test specimens of circular cross section) | Ratio of endurance limit to modulus of rupture of beams of circular cross section | Ratio of endurance limit to modulus of rupture of beams of square cross section [2] |
|---|---|---|---|---|---|---|
| | *Percent* | | *Lb. per sq. in.* | *Cycles* | | |
| Sitka spruce | 13.8 | 0.38 | 12,100 | 3,200 | 0.27 | 0.32 |
| Southern white oak | 82.4 | .58 | 10,600 | 3,200 | .30 | .35 |
| Douglas fir | 14.3 | .50 | 15,000 | 4,000 | .27 | .32 |
| Do | 23.8 | .52 | 12,500 | 3,900 | .31 | .37 |

[1] Specific gravity, oven dry, based on volume at test.
[2] Calculated on basis that form factor of beam of circular cross section is 1.18.

Studies made on cantilever beams having an enlarged cross section at the point of support demonstrated that the fatigue limit varied greatly depending on whether the change of cross section was abrupt or gradual.

With even what is normally considered a generous fillet the fatigue limit is lowered markedly. This effect, together with the influence of form factors, has led some investigators erroneously to place the fatigue limit for wood as low as one-sixth of the static modulus of rupture.

Tests made at the Forest Products Laboratory on tapered specimens of a form to obviate changes in cross section that would influence failure show that, for a stress just slightly greater than the fatigue limit, failure occurs at not more than 2,000,000 load reversals and in some species at less than 1,000,000 reversals. Tests at stresses only slightly less than the fatigue limit showed no failure after reversals ranging in number from 14,000,000 to 125,000,000.

Other tests on Sitka spruce in which specimens of rectangular cross section were vibrated through approximately 5,000,000 cycles indicate that the modulus of elasticity is not greatly affected by vibration. No effect on fiber stress at proportional limit and modulus of rupture could be detected from these tests, the values being about the same for specimens which had and which had not been vibrated. The tests indicate that the same stress prevails at the fatigue limit with vibrated specimens of rectangular cross section as with rotated specimens of circular cross section.

Further studies to obtain more specific information on the effects of vibration and fatigue, particularly when subjected to a large number of stress cycles, and to determine the variation of these properties with different species are needed.

## EFFECT OF TIME OR LENGTH OF SERVICE ON THE STRENGTH OF WOOD

It is sometimes assumed that wood is perishable and is suitable only for use in temporary structures. Although wood, like other materials, is subject to attack by destructive agents, there is ample historical evidence of its permanence when protected from attack by such agencies as fungi, insects, marine borers, and rodents.

So far as is known the lignin and cellulose which constitute the wood substance are not subject to chemical change with time when wood is adequately protected from the elements and other destructive agencies, although the color of wood may be slightly changed by long-continued exposure to air. Possibly this change of color results from oxidation of substances that are not parts of the wood substance.

The effect of time cannot be appraised accurately by tests of wood from old structures since the original strength of the material is unknown. The evidence from such tests as are on record is that no significant loss of strength has occurred in the absence of the destructive agencies enumerated (*1, 2, 14*).

The shrinkage that occurs in the drying of wood induces internal stresses. In time, equalization of differentials of moisture content combined with the action of wood as a plastic material relieves such stresses. This effect would tend to increase the resistance to external forces but its effect is probably not great enough to be significant in most uses of wood.

A recent survey has shown that literally hundreds of bridges made entirely or partly of wood have served satisfactorily and with but little attention for long periods. Many that are more than a century old are still in service. Others have given way, while still in good condition, to the demands for greater width of roadway and higher load capacity than that for which they were built (*11*).

## SIZE OF PIECE AS RELATED TO STRENGTH

It is well known that the size and form of a timber have a definite bearing on its load-carrying ability for different purposes, but the manner in which the load-carrying ability and stiffness vary with dimensions is not so generally understood.

### SIZE OF COLUMNS OR COMPRESSION MEMBERS

In a short column, that is, a column whose ratio of length to least dimension is 11 to 1 or less, the end load that can be carried varies simply with the area of the cross section of the piece, other factors being equal. However, with a long column, one whose length exceeds about 20 times its least dimension, the end load that can be supported (with a given "end condition") varies not as the cross-sectional area, but directly as the greater dimension of the cross section, directly as the cube of the lesser, and inversely as the square of the length. Columns are usually either square or round. Hence the load that can be carried by a long column of square or circular cross section varies directly as the fourth power of the side of the square or diameter of circle, and inversely as the square of the length. The load that can be supported by columns of intermediate length is intermediate between that for the short and long column (*32*).

### SIZE OF BEAMS

The load that a beam of rectangular cross section can carry, other factors being equal, varies directly as the width, directly as the square of the depth, and inversely as the span. The deflection for a given load varies inversely as the width, inversely as the cube of the depth, and directly as the cube of the span.

A few numerical examples will serve to illustrate these relations. Let it be assumed that a beam 1⅝ by 7½ inches (nominal 2 by 8) is used on edge on a 12-foot span.

###### EFFECT OF WIDTH

If the width of beam were increased from 1⅝ to 3⅝ inches (nominal 4-inch width) a total load about two and one-fourth times as large ($3\frac{5}{8} \div 1\frac{5}{8} = 2.23$) could be carried, and the deflection for a given load would be about 45 percent as great

$$\left(\frac{1}{3\frac{5}{8}} \div \frac{1}{1\frac{5}{8}} = 0.448\right)$$

###### EFFECT OF DEPTH

If the depth were increased from 7½ to 9½ inches (nominal 10-inch depth) a total load 1.6 times as large, $(9\frac{1}{2})^2 \div (7\frac{1}{2})^2 = 1.60$, could be carried, and the deflection for a given load would be about 49 percent as great

$$\left(\frac{1}{(9\frac{1}{2})^3} \div \frac{1}{(7\frac{1}{2})^3} = 0.492\right)$$

###### EFFECT OF LENGTH

If the span were increased from 12 to 15 feet a total load 80 percent as large $\left(\frac{1}{15} \div \frac{1}{12} = 0.80\right)$ could be carried, and the deflection for a given load would be nearly twice as great ($15^3 \div 12^3 = 1.95$).

The preceding relations are those expressed by the usually accepted engineering formulas and are based on assumptions that are more or less inaccurate under certain conditions. Their use, however, has been long established and they may be regarded as the best general basis for calculation.

Since strength and stiffness are dependent on the form and size of piece as well as on the inherent strength of the wood, it is usually possible to compensate for the lower strength of the weaker species by increasing the size of members in accordance with engineering principles.

## FORM OF CROSS SECTION AS RELATED TO STRENGTH OF WOODEN BEAMS

Calculations by the commonly accepted engineering formulas as previously illustrated are sufficiently accurate for use in the design of members of rectangular cross section for common structural purposes. Experiments have demonstrated, however, that beams may carry more or less load, depending on the form of the cross section, than would be calculated from the general beam formula, using the modulus-of-rupture value based on specimens 2 by 2 inches in cross section as given in table 1. Hence, when members of other than rectangular section are used, or when maximum accuracy is essential, as in the design of aircraft parts, modification of these formulas is necessary (*36*).

Tests have shown that a beam of given cross-sectional area carries the same load regardless of whether the cross section is circular, square, or diamond shape (square with diagonal in the direction of load). This is true both of loads at proportional limit and of maximum load. The corresponding stresses computed from the usual formula are 18 percent higher for the circular and 41 percent higher for the diamond-shaped beam than for the square. Thus the circular and diamond-shaped sections may be said to have form factors of 1.18 and 1.41, respectively. On the other hand, the form factor for beams with I and box-shaped sections has been found to be less than unity and may in extreme instances be as small as 0.50.

The stresses developed in a wooden beam also depend on its size—or rather its depth. In general, the shallower the beam the greater the stresses that will be developed and conversely. This effect is sufficient to make about 7 percent difference between depths of 8 and 2 inches.

Theoretically, also, the stresses developed are affected by the width of the piece. As far as is known, this effect is not sufficiently large to be of practical significance. If, however, the width is too small in comparison with the height and span a beam may deflect sideways and fail at a lower stress than would a wider beam with other dimensions the same or than the same beam if braced against deflection sideways (*52*).

The effects of shape and depth of beams as just discussed apply to loads and stresses. Modulus of elasticity is not affected. Consequently, the same value of modulus of elasticity may be used for computing deflections by the usual engineering formulas regardless of the shape or depth of a beam. When, however, the relation of depth to span is such that high horizontal shearing stress is involved, the effect of shearing deformation should be considered in computing deflections (*35*).

## DEFECTS

Defects are any irregularities occurring in or on wood that may lower some of the strength, durability, or utility values. Defects may be divided into two groups on the basis of their effect on structural timbers: (1) Those that materially affect the strength and must be considered in formulating specifications. This group includes decay, cross grain, knots, shakes, checks, and splits; and structural grading rules definitely limit the sizes of such defects according to the grade (*9, 33, 34, 61*). (2) Those that would normally be excluded for other reasons than their effect on the strength. This second group includes pitch pockets, wane, wormholes, warp, pith, and imperfect manufacture. These may ordinarily be disregarded in grading structural timbers but must be considered in selecting material of smaller size for special uses, such as handles or ladder parts.

### DECAY

Vegetable organisms known as fungi, of which there are many varieties, are the cause of decay or rot in timber. Aside from food, which is supplied by the wood, the three essentials to their development are air, suitable temperature, and favorable moisture content. Wood that is completely submerged in water does not decay because the necessary air is lacking. Wood whose moisture content is constantly below about 16 percent does not decay because insufficient moisture is available for decay-producing organisms. The so-called dry rot develops in timber that is apparently below such a moisture content because the producing organism is capable of conducting the needed moisture from sources outside the timber itself.

Wood decays more rapidly in warm humid climates than in cool dry regions. High altitudes are as a rule less favorable to decay than nearby low areas because the average temperature is lower and the growing season for fungi is shorter.

Not all properties are affected to the same extent by a given degree of decay. Shock-resisting ability as reflected in the work values in static bending, or the height of drop in impact bending, is one of the first properties to be affected, and decay which has not progressed far enough to be visible may seriously impair this quality. Crushing strength parallel to the grain is slowest to give way, with hardness and strength as a beam holding an intermediate position. Decay often develops in localized regions or pockets and may not affect the strength of a piece uniformly.

Because of the fact that it is impossible to estimate satisfactorily either the extent to which decay has progressed, or the probability of its further development, timber containing decay in any stage should be regarded with misgiving for use where strength is important.

Two methods are available for prolonging the life of timber exposed to conditions favorable to decay: (1) Use the heartwood of species that are naturally resistant to decay; (2) impregnate the wood with a preservative (*18*).

The danger of decay can in many instances be lessened materially by careful attention to details of design and construction. For example, proper insulation of water pipes will prevent excess humidity and the deposition of water on woodwork in their vicinity; joints in exterior woodwork can be made so that they are readily drained or ventilated; ventilation can be provided beneath the floors of houses without basements; basement posts or columns can be raised a few inches above the floor by means of pedestals.

The sapwood of all species has low natural decay resistance and generally short life under decay-producing conditions. Common native species vary greatly with respect to the durability of the heartwood. Furthermore, all pieces of the heartwood of a species are not equally durable.

General comparisons of the relative decay resistance of different species must be estimates. They cannot be exact and they may be very misleading if interpreted as mathematically accurate and applicable in all instances. They may be very useful, however, if understood as approximate averages only, from which specific cases may vary considerably, and as having application only where conditions are favorable to decay. The classification of a number of common native species with respect to the durability of the untreated heartwood as presented in table 7 is to be so understood.

## CROSS GRAIN

The term "cross grain" denotes any deviation of wood fibers from a direction parallel to the longitudinal axis of a piece.

In order to correlate cross grain with the strength properties of timber, a definite method of measurement is necessary. This is afforded by the angle between the direction of the fibers and the axis of the piece, or edge if it is parallel to the axis. The angle is usually expressed as a slope; for instance, 1 in 15, or 1 to 15, means that the grain deviates 1 inch from the edge of the piece in a distance of 15 inches.

120693°—35——6

An extensive series of tests on Sitka spruce, Douglas fir, and commercial white ash has shown that the several strength properties differ in the degree to which they are affected by cross grain and that for properties materially affected the tendency of values to fall off occurs with even slight deviations of grain (*19*, *57*). Values presented

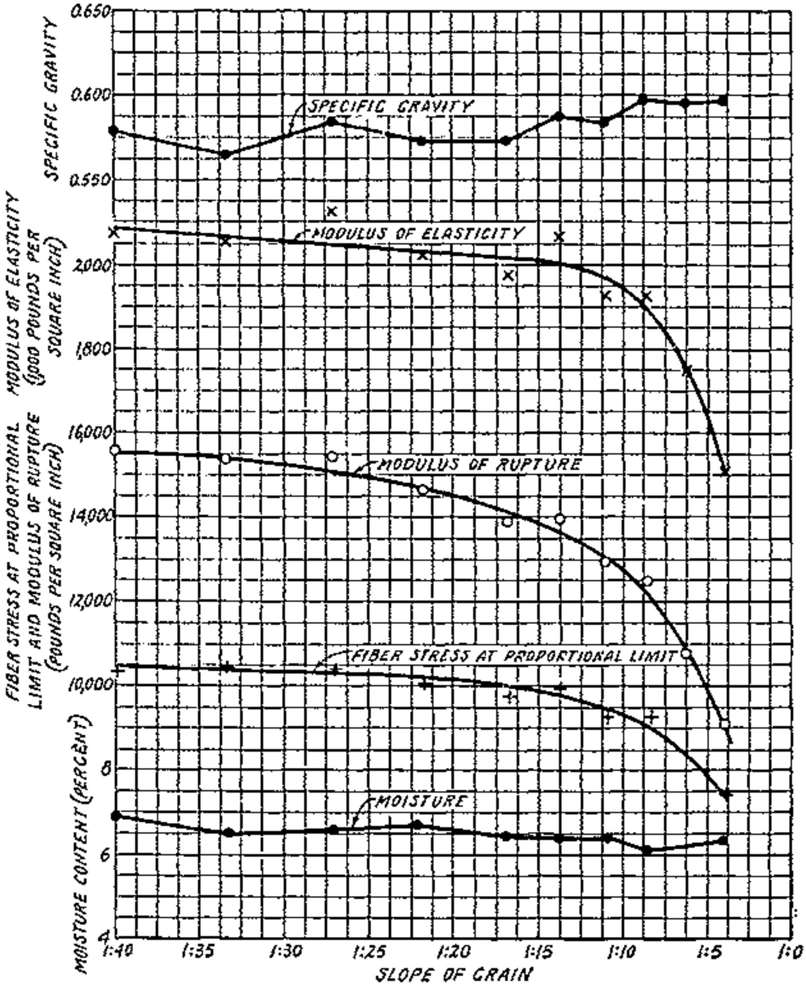



FIGURE 13.—Effect of spiral and diagonal grain on fiber stress at proportional limit, modulus of rupture, and modulus of elasticity in static bending on white ash.

in table 18 are the average percentage deficiencies for various slopes of cross grain in material that is free from checks and other defects, as compared with straight-grained stock. Figure 13 presents the results for white ash graphically. Specific gravity and moisture content are plotted in this figure merely to show that they do not vary greatly among the groups of material representing various slopes of grain.

TABLE 18.—*Average percentage deficiency in strength properties of cross-grained material of various slopes with respect to straight-grained material*

[From tests of kiln-dried material with moisture content as shown in fig. 13]

| Species of wood and slope of grain | Static bending | | | Impact bending maximum drop | Compression parallel to grain, maximum crushing strength |
|---|---|---|---|---|---|
| | Modulus of rupture | Modulus of elasticity | Work to maximum load | | |
| White ash: | | | | | |
| 1:25 | 4 | 2 | 9 | 6 | 0 |
| 1:20 | 6 | 3 | 17 | 12 | 0 |
| 1:15 | 11 | 4 | 27 | 22 | 0 |
| 1:10 | 18 | 7 | 43 | 37 | 1 |
| 1:5 | 36 | 22 | 61 | 50 | 7 |
| Douglas fir: | | | | | |
| 1:25 | 7 | 4 | 17 | 1 | |
| 1:20 | 10 | 6 | 24 | 4 | |
| 1:15 | 15 | 8 | 34 | 13 | |
| 1:10 | 25 | 14 | 46 | 31 | |
| 1:5 | 54 | 40 | 68 | 65 | |
| Sitka spruce: | | | | | |
| 1:25 | 2 | 2 | 14 | 8 | |
| 1:20 | 4 | 4 | 21 | 13 | |
| 1:15 | 8 | 7 | 33 | 22 | |
| 1:10 | 17 | 13 | 55 | 45 | |
| 1:5 | 44 | 36 | 76 | 60 | |
| Average: | | | | | |
| 1:25 | 4 | 3 | 13 | 5 | |
| 1:20 | 7 | 4 | 21 | 10 | |
| 1:15 | 11 | 6 | 31 | 19 | |
| 1:10 | 19 | 11 | 48 | 38 | |
| 1:5 | 45 | 33 | 68 | 61 | |

The weakening effect of cross grain results from the wide difference in properties of wood along and across the grain. Cross grain is accompanied by an increased variability of properties, increased checking, and a tendency of the wood to twist and warp.

The data presented on the influence of cross grain are based on tests of clear pieces 2 by 2 inches in cross section, free from checks. In larger sizes, and when other defects are present, checks are apt to be present along with the cross grain, and in such instances greater weakening occurs than in the test results cited. The values given are thus indicative of the minimum effect.

The weakening effect on stress in extreme fiber in bending becomes significant with a slope of about 1 in 20 and increases rapidly with increase in slope. The permissible slope of grain depends on the use to which the wood is put. In general a slope greater than 1 in 20 should not be permitted in a main structural aircraft member. In structural timbers, the permissible slope varies with the grade and with the kind of stress, and ranges from 1 in 20 for high-grade beams to 1 in 8 for low-grade posts.

Cross grain may be of three fundamentally different types as follows:

### DIAGONAL GRAIN

This form of deviation of grain is caused by failure to saw parallel to the annual growth layers because of either crooked logs, carelessness in manufacture, or the practice of sawing parallel to the pith instead of parallel to the bark in logs of large taper. Diagonal grain shows on the edge-grain or quarter-sawed face of a board or timber.

### SPIRAL GRAIN

This form of deviation of grain results from a corkscrew or spiral rather than vertical arrangement of fibers in a tree. Spiral grain thus refers to the direction of fibers within the annual growth layers and its true direction is evident only on a plain or flat-sawed surface where it is measured by the direction of checks, splits, or other indication of the direction in which the grain runs. Interlocked grain is a special form of spiral grain varying in slope or reversing slope between successive growth periods. An approximation to spiral grain results when a piece is cut so that the grain of the wood on the flat-sawn face is at an angle to the axis.

### IRREGULAR GRAIN

This term applies to a more or less irregular wood structure usually accompanying knots, or occasionally appearing as waves in otherwise clear wood.

### METHODS OF CALCULATING CROSS-GRAIN

When the grain slopes on both flat-sawn and quarter-sawn faces of a piece these slopes being 1 in $a$ and 1 in $b$, the resultant or effective slope is given by the expression

$$\frac{\sqrt{a^2+b^2}}{ab};$$

for example, if the slopes are 1 in 12 and 1 in 5 the effective slope is

$$\frac{\sqrt{5^2+12^2}}{5\times12}=\frac{13}{60}=1 \text{ in } 4.6,$$

or if the slopes are both 1 in 20 the effective slope is

$$\frac{\sqrt{20^2+20^2}}{20\times20}=\frac{28.3}{400}=1 \text{ in } 14.1$$

### KNOTS

A knot is that portion of a branch which has become incorporated in the body of a tree. The influence on strength is due to the fact that the knot interrupts the continuity and direction of fibers and that the direction of fibers in the knot is essentially at right angles to those in the adjacent wood.

The influence of knots depends on their size, location, shape, and soundness; the kind, size, and proportions of the piece; the kind of stress to which the piece is subjected; and the amount of the attendant cross-grain.

Knots actually increase hardness and strength in compression perpendicular to grain, and are objectionable in regard to these properties only to the extent that they cause nonuniform wear or a nonuniform distribution of pressure at contact surfaces. Knots, however, are harder to work and machine than the surrounding wood, may project from the surface when shrinkage occurs, and also are a cause of twisting.

Knots have relatively little effect on the stiffness of a member. Hence, it is possible to effect some economy by using low-grade material where stiffness is the controlling factor as in joists in small buildings. In such instances the size of the member is usually governed by stiffness, and hence relatively knotty material can be satisfactorily used, although at some sacrifice of bending strength. For example, tests of two 2- by 8-inch by 10-foot joists cut from the same species showed, in pounds per square inch, a modulus of elasticity of 1,100,000 and a modulus of rupture of 5,470 for a practically clear joist and a modulus of elasticity of 1,246,000 and a modulus of rupture of 2,940 for a knotty joist. The slightly higher modulus of elasticity of the knotty joist is attributed to the slightly higher specific gravity of the wood over that of the clear joist.

In a long column, that is, a column in which the length exceeds about 20 times its least dimension, the maximum load depends on the stiffness alone, and knots are consequently less detrimental than in a short column in which the crushing strength of the wood determines the maximum load (*32*).

Knots have approximately one-half as much effect on compressive as on tensile strength. Hence, for a given percentage reduction in strength larger knots are permissible in a short column than on the tension side of a beam.

Knots are most serious in their effect on the bending strength of beams. The influence of a knot on the tension face is approximately measured by the ratio of the diameter of the knot to the width of the face, the diameter being taken as the distance between lines enclosing the knot and parallel to the edges of the face. Thus, a knot which measures one-fourth the width of the tension face reduces the bending strength 25 percent. The same knot on the compression side of the beam would have about half the influence. Large knots have a somewhat greater influence on the bending strength than is indicated by the foregoing rule, owing to the increased distortion of grain around them. This effect is taken care of in the structural grading rules conforming to American lumber standards (*54*, *61* ). The effect of knots is greater in the center half of the length of a beam than near the ends, and is greater near the upper and lower faces than at the center of the height (*9*).

### SHAKES

A shake is a separation of wood along the grain, the greater part of which occurs between or within the rings of annual growth. Shakes can best be detected at the end of the piece where they extend in a general circumferential direction. In structural grading, shakes that appear on an end of a piece are assumed to extend to the center of its length. In beams the principal effect of shakes and one effect of checks is to reduce resistance to horizontal shear or the sliding of the upper on the lower part of the piece. Not only do shakes and checks reduce the area acting in resistance to shear but because of concentration of stress at their extremities the average shearing strength of the remaining area is much less than the shearing strength of unchecked wood as found from shear or torsion tests. These effects are important in large timbers in which the concentration of stress accompanying shakes and/or the checking that usually occurs either prior or subsequent to the placement of timbers in service is sufficient to cause failure at a shearing stress, as averaged over the unchecked area, of less than half the ultimate value found in standard shear block tests (table 1). The effect of shakes on strength in horizontal shear is appraised in the grading of beams by determining the width of the shake, as measured on the end between lines parallel to the faces, in terms of the width of the piece. For green timbers the allowable shake is the same percentage of the width of the piece as the grade is below an assumed strength for the clear wood (*61*). Thus, in beams of a grade that permits defects that reduce the strength by one-fourth, the allowable shake would be one-fourth the width of the piece. Shakes tend to increase in size with seasoning. A slightly larger shake is allowable in seasoned material.

### CHECKS

A check is a separation along the grain, the greater part of which occurs across the rings of annual growth. Checks other than heart and star checks which occur in green wood and whose cause is unknown occur in seasoning and are due to difference in shrinkage in radial and tangential, or circumferential, directions, and to difference in shrinkage between adjacent parts induced by differences in moisture content. Checks are classed as end checks, heart checks, star checks, surface checks, and through checks. An end check is one at an end of a piece; a heart check is one starting near the pith and extending toward but not to the surface of the piece; a star check consists of a number of heart checks; a surface check is one into a piece from the surface, and a through check is one extending through the piece from one surface to another. Difference between forms of checks need not be considered in determining their effect on strength.

Checks, like shakes, are injurious to beams to the extent that they reduce the area resisting horizontal shear. It is evident that checks in the narrow or horizontal face have practically no effect upon the strength of straight-grained beams. Checks in the wide or vertical faces are most serious in their effect on resistances to horizontal shear when straight and at or near the center of the height.

The effect of checks in beams and columns depends on the area of the longitudinal section they cover, but, unlike shakes, they are not assumed to extend from the end of the piece to the center of the length. The same method of measurement and limitation may be applied as for shakes. If more refinement is desired, however, it may be obtained by estimating the actual reduction of area in a longitudinal plane within that portion of the length extending from the end to a distance three times the depth from the end. The aggregate area of checks permissible within this distance is equal to the width of the allowable shake multiplied by three times the height of the beam (*61*).

Checks also cause serious weakening in tension perpendicular to grain, but are less injurious in straight-grained members subjected to direct compression or tension along the grain.

Checks are more difficult to prevent in large timbers than in small pieces, and they increase in size and depth with the degree of seasoning during the earlier stages but later close partially or entirely. Checks usually appear first on the ends of a piece, but the development of end checks can be retarded, and in smaller sizes prevented, by the application of an end coating, such as hardened gloss oil prior to seasoning. Season checks form in round timbers because the radial shrinkage differs from the tangential or circumferential.

### PITCH POCKETS

Pitch pockets are openings within or between the annual growth rings that contain more or less pitch or bark. Pitch pockets vary greatly in size. Ordinarily, their dimension at right angles to the annual rings is less than one-half inch, whereas they may extend for several inches along the grain (vertically in the tree) and/or in the direction of the annual rings (circumferentially in the tree).

Native species in which pitch pockets are found are the pines, the spruces, Douglas fir, western larch, and tamarack. Pitch pockets in structural timbers ordinarily are not important as (1) their extent is not sufficient to cause significant weakening in shear, (2) they do not cause serious deviations of grain, and (3) they occupy only a small proportion of the cross section of a piece. However, numerous pitch pockets in or close to the same annual growth layer may denote the presence of shakes or may be equivalent in effect to a shake.

In small members the size of the pitch pockets may represent an appreciable portion of the cross section and be located so as to have a marked effect on the strength.

The weakening effect of pitch pockets is more serious when they cause distortion or "dip" of the grain. It is, of course, necessary to limit pitch pockets in aircraft parts, and rules have been established for this purpose (*53*, *55*) but in general they are of importance chiefly because of their effect on appearance.

### COMPRESSION FAILURES

A compression failure is a local buckling of the fibers, essentially at right angles to the length, due to excessive compression along the grain. Compression failures appear as wrinkles on the surface of a piece, and range from a well-defined buckling of the fibers visible with the unaided eye to a slight crinkling visible only with a microscope (*7*, *21*, *25*).

Compression failures may occur when standing trees are bent severely by wind or snow, when trees are felled over logs or irregularities of the ground, from rough handling of logs or sawed stock, and excessive stresses in service. They weaken the wood in tension, and when on the tension side of a beam produce brash appearing and sudden failures. Material containing compression failures should be rejected for uses in which strength and shock resistance are important, such as in handles and ladder parts. Compression failures are usually so inconspicuous that careful search is necessary to detect them. Often tilting of a piece of wood with respect to the line of vision or source of light will help make them visible. It is seldom possible to detect them in rough-sawn material.

The results of static bending tests on four specimens from a board containing compression failures sufficiently prominent to be readily detected, as compared with the average of uninjured material are given in table 19. These data, while but fragmentary, illustrate the serious reduction in modulus of rupture caused by pronounced compression failures, the even greater reduction in shock resistance as shown by work to maximum load. and the variability in strength properties which they cause.

TABLE 10.—*Results of static bending test on 4 specimens*[1] *from a board containing prominent compression failures*

| Kind of specimen | Specific gravity[2] | Moisture content | Modulus of rupture | Work to maximum load |
|---|---|---|---|---|
| | | *Percent* | *Lb. per sq. in.* | *In.-lb. per cu. in.* |
| Containing compression failures | 0.53 | 10.3 | 5,770 | 1.44 |
| | .48 | 11.3 | 3,050 | .59 |
| | .40 | 11.2 | 2,510 | .38 |
| | .52 | 11.3 | 6,830 | 1.30 |
| Average figures for uninjured material | .45 | 12 | 10,600 | 7.8 |

[1] The bending tests were made on specimens ¾ by 2 by 20 inches, using center loading and an 18-inch span. Specimens 1, 2, 3, and 4 were cut so that the compression failures were located at the center of the span.

[2] Specific gravity based on weight when oven dry and volume when green.

## COMPRESSION WOOD

Compression wood, also known as red wood (rotholz), is wood of abnormal growth and structure, slightly above the average in weight, which is usually distinguished by very wide and eccentric annual rings, a lack of contrast between spring and summer wood, and a more or less dark-reddish to brown color. This growth occurs on the under side of limbs and leaning trunks of coniferous trees (*16, 21*).

Table 20 compares compression wood with normal wood in ponderosa pine, southern yellow pine, and redwood. The values given should not be regarded as the true averages either for normal wood or compression wood, but as indicative of the relationships between the two types. The reason for this is that compression wood varies greatly in degree from material bordering on normal wood to pronounced types. The normal wood represented was cut from the same pieces as the compression wood, and hence was selected to match the latter rather than to be representative of the species.

TABLE 20.—*Strength properties of compression wood compared with normal wood of redwood, ponderosa pine, and southern yellow pine* [1]

| Average values | Redwood | | | | Ponderosa pine | | | | Southern yellow pine, air-dry | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Green | | Air-dry | | Green | | Air-dry | | | |
| | Normal wood | Compression wood | Normal wood | Compression wood | Normal wood | Compression wood | Normal wood | Compression wood | Normal wood | Compression wood |
| Specific gravity, based on oven-dry volume | | | | | | | | | 0.57 | 0.66 |
| Shrinkage, longitudinal, green to oven-dry ... percent | 0.14 | 1.19 | | | 0.21 | 0.80 | | | .4 | 2.5 |
| Shrinkage, radial, green to oven-dry ... do | 2.4 | | | | | | | | 4.6 | 2.2 |
| Shrinkage, tangential, green to oven-dry ... do | 4.0 | | | | | | | | 6.2 | 2.6 |
| Static bending: | | | | | | | | | | |
| Moisture content ... do | 114 | 102 | 9.9 | 10.5 | 133 | 88 | 12.0 | 12.6 | 11.6 | 12.4 |
| Specific gravity, based on volume as tested | .38 | .51 | .38 | .51 | .35 | .47 | .37 | .50 | | |
| Fiber stress at proportional limit ... pounds per square inch | | | | | 3,010 | 3,730 | 7,250 | 6,620 | 8,550 | 6,520 |
| Modulus of rupture ... do | 7,310 | 7,470 | 10,210 | 8,890 | 4,640 | 6,120 | 9,840 | 11,710 | 11,730 | 9,000 |
| Modulus of elasticity ... 1,000 pounds per square inch | 1,110 | 685 | 1,253 | 788 | 1,074 | 842 | 1,345 | 1,019 | 1,495 | 994 |
| Work to proportional limit ... inch pounds per cubic inch | | | | | .47 | .94 | 2.19 | .63 | | |
| Work to maximum load ... do | 7.5 | 6.9 | 6.0 | 6.5 | 4.0 | 8.8 | 7.6 | 15.7 | 8.2 | 5.5 |
| Work, total ... do | | | | | 14.4 | 45.6 | 10.8 | 16.2 | | |
| Toughness: | | | | | | | | | | |
| Moisture content ... percent | 129 | 89 | 8.8 | 9.7 | 121 | 85 | 10.0 | 10.6 | | |
| Specific gravity, based on volume as tested | .37 | .52 | .37 | .49 | .37 | .49 | .38 | .53 | | |
| Toughness per specimen ... inch-pounds | 83.0 | 69.5 | 64.5 | 64.4 | 100.7 | 173.4 | 79.2 | 100.4 | | |
| Compression parallel to grain: | | | | | | | | | | |
| Moisture content ... percent | 126 | 106 | 8.6 | 10.0 | 138 | 78 | 12.1 | 12.7 | 11.7 | 10.8 |
| Specific gravity, based on volume as tested | .37 | .51 | .38 | .51 | .35 | .47 | .37 | .50 | .55 | .68 |
| Crushing strength at proportional limit ... pounds per square inch | 3,950 | 4,640 | 7,160 | 7,250 | 2,140 | 2,090 | | | | |
| Maximum crushing strength ... do | | | | | 2,340 | 3,300 | 5,210 | 5,970 | 7,370 | 8,100 |
| Modulus of elasticity ... 1,000 pounds per square inch | | | | | 1,476 | 996 | | | | |

[1] Exact species unknown.

It may be noted that compression wood is characterized by high longitudinal shrinkage, by low stiffness, and for its weight, a general deficiency in most other properties.

When compression wood and wood of normal structure are present in the same piece very high stresses are set up in drying on account of the large difference in longitudinal shrinkage of the two types of wood. This causes bowing or other distortion and may even result in splitting of the piece or in tension failure in the compression wood.

### INSECT HOLES

The effect of wormholes on strength is somewhat similar to that of knots or knot holes, except that they do not involve distortion of grain. Inasmuch as wormholes found in lumber usually have only small diameters, occasional ones do not seriously weaken the wood.

In lumber which has been in storage for some time wormholes may be more serious on the interior than is indicated on the surface. This is especially true of the sapwood of ash, oak, hickory, elm, and some other hardwoods that are subject to attack by the powder post beetle (*45*).

### SAP STAIN

Sap stains (blue, red, and yellow) are caused by organisms which germinate in the sapwood, absorbing starches and sugars. Most sap stains, unlike wood-destroying fungi, do not as a rule penetrate the cell walls and consume the wood substance, and therefore sap stain is not in itself so serious from the strength standpoint. However, severe sap stain of certain varieties causes sufficient injury to appreciably reduce the shock resistance or toughness.

Sap stain exerts a marked effect on appearance. Its presence, furthermore, indicates that the wood has been subjected to unfavorable conditions and the possible development of wood-destroying fungi should be considered in the use of such material (*17*).

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# APPENDIX

## DETAILS OF TEST PROCEDURE

The information on strength and related properties of woods grown in the United States, which is given in table 1, was obtained from tests in static bending, impact bending, compression parallel to grain, compression perpendicular to grain, hardness, shear parallel to grain, tension perpendicular to grain, and cleavage. Data on weight and shrinkage were also obtained by means of standardized tests. The foregoing 8 tests furnish information on more than 25 different properties of wood.

### SELECTION OF MATERIAL

The material for test was identified botanically in the woods, and was brought to the Forest Products Laboratory in the green condition in log form. The logs were generally 4 or 8 feet in length and were usually taken from each of five or more representative trees of each species, the upper end of the log selected being in most instances 16 feet above the stump. Each 4-foot log or bolt was divided into sticks as shown in figure 14. Insofar as was possible without testing pieces having imperfections that would reduce their strength, the following procedure was followed: A test in compression parallel to the grain was made on a specimen from each stick and a test in static bending on a specimen from one stick of each pair. A pair consists of two tangentially adjacent sticks as N1 and N2, W7 and W8, and so forth. Tests in compression perpendicular to grain were made on specimens cut from one-half the sticks that supplied the static bending specimens, and hardness tests on the other half. Sticks from various parts of the cross section were tested in impact bending, shear, cleavage, and tension perpendicular to grain. This was the system followed when the tree furnished material for tests in the green condition only. For each species from each locality tests were also made on both green and air-dry material from one or more trees. Two adjacent bolts from each of such trees were cut into sticks as indicated by figure 14. Two composite bolts each consisting of one stick from each pair from each of the two adjacent bolts were then formed. The sticks from one composite bolt were tested in the green condition, those from the other after air drying; the assignment of sticks to the various tests being as previously described. This system of division of logs and assignment of sticks provided tests of each kind from various parts of the cross section of the log and afforded for test air-dry material closely matched to that tested in the green condition.

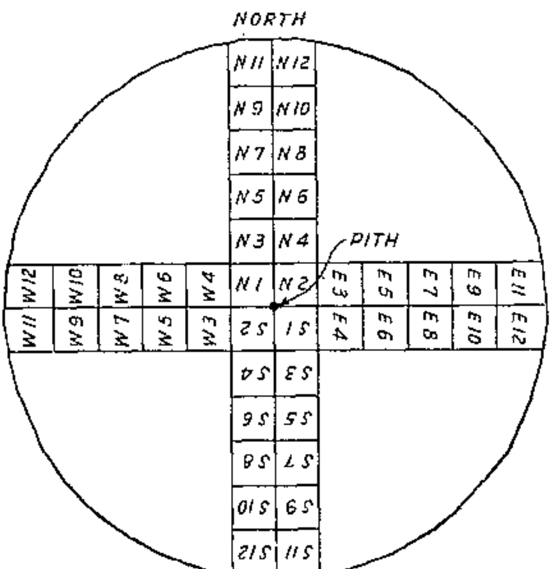



FIGURE 14.—Method of cutting up the bolt and marking the sticks.

A further feature was the testing in a similar manner of green material taken at various heights above the stump from one or more trees of a number of species. The resulting data are not tabulated herein but are the basis of the discussion of variation of properties with height in tree (p. 40).

### TESTING METHODS

The detailed procedure of testing conformed closely to standards of the American Society for Testing Material (*4*). Specimens for mechanical tests are 2 by 2 inches in cross section and of different lengths, depending on the kind of test. Those for radial and tangential shrinkage are 1 inch thick, 4 inches wide, and 1 inch in length along the grain, the width being radial or tangential according to

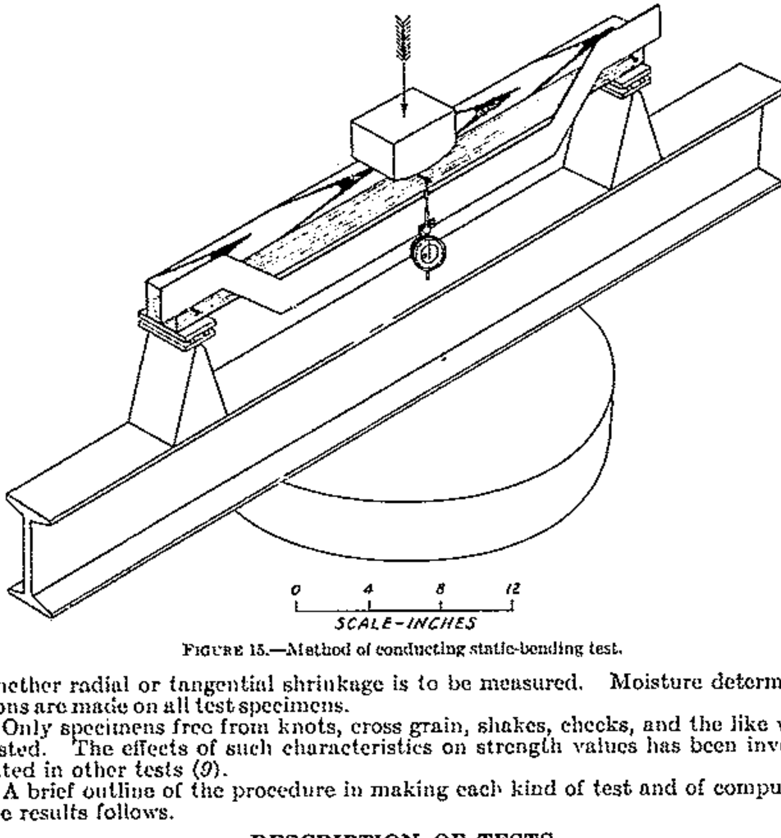



FIGURE 15.—Method of conducting static-bending test.

whether radial or tangential shrinkage is to be measured. Moisture determinations are made on all test specimens.

Only specimens free from knots, cross grain, shakes, checks, and the like were tested. The effects of such characteristics on strength values has been investigated in other tests (*9*).

A brief outline of the procedure in making each kind of test and of computing the results follows.

## DESCRIPTION OF TESTS

### STATIC BENDING

In the static-bending test resistance of a beam to slowly applied loads is measured. The specimen is 2 by 2 inches in cross section and 30 inches long and is supported on roller bearings which rest on knife edges placed 28 inches apart (fig. 15). Load is applied at the center of the length through a hard maple block, $3\frac{13}{16}$ inches wide, having a compound curvature. The curvature has a radius of 3 inches over the central $2\frac{1}{8}$ inches of arc, and is joined by an arc of 2 inches radius on each side (fig. 15). The standard placement is with the annual rings of the specimen horizontal. A constant rate of deflection (0.1 inch per minute) is maintained until the beam fails. Load and deflection are read simultaneously at suitable intervals. Figure 16 is a sample data sheet on which such readings are plotted and other information is shown, and figure 17 is a sample computation data card. In figure 16 it may be noted that a line is drawn through the origin parallel to that through the initial points of the curve in order to determine the deflection at proportional limit.

Data on a number of properties are obtained from static-bending tests, the most important of which are stress at proportional limit, modulus of rupture, modulus of elasticity, work to proportional limit, work to maximum load, and total work, discussions of which follow.

### STRESS AT PROPORTIONAL LIMIT

As may be noted the first several plotted points in figure 16 are approximately on a straight line showing that the load is proportional to the deflection. As the test progresses, however, the load ceases to increase in direct proportion

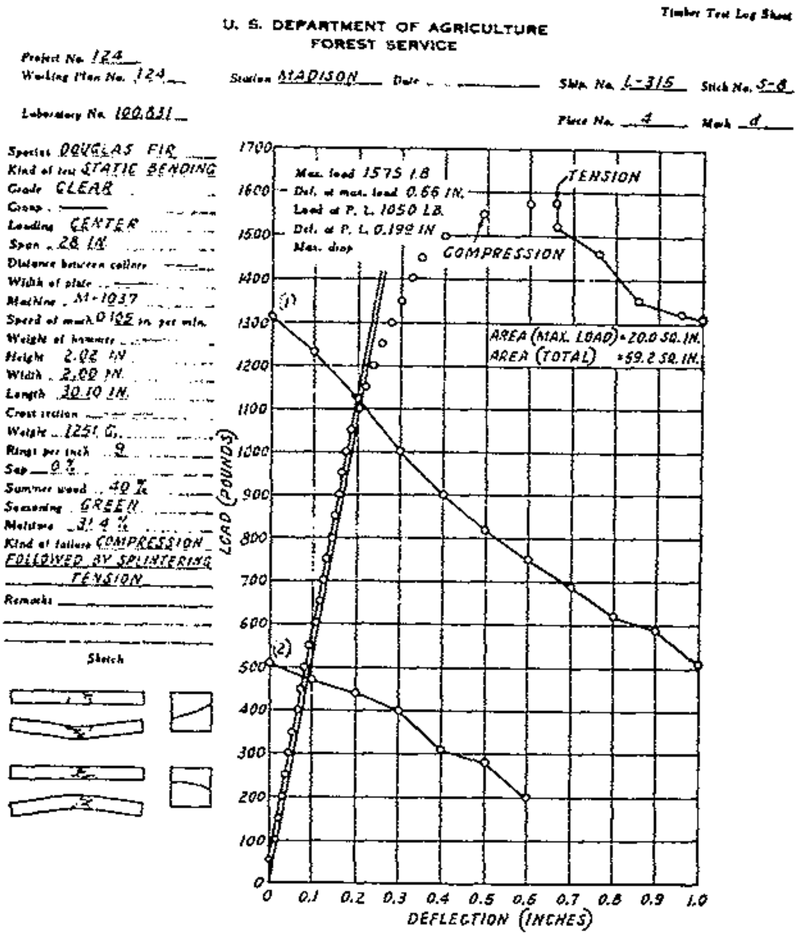



FIGURE 16.—Data sheet for static-bending test.

to the deflection. The point where this occurs, at a load of 1,050 pounds in figure 16, is known as the proportional limit. The corresponding stress in the top and bottom fibers of the beam is the stress at proportional limit.

Using formula 1 on page 98, the stress at proportional limit for the specimen represented by figure 16 is

$$S_{PL}=\frac{3\times 1050\times 28}{2\times 2.00\times (2.02)^2}=5{,}400 \text{ pounds per square inch}$$

### MODULUS OF RUPTURE

The modulus of rupture is computed by the same formula as stress at proportional limit, using the maximum load instead of the load at proportional limit. From formula 2 (p. 98), the modulus of rupture of the test specimen of figure 16 is

$$R=\frac{3\times 1{,}575\times 28}{2\times 2.00\times (2.02)^2}=8{,}110 \text{ pounds per square inch}$$

### MODULUS OF ELASTICITY

The modulus of elasticity is determined by the slope of the straight line portion of the load-deflection graph (fig. 16), the steeper the line the higher being the modulus. From formula 3 (p. 98), the modulus of elasticity of the test specimen of figure 16 is

$$E=\frac{1{,}050\times (28)^3}{4\times 2.00\times (2.02)^3\times 0.199}=1{,}757{,}000 \text{ pounds per square inch}$$

The value of 0.199 used in this computation is the deflection in inches at the proportional limit.

Form 507.
(Revised January, )

**STATIC BENDING**

L-315 (Ship No.) S-8 (Bolt No.) CENTER Loading 100,831 (Lab. No.)
4 (Piece No.) d (Mark) Station MADISON Date AUG. 24, 124 (Project No.)

Species DOUGLAS FIR Grade CLEAR Seasoning GREEN
Rings 9 Sap 0 % Summer wood 40 % Moisture 31.4 %
Span 28 IN. Length 30.10 IN. Height 2.02 IN. Width 2.00 IN. Weight 1251 G.

| Specific gravity. | | F. S. at P. L. | M. of R. | M. of E. | Shear. | Work to P. L. | Work to max. load. | Total work. | |
|---|---|---|---|---|---|---|---|---|---|
| As test. | Ov. dry. | | | | | | | | |
| 0.628 | 0.478 | 5410 | 8120 | 1756 | 292 | 0.92 | 7.1 | 20.9 | |
| | | | | | | | | | |
| | | | | | | | | | |

Rings: Up. ⅓ ______ Mid. ⅓ ______ Low. ⅓ ______
Sum. wood: Up. ⅓ ______ Mid. ⅓ ______ Low. ⅓ ______
Defects ______
Failure COMPRESSION FOLLOWED BY
SPLINTERING TENSION

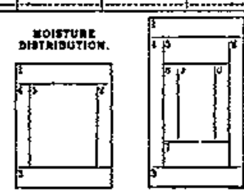



FIGURE 17.—Sample computation card for static-bending test.

### WORK TO PROPORTIONAL LIMIT

Work to proportional limit is the product of the average load up to the proportional limit times the deflection at the proportional limit. It is represented by the area under the load-deflection curve from the origin to a vertical line through the abscissae representing the deflection at proportional limit, and is expressed in inch-pounds per cubic inch (fig. 16). From formula 5 (p. 98), the work to proportional limit for the test specimen of figure 16 is

$$W_{PL}=\frac{1{,}050\times 0.199}{2\times 2.00\times 2.02\times 28}=0.92 \text{ inch-pounds per cubic inch}$$

### WORK TO MAXIMUM LOAD

The work to maximum load is represented by the area under the load-deflection curve from the origin to the vertical line through the abscissae representing the maximum deflection at which the maximum load is sustained. It is expressed in the same units as work to proportional limit.

From formula 6 (p. 98), the work to maximum load for the test specimen of figure 16 is

$$W_{ML}=\frac{20\times 200\times 0.2}{2.00\times 2.02\times 28}=7.1 \text{ inch-pounds per cubic inch}$$

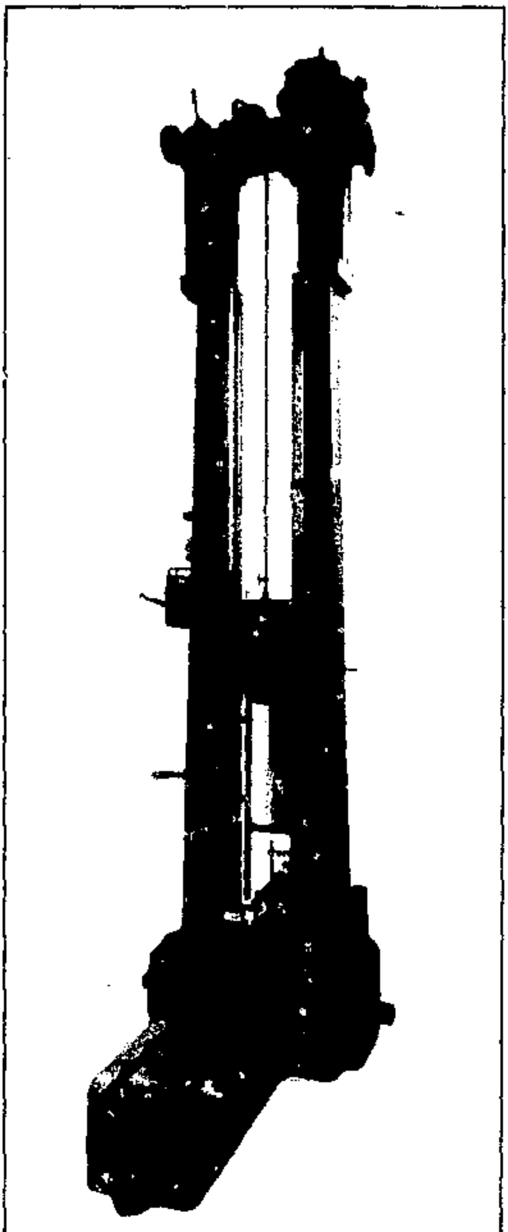


FIGURE 18.—Machine used for impact-bending test.

(The area under the curve in the graph reproduced in figure 16 was 20 square inches, and with the scales used in plotting, each square inch represents 200 (pounds) times 0.2 (inch) or 40 inch-pounds.)

TOTAL WORK

The total work is represented by the complete area under the curve from the beginning of the test until it is discontinued. The test is arbitrarily discontinued in this series when the load after attaining its maximum value first decreases to 200 pounds, or when a deflection of 6 inches is reached, whichever occurs first.

From formula 7 (p. 98), the total work for the test specimen of figure 16 is

$$W_T=\frac{59.2\times 40}{2\times 2.02\times 28}=20.9$$
inch-pounds per cubic inch

The total area under the curve in the original graph represented by figure 16 was 59.2 square inches.

IMPACT BENDING

The impact-bending test is made to determine the resistance of beams to suddenly applied loads. The specimen is 2 by 2 inches in cross section and 30 inches long, and the span is 28 inches. A 50-pound ram or hammer falling between two vertical guides is dropped upon the stick at the center of the span; first from a height of 1 inch, next 2 inches, and so on to 10 inches, then increasing 2 inches at a time until complete failure occurs (fig. 18). A stylus attached to the hammer moves against paper mounted on a revolving drum and records the deflection at each blow, and the position of the specimen when the hammer comes to rest after rebounding. Thus, data are obtained for determining various properties of the wood. Figure 19 is a sample record taken on the drum. Figure 20 is a sample computation card, and figure 21 is a sample data sheet on which the test results are plotted to determine the stress at proportional limit and the modulus of elasticity. Other properties on which data are obtained are height of drop in impact bending and work to proportional limit.

STRESS AT PROPORTIONAL LIMIT

In figure 21, height of drop is plotted against the square of the deflection. The first several points are approximately on a straight line, and are used to determine the limit of proportionality. Practically all the factors influencing the test tend to reduce the deflection for a given height of drop, so that after finding the deflection at proportional limit as usual, the head or drop at this deflection is read from a line passing through the origin and the point within the proportional limit which gives this line the least slope. From formula 13 (p. 98), the stress at proportional limit for the specimen represented by figure 21 is

$$S_{PL}=\frac{3\times 50\times 7.88\times 28}{2.00\times (2.00)^2\times 0.39}=$$
10,610 pounds per square inch

WORK TO PROPORTIONAL LIMIT

The work to proportional limit is equivalent to the energy of the drop that stresses the piece to the proportional limit. From formula 14 (p. 98), the work to the proportional limit for the test specimen of figure 21 is

$$W_{PL}=\frac{50\times 7.88}{28\times 2\times 2}=3.51$$
inch-pounds per cubic inch

HEIGHT OF DROP

The height of drop is recorded as the maximum drop of the hammer causing complete failure of the specimen, or causing a 6-inch deflection. When it is necessary to use a hammer heavier than the 50-pound standard, the height of drop is converted to the equivalent value for a 50-pound hammer.

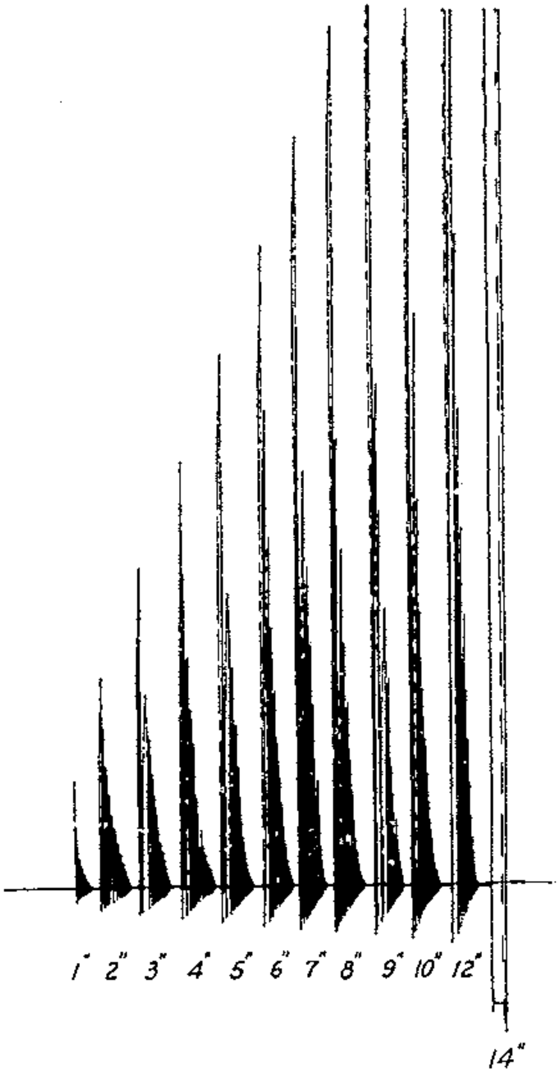


FIGURE 10.—Record taken on the drum of the impact-bending machine in testing northern white pine in a green condition. A maximum drop of 14 inches is recorded.

Form 600 (Revised Jan.,

**IMPACT BENDING**

L-315 (Ship. No.) E-12 (Stick No.) 101151 (Lab. No.)

1 (Piece No.) C (Mark) Station MADISON Date AUG. 20, 124 (Project No.)

Species DOUGLAS FIR Grade CLEAR Seasoning GREEN

Rings 8 Sap 100 % Summer wood 30 % Moisture 61.4 %

Hammer 50 lbs. Span 28 IN. Length 29.94 IN. Height 2.00 IN. Width 2.00 IN. Weight 1370 G.

| Drop No. | Drop | Def. | (Def.)² | Set | Drop No. | Drop | Def. | (Def.)² | Set | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.0 | 0.13 | 0.017 | | 11 | 12.0 | 0.50 | 0.250 | | Sp. Gr. (at test), | 0.698 |
| 2 | 2.0 | 0.18 | 0.032 | | 12 | 14.0 | 0.55 | 0.302 | | Sp. Gr. (oven dry), | 0.432 |
| 3 | 3.0 | 0.22 | 0.048 | | 13 | 16.0 | 0.62 | 0.384 | | F. S. at P. L., | 10610 |
| 4 | 4.0 | 0.26 | 0.068 | | 14 | 18.0 | 0.67 | 0.593 | | M. of E., | 1776 |
| 5 | 5.0 | 0.30 | 0.090 | | 15 | | | | | E. Resil., | 3.51 |
| 6 | 6.0 | 0.34 | 0.116 | | 16 | | | | | Max. Drop, | 22 IN. |
| 7 | 7.0 | 0.36 | 0.130 | | 17 | | | | | d, | 0.010 |
| 8 | 8.0 | 0.38 | 0.144 | | 18 | | | | | H | 7.88 |
| 9 | 9.0 | 0.43 | 0.185 | | 19 | | | | | | |
| 10 | 10.0 | 0.46 | 0.212 | | 20 | | | | | Δ | 0.39 |

Failure: COMPRESSION FOLLOWED BY SPLINTERING TENSION

FIGURE 20.—Sample computation card for impact-bending test. 8—1431

Timber Test Log Sheet

**U. S. DEPARTMENT OF AGRICULTURE**
**FOREST SERVICE**

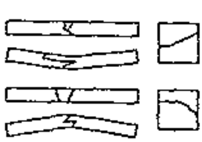
Project No. 124

Working Plan No. 124 Station MADISON Date ______ Ship. No. L-315 Stick No. E-12

Laboratory No. 101,151 Piece No. 1 Mark C

Species DOUGLAS FIR
Kind of test IMPACT BENDING
Grade CLEAR
Group ——
Loading CENTER
Span 28 IN.
Distance between collars ——
Width of plate ——
Machine M-1036
Speed of mach. —— in. per min. ——
Weight of hammer 50 LB.
Height 2.00 IN.
Width 2.00 IN.
Length 29.94 IN.
Cross section ——
Weight 1370 G.
Rings per inch 8
Sap 100 %
Summer wood 30 %
Seasoning GREEN
Moisture 61.4 %
Kind of failure COMPRESSION FOLLOWED BY SPLINTERING TENSION
Remarks

Sketch



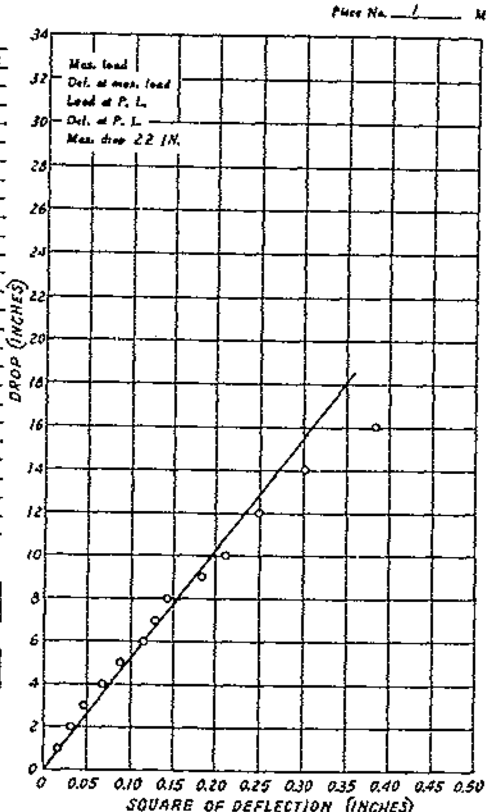



FIGURE 21.—Data sheet for impact-bending test.

### 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 (fig. 22) at a constant rate (0.024 inch per minute). The load is applied through a spherical bearing block, preferably of the suspended self-aligning type, to insure uniform distribution of stress. On some of the specimens, the load and the deformation in a 6-inch central gage length are read simultaneously until the proportional limit is passed. The test is discontinued when the maximum load is passed, and the failure appears. Figure 23 is a sample data sheet on which the test readings are plotted and figure 24 is a sample computation data card.

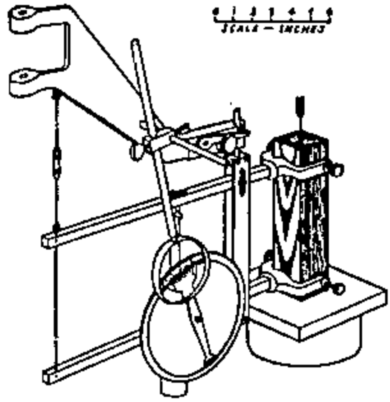



FIGURE 22.—Diagrammatic sketch of compressometer and method of conducting compression-parallel-to-grain tests.

An alternate form of test specimen has a circular cross section 1⅝ inches in diameter except at the ends which are left 2 inches square (*4*). This specimen requires less exacting technic than the square prism, to get good results in testing, but is less simple to prepare.

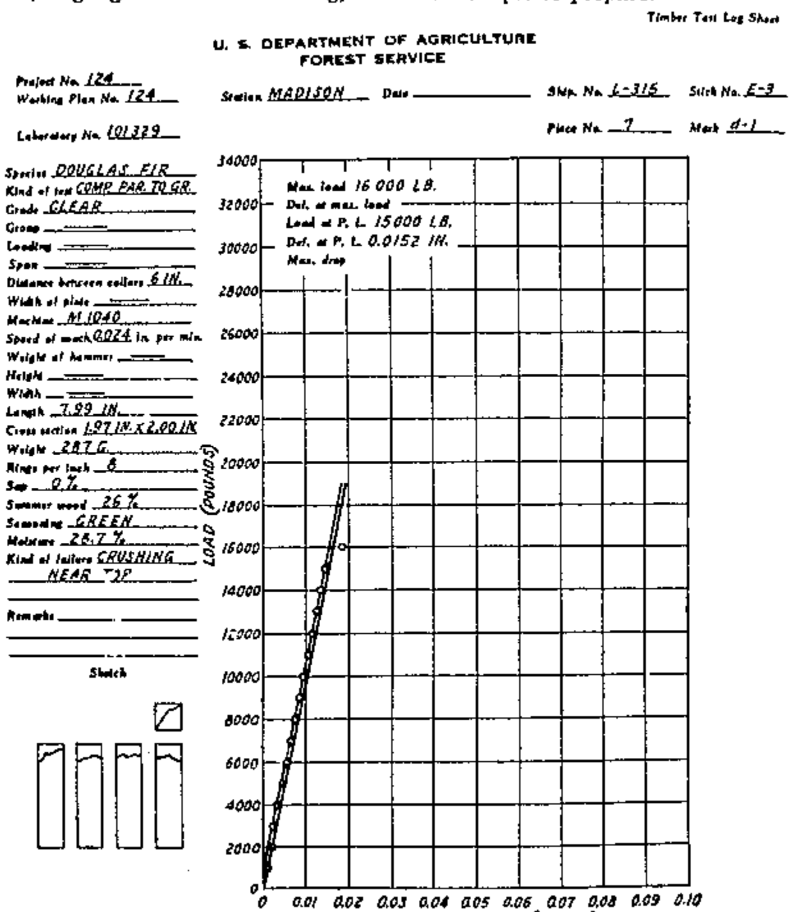



FIGURE 23.—Data sheet for compression-parallel-to grain test.

Form 506
(Revised Nov. 27,

## COMPRESSION PARALLEL TO GRAIN

L-315 (Ship. No.) E-3 (Stick No.) 101 329 (Lab. No.)

7 (Piece No.) d-1 (Mark) Station MADISON Date AUG. 26 124 (Project No.)

Species DOUGLAS FIR Grade CLEAR Seasoning GREEN

Rings 8 Sap 0 % Summer wood 26 % Moisture 28.7 %

Length 7.99 IN. Cross section 1.97 IN. X 2.00 IN. Weight 287 G.

| Specific Gravity | | Max. Load | Crush. St. at P. L. | Max. Crush. St. | M. of E. | Load at P.L. | Def. at P.L. |
|---|---|---|---|---|---|---|---|
| At Test | Ov. Dry | | | | | | |
| 0.556 | 0.432 | 16000 | 3810 | 4060 | 1[illegible]02 | 15000 | 0.0152 |
| | | | | | | | |
| | | | | | | | |

Defects

Failure CRUSHING AT TOP

FIGURE 24.—Sample computation card for compression-parallel-to-grain test.

Data on stress at proportional limit, stress at maximum load (maximum crushing strength), and modulus of elasticity are obtained. The data on modulus of elasticity from this test, however, are not included in table 1.

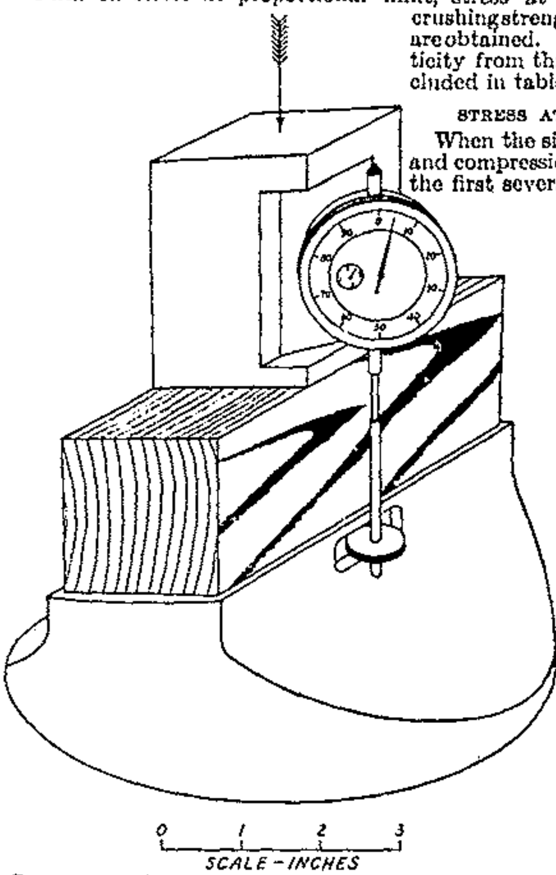



FIGURE 25.—Method of conducting compression-perpendicular-to-grain test.

### STRESS AT PROPORTIONAL LIMIT

When the simultaneous readings of load and compression are plotted as in figure 23, the first several points are approximately on a straight line. The point beyond which the compression increases at more rapid rate than the load is the proportional limit, and the accompanying stress is the stress at proportional limit. From formula 15, (p. 98), the stress at proportional limit for the test specimen represented by figure 23 is

$$S_{PL}=\frac{15,000}{1.97\times 2.00}=3,810$$

pounds per square inch

### MAXIMUM CRUSHING STRENGTH

The maximum crushing strength is computed from the same formula as stress at proportional limit, using the maximum load instead of load at proportional limit. From formula 16, (p. 98), the maximum crushing strength of the test specimen of figure 23 is

$$S_c=\frac{16,000}{1.97\times 2}=4,060$$

pounds per square inch

TB 479 (1935) USDA TECHNICAL BULLETINS UPDATA
STRENGTH AND RELATED PROPERTIES OF WOODS GROWN IN THE UNITED STATES
MARKWARDT, L. J. ; WILSON, T. R. C. 2 OF 2

### COMPRESSION PERPENDICULAR TO GRAIN

The specimen for the compression-perpendicular-to-grain test is 2 by 2 inches in cross section and 6 inches long. Pressure is applied through an iron plate 2 inches wide placed across the center of the specimen and at right angles to its length (fig. 27). Hence the plate covers one-third of the surface. The standard placement is with the growth rings vertical. The rate of descent of the movable head of the testing machine is 0.024 inch per minute. Simultaneous readings of load and compression are taken until the test is discontinued at 0.1-inch compression. The principal property determined is the stress at proportional limit. Figure 25 is a sample data sheet and figure 26 a sample computation card for compression-perpendicular-to-grain test.

#### STRESS AT PROPORTIONAL LIMIT

Figure 25 illustrates a load compression curve. The proportional limit is located as indicated from the straight-line portion of the curve. From formula 18, (p. 98), the stress at proportional limit for the test specimen represented by figure 25 is

$$S_{PL}=\frac{2000}{2\times 2.01}=498 \text{ pounds per square inch}$$

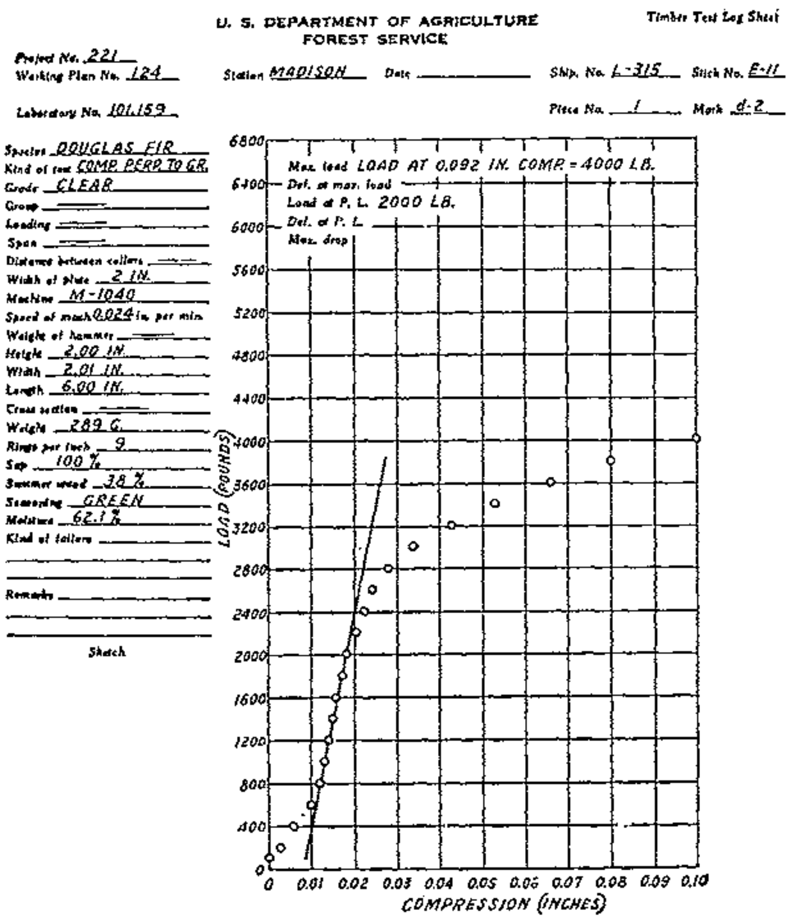



FIGURE 25.—Data sheet for compression-perpendicular-to-grain test.

Form 800
(Revised January, )

L-315 (Ship. No.) E-11 (Stick No.) **COMPRESSION AT RIGHT ANGLES TO GRAIN** 101159 (Lab. No.)

1 (Piece No.) d-2 (Mark) *Station* MADISON *Date* AUG. 20. 124 (Project No.)

*Species* DOUGLAS FIR *Grade* CLEAR *Seasoning* GREEN

*Rings* 9 *Sap* 100 % *Summer wood* 38 % *Moisture* 62.1 %

*Width of plate* 2 IN. *Length* 6.00 IN. *Height* 2.00 IN. *Width* 2.01 IN. *Weight* 289 G.

| Specific Gravity | | Load at P. L. | Crush. St. at P. L. | Δ ÷ h | |
|---|---|---|---|---|---|
| At Test. | Ov. Dry | | | | |
| 0.732 | 0.452 | 2000 | 498 | | |
| | | | | | |
| | | | | | |

FIGURE 27.—Sample computation card for compression-perpendicular-to-grain test.

## HARDNESS

Hardness is measured by the load required to embed a 0.444-inch ball (fig. 28) to one-half its diameter in the wood. (The diameter of the ball is such that its projected area is 1 square centimeter). The rate of penetration of the ball is 0.25 inch per minute. Two penetrations are made on each end, two on a radial, and two on a tangential surface of the wood. A special tool makes it easy to determine when the proper penetration of the ball has been reached. The accompanying load is recorded as the hardness value (fig. 29).

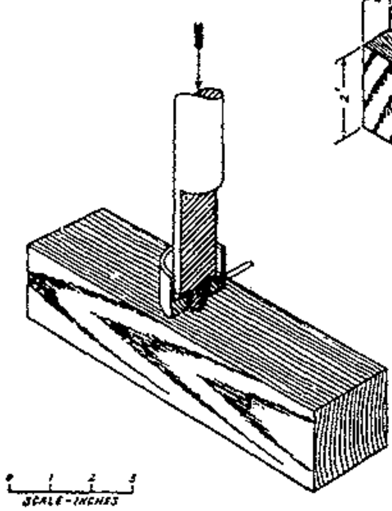



FIGURE 28.—Method of conducting hardness test.

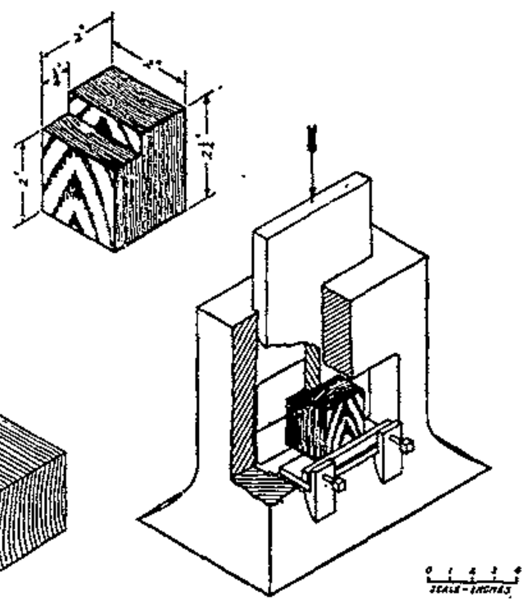



FIGURE 30.—Method of conducting shear-parallel-to-grain test.

## SHEAR PARALLEL TO GRAIN

The shearing-parallel-to-grain test is made by applying force to a 2- by 2-inch lip projecting three-fourths of an inch from the side of a block 2½ inches long (fig. 30). The block is placed in a special tool having a plate that is seated on the lip and moved downward at a rate of 0.015 inch per minute. The specimen is supported at the base so that a ⅛-inch off-set exists between the outer edge of the support and the inner surface of the plate. The improved shear tool has

Form 801
(Revised Dec. 30, )

**HARDNESS**

L-315 (Ship. No.) E-10 (Stick No.) 101170 (Lab. No.)

1 (Piece No.) d-4 (Mark) Station MADISON Date AUG. 20 124 (Project No.)

Species DOUGLAS FIR Grade CLEAR Seasoning GREEN

Rings 8 Sap ——— % Summer wood 33 % Moisture 31.7 %

Length 6.01 IN. Cross section 2.00 IN. x 2.00 IN. Weight 246 G.

| | Specific Gravity. | | Radial Surface. | Tangential Surface. | End Surface. |
|---|---|---|---|---|---|
| | At Test. | Ov. Dry. | | | |
| 1 | 0.622 | 0.472 | 460 | 570 | 525 |
| 2 | | | 520 | 460 | 500 |
| 3 | | | | | 510 |
| 4 | | | | | 510 |
| Avg., | | | 490 | 515 | 511 |
| Avg. Rad. and Tang., | 502 | | | | |

Sketch.

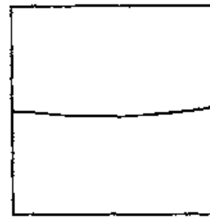


Figure 29.—Sample computation card for hardness test.

roller guides to reduce the friction of the plate, and an adjustable seat in the plate to insure uniform lateral distribution of the load.

Specimens are cut so that a radial surface of failure is obtained in some and a tangential surface of failure in others. The property obtained from the shear parallel-to-grain test is the maximum shearing strength.

### MAXIMUM SHEARING STRENGTH

The maximum load required to shear off the lip of the specimen is recorded in the test. From formula 19, (p. 99) the maximum shear strength for the test specimen represented by figure 31 is

$$S_S=\frac{3600}{2.02\times 2.01}=887 \text{ pounds per square inch}$$

Form 810
(Revised Dec., )

TANGENTIAL **SHEAR**

L-315 (Ship. No.) E-12 (Stick No.) 101183 (Lab. No.)

1 (Piece No.) C-5 (Mark) Station MADISON Date AUG. 21 124 (Project No.)

Species DOUGLAS FIR Grade CLEAR Seasoning GREEN

Rings 8 Sap 75 % Summer wood 30 % Moisture 80.0 %

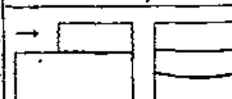
| Shearing Area | Max. Load | Shearing Str. | Time | | Sketch |
|---|---|---|---|---|---|
| 2.02 x 2.01 | 3600 | 887 | | |  |
| | | | | | |
| | | | | | |

Figure 31.—Sample computation card for shear-parallel-to-grain test.

### CLEAVAGE

The cleavage test is made to determine the resistance of wood to forces that produce a splitting action. The specimen is 2 by 2 inches in cross section, and 3¾ inches in overall length, with a cleavage section 3 inches long. The forces are applied with special grips as shown in figure 32, the rate of motion of the movable head of the testing machine being 0.25 inch per minute. Tests are made on some specimens cut so as to give a radial surface of failure, and on others cut to give a tangential surface of failure. The value obtained from the cleavage test is the load to cause splitting.

The maximum load causing failure of the specimen is observed. From formula 20 (p. 99), the load to cause splitting, for the specimen represented by figure 33, is

$$S_{CL}=\frac{365}{2.01}=182 \text{ pounds per inch of width.}$$

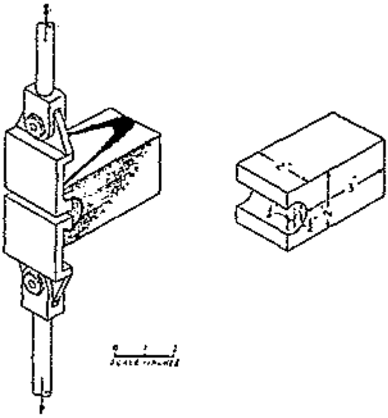
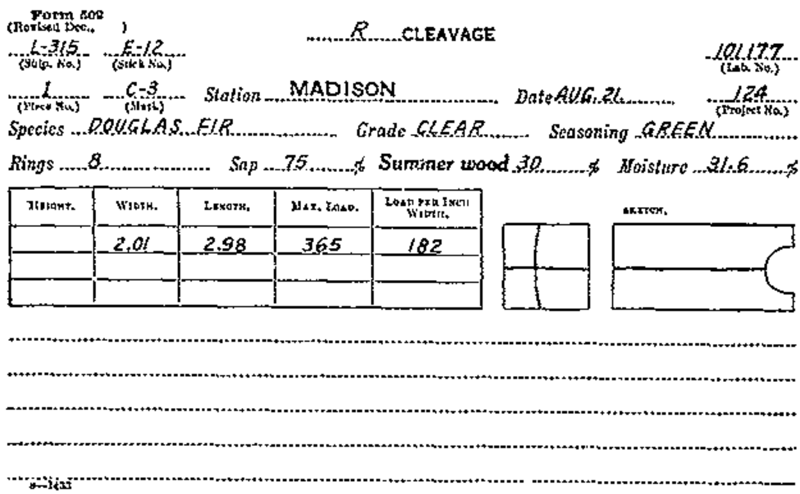


FIGURE 32.—Method of conducting cleavage test.



Form 502 (Revised Dec., )

R CLEAVAGE

L-315 (Ship. No.) E-12 (Stick No.) 101177 (Lab. No.)

1 (Piece No.) C-3 (Mark) Station MADISON Date AUG. 21 124 (Project No.)

Species DOUGLAS FIR Grade CLEAR Seasoning GREEN

Rings 8 Sap 75 % Summer wood 30 % Moisture 31.6 %

| HEIGHT. | WIDTH. | LENGTH. | MAX. LOAD. | LOAD PER INCH WIDTH. |
|---|---|---|---|---|
| | 2.01 | 2.98 | 365 | 182 |
| | | | | |
| | | | | |

SKETCH.

8—1433

FIGURE 33.—Sample computation card for cleavage test.

### TENSION PERPENDICULAR TO GRAIN

The tension-perpendicular-to-grain test is made to determine the resistance of wood across the grain to slowly applied loads. The test specimen is 2 by 2 inches in cross section, and 2½ inches in over-all length, with a length at mid-height of 1 inch. The load is applied with the special grips shown in figure 34, the rate of motion of the movable head of the testing machine being 0.25 inch per minute. Some specimens are cut to give a radial, and others to give a tangential surface of failure.

#### MAXIMUM TENSILE STRENGTH

The maximum tensile strength is the only property evaluated. From formula 21 (p. 99) the maximum tensile strength (perpendicular to the grain) for the specimen represented by figure 35 is

$$S_{TP}=\frac{533}{2.01\times0.97}=273 \text{ pounds per square inch.}$$

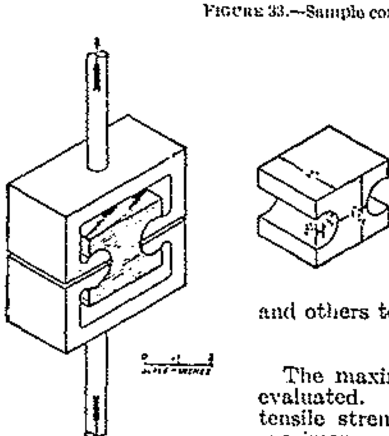


FIGURE 34.—Method of conducting tension-perpendicular-to-grain test.

Form 511 (Revised Dec., ) R TENSION PERPENDICULAR TO GRAIN

L-315 (Ship. No.) E-12 (Stick No.) 101189 (Lab. No.)

1 (Piece No.) C-6 (Mark) Station MADISON Date AUG. 21 124 (Project No.)

Species DOUGLAS FIR Grade CLEAR Seasoning GREEN

Rings 8 Sap 80 % Summer wood 30 % Moisture 44.2 %

| Height. | Width. | Length. | Maximum Load. | Tension, Lbs. per sq. in. |
|---|---|---|---|---|
| | 2.01 | 0.97 | 533 | 273 |
| | | | | |
| | | | | |

Sketch.

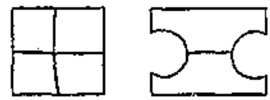


Figure 35.—Sample computation card for tension-perpendicular-to-grain test.

## TENSION PARALLEL TO GRAIN

The tension-parallel-to-grain test is made to determine the resistance of wood to slowly applied loads acting along the grain. The test specimen is 30 inches long (fig. 1). The specimen is supported by the shoulders near the ends. The rate of motion of the movable head of the testing machine is 0.05 inch per minute. Simultaneous readings of load and of deformation over a 2-inch or 4-inch gage length are taken when it is desired to determine modulus of elasticity.

### MAXIMUM TENSILE STRENGTH

From formula 22 (p. 99), the maximum tensile strength parallel to the grain for the specimen represented by figure 36 is

$$S_{TPA}=\frac{2{,}085}{0.485\times 0.482}=8{,}920 \text{ pounds per square inch.}$$

Form 511-B TENSION PARALLEL TO GRAIN

1326 (Ship. No.) L-3 (Stick No.) 632170 (Lab. No.)

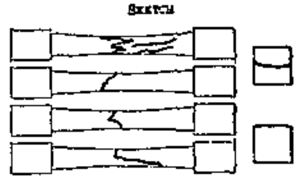
6 (Piece No.) a (Mark) Station MADISON Date 124 (Project No.)

Species LOBLOLLY PINE Grade CLEAR Seasoning GREEN

Rings 6 Sap 100 % Summer wood 35 % Moisture 29.3 %

| Cross Section | Length | Maximum Load | Tension Lbs. per sq. in. |
|---|---|---|---|
| 0.485" x 0.482" | | 2085 | 8920 |
| | | | |
| | | | |
| | | | |

Sketch



FAILURE: SPLINTERING TENSION

Figure 36.—Sample computation card for tension-parallel-to-grain test.

### LINEAR SHRINKAGE

Shrinkage measurements are made to determine the change in dimension with change in moisture content. The test specimen is 1 inch thick, 4 inches wide, and 1 inch in length along the grain. Two specimens are taken from each tree, one for measuring radial shrinkage, the other tangential. The width is measured in the apparatus shown in figure 37, which employs a micrometer reading to 0.001

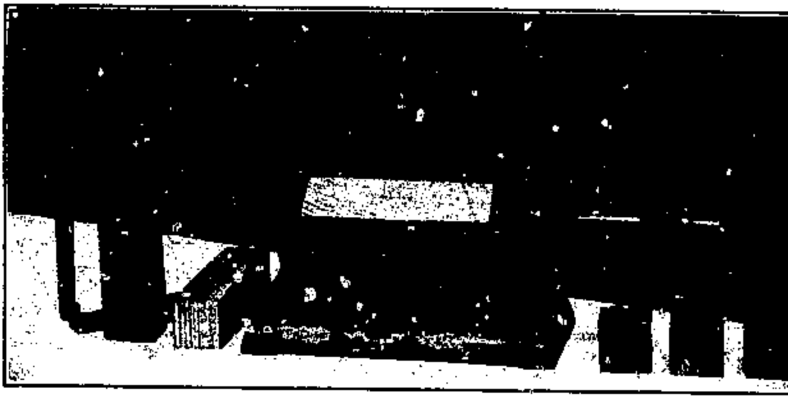


FIGURE 37.—Method of measuring linear shrinkage.

inch. The width of the specimens is measured when green, and after oven drying. In some instances measurements are also taken at intermediate stages of drying.

The linear skrinkage from the green to the oven-dry condition is the original width minus the width when oven-dry, divided by the original width. This ratio is expressed as a percentage.

From formula 23 (p. 99), the radial shrinkage for the specimen represented by figure 38 is

$$F_R = \frac{4.006 - 3.808}{4.006} \times 100 = 4.9 \text{ percent.}$$

Form 541

SHRINKAGE—RADIAL AND TANGENTIAL

L-315 (SHIP NO.) ______ (STICK NO.) — 101 200 / 101 199 (LAB. NOS.)

1 (PIECE NO.) d (MARK) STATION—MADISON, WIS. 124 (PROJECT NO.)

SPECIES DOUGLAS FIR

NOMINAL SIZE OF SPECIMEN 1 IN. X 4 IN. X 1 IN.

| SEASONING | DATE | RINGS PER INCH | % SAP | % SUMMER WOOD | WIDTH INCHES | WEIGHT GRAMS | % MOISTURE | x % SHRINKAGE |
|---|---|---|---|---|---|---|---|---|
| RADIAL | | | | | | | | |
| GREEN | AUG. 19 | 11 | 30 | 41 | 4.006 | 49.8 | 66.5 | |
| OVEN-DRY | OCT. 5 | | | | 3.808 | 29.9 | | 4.9 |
| TANGENTIAL | | | | | | | | |
| GREEN | AUG. 19 | 12 | 95 | 34 | 4.016 | 64.0 | 119.1 | |
| OVEN-DRY | OCT. 5 | | | | 3.632 | 29.2 | | 9.5 |

X BASED ON GREEN WIDTH

FIGURE 38.—Sample computation card for linear shrinkage measurements.

### SHRINKAGE IN VOLUME

Shrinkage-in-volume determinations are made on specimens 2 by 2 inches cross section and 6 inches long. Volume measurements are made by an immersion method (fig. 39). The specimens when oven dry are dipped in hot paraffin before immersion to prevent the absorption of moisture, the oven-dry weight being taken before the paraffin is applied. These final measurements afford data for computing specific gravity based on volume when oven dry.

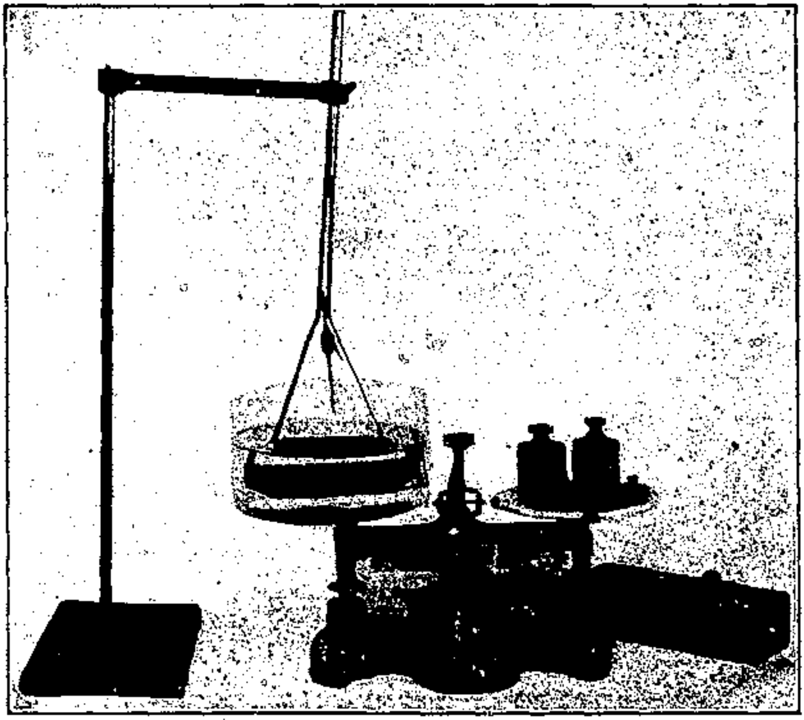


FIGURE 39.—Method of determining volume by means of immersion.

Form [illegible] (Rev. July, )

**SPECIFIC GRAVITY AND VOLUMETRIC SHRINKAGE**

L-315 (SHIP. NO.) S-6 (STION NO.) 101197 (LAB. NO.)

1 (PIECE NO.) d-8 (MARK) STATION, Madison AUG. 20 (DATE) 124 (PROJECT NO.)

SPECIES DOUGLAS FIR

NOMINAL SIZE OF SPECIMEN 2 IN. X 2 IN. X 6 IN. % SAP 0 % SUMMER WOOD 40

| | DATE | RINGS PER INCH | WEIGHT, GRAMS | % MOIST | VOLUME C. C. | SPECIFIC GRAVITY | WEIGHT, LBS. PER CU. FT. | X % VOL. SHRINKAGE |
|---|---|---|---|---|---|---|---|---|
| GREEN | AUG. 20. | 8 | 253 | 33.2 | 398 | 0.477 | 39.6 | 13.8 |
| AIR DRY | | | | | | | | |
| KILN DRY | | | | | | | | |
| OVEN DRY | SEP. 25. | | 190 | | 343 | 0.554 | 34.5 | |

X BASED ON ORIGINAL VOLUME (GREEN, AIR-DRY, KILN-DRY)

NOTE—USE BACK OF CARD FOR CARBON IMPRESSIONS

1ST WT.

2D WT.

REMARKS: VOL.

FIGURE 40.—Sample computation card for specific gravity and volumetric shrinkage determinations.

From formula 24 (p. 99), the shrinkage in volume for the specimen represented by figure 40 is

$$F_B=\frac{398-343}{398}\times 100=13.8 \text{ percent.}$$

## STRENGTH AND RELATED PROPERTIES, BY LOCALITIES, OF WOODS GROWN IN THE UNITED STATES

In table 1 only average values for each species are presented. Table 21 records the average values, by localities, of the several lots of material comprising the test specimens for each species. These values were combined to form the species averages of table 1. In forming the averages given in table 1 each value in table 21 was weighted according to the number of trees listed in column 5 on the line with "green" in column 4.

The values given in table 21 for dry material are those for the moisture content prevailing in the material at time of test, and comprise the basic data. Because of differences in moisture content, values given in table 21 for different lots of dry material are not directly comparable but those for green material afford an opportunity for comparing localities. With the aid of the data on variability previously presented and discussed (p. 17), it can be estimated whether or not differences among localities with respect to the strength properties of a species are significant and thus can be decided whether one locality is to be preferred as a source of a supply of the species under consideration.

Important features in which table 21 differs from table 1 are the following:

1. The data in each pair of lines represents material from a single county or other local subdivision.

2. For "dry" wood the specific-gravity value given in column 9 and the various strength values listed have not been adjusted to a moisture content of 12 percent as have the corresponding figures in table 1 but are the actual values as found from the tests. The values of moisture content in column 8 apply to specific gravity (column 9) and to the values in columns 24 and 25 under compression parallel to grain. The actual value of moisture content at which other tests were made differs only slightly, usually by a fraction of a percent, from those given in column 8. As may be noted, the moisture-content values for dry material vary over a considerable range. This variability is for the most part due to variations in the conditions under which the various groups of material were dried. These moisture-content values are accordingly not those to which the various species or groups of material would be dried by any one set of drying conditions. Under continued exposure to an unchanging combination of temperature and relative humidity wood reaches a fixed moisture content known as the equilibrium moisture content for that combination. Values of equilibrium moisture content vary only slightly among different species.

## NOMENCLATURE OF COMMERCIAL WOODS

The names of lumber used by the trade are not always identical with those adopted as official by the Forest Service. Where the names are not identical some confusion may result. Table 22 has therefore been prepared to show the standard commercial names for softwood lumber as prescribed in American lumber standards and the hardwood lumber names current in the trade together with the corresponding botanical names and official Forest Service names used in this bulletin.

TABLE 22.—*Nomenclature of commercial woods*

| Commercial name | Botanical name | Forest Service name used in this bulletin |
|---|---|---|
| HARDWOODS | | |
| Red alder | *Alnus rubra* | Red alder. |
| | *Alnus rhombifolia* | White alder. |
| White ash | *Fraxinus americana* | White ash. |
| | *Fraxinus biltmoreana* | Biltmore white ash. |
| | *Fraxinus pennsylvanica lanceolata* | Green ash. |
| | *Fraxinus pennsylvanica* | Red ash. |
| | *Fraxinus quadrangulata* | Blue ash. |
| Black ash | *Fraxinus nigra* | Black ash. |
| Oregon ash | *Fraxinus oregona* | Oregon ash. |
| Aspen | *Populus tremuloides* | Aspen. |
| | *Populus grandidentata* | Largetooth aspen. |
| Basswood | *Tilia glabra* | Basswood. |
| | *Tilia heterophylla* | White basswood. |
| Beech | *Fagus grandifolia* | Beech. |
| Birch | *Betula lutea* | Yellow birch. |
| | *Betula lenta* | Sweet birch. |
| | *Betula nigra* | River birch. |
| Paper birch | *Betula papyrifera* | Paper birch. |
| | *Betula populifolia* | Gray birch. |
| Alaska birch | *Betula kenaica* | Kenai birch. |
| Buckeye | *Aesculus octandra* | Yellow buckeye. |
| | *Aesculus glabra* | Ohio buckeye. |
| Butternut | *Juglans cinerea* | Butternut. |
| Catalpa | *Catalpa speciosa* | Hardy catalpa. |
| Cherry | *Prunus serotina* | Black cherry. |
| Chestnut | *Castanea dentata* | Chestnut. |
| | *Castanea pumila* | Chinquapin. |
| Chinquapin | *Castanopsis chrysophylla* | Golden chinquapin. |
| Black cottonwood | *Populus trichocarpa* | Black cottonwood. |
| | *Populus trichocarpa hastata* | Northern black cottonwood. |
| | *Populus macdougalii* | Macdougal cottonwood. |
| | *Populus fremontii* | Cottonwood. |
| Cottonwood | *Populus deltoides virginiana* | Southern cottonwood. |
| | *Populus heterophylla* | Swamp cottonwood. |
| | *Populus balsamifera* | Balsam poplar. |
| | *Populus deltoides* | Eastern cottonwood. |
| | *Populus sargentii* | Cottonwood. |
| Cucumber | *Magnolia acuminata* | Cucumber magnolia. |
| Dogwood | *Cornus florida* | Dogwood. |
| Pacific dogwood | *Cornus nuttallii* | Pacific dogwood. |
| Rock elm | *Ulmus racemosa* | Rock elm. |
| Soft elm | *Ulmus americana* | American elm. |
| | *Ulmus fulva* | Slippery elm. |
| Black gum | *Nyssa sylvatica* | Black gum. |
| | *Nyssa biflora* | Swamp black gum. |
| Red gum (heartwood only) | *Liquidambar styraciflua* | Red gum. |
| Sap gum (sapwood only) | *Liquidambar styraciflua* | Do. |
| Hackberry | *Celtis occidentalis* | Hackberry. |
| | *Celtis laevigata* | Sugarberry. |
| Hickory | *Hicoria ovata* | Shagbark hickory. |
| | *Hicoria laciniosa* | Bigleaf shagbark hickory. |
| | *Hicoria alba* | Mockernut hickory. |
| | *Hicoria glabra* | Pignut hickory. |
| | *Hicoria cordiformis* | Bitternut hickory. |
| | *Hicoria cordiformis elongata* | Do. |
| Holly | *Ilex opaca* | Holly. |
| Ironwood | *Ostrya virginiana* | Hophornbeam. |
| Black ironwood | *Krugiodendron ferreum* | Black ironwood. |
| Black locust | *Robinia pseudoacacia* | Black locust. |
| Honeylocust | *Gleditsia triacanthos* | Honeylocust. |
| Madrono | *Arbutus menziesii* | Pacific madrone. |
| Magnolia | *Magnolia grandiflora* | Evergreen magnolia. |
| Hard maple | *Acer saccharum* | Sugar maple. |
| | *Acer nigrum* | Black maple. |
| Soft maple | *Acer saccharinum* | Silver maple. |
| | *Acer rubrum* | Red maple. |
| White maple (unstained sapwood) | *Acer saccharum* | Sugar maple. |
| Oregon maple | *Acer macrophyllum* | Bigleaf maple. |
| Red oak | *Quercus borealis maxima* | Red oak. |
| | *Quercus borealis* | Do. |
| | *Quercus velutina* | Black oak. |
| | *Quercus shumardii* | Shumard red oak. |
| | *Quercus texana* | Texas red oak. |
| | *Quercus palustris* | Pin oak. |
| | *Quercus phellos* | Willow oak. |
| | *Quercus laurifolia* | Laurel oak. |
| | *Quercus rubra* | Southern red oak. |
| | *Quercus rubra pagodaefolia* | Swamp red oak. |
| | *Quercus nigra* | Water oak. |
| | *Quercus ellipsoidalis* | Jack oak. |
| | *Quercus coccinea* | Scarlet oak. |
| | *Quercus marilandica* | Blackjack oak. |

TABLE 22.—*Nomenclature of commercial woods*—Continued

| Commercial name | Botanical name | Forest Service name used in this bulletin |
|---|---|---|
| HARDWOODS—continued | | |
| Red oak | *Quercus kelloggii* | California black oak. |
| | *Quercus catesbaei* | Turkey oak. |
| White oak | *Quercus alba* | White oak. |
| | *Quercus stellata* | Post oak. |
| | *Quercus lyrata* | Overcup oak. |
| | *Quercus bicolor* | Swamp white oak. |
| | *Quercus muehlenbergii* | Chinquapin oak. |
| | *Quercus garryana* | Oregon white oak. |
| | *Quercus prinus* | Swamp chestnut oak. |
| | *Quercus montana* | Chestnut oak. |
| | *Quercus macrocarpa* | Bur oak. |
| | *Quercus utahensis* | Rocky mountain white oak. |
| Live oak | *Quercus wislizenii* | Highland live oak. |
| | *Quercus agrifolia* | Coast live oak. |
| | *Quercus chrysolepis* | Canyon live oak. |
| | *Quercus virginiana* | Live oak. |
| Osage-orange | *Toxylon pomiferum* | Osage-orange. |
| Pecan | *Hicora pecan* | Pecan. |
| | *Hicora cordiformis* | Bitternut hickory. |
| | *Hicora cordiformis elongata* | Do. |
| Persimmon | *Diospyros virginiana* | Persimmon. |
| Sassafras | *Sassafras variifolium* | Sassafras. |
| Silverbell | *Halesia carolina* | Silverbell. |
| Sycamore | *Platanus occidentalis* | Sycamore. |
| Tupelo | *Nyssa aquatica* | Tupelo gum. |
| Black walnut | *Juglans nigra* | Black walnut. |
| Willow | *Salix nigra* | Black willow. |
| Yellow poplar | *Liriodendron tulipifera* | Yellow poplar. |
| SOFTWOODS | | |
| Alaska cedar | *Chamaecyparis nootkatensis* | Alaska cedar. |
| Eastern red cedar | *Juniperus virginiana* | Eastern red cedar. |
| | *Juniperus lucayana* | Southern red cedar. |
| | *Juniperus mexicana* | Mountain cedar. |
| Incense cedar | *Libocedrus decurrens* | Incense cedar. |
| Northern white cedar | *Thuja occidentalis* | Northern white cedar. |
| Port Orford cedar | *Chamaecyparis lawsoniana* | Port Orford cedar. |
| Southern white cedar | *Chamaecyparis thyoides* | Southern white cedar. |
| Western juniper | *Juniperus utahensis* | Utah juniper. |
| | *Juniperus pachyphloea* | Alligator juniper. |
| | *Juniperus scopulorum* | Rocky mountain red cedar. |
| | *Juniperus occidentalis* | Western juniper. |
| Western red cedar | *Thuja plicata* | Western red cedar. |
| Red cypress (coast type) | *Taxodium distichum* | Southern cypress. |
| Yellow cypress (inland type) | *Taxodium distichum* | Do. |
| White cypress (inland type) | *Taxodium distichum* | Do. |
| Douglas fir | *Pseudotsuga taxifolia* | Douglas fir. |
| Red fir (intermountain type) | *Pseudotsuga taxifolia* | Do. |
| Red fir (Rocky Mountain type) | *Pseudotsuga taxifolia* | Do. |
| Alpine fir | *Abies lasiocarpa* | Alpine fir. |
| | *Abies arizonica* | Corkbark fir. |
| Balsam fir | *Abies balsamea* | Balsam fir. |
| | *Abies fraseri* | Southern balsam fir. |
| Golden fir | *Abies magnifica* | California red fir. |
| Noble fir | *Abies nobilis* | Noble fir. |
| Silver fir | *Abies amabilis* | Silver fir. |
| White fir | *Abies concolor* | White fir. |
| | *Abies grandis* | Lowland white fir. |
| Eastern hemlock | *Tsuga canadensis* | Eastern hemlock. |
| | *Tsuga caroliniana* | Carolina hemlock. |
| Mountain hemlock | *Tsuga mertensiana* | Mountain hemlock. |
| West coast hemlock | *Tsuga heterophylla* | Western hemlock. |
| Western larch | *Larix occidentalis* | Western larch. |
| Arkansas soft pine | *Pinus echinata* | Shortleaf pine. |
| | *Pinus taeda* | Loblolly pine. |
| Idaho white pine | *Pinus monticola* | Western white pine. |
| Jack pine | *Pinus banksiana* | Jack pine. |
| Loblolly pine | *Pinus taeda* | Loblolly pine. |
| Lodgepole pine | *Pinus contorta* | Lodgepole pine. |
| Longleaf pine | *Pinus palustris* | Longleaf pine. |
| North Carolina pine | *Pinus taeda* | Loblolly pine. |
| | *Pinus echinata* | Shortleaf pine. |
| | *Pinus virginiana* | Virginia pine. |
| | *Pinus strobus* | Northern white pine. |
| Norway pine | *Pinus resinosa* | Norway pine. |
| Pond pine | *Pinus rigida serotina* | Pond pine. |
| Ponderosa pine | *Pinus ponderosa* | Ponderosa pine. |
| Pondosa pine | *Pinus ponderosa* | Do. |

TABLE 22.—*Nomenclature of commercial woods*—Continued

| Commercial name | Botanical name | Forest Service name used in this bulletin |
|---|---|---|
| SOFTWOODS—continued | | |
| Shortleaf pine | *Pinus echinata* | Shortleaf pine. |
| Slash pine | *Pinus caribaea* | Slash pine. |
| Southern pine | *Pinus taeda* | Loblolly pine. |
| | *Pinus palustris* | Longleaf pine. |
| | *Pinus rigida serotina* | Pond pine. |
| | *Pinus echinata* | Shortleaf pine. |
| | *Pinus caribaea* | Slash pine. |
| | *Pinus rigida* | Pitch pine. |
| | *Pinus glabra* | Spruce pine. |
| Sugar pine | *Pinus lambertiana* | Sugar pine. |
| Redwood | *Sequoia sempervirens* | Redwood. |
| Eastern spruce | *Picea mariana* | Black spruce. |
| | *Picea rubra* | Red spruce. |
| | *Picea glauca* | White spruce. |
| Engelmann spruce | *Picea engelmannii* | Engelmann spruce. |
| | *Picea pungens* | Blue spruce. |
| Sitka spruce | *Picea sitchensis* | Sitka spruce. |
| Tamarack | *Larix laricina* | Tamarack. |
| Pacific yew | *Taxus brevifolia* | Pacific yew. |

## FORMULAS USED IN COMPUTING

### LEGEND

$S_{CL}$=strength in cleavage, pounds per inch of width.
$S_{PL}$=stress at proportional limit, pounds per square inch.
$S_{TP}$=stress in tension perpendicular to grain, pounds per square inch.
$S_{TP\parallel}$=stress in tension parallel to grain, pounds per square inch.
$P'$=load at proportional limit, pounds.
$P$=maximum load, pounds.
$R$=modulus of rupture, pounds per square inch.
$S_s$=shear stress, pounds per square inch.
$M$=bending moment, in inch-pounds.
$S$=computed unit stress, pounds per square inch.

$$I=\text{moment of inertia, inches}^4\left(\text{for a rectangular beam } I=\frac{b\times d^3}{12}\right).$$

$c$=distance from neutral axis of beam to extreme fiber, inches.
$V$=total vertical shear at any cross section of a beam, pounds.
$L$=length, inches; in static bending, $L$=span, inches.
$b$=breadth, inches.
$d$=depth, inches.
$y$=deflection, inches.
$b_1$=width of specimen when green, inches.
$b_2$=width of specimen when oven-dry, inches.
$K_1$=volume of specimen when green, cubic inches.
$K_2$=volume of specimen when oven-dry, cubic inches.
$G$=specific gravity.
$W$=work, inch-pounds per cubic inch.
$W_{PL}$=work to proportional limit, inch-pounds per cubic inch.
$W_{ML}$=work to maximum load, inch-pounds per cubic inch.
$W_T$=total work, inch-pounds per cubic inch.
$E$=modulus of elasticity, pounds per square inch.
$A$=area under direct stress, square inches.
$H$=head or total drop of hammer, plus impact deflection, inches.
$W$=weight of hammer, impact bending test, pounds.
$\Delta$=impact deflection plus static deflection (0.01 inch).
$F_R$=radial shrinkage from green to oven-dry condition.
$F_T$=tangential shrinkage from green to oven-dry condition.
$F_V$=volumetric shrinkage from green to oven-dry condition.

126695°—35——7

## BENDING (SQUARE OR RECTANGULAR BEAMS)

### LOAD APPLIED AT CENTER

$$S_{PL}=\frac{3\times P'\times L}{2\times b\times d^2} \tag{1}$$

$$R=\frac{3\times P\times L}{2\times b\times d^2} \tag{2}$$

$$E=\frac{P'\times L^3}{4\times b\times d^3\times y} \tag{3}$$

$$S_s=\frac{3\times P}{4\times b\times h} \tag{4}$$

$$W_{PL}=\frac{P'y}{2\times b\times d\times L} \tag{5}$$

$$W_{ML}=\frac{\text{area under curve to maximum load in inch-pounds}}{b\times d\times L} \tag{6}$$

$$W_T=\frac{\text{total area under curve in inch-pounds}}{b\times d\times L} \tag{7}$$

### UNIFORMLY DISTRIBUTED LOAD

$$S_{PL}=\frac{3\times P'\times L}{4\times b\times d^2} \tag{8}$$

$$\mathrm{R}=\frac{3\times P\times L}{4\times b\times d^2} \tag{9}$$

$$E=\frac{5\times P'\times L^3}{32\times b\times d^3\times y} \tag{10}$$

### ANY LOADING

$$M=\frac{SI}{c} \qquad M_{max}=\frac{RI}{c} \tag{11}$$

$$S_s=\frac{3\times V}{2\times b\times d} \tag{12}$$

### IMPACT BENDING

$$S_{PL}=\frac{3WHL}{bd^2\Delta} \tag{13}$$

$$W_{PL}=\frac{WH}{Lbh} \tag{14}$$

### COMPRESSION PARALLEL TO GRAIN

$$S_{PL}=\frac{P'}{A} \tag{15}$$

$$S_c=\frac{P}{A} \tag{16}$$

$$E=\frac{P'L}{Ay} \tag{17}$$

### COMPRESSION PERPENDICULAR TO GRAIN

$$S_{PL}=\frac{P'}{A}\text{, where } A=\text{area of specimen under plate, square inches} \tag{18}$$

SHEAR PARALLEL TO GRAIN

$S_s=\frac{P}{A}$, where $A$=area under shear, square inches (19)

CLEAVAGE PARALLEL TO GRAIN

$$S_{CL}=\frac{P}{b} \qquad (20)$$

TENSION PERPENDICULAR TO GRAIN

$$S_{TP}=\frac{P}{A} \qquad (21)$$

TENSION PARALLEL TO GRAIN

$$S_{TP,1}=\frac{P}{A} \qquad (22)$$

LINEAR SHRINKAGE (PERCENT)

$$F_R \text{ or } F_T=\frac{b_1-b_2}{b_1}\times 100 \qquad (23)$$

VOLUMETRIC SHRINKAGE (PERCENT)

$$F_V=\frac{K_1-K_2}{K_1}\times 100 \qquad (24)$$

SPECIFIC GRAVITY

$$G=\frac{\text{weight in grams}}{\left(1+\frac{\text{percent moisture}}{100}\right)\times\text{volume in cubic centimeters}} \qquad (25)$$

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TABLE 21.—*Strength and related properties, by localities, of woods grown in the United States*

| Shipment no. | Species (common and botanical names) | Place of growth of material tested | Moisture condition | Trees tested | Rings per inch | Summer wood | Moisture content | Specific gravity, oven-dry, based on volume— | | Weight per cubic foot | Shrinkage from green to oven-dry condition based on dimensions when green | | | Static bending | | | | | | Impact bending | | | Compression parallel to grain | | Compression perpendicular to grain; stress at proportional limit | Hardness; load required to embed a 0.444-inch ball to ½ its diameter | | Shear parallel to grain; maximum shearing strength | Cleavage; load to cause splitting | Tension perpendicular to grain; maximum tensile strength |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | At test | When oven-dry | | Volumetric | Radial | Tangential | Stress at proportional limit | Modulus of rupture | Modulus of elasticity | Work: Proportional limit | Work: Maximum load | Work: Total | Stress at proportional limit | Work to proportional limit | Height of drop causing complete failure (50-pound hammer) | Stress at proportional limit | Maximum crushing strength | | End | Side | | | |
| 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 | 28 | 29 | 30 | 31 |
| | HARDWOODS | | | *Number* | *Number* | *Percent* | *Percent* | | | *Pounds* | *Percent* | *Percent* | *Percent* | *Lb. per sq. in.* | *Lb. per sq. in.* | *1,000 lb. per sq. in.* | *In.-lb. per cu. in.* | *In.-lb. per cu. in.* | *In.-lb. per cu. in.* | *Lb. per sq. in.* | *In.-lb. per cu. in.* | *Inches* | *Lb. per sq. in.* | *Lb. per sq. in.* | *Lb. per sq. in.* | *Pounds* | *Pounds* | *Lb. per sq. in.* | *Lb. per in. of width* | *Lb. per sq. in.* |
| 203 | Alder, red (*Alnus rubra*) | Snohomish County, Wash. | Green | 6 | 10.8 | | 98.2 | 0.368 | 0.434 | 46 | 12.6 | 4.4 | 7.3 | 3,750 | 6,540 | 1,167 | 0.70 | 8.0 | 15.3 | 8,040 | 2.0 | 22 | 2,620 | 2,960 | 313 | 554 | 440 | 770 | 217 | 394 |
| | | | Dry | 2 | | | 8.4 | .418 | | | | | | 8,140 | 10,850 | 1,435 | 2.37 | 8.5 | 9.8 | 13,040 | 5.9 | 23 | 5,290 | 7,030 | 651 | 1,170 | 652 | 1,210 | 284 | 431 |
| 746 | Apple (*Malus pumila* var.) | Botetourt County, Va. | Green | 10 | 5.8 | | 46.5 | .606 | .745 | 55 | 17.6 | 5.6 | 10.1 | 3,640 | 7,400 | 1,047 | .75 | 15.7 | 30.4 | 7,590 | 3.0 | 33 | 1,990 | 3,000 | 854 | 1,041 | 1,088 | 1,636 | 476 | 905 |
| | | | Dry | 4 | | | 10.2 | .678 | | | | | | 6,770 | 13,070 | 1,217 | 2.40 | 23.3 | 44.0 | 16,850 | 8.6 | 44 | 2,340 | 6,600 | 1,418 | 2,300 | 1,800 | 1,784 | | |
| 257 | Ash, biltmore white (*Fraxinus biltmoreana*) | Overton County, Tenn. | Green | 5 | 16.6 | 49 | 41.5 | .507 | .584 | 45 | 12.6 | 4.2 | 6.9 | 5,530 | 9,270 | 1,335 | 1.31 | 11.6 | 27.4 | 11,930 | 4.9 | 30 | 3,530 | 3,980 | 875 | 953 | 853 | 1,232 | 343 | 534 |
| | | | Dry | 1 | | | 5.4 | .573 | | | | | | 12,110 | 15,500 | 1,760 | 4.60 | 11.7 | 17.2 | 19,850 | 10.4 | 46 | 7,300 | 10,270 | 2,020 | 2,060 | 1,300 | 1,972 | 482 | 818 |
| 219 | Ash, black (*Fraxinus nigra*) | Ontonagon County, Mich. | Green | 6 | 23.1 | 53 | 90.6 | .447 | .526 | 53 | 15.2 | 5.0 | 7.8 | 2,610 | 6,000 | 1,107 | .42 | 11.3 | 28.9 | 7,230 | 2.5 | 35 | 1,720 | 2,340 | 409 | 610 | 552 | 866 | 266 | 490 |
| | | | Dry | 1 | | | 9.1 | .500 | | | | | | 10,240 | 16,130 | 1,975 | 2.65 | 17.9 | 43.6 | | | 44 | 8,020 | 8,190 | 1,270 | 1,338 | 994 | 1,794 | 307 | 700 |
| 5 | do | Marathon County, Wis. | Green | | 25.0 | | 78.9 | .456 | | 51 | | | | 2,580 | 6,000 | 967 | .40 | 13.1 | 35.0 | | | 30 | | 2,260 | 452 | 565 | 490 | 854 | 292 | 490 |
| | | | Dry | | | | 11.6 | .497 | | | | | | 6,310 | 11,620 | 1,395 | 1.64 | 13.1 | 27.3 | 12,180 | 5.3 | 27 | 3,950 | 5,500 | 893 | 1,101 | 792 | 1,660 | 407 | 606 |
| 222 | Ash, blue (*Fraxinus quadrangulata*) | Bourbon County, Ky. | Green | 5 | 12.5 | 49 | 39.3 | .532 | .603 | 46 | 11.7 | 3.9 | 6.5 | 5,700 | 9,650 | 1,241 | 1.47 | 14.7 | 38.2 | 11,140 | 5.0 | 43 | 3,580 | 4,180 | 904 | 1,140 | 1,028 | 1,544 | 353 | 584 |
| | | | Dry | 1 | | | 9.6 | .575 | | | | | | 8,720 | 14,770 | 1,483 | 3.00 | 14.3 | 30.1 | 20,350 | 10.5 | 42 | 5,940 | 7,740 | 1,911 | 1,833 | 1,356 | 2,153 | 454 | |
| 75 | Ash, green (*Fraxinus pennsylvanica lanceolata*) | Richland Parish, La. | Green | 5 | 20.6 | 60 | 47.4 | .516 | .590 | 47 | 11.7 | | | 4,450 | 8,880 | 1,319 | .87 | 10.6 | 23.7 | 11,720 | 5.6 | 32 | 3,240 | 4,040 | 801 | 842 | 732 | 1,202 | 349 | 614 |
| | | | Dry | 1 | | | 11.2 | .552 | | | | | | 8,950 | 13,050 | 1,615 | 2.82 | 12.6 | 22.0 | 15,850 | 7.2 | 32 | 5,180 | 7,300 | 1,232 | 1,670 | 1,153 | 1,532 | 372 | 718 |
| 223 | do | New Madrid County, Mo. | Green | 5 | 13.7 | 56 | 43.3 | .536 | .631 | 50 | 13.8 | 4.6 | 7.1 | 6,110 | 10,040 | 1,480 | 1.42 | 13.0 | 31.6 | 11,160 | 4.4 | 37 | 3,690 | 4,300 | 1,012 | 1,073 | 1,007 | 1,318 | 345 | 564 |
| | | | Dry | 1 | | | 9.6 | .518 | | | | | | 9,970 | 16,110 | 1,768 | 3.18 | 14.6 | 22.4 | 18,000 | 9.6 | 30 | 5,520 | 7,850 | 2,220 | 1,870 | 1,302 | 2,356 | 464 | 748 |
| 318 | Ash, Oregon (*Fraxinus oregona*) | Lane County, Oreg. | Green | 3 | 12.5 | 63 | 48.5 | .497 | .575 | 46 | 13.2 | 4.1 | 8.1 | 4,230 | 7,570 | 1,132 | .92 | 12.2 | 33.3 | 8,920 | 3.0 | 39 | 2,760 | 3,510 | 653 | 851 | 790 | 1,191 | 309 | 587 |
| | | | Dry | 2 | | | 8.4 | .560 | | | | | | 7,940 | 14,540 | 1,426 | 2.58 | 15.1 | 20.0 | 15,000 | 6.2 | 31 | 4,610 | 7,120 | 1,998 | 1,886 | 1,296 | 2,002 | 481 | 775 |
| 223 | Ash, pumpkin (*Fraxinus profunda*) | New Madrid County, Mo. | Green | 3 | 21.0 | 46 | 51.4 | .485 | .551 | 46 | 12.0 | 3.7 | 6.3 | 4,470 | 7,600 | 1,043 | 1.08 | 9.4 | 18.4 | 8,760 | 3.7 | 31 | 2,850 | 3,360 | 989 | 885 | 752 | 1,214 | 357 | 574 |
| | | | Dry | 1 | | | 9.6 | .526 | | | | | | 6,980 | 11,810 | 1,312 | 2.11 | 7.8 | 14.8 | 15,150 | 7.9 | 22 | 4,220 | 8,320 | 1,905 | 1,585 | 1,024 | 1,802 | 459 | 828 |
| 101 | Ash, white (*Fraxinus americana*) | Stone County, Ark. | Green | 5 | 14.8 | 51 | 38.2 | .550 | .640 | 47 | 12.6 | 4.3 | 6.4 | 5,180 | 9,920 | 1,416 | 1.10 | 13.3 | 34.3 | 11,710 | 4.9 | 33 | 3,450 | 4,220 | 880 | 1,121 | 1,008 | 1,336 | 340 | 658 |
| | | | Dry | 1 | | | 10.5 | .620 | | | | | | 10,770 | 17,450 | 1,942 | 3.42 | 16.8 | 30.9 | 14,920 | 6.5 | 34 | 6,240 | 7,900 | 1,315 | 2,063 | 1,418 | 2,215 | 388 | 908 |
| 214 | Ash, white (second growth) (*Fraxinus americana*) | Oswego County, N. Y. | Green | 5 | 8.8 | 63 | 40.3 | .582 | .708 | 51 | 14.0 | 5.3 | 8.7 | 6,140 | 10,760 | 1,635 | 1.30 | 16.3 | 41.9 | 13,780 | 5.9 | 47 | 3,960 | 4,610 | 794 | 1,145 | 1,083 | 1,604 | 440 | 787 |
| | | | Dry | 1 | | | 9.5 | .637 | | | | | | 12,010 | 18,650 | 1,985 | 4.80 | 17.0 | 35.9 | 23,840 | 12.8 | 46 | 8,060 | 9,420 | 2,000 | 2,240 | 1,580 | 2,575 | 471 | 1,125 |
| 250 | Ash, white (*Fraxinus americana*) | Pocahontas County, W. Va. | Green | 5 | 17.2 | 49 | 48.1 | .495 | .565 | 46 | 12.2 | 4.1 | 6.6 | 4,600 | 8,310 | 1,225 | .96 | 13.6 | 32.4 | 11,620 | 5.1 | 38 | 2,870 | 3,390 | 705 | 872 | 785 | 1,183 | 336 | 590 |
| | | | Dry | 1 | | | 6.9 | .534 | | | | | | 8,580 | 13,960 | 1,684 | 3.16 | 13.4 | 25.9 | 19,050 | 11.0 | 37 | 5,540 | 8,480 | 1,762 | 1,833 | 1,224 | 2,008 | 310 | 807 |
| 904 | Ash, white (second growth) (*Fraxinus americana*) | Bennington County, Vt., Hampshire County, Mass. | Green | 8 | 10.2 | 52 | 40.4 | .566 | .630 | 40 | 13.9 | 5.5 | 9.1 | 4,720 | 9,340 | 1,452 | .88 | 20.8 | 51.6 | 16,780 | 6.9 | 35 | 2,750 | 3,840 | 842 | 940 | 908 | 1,392 | 258 | 430 |
| | | | Dry | 2 | | | 11.9 | .611 | | | | | | 7,740 | 15,500 | 1,752 | 1.97 | 21.6 | 33.2 | 13,250 | 7.2 | 50 | 5,720 | 7,520 | 1,364 | 1,635 | 1,312 | 1,877 | 556 | 1,000 |
| 300 | Aspen (*Populus tremuloides*) | Rusk County, Wis. | Green | 5 | 8.5 | | 106.6 | .360 | .422 | 46 | 11.1 | 3.3 | 6.9 | 2,040 | 5,280 | 840 | .65 | 6.9 | 16.0 | 6,880 | 2.5 | 28 | 1,600 | 2,160 | 203 | 206 | 318 | 625 | 116 | 182 |
| | | | Dry | 1 | | | 5.3 | .421 | | | | | | 7,600 | 10,770 | 1,290 | 2.43 | 7.2 | | 10,470 | 4.0 | 24 | 4,320 | 6,440 | 532 | 848 | 420 | 900 | 224 | 300 |
| 405 | do | San Miguel County, N. Mex. | Green | 6 | 7.3 | | 84.3 | .344 | .383 | 40 | 11.8 | 3.6 | 6.6 | 3,340 | 5,000 | 877 | .73 | 5.9 | 11.2 | 7,010 | 2.8 | 18 | 1,720 | 2,130 | 239 | 289 | 286 | 683 | 152 | 276 |
| | | | Dry | 2 | | | 7.8 | .372 | | | | | | 7,150 | 10,500 | 1,410 | 2.07 | 9.1 | 13.5 | 9,480 | 3.6 | 18 | | 5,520 | 718 | 567 | 328 | 1,023 | | 320 |
| 211 | Aspen, largetooth (*Populus grandidentata*) | Sauk County, Wis. | Green | 5 | 8.2 | | 96.4 | .354 | .412 | 43 | 11.6 | 3.1 | 7.9 | 3,190 | 5,850 | 1,185 | .50 | 6.1 | 10.6 | 7,600 | 2.7 | 18 | 2,210 | 2,720 | 269 | 443 | 366 | 813 | 216 | 394 |
| | | | Dry | 2 | | | 8.0 | .404 | | | | | | 7,140 | 10,890 | 1,635 | 1.83 | 6.7 | 13.5 | 15,100 | 7.0 | 27 | 5,100 | 7,060 | 446 | 710 | 462 | 1,305 | 234 | 390 |
| 904 | Aspen, largetooth (second growth) (*Populus grandidentata*) | Bennington County, Vt. | Green | 5 | 8.1 | | 100.7 | .343 | .411 | 43 | 11.9 | 3.5 | 7.9 | 2,660 | 4,950 | 1,056 | .38 | 5.2 | 14.5 | 7,220 | 2.3 | 19 | 1,830 | 2,280 | 239 | 352 | 374 | 651 | 164 | 230 |
| | | | Dry | 5 | | | 12.3 | .386 | | | | | | 5,380 | 8,930 | 1,345 | 1.19 | 8.9 | 15.1 | 9,900 | 3.9 | 20 | 3,060 | 4,930 | 396 | 642 | 492 | 974 | 216 | 406 |
| 165 | Basswood (*Tilia glabra*) | Marathon County, Wis. | Green | 3 | 21.8 | | 115.1 | .378 | .374 | 42 | 14.5 | 6.2 | 8.4 | 2,370 | 4,440 | 852 | .39 | 5.9 | 8.6 | 5,760 | 2.0 | 15 | 1,180 | 1,830 | 191 | 283 | 220 | 654 | 146 | 295 |
| | | | Dry | 1 | | | 9.2 | .348 | | | | | | 5,640 | 7,280 | 1,690 | 1.03 | 3.2 | 4.4 | 6,390 | 1.8 | 8 | 3,420 | 4,800 | 540 | 481 | 364 | 1,433 | 278 | 408 |
| 197 | do | Potter County, Pa. | Green | 5 | 17.3 | | 98.9 | .331 | .412 | 41 | 10.5 | 6.8 | 9.9 | 2,840 | 5,270 | 1,149 | .41 | 4.9 | 11.3 | 6,590 | 2.1 | 17 | 2,000 | 2,450 | 221 | 292 | 263 | 626 | 149 | 282 |
| | | | Dry | 1 | | | 7.9 | .404 | | | | | | 8,120 | 11,860 | 1,525 | 2.40 | 11.1 | 11.7 | 14,300 | 8.3 | 21 | 5,700 | 6,700 | 591 | 672 | 508 | 1,074 | 300 | 360 |
| 111 | Beech (*Fagus grandifolia*) | Hendricks and Morgan Counties, Ind. | Green | 5 | 16.9 | | 60.9 | .556 | .669 | 55 | 16.5 | 4.6 | 10.5 | 4,490 | 8,610 | 1,353 | .96 | 14.1 | 30.9 | 11,760 | 5.1 | 43 | 2,750 | 3,480 | 605 | 1,012 | 908 | 1,264 | 433 | 801 |
| | | | Dry | 1 | | | 13.1 | .620 | | | | | | 8,140 | 14,830 | 1,830 | 2.31 | 10.4 | 40.2 | 17,200 | 8.1 | 40 | 4,020 | 8,450 | 1,185 | 1,463 | 1,217 | 1,900 | 546 | 1,140 |
| 197 | do | Potter County, Pa. | Green | 5 | 21.0 | | 63.6 | .531 | .641 | 54 | 15.8 | 5.1 | 10.6 | 4,500 | 7,720 | 1,131 | 1.02 | 10.9 | 22.5 | 9,130 | 3.3 | 38 | 2,300 | 3,080 | 609 | 891 | 740 | 1,156 | 395 | 714 |
| | | | Dry | 1 | | | 9.3 | .644 | | | | | | 9,800 | 15,160 | 1,537 | 3.51 | 11.0 | 18.4 | 20,150 | 10.3 | 30 | 5,820 | 8,350 | 1,504 | 1,341 | 1,198 | 2,032 | 400 | 643 |
| 904 | Beech (second growth) (*Fagus grandifolia*) | Bennington County, Vt. | Green | 7 | 10.4 | | 42.1 | .590 | .603 | 52 | 16.5 | 5.4 | 11.6 | 4,110 | 9,150 | 1,580 | .64 | 11.1 | 36.6 | 13,020 | 4.8 | 46 | 2,590 | 3,940 | 765 | 996 | 886 | 1,398 | 397 | 666 |
| | | | Dry | 4 | | | 11.7 | .641 | | | | | | 9,210 | 15,720 | 1,800 | 2.73 | 17.3 | 31.8 | 13,430 | 4.7 | 49 | 5,470 | 8,000 | 1,278 | 1,932 | 1,552 | 2,306 | 454 | 1,170 |
| 904 | Beech, blue (*Carpinus caroliniana*) | Franklin County, Mass., Bennington County, Vt. | Green | 12 | 15.2 | | 47.8 | .575 | .727 | 53 | 19.1 | 5.7 | 11.4 | 3,200 | 6,790 | 992 | .61 | 19.1 | 60.0 | 10,080 | 4.0 | 106 | 1,420 | 2,670 | 733 | 895 | 940 | 1,164 | 256 | 350 |
| | | | Dry | 12 | | | 12.7 | .677 | | | | | | 2,750 | 11,060 | 1,062 | .74 | 33.2 | 72.7 | 10,270 | 4.3 | | 2,850 | 5,100 | 1,683 | 1,331 | 1,076 | 2,261 | 504 | |
| 930 | Birch, Alaska white (*Betula neoalaskana*) | Near Anchorage, Alaska | Green | 10 | 29.4 | | 58.2 | .488 | .594 | 48 | 16.7 | 6.5 | 9.9 | 3,770 | 7,090 | 1,354 | .80 | 11.6 | 32.5 | 9,800 | 3.7 | 37 | 2,050 | 3,030 | 434 | 653 | 564 | 917 | 176 | 196 |
| | | | Dry | 7 | | | 11.8 | .552 | | | | | | 6,180 | 14,350 | 1,950 | 2.03 | 14.1 | 20.6 | 14,020 | 4.9 | 41 | 5,720 | 8,030 | 877 | 900 | 844 | 1,400 | 400 | 700 |
| 865 | Birch, gray (*Betula populifolia*) | Strafford County, N. H. | Green | 5 | | | 63.0 | .448 | .552 | 46 | 14.7 | 5.2 | | 1,840 | 4,920 | 401 | .47 | 13.9 | 37.8 | 7,380 | 2.6 | 59 | 1,080 | 1,860 | 249 | 435 | 482 | | | |
| | | | Dry | 5 | | | 11.4 | .508 | | | | | | 5,370 | 9,420 | 1,117 | 1.59 | 10.9 | 35.3 | 10,270 | 3.5 | 35 | 2,750 | 5,610 | 1,050 | 730 | 830 | 1,383 | 374 | |
| 300 | Birch, paper (*Betula papyrifera*) | Rusk County, Wis. | Green | 5 | 5.5 | | 72.0 | .473 | .600 | 51 | 16.3 | 6.6 | 8.8 | 2,920 | 5,770 | 1,013 | .49 | 15.0 | 38.9 | 7,780 | 2.7 | 45 | 1,640 | 2,210 | 304 | 400 | 486 | 786 | 239 | 382 |
| | | | Dry | 2 | | | 4.2 | .582 | | | | | | 11,440 | 16,030 | 1,814 | 4.32 | 13.2 | 19.2 | 13,840 | 6.6 | 24 | 6,140 | 9,470 | 912 | 1,487 | 1,278 | 1,427 | | |
| 865 | do | Strafford County, N. H. | Green | 5 | 6.8 | | 58.7 | .494 | .600 | 49 | 16.0 | 6.0 | 8.5 | 3,020 | 7,000 | 1,328 | .40 | 17.4 | 48.8 | 8,320 | 2.6 | 53 | 1,630 | 2,510 | 370 | 532 | 632 | 886 | 181 | |
| | | | Dry | 5 | | | 11.6 | .548 | | | | | | 7,330 | 14,060 | 1,744 | 1.85 | 18.2 | 46.8 | 13,320 | 4.8 | 48 | 3,670 | 8,140 | 1,002 | 928 | 996 | 1,214 | 444 | |
| 197 | Birch, sweet (*Betula lenta*) | Potter County, Pa. | Green | 5 | 26.8 | | 61.3 | .588 | .698 | 59 | 15.0 | 6.3 | 7.6 | 4,510 | 8,590 | 1,490 | .81 | 15.6 | 36.9 | 9,540 | 3.1 | 44 | 2,560 | 3,560 | 525 | 1,023 | 894 | 1,220 | 337 | 552 |
| | | | Dry | 1 | | | 9.0 | .665 | | | | | | 13,280 | 19,850 | 2,138 | 4.56 | 17.6 | 21.8 | 26,780 | 12.2 | 48 | 8,460 | 10,650 | 1,750 | 2,000 | 1,486 | 2,280 | 494 | |
| 865 | do | Strafford County, N. H. | Green | 5 | | | 43.9 | .614 | .726 | 55 | 16.3 | 6.7 | 9.4 | 5,090 | 10,190 | 1,810 | 1.08 | 15.8 | 45.9 | 11,550 | 3.2 | 52 | 2,810 | 3,930 | 643 | 1,125 | 1,040 | 1,270 | 257 | 317 |
| | | | Dry | 2 | | | 14.0 | .651 | | | | | | 10,830 | 15,590 | 2,244 | 1.90 | 15.6 | 23.8 | | | 48 | 4,120 | 7,470 | 1,132 | 1,548 | 1,449 | 2,018 | 550 | 553 |
| 165 | Birch, yellow (*Betula lutea*) | Marathon County, Wis. | Green | 5 | 19.7 | | 71.8 | .545 | .661 | 58 | 17.0 | 7.9 | 9.0 | 4,190 | 8,390 | 1,597 | .52 | 14.2 | 33.7 | 11,060 | 3.8 | 36 | 2,540 | 3,400 | 439 | 827 | 754 | 1,146 | 290 | 486 |
| | | | Dry | 1 | | | 10.3 | .624 | | | | | | 13,300 | 19,490 | 2,306 | 4.18 | 17.9 | 40.5 | 18,290 | 5.2 | 53 | 7,100 | 9,250 | 1,240 | 1,542 | 1,290 | 1,428 | 400 | 1,112 |
| 197 | do | Potter County, Pa. | Green | 5 | 17.9 | | 63.9 | .554 | .674 | 57 | 16.7 | 6.9 | 8.9 | 4,970 | 8,810 | 1,490 | .99 | 19.0 | 52.1 | 12,240 | 5.2 | 44 | 3,240 | 3,520 | 469 | 808 | 738 | 1,084 | 316 | 470 |
| | | | Dry | 1 | | | 9.0 | .637 | | | | | | 11,300 | 18,420 | 2,013 | 3.68 | 22.6 | 38.2 | 24,600 | 11.7 | 68 | 8,620 | 9,350 | 1,480 | 1,642 | 1,350 | 2,376 | 475 | 672 |
| 904 | Birch, yellow (second growth) (*Betula lutea*) | Bennington County, Vt. | Green | 7 | 11.0 | | 66.4 | .546 | .652 | 57 | 16.5 | 7.0 | 9.6 | 3,640 | 7,770 | 1,447 | .54 | 15.3 | 44.3 | 11,220 | 4.2 | 59 | 2,240 | 3,260 | 633 | 810 | 822 | 1,094 | 210 | 352 |
| | | | Dry | 5 | | | 11.2 | .628 | | | | | | 9,210 | 16,490 | 1,825 | 2.66 | 22.7 | 49.4 | 13,500 | 4.7 | 54 | 5,290 | 8,060 | 1,228 | 1,584 | 1,352 | 2,170 | 630 | 1,650 |
| 752 | Blackwood (*Avicennia nitida*) | Dade County, Fla. | Green | 6 | 15.8 | | 42.3 | .830 | .963 | 74 | 15.6 | 6.2 | 9.7 | 5,540 | 11,110 | 1,546 | 1.16 | 12.3 | 39.0 | 15,870 | 6.8 | 42 | 3,760 | 4,940 | 1,869 | 1,568 | 1,703 | 1,373 | 278 | 662 |
| | | | Dry | 2 | | | 12.4 | .830 | | | | | | 8,310 | 15,760 | 2,023 | 1.72 | 17.2 | 20.5 | | | | | 8,300 | 2,390 | | | | | |
| 226 | Buckeye, yellow (*Aesculus octandra*) | Sevier County, Tenn. | Green | 5 | 14.7 | | 141.4 | .326 | .353 | 49 | 12.0 | 3.5 | 7.8 | 2,650 | 4,820 | 981 | .41 | 5.4 | 10.5 | 6,510 | 2.1 | 18 | 1,680 | 2,050 | 210 | 357 | 286 | 662 | 181 | 319 |
| | | | Dry | 1 | | | 4.2 | .381 | | | | | | 7,000 | 9,300 | 1,250 | 2.20 | 6.2 | 6.6 | 12,720 | 6.4 | 14 | 4,000 | 5,870 | 640 | 552 | 396 | 1,142 | 308 | 388 |

TABLE 21.—*Strength and related properties, by localities, of woods grown in the United States*—Continued

| Shipment no. | Species (common and botanical names) | Place of growth of material tested | Moisture condition | Trees tested | Rings per inch | Summer wood | Moisture content | Specific gravity, oven dry, based on volume— At test | Specific gravity, oven dry, based on volume— When oven-dry | Weight per cubic foot | Shrinkage from green to oven-dry condition based on dimensions when green: Volumetric | Shrinkage: Radial | Shrinkage: Tangential | Static bending: Stress at proportional limit | Static bending: Modulus of rupture | Static bending: Modulus of elasticity | Static bending: Work: Proportional limit | Static bending: Work: Maximum load | Static bending: Work: Total | Impact bending: Stress at proportional limit | Impact bending: Work to proportional limit | Impact bending: Height of drop causing complete failure (50-pound hammer) | Compression parallel to grain: Stress at proportional limit | Compression parallel to grain: Maximum crushing strength | Compression perpendicular to grain; stress at proportional limit | Hardness; load required to embed a 0.444-inch ball to ½ its diameter: End | Hardness: Side | Shear parallel to grain; maximum shearing strength | Cleavage; load to cause splitting | Tension perpendicular to grain; maximum tensile strength |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 | 28 | 29 | 30 | 31 |
| | HARDWOODS—continued | | | *Number* | *Number* | *Percent* | *Percent* | | | *Pounds* | *Percent* | *Percent* | *Percent* | *Lb. per sq. in.* | *Lb. per sq. in.* | *1,000 lb. per sq. in.* | *In.-lb. per cu. in.* | *In.-lb. per cu. in.* | *In.-lb. per cu. in.* | *Lb. per sq. in.* | *In.-lb. per cu. in.* | *Inches* | *Lb. per sq. in.* | *Lb. per sq. in.* | *Lb. per sq. in.* | *Pounds* | *Pounds* | *Lb. per sq. in.* | *Lb. per in. of width* | *Lb. per sq. in.* |
| 752 | Bustic (*Dipholis salicifolia*) | Dade County, Fla. | Green | 1 | | | 44.0 | 0.861 | | 77 | | | | 5,790 | 12,360 | 1,860 | 1.00 | 17.1 | | | | | 3,750 | 5,330 | 1,700 | | | | | |
| | | | Dry | 1 | | | 11.8 | .885 | | | | | | | | | | | | 18,430 | 6.6 | 26 | 4,970 | 9,620 | | | | | | |
| 211 | Butternut (*Juglans cinerea*) | Sauk County, Wis. | Green | 5 | 9.1 | | 102.2 | .354 | 0.397 | 45 | 9.4 | 3.6 | 5.7 | 3,140 | 5,870 | 1,008 | .61 | 8.4 | 22.5 | 8,900 | 2.3 | 21 | 2,130 | 2,580 | 258 | 414 | 394 | 762 | 225 | 419 |
| | | | Dry | 2 | | | 8.0 | .382 | | | | | | 8,549 | 11,940 | 1,321 | 2.89 | 7.2 | 8.5 | 13,840 | 6.8 | 21 | 5,680 | 7,180 | 704 | 621 | 514 | 1,417 | 227 | 461 |
| 226 | do | Sevier County, Tenn. | Green | 5 | 9.0 | | 105.9 | .364 | .410 | 47 | 11.1 | 3.0 | 6.5 | 2,610 | 4,880 | 931 | .43 | 7.9 | 19.9 | 7,700 | 2.7 | 26 | 1,910 | 2,250 | 287 | 400 | 379 | 750 | 225 | 443 |
| | | | Dry | 1 | | | 7.3 | .401 | | | | | | 6,400 | 7,470 | 1,202 | 1.75 | 7.2 | 21.3 | 11,960 | 4.7 | 28 | 5,240 | 6,160 | 749 | 677 | 547 | 1,312 | 300 | 472 |
| 752 | Buttonwood (*Conocarpus erecta*) | Dade County, Fla. | Green | 5 | | | 47.2 | .694 | .851 | 64 | 14.6 | 5.4 | 8.5 | 4,560 | 7,440 | 1,192 | 1.00 | 8.2 | 15.6 | 14,060 | 6.8 | 40 | 3,050 | 4,110 | 1,139 | 1,079 | 1,111 | 1,222 | 366 | 471 |
| | | | Dry | 2 | | | 12.7 | .768 | | | | | | 6,180 | 9,870 | 1,525 | 1.68 | 4.0 | | | | | | 7,560 | 1,549 | | | | | |
| 318 | Cascara (*Rhamnus purshiana*) | Lane County, Oreg. | Green | 5 | 16.7 | | 61.1 | .496 | .548 | 50 | 7.6 | 3.2 | 4.6 | 3,360 | 6,320 | 631 | 1.04 | 13.4 | 49.7 | 8,690 | 3.6 | 58 | 1,890 | 3,270 | 670 | 679 | 731 | 1,152 | 260 | 514 |
| | | | Dry | 4 | | | 6.0 | .519 | | | | | | 8,400 | 10,470 | 1,248 | 3.28 | 4.7 | | 11,250 | 5.4 | 13 | 5,180 | 8,190 | 2,000 | 1,792 | 1,281 | 1,950 | | |
| 1054 | Catalpa, hardy (*Catalpa speciosa*) | Henry County, Ind. | Green | 10 | 8.2 | 58 | 72.3 | .370 | .414 | 40 | 7.4 | 2.7 | 4.9 | 2,590 | 4,940 | 801 | .48 | 6.8 | 19.8 | 7,360 | 3.2 | 31 | 1,440 | 2,280 | 284 | 404 | 398 | 649 | 206 | 404 |
| | | | Dry | 10 | | | 11.2 | .404 | | | | | | 4,500 | 9,040 | 1,213 | .99 | 8.2 | 13.0 | 11,470 | 4.6 | 25 | 2,480 | 4,990 | 565 | 550 | 526 | 1,142 | 284 | 585 |
| 1054 | do | Hancock County, Ind. | Green | 5 | 9.3 | 58 | 69.8 | .396 | .436 | 42 | 7.1 | 2.2 | 4.8 | 2,980 | 5,630 | 908 | .50 | 10.0 | 35.8 | 7,730 | 3.0 | 42 | 1,480 | 2,530 | 377 | 443 | 432 | 738 | 258 | 472 |
| | | | Dry | 5 | | | 11.5 | .426 | | | | | | 5,410 | 10,410 | 1,240 | 1.32 | 12.3 | 31.0 | 10,500 | 4.1 | 32 | 3,560 | 5,500 | 572 | 548 | 636 | 1,154 | 326 | 570 |
| 197 | Cherry, black (*Prunus serotina*) | Potter County, Pa. | Green | 5 | 10.6 | | 54.8 | .471 | .534 | 45 | 11.5 | 3.7 | 7.1 | 4,180 | 8,030 | 1,308 | .80 | 12.8 | 31.8 | 10,180 | 4.1 | 33 | 2,940 | 3,540 | 444 | 754 | 664 | 1,127 | 330 | 574 |
| | | | Dry | 1 | | | 9.2 | .514 | | | | | | 11,000 | 13,830 | 1,544 | 4.48 | 11.0 | 11.4 | 14,780 | 5.9 | 28 | 7,020 | 8,370 | 1,024 | 1,000 | 1,030 | 1,928 | 354 | 550 |
| 226 | Cherry, pin (*Prunus pennsylvanica*) | Sevier County, Tenn. | Green | 5 | 5.8 | | 45.7 | .351 | .425 | 33 | 12.8 | 2.8 | 10.3 | 2,880 | 5,040 | 1,042 | .47 | 6.2 | 18.3 | 6,580 | 2.1 | 22 | 1,810 | 2,170 | 265 | 435 | 386 | 678 | 174 | 296 |
| | | | Dry | 2 | | | 6.6 | .406 | | | | | | 7,760 | 10,700 | 1,306 | 2.54 | 9.3 | 28.9 | 12,100 | 5.2 | 36 | 5,520 | 6,490 | 700 | 930 | 579 | 1,241 | 261 | 339 |
| 226 | Chestnut (*Castanea dentata*) | do | Green | 5 | 11.8 | 51 | 133.4 | .338 | .449 | 57 | 12.9 | 3.4 | 6.8 | 2,840 | 5,230 | 910 | .53 | 6.7 | 14.8 | 7,870 | 3.0 | 24 | 1,890 | 2,230 | 366 | 493 | 402 | 749 | 234 | 398 |
| | | | Dry | 2 | | | 8.6 | .430 | | | | | | 6,000 | 9,240 | 1,255 | 2.25 | 6.3 | 13.0 | 11,800 | 8.8 | 18 | 4,360 | 6,440 | 828 | 780 | 546 | 1,192 | 280 | 491 |
| 245 | do | Baltimore County, Md. | Green | 5 | 9.4 | 46 | 109.7 | .404 | .459 | 53 | 10.4 | 3.3 | 6.6 | 3,270 | 6,010 | 949 | .65 | 7.4 | 19.2 | 8,000 | 2.6 | 23 | 2,260 | 2,710 | 400 | 571 | 448 | 845 | 246 | 471 |
| | | | Dry | 5 | | | 8.6 | .447 | | | | | | 7,940 | 10,100 | 1,485 | 2.57 | 8.5 | 10.0 | 11,290 | 4.7 | 18 | 4,500 | 6,800 | 1,032 | 773 | 612 | 1,138 | 238 | 480 |
| 318 | Chinquapin, golden (*Castanopsis chrysophylla*) | Lane County, Oreg. | Green | 5 | 14.8 | | 133.7 | .417 | .483 | 61 | 13.2 | 4.6 | 7.4 | 4,250 | 7,030 | 1,016 | 1.09 | 9.5 | 20.4 | 8,620 | 3.4 | 31 | 2,030 | 3,020 | 491 | 733 | 602 | 1,014 | 234 | 477 |
| | | | Dry | 2 | | | 4.8 | .484 | | | | | | 11,900 | 14,060 | 1,412 | 6.14 | 9.5 | 18.3 | 12,520 | 6.6 | 29 | 6,380 | 7,970 | 850 | 924 | 834 | 1,454 | | |
| 368 | Cottonwood, eastern (*Populus deltoides*) | Pemiscot County, Mo. | Green | 5 | 5.6 | | 113.4 | .372 | .433 | 40 | 14.1 | 3.9 | 9.2 | 2,880 | 5,200 | 1,013 | .49 | 7.3 | 16.9 | 7,150 | 2.3 | 21 | 1,740 | 2,280 | 242 | 383 | 344 | 882 | 222 | 408 |
| | | | Dry | 1 | | | 4.7 | .423 | | | | | | 8,610 | 11,420 | 1,637 | 2.81 | 7.4 | 21.2 | 7,480 | 2.4 | 19 | 5,270 | 7,830 | 734 | 744 | 464 | 1,115 | 313 | 406 |
| 203 | Cottonwood, northern black (*Populus trichocarpa hastata*) | Snohomish County, Wash. | Green | 5 | 5.6 | | 131.6 | .315 | .368 | 40 | 12.4 | 3.6 | 8.6 | 2,860 | 4,830 | 1,073 | .44 | 5.0 | 12.7 | 6,820 | 2.2 | 20 | 1,760 | 2,160 | 204 | 277 | 253 | 602 | 170 | 274 |
| | | | Dry | 1 | | | 4.5 | .358 | | | | | | 6,190 | 9,560 | 1,312 | 1.62 | 7.2 | 18.4 | 10,660 | 4.4 | 22 | 3,920 | 5,440 | 487 | 466 | 366 | 1,156 | 234 | 344 |
| 226 | Dogwood (*Cornus florida*) | Sevier County, Tenn. | Green | 5 | 24.1 | | 61.6 | .638 | .796 | 64 | 19.9 | 7.1 | 11.3 | 4,820 | 8,700 | 1,175 | 1.11 | 21.0 | 49.1 | 7,090 | 3.5 | 58 | | 3,040 | 1,033 | 1,413 | 1,406 | 1,516 | | |
| | | | Dry | 5 | | | 7.5 | .774 | | | | | | 11,770 | 18,340 | 1,807 | 4.63 | 18.9 | 24.6 | 19,320 | 10.1 | 46 | 6,640 | 10,260 | 2,464 | 2,363 | 2,532 | | 686 | |
| 318 | Dogwood, Pacific (*Cornus nuttallii*) | Lane County, Oreg. | Green | 5 | 21.4 | | 51.3 | .578 | .701 | 55 | 17.2 | 6.4 | 9.6 | 4,220 | 8,210 | 1,090 | .92 | 17.0 | 38.7 | 9,820 | 3.6 | 56 | 2,410 | 3,640 | 872 | 1,140 | 979 | 1,298 | 335 | 736 |
| | | | Dry | 4 | | | 5.2 | .682 | | | | | | 10,000 | 12,150 | 1,755 | 3.26 | 8.5 | 32.8 | 10,900 | 3.8 | 28 | 5,930 | 11,310 | 2,408 | 2,510 | 1,644 | 2,030 | 478 | |
| 319 | Elder, blueberry (*Sambucus coerulea*) | Douglas County, Oreg. | Green | 5 | 5.7 | | 123.8 | .464 | .570 | 65 | 15.6 | 4.4 | 9.0 | 3,400 | 6,590 | 904 | .72 | 8.8 | 30.7 | 7,980 | 2.9 | 38 | 2,380 | 3,040 | 519 | 758 | 718 | 1,092 | 318 | 562 |
| | | | Dry | 3 | | | 4.8 | .552 | | | | | | 7,450 | 11,240 | 1,120 | 2.51 | 10.7 | | 12,130 | 4.9 | 30 | 5,100 | 6,990 | 960 | 917 | 905 | | | |
| 5 | Elm, American (*Ulmus americana*) | Marathon County, Wis. | Green | | 19.0 | | 70.2 | .421 | | 45 | | | | 2,850 | 6,940 | 1,052 | .44 | 11.8 | 28.0 | | | 34 | | 2,700 | 292 | 536 | 486 | 825 | | 578 |
| | | | Dry | | | | 10.8 | .460 | | | | | | 6,790 | 12,140 | 1,504 | 1.75 | 13.4 | 21.0 | 14,470 | 7.4 | 35 | 4,040 | 5,640 | 727 | 902 | 479 | 1,447 | 321 | 644 |
| 197 | do | Potter County, Pa. | Green | 5 | 18.5 | 31 | 91.6 | .438 | .537 | 52 | 14.4 | 4.2 | 9.5 | 3,830 | 7,010 | 1,020 | .85 | 11.2 | 27.2 | 8,120 | 2.9 | 34 | 2,260 | 2,920 | 410 | 625 | 546 | 922 | 310 | 558 |
| | | | Dry | 1 | | | 8.4 | .517 | | | | | | 9,770 | 15,290 | 1,450 | 3.60 | 14.2 | 31.6 | 17,000 | 10.4 | 46 | 5,420 | 7,050 | 874 | 1,307 | 914 | 1,802 | 349 | 605 |
| 534 | do | Grafton County, N. H. | Green | 6 | 7.5 | 73 | 89.6 | .480 | .568 | 57 | 14.8 | | | 4,130 | 7,390 | 1,202 | .83 | 12.3 | 32.1 | 8,830 | 3.0 | 42 | 1,630 | 2,930 | 486 | 743 | 708 | 1,098 | 353 | 626 |
| | | | Dry | 6 | | | 10.3 | .524 | | | | | | 7,650 | 11,330 | 1,315 | 2.64 | 12.7 | 30.2 | 13,400 | 6.5 | 35 | 4,020 | 5,680 | 1,206 | 1,202 | 892 | 1,684 | 350 | 750 |
| 5 | Elm, rock (*Ulmus racemosa*) | Marathon County, Wis. | Green | | 30.0 | | 43.8 | .579 | | 62 | | | | 4,290 | 9,430 | 1,212 | .90 | 19.4 | 52.5 | | 5.0 | 48 | | 3,740 | 693 | 954 | 898 | 1,270 | | |
| | | | Dry | | | | 11.2 | .630 | | | | | | 8,000 | 15,250 | 1,755 | 2.10 | 20.4 | 38.9 | 18,370 | 9.0 | 52 | 4,300 | 7,570 | 1,083 | 1,503 | 1,257 | 2,154 | 518 | 1,065 |
| 300 | do | Rusk County, Wis. | Green | 5 | 27.1 | 50 | 52.7 | .569 | .658 | 54 | 14.1 | 4.8 | 8.1 | 4,800 | 9,550 | 1,165 | 1.20 | 20.3 | 47.2 | 10,950 | 4.1 | 59 | 3,000 | 3,820 | 813 | 1,013 | 968 | 1,276 | 406 | 662 |
| | | | Dry | 1 | | | 5.8 | .618 | | | | | | 10,700 | 16,000 | 1,472 | 4.54 | 17.6 | 46.3 | 18,700 | 9.8 | 66 | 5,700 | 9,280 | 2,100 | 1,361 | 1,094 | 2,128 | 382 | 419 |
| 111 | Elm, slippery (*Ulmus fulva*) | Hendricks County, Ind. | Green | 1 | 8.4 | 68 | 57.5 | .541 | .639 | 53 | 15.5 | 5.1 | 9.9 | 5,660 | 9,510 | 1,314 | 1.32 | 11.7 | 38.1 | 11,700 | 4.9 | 40 | 3,450 | 3,990 | 730 | 919 | 722 | 1,186 | 412 | 796 |
| | | | Dry | 1 | | | 11.6 | .561 | | | | | | 7,940 | 12,930 | 1,622 | 2.20 | 14.4 | 33.7 | 16,400 | 8.5 | 40 | 5,240 | 7,060 | 1,145 | 1,631 | 1,214 | 2,000 | 544 | 947 |
| 211 | do | Sauk County, Wis. | Green | 5 | 17.2 | 51 | 90.0 | .474 | .554 | 56 | 13.4 | 4.9 | 8.7 | 3,740 | 7,710 | 1,215 | .72 | 16.1 | 38.6 | 8,640 | 3.1 | 48 | 2,660 | 3,180 | 468 | 715 | 653 | 1,090 | 373 | 614 |
| | | | Dry | 2 | | | 7.7 | .531 | | | | | | 9,600 | 15,110 | 1,556 | 2.50 | 17.9 | 42.5 | 17,960 | 9.6 | 46 | 5,740 | 7,910 | 1,254 | 1,144 | 836 | 1,754 | 394 | 398 |
| 752 | Fig, golden (*Ficus aurea*) | Dade Co., Fla. | Green | 1 | | | 88.0 | .438 | | 51 | | | | 3,150 | 5,840 | 597 | .92 | 6.6 | 15.2 | | | | | 2,630 | 646 | 615 | 582 | | | |
| | | | Dry | 1 | | | 9.5 | .446 | | | | | | 4,090 | 7,430 | 864 | 1.07 | 6.9 | 10.2 | | | | | 4,910 | | | | | | |
| 226 | Gum, black (*Nyssa sylvatica*) | Sevier County, Tenn. | Green | 5 | 26.9 | | 54.9 | .462 | .552 | 45 | 13.9 | 4.4 | 7.7 | 4,040 | 7,040 | 1,031 | .91 | 8.0 | 15.3 | 9,810 | 4.0 | 30 | 2,490 | 3,040 | 599 | 786 | 642 | 1,098 | 334 | 574 |
| | | | Dry | 1 | | | 7.2 | .525 | | | | | | 9,250 | 10,800 | 1,270 | 3.84 | 5.6 | 9.2 | 17,120 | 9.1 | 19 | 3,900 | 7,000 | 1,500 | 1,300 | 844 | 1,434 | 336 | 474 |
| 294 | Gum, blue (*Eucalyptus globulus*) | Alameda County, Calif. | Green | 5 | | | 78.8 | .625 | .796 | 70 | 22.5 | 7.6 | 15.3 | 7,610 | 11,230 | 2,006 | 1.65 | 13.9 | 38.5 | 14,150 | 4.7 | 40 | 4,840 | 5,250 | 1,019 | 1,311 | 1,344 | 1,540 | 362 | 645 |
| | | | Dry | 1 | | | 6.7 | .924 | | | | | | 14,200 | 20,610 | 2,601 | 4.67 | 11.6 | 22.5 | 25,300 | 12.6 | 42 | 10,700 | 12,000 | 2,354 | 1,685 | 1,646 | 2,652 | | |
| 368 | Gum, red (*Liquidambar styraciflua*) | Pemiscot County, Mo. | Green | 5 | 11.4 | | 90.6 | .452 | .530 | 54 | 15.0 | 5.2 | 9.9 | 3,990 | 7,230 | 1,154 | .81 | 9.4 | 21.7 | 10,050 | 2.9 | 33 | 2,350 | 2,990 | 455 | 634 | 522 | 1,072 | 329 | 512 |
| | | | Dry | 2 | | | 8.9 | .525 | | | | | | 9,500 | 14,100 | 1,500 | 3.30 | 11.6 | 14.6 | 19,300 | 10.4 | 32 | 5,570 | 6,820 | 902 | 1,014 | 725 | 1,750 | 400 | 808 |
| | do | New Madrid Co., Mo. | Green | | 20.0 | | 71.0 | .430 | | 46 | | | | 2,460 | 6,450 | 1,138 | | | | | | | 2,110 | 2,690 | | | | | | |
| | | | Dry | | | | 13.7 | .440 | | | | | | 7,180 | 10,490 | 1,441 | | | | | | | | 5,220 | | | | | | |
| 175 | Gum, tupelo (*Nyssa aquatica*) | St. John the Baptist Parish, La. | Green | 1 | 15.9 | | 120.8 | .475 | .545 | 65 | 12.4 | 4.4 | 7.9 | 4,800 | 7,380 | 1,045 | 1.00 | 7.8 | 19.4 | 7,050 | 2.5 | 25 | 2,320 | 3,550 | 451 | 814 | 700 | 1,031 | 328 | 634 |
| | | | Dry | 1 | | | 12.8 | .510 | | | | | | 6,310 | 8,970 | 1,288 | 1.76 | 5.4 | 10.3 | 11,030 | 4.8 | 17 | 4,040 | 5,850 | 985 | 1,344 | 847 | 1,577 | 363 | 502 |
| 368 | do | Pemiscot County, Mo. | Green | 5 | 8.6 | | 92.0 | .451 | .520 | 54 | 12.5 | 4.2 | 7.5 | 4,220 | 7,290 | 1,054 | .98 | 8.4 | 17.1 | 9,330 | 3.5 | 31 | 2,760 | 3,330 | 620 | 802 | 710 | 1,227 | 346 | 596 |
| | | | Dry | 2 | | | 4.8 | .510 | | | | | | 10,500 | 11,810 | 1,307 | 4.63 | 6.6 | 9.2 | 15,400 | 8.4 | 21 | 5,000 | 6,820 | 1,608 | 1,315 | 1,012 | 1,606 | 364 | |
| 752 | Gumbo limbo (*Bursera simaruba*) | Dade County, Fla. | Green | 5 | | | 96.7 | .305 | .320 | 38 | 8.6 | 2.3 | 3.6 | 1,960 | 3,290 | 556 | .45 | 3.5 | 4.1 | 5,030 | 2.3 | 13 | 930 | 1,510 | 288 | 286 | 226 | 588 | 166 | 284 |
| | | | Dry | 4 | | | 8.6 | .300 | | | | | | 3,540 | 3,000 | 778 | .94 | 2.9 | 2.0 | 6,540 | 2.4 | 8 | 2,050 | 3,780 | 714 | 401 | 280 | 800 | 210 | 330 |
| 111 | Hackberry (*Celtis occidentalis*) | Hendricks County, Ind. | Green | 1 | 8.3 | 70 | 50.2 | .504 | .576 | 47 | 14.0 | 4.2 | 8.9 | 3,320 | 7,800 | 1,170 | .56 | 19.6 | 52.2 | 10,420 | 4.5 | 62 | 2,760 | 3,310 | 575 | 829 | 784 | 1,128 | 429 | 724 |
| | | | Dry | 1 | | | 11.4 | .577 | | | | | | 7,250 | 14,070 | 1,430 | 2.10 | 16.0 | 25.9 | 17,450 | 8.8 | 65 | 4,400 | 6,730 | 1,330 | 1,505 | 1,160 | 1,706 | 396 | 700 |
| 211 | do | Sauk County, Wis. | Green | 5 | 13.4 | 53 | 67.8 | .482 | .554 | 50 | 13.8 | 4.9 | 8.9 | 2,840 | 6,210 | 911 | .58 | 13.5 | 35.4 | 7,350 | 2.8 | 45 | 1,930 | 2,520 | 473 | 740 | 677 | 1,058 | 331 | 607 |
| | | | Dry | 2 | | | 8.7 | .540 | | | | | | 6,840 | 12,000 | 1,270 | 2.10 | 11.3 | 22.4 | 15,500 | 8.7 | 37 | 4,250 | 6,400 | 1,330 | 1,154 | 867 | 1,794 | 310 | 543 |

TABLE 21.—*Strength and related properties, by localities, of woods grown in the United States*—Continued

| Shipment no. | Species (common and botanical names) | Place of growth of material tested | Moisture condition | Trees tested | Rings per inch | Summer wood | Moisture content | Specific gravity, oven dry, based on volume— At test | Specific gravity— When oven-dry | Weight per cubic foot | Shrinkage from green to oven-dry condition based on dimensions when green— Volumetric | Shrinkage— Radial | Shrinkage— Tangential | Static bending— Stress at proportional limit | Static bending— Modulus of rupture | Static bending— Modulus of elasticity | Static bending— Work— Proportional limit | Static bending— Work— Maximum load | Static bending— Work— Total | Impact bending— Stress at proportional limit | Impact bending— Work to proportional limit | Impact bending— Height of drop causing complete failure (50-pound hammer) | Compression parallel to grain— Stress at proportional limit | Compression parallel to grain— Maximum crushing strength | Compression perpendicular to grain; stress at proportional limit | Hardness; load required to embed a 0.444-inch ball to ½ its diameter— End | Hardness— Side | Shear parallel to grain; maximum shearing strength | Cleavage; load to cause splitting | Tension perpendicular to grain; maximum tensile strength |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 | 28 | 29 | 30 | 31 |
| | HARDWOODS—continued | | | *Number* | *Number* | *Percent* | *Percent* | | | *Pounds* | *Percent* | *Percent* | *Percent* | *Lb. per sq. in.* | *Lb. per sq. in.* | *1,000 lb. per sq. in.* | *In.-lb. per cu. in.* | *In.-lb. per cu. in.* | *In.-lb. per cu. in.* | *Lb. per sq. in.* | *In.-lb. per cu. in.* | *Inches* | *Lb. per sq. in.* | *Lb. per sq. in.* | *Lb. per sq. in.* | *Pounds* | *Pounds* | *Lb. per sq. in.* | *Lb. per in. of width* | *Lb. per sq. in.* |
| 211 | Haw, pear (*Crataegus tomentosa*) | Sauk County, Wis. | Green | 2 | 10.6 | | 63.4 | 0.623 | | 64 | | | | 3,880 | 7,050 | 964 | 0.89 | 22.7 | 52.0 | | | | | 3,110 | 980 | 1,218 | 1,204 | 1,350 | | |
| | | | Dry | 1 | | | 8.6 | .695 | | | | | | 9,920 | 17,250 | 1,368 | 3.30 | 23.8 | 30.2 | 13,500 | 5.5 | 29 | 4,730 | 8,420 | 1,880 | 2,270 | 1,675 | | | |
| 43 | Hickory, bigleaf shagbark (*Hicoria laciniosa*) | Fulton County, Ohio | Green | 9 | 13.8 | 71 | 58.0 | .647 | | 64 | 20.9 | 7.9 | 14.2 | 4,800 | 9,880 | 1,099 | 1.23 | 36.2 | 99.0 | 14,350 | 7.8 | 130 | 1,820 | 3,260 | 1,000 | | | 1,212 | | |
| | | | Dry | 1 | | | 9.1 | .734 | | | | | | 9,250 | 21,800 | 2,060 | 2.09 | 23.3 | | | | 100 | | 11,600 | 2,920 | | | 2,348 | | |
| 42 | do | Sardis, Miss. | Green | 10 | 23.3 | 60 | 63.2 | .599 | | 61 | 17.6 | 7.4 | 11.2 | 6,370 | 11,110 | 1,562 | 1.47 | 24.3 | 78.0 | 13,970 | 6.3 | 80 | 3,570 | 4,520 | 994 | | | 1,102 | | |
| | | | Dry | 1 | | | 8.4 | .690 | | | | | | 10,350 | 19,300 | 2,010 | 3.04 | 21.8 | 56.8 | 23,060 | 14.5 | 78 | | 8,450 | 2,386 | | | 2,512 | | |
| 43 | Hickory, bitternut (*Hicoria cordiformis*) | Fulton County, Ohio | Green | 11 | 11.4 | 70 | 66.0 | .604 | | 63 | | | | 5,470 | 10,280 | 1,399 | 1.22 | 20.0 | 75.5 | 15,860 | 8.5 | 66 | 4,330 | 4,570 | 986 | | | 1,237 | | |
| | | | Dry | 1 | | | 9.2 | .676 | | | | | | 10,240 | 18,850 | 1,890 | 3.10 | 17.9 | 67.5 | 20,540 | 14.0 | 66 | | 10,600 | 2,390 | | | | | |
| 48 | Hickory, mockernut (*Hicoria alba*) | Chester County, Pa. | Green | 11 | 18.4 | 69 | 57.0 | .663 | | 65 | 18.9 | 8.4 | 11.4 | 6,550 | 11,110 | 1,508 | 1.50 | 31.7 | 64.4 | 16,300 | 6.7 | 120 | 3,990 | 4,320 | 958 | | | 1,282 | | |
| | | | Dry | 1 | | | 8.8 | .771 | | | | | | 14,300 | 21,950 | 2,355 | 4.94 | 24.2 | 74.1 | 24,130 | 12.9 | 96 | | 10,400 | 2,719 | | | | | |
| 42 | do | Sardis, Miss. | Green | 8 | 19.4 | 55 | 63.0 | .613 | | 62 | 16.5 | 6.0 | 10.4 | 5,900 | 10,840 | 1,625 | 1.22 | 18.5 | 58.2 | 14,070 | 6.8 | 44 | 3,600 | 4,600 | 1,065 | | | 1,270 | | |
| | | | Dry | 1 | | | 9.9 | .715 | | | | | | 12,800 | 21,200 | 2,150 | 4.39 | 15.9 | 52.0 | 18,860 | 8.9 | 44 | | 10,900 | 2,302 | | | 1,890 | | |
| 46 | do | Webster County, W. Va. | Green | 1 | 31.0 | 62 | 48.7 | .656 | | 61 | | | | 6,890 | 12,720 | 1,883 | 1.41 | 24.1 | 98.7 | | | | 5,230 | 5,240 | | | | | | |
| | | | Dry | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 42 | Hickory, nutmeg (*Hicoria myristicaeformis*) | Sardis, Miss. | Green | 5 | 21.0 | 59 | 74.0 | .558 | | 60 | | | | 4,860 | 9,050 | 1,829 | 1.06 | 22.8 | 58.2 | 12,780 | 6.1 | 54 | 3,620 | 3,980 | 938 | | | 1,032 | | |
| | | | Dry | 1 | | | 8.0 | .617 | | | | | | 9,150 | 19,270 | 1,821 | 2.40 | 25.7 | | | | | | 7,900 | 2,315 | | | | | |
| 46 | Hickory, pignut (*Hicoria glabra*) | Webster County, W. Va. | Green | 19 | 22.0 | 63 | 52.0 | .667 | | 63 | 21.2 | 8.5 | 13.8 | 5,860 | 11,810 | 1,769 | 1.12 | 30.6 | 80.7 | 19,520 | 10.6 | 74 | 3,520 | 4,820 | 1,114 | | | 1,300 | | |
| | | | Dry | 1 | | | | .780 | | | | | | 12,900 | 20,070 | 2,405 | 4.12 | 29.9 | | | | 68 | | 10,200 | 2,818 | | | 2,497 | | |
| 42 | do | Sardis, Miss. | Green | 4 | 17.3 | 60 | 59.0 | .626 | | 62 | 15.0 | 5.6 | 9.8 | 6,430 | 11,780 | 1,565 | 1.42 | 24.7 | 65.1 | 10,610 | 8.7 | 96 | 3,450 | 4,870 | 1,101 | | | 1,208 | | |
| | | | Dry | 1 | | | 9.4 | .732 | | | | | | 12,900 | 23,400 | 2,320 | 3.74 | 23.9 | 58.6 | 25,600 | 13.6 | 58 | | 10,700 | 2,875 | | | | | |
| 43 | do | Fulton County, Ohio | Green | 10 | 18.9 | 63 | 65.0 | .657 | | 64 | 15.3 | 6.3 | 9.5 | 6,820 | 12,360 | 1,553 | 1.71 | 27.7 | 88.7 | 13,520 | 7.9 | 98 | 4,100 | 4,760 | 1,224 | | | 1,428 | | |
| | | | Dry | 1 | | | | .767 | | | | | | 11,680 | 22,800 | 2,608 | 3.40 | 23.8 | 88.5 | 22,930 | 9.9 | 78 | | 10,110 | 2,994 | | | 2,798 | | |
| 48 | do | Chester County, Pa. | Green | 27 | 18.6 | 67 | 54.0 | .604 | | 64 | 16.9 | 6.8 | 10.9 | 6,140 | 11,450 | 1,605 | 1.34 | 34.9 | 87.9 | 10,270 | 7.8 | 93 | 4,270 | 4,820 | 1,130 | | | 1,358 | | |
| | | | Dry | 1 | | | | .776 | | | | | | 12,900 | 24,000 | 2,370 | 3.89 | 33.7 | 90.9 | 27,460 | 14.6 | 72 | | 11,130 | 2,918 | | | 2,316 | | |
| 42 | Hickory, shagbark (*Hicoria ovata*) | Sardis, Miss. | Green | 4 | 20.4 | 61 | 64.0 | .606 | | 62 | 18.0 | 6.5 | 10.2 | 6,220 | 11,330 | 1,638 | 1.34 | 16.7 | 64.2 | 14,380 | 6.6 | 52 | 4,100 | 5,060 | 1,158 | | | 1,262 | | |
| | | | Dry | 1 | | | 9.0 | .706 | | | | | | 12,220 | 21,700 | 2,245 | 3.68 | 20.7 | 66.1 | 17,890 | 8.1 | 48 | | 10,120 | 2,197 | | | 2,360 | | |
| 43 | do | Fulton County, Ohio | Green | 9 | 17.1 | 70 | 58.0 | .642 | | 63 | 18.4 | 7.9 | 11.4 | 5,430 | 10,990 | 1,346 | 1.27 | 34.1 | 80.4 | 12,460 | 5.5 | 100 | 2,840 | 4,360 | 1,080 | | | 1,421 | | |
| | | | Dry | 1 | | | 9.4 | .748 | | | | | | 10,900 | 22,600 | 2,120 | 2.53 | 29.9 | | | | 74 | | 10,500 | 2,717 | | | | | |
| 46 | do | Webster County, W. Va. | Green | 10 | 20.0 | 64 | 60.0 | .647 | | 65 | 15.5 | 6.5 | 9.7 | 6,120 | 11,000 | 1,752 | 1.22 | 18.3 | 72.3 | 10,060 | 7.2 | 60 | 3,730 | 4,000 | 972 | | | 1,204 | | |
| | | | Dry | 1 | | | 9.6 | .754 | | | | | | 13,360 | 22,900 | 2,195 | 4.02 | 26.3 | | 24,350 | 11.9 | 64 | | 11,200 | 2,379 | | | 2,396 | | |
| 48 | do | Chester County, Pa. | Green | 1 | 24.2 | 63 | 64.1 | .609 | | 62 | | | | 5,900 | 10,170 | 1,392 | 1.61 | 11.9 | 75.3 | | | | 2,780 | 4,370 | | | | | | |
| | | | Dry | 1 | | | 9.1 | .716 | | | | | | 14,000 | 22,000 | 1,885 | 6.65 | 16.8 | | | | | | 9,850 | 2,250 | | | | | |
| 42 | Hickory, water (*Hicoria aquatica*) | Sardis, Miss. | Green | 2 | 15.3 | 67 | 80.0 | .606 | | 58 | | | | 5,980 | 10,740 | 1,563 | 1.29 | 18.8 | 52.9 | 13,730 | 6.1 | 56 | 3,240 | 4,600 | 1,088 | | | 1,440 | | |
| | | | Dry | 1 | | | 8.9 | .624 | | | | | | 11,750 | 20,200 | 2,185 | 3.55 | 19.4 | 39.9 | | | 52 | 6,100 | 10,140 | 2,208 | | | | | |
| 226 | Holly (*Ilex opaca*) | Sevier County, Tenn. | Green | 5 | 26.9 | | 81.7 | .503 | 0.606 | 57 | 16.2 | 4.5 | 9.5 | 3,370 | 6,540 | 807 | .72 | 10.8 | 20.7 | 8,900 | 4.4 | 51 | 2,050 | 2,640 | 610 | 853 | 792 | 1,130 | 362 | 606 |
| | | | Dry | 2 | | | 6.4 | .604 | | | | | | 8,020 | 12,700 | 1,226 | 2.95 | 10.6 | 19.1 | 14,780 | 8.5 | 27 | 4,260 | 7,820 | 1,525 | 1,776 | 1,150 | 2,055 | | 742 |
| 111 | Honey locust (*Gleditsia triacanthos*) | Hendricks County, Ind. | Green | 1 | 3.6 | 84 | 52.8 | .605 | .759 | 66 | 8.6 | | | 6,020 | 12,360 | 1,732 | 1.28 | 17.3 | 64.4 | 13,460 | 4.8 | 56 | 4,300 | 4,970 | 1,684 | 1,802 | 1,846 | 1,990 | 581 | 1,289 |
| | | | Dry | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 358 | do | Pemiscot County, Mo. | Green | 5 | 10.3 | 37 | 65.0 | .676 | .648 | 59 | 11.3 | 4.2 | 6.8 | 5,610 | 9,800 | 1,201 | 1.42 | 11.7 | 28.4 | 11,450 | 4.6 | 45 | 3,130 | 4,310 | 1,366 | 1,365 | 1,208 | 1,592 | 471 | 858 |
| | | | Dry | 3 | | | 6.6 | .634 | | | | | | 10,490 | 16,660 | 1,604 | 3.76 | 12.6 | 35.3 | 16,950 | 9.3 | 45 | 6,200 | 9,520 | 2,800 | 2,032 | 1,595 | 2,585 | 336 | 820 |
| 300 | Hophornbeam (*Ostrya virginiana*) | Rusk County, Wis. | Green | 5 | 28.8 | | 52.0 | .632 | .762 | 60 | 18.6 | 8.2 | 9.6 | 4,540 | 8,540 | 1,153 | 1.02 | 13.3 | 39.1 | 10,580 | 3.5 | 73 | 2,570 | 3,570 | 733 | 1,157 | 1,170 | 1,374 | 334 | 450 |
| | | | Dry | 4 | | | 5.8 | .748 | | | | | | 13,920 | 18,600 | 2,107 | 5.34 | 14.4 | 27.9 | 18,560 | 7.6 | 49 | 8,890 | 11,750 | 2,303 | 2,148 | 2,304 | 2,114 | | |
| 752 | Inkwood (*Exothea paniculata*) | Dade County, Fla. | Green | 2 | | | 55.8 | .731 | .917 | 71 | 18.8 | 6.6 | 10.9 | 7,200 | 10,060 | 1,535 | 1.88 | 16.0 | 64.1 | 15,230 | 6.8 | 50 | 3,310 | 4,480 | 1,001 | 1,319 | 1,436 | 1,748 | 450 | |
| | | | Dry | 2 | | | 11.8 | .803 | | | | | | 8,680 | 14,790 | 1,900 | 2.33 | 10.4 | 27.8 | | | 29 | 4,570 | 8,600 | 2,630 | 3,026 | 2,209 | 2,335 | | |
| 752 | Ironwood, black (*Krugiodendron ferreum*) | do | Green | 4 | | | 32.0 | 1.045 | 1.077 | 86 | 11.6 | 6.2 | 8.0 | 10,120 | 10,390 | 2,195 | 2.64 | 12.6 | 37.2 | 18,470 | 7.7 | 35 | 5,660 | 7,570 | 3,462 | | | | | |
| | | | Dry | 1 | | | 15.8 | 1.119 | | | | | | 8,190 | 17,530 | 2,686 | 1.42 | 8.4 | 21.2 | 17,000 | 5.8 | 18 | 3,963 | 9,160 | 2,960 | | | | | |
| 319 | Laurel, California (*Umbellularia californica*) | Douglas County, Oreg. | Green | 5 | 5.5 | | 70.5 | .512 | .589 | 54 | 11.9 | 2.8 | 8.1 | 3,870 | 6,640 | 715 | 1.23 | 18.8 | 45.6 | 8,280 | 4.1 | 57 | 1,980 | 3,020 | 801 | 1,015 | 1,003 | 1,272 | 429 | 776 |
| | | | Dry | 2 | | | 4.9 | .583 | | | | | | 6,700 | 9,000 | 1,114 | 2.46 | 5.2 | 5.8 | 12,500 | 6.2 | 22 | 4,058 | 8,140 | 1,930 | 1,960 | 1,466 | 2,242 | 425 | 846 |
| 226 | Laurel, mountain (*Kalmia latifolia*) | Sevier County, Tenn. | Green | 5 | 24.5 | | 62.0 | .616 | .744 | 62 | 14.4 | 5.6 | 8.8 | 5,800 | 8,440 | 924 | 2.03 | 12.5 | 28.6 | 10,230 | 5.2 | 32 | | 4,310 | 1,110 | 1,401 | 1,299 | 1,669 | | |
| | | | Dry | 1 | | | 5.9 | .724 | | | | | | 10,340 | 13,100 | 1,489 | 4.77 | 9.1 | 13.9 | 17,450 | 9.3 | 18 | 3,620 | 7,120 | 2,422 | 2,670 | 2,175 | | | |
| 226 | Locust, black (*Robinia pseudoacacia*) | do | Green | 3 | 11.1 | 51 | 40.5 | .659 | .708 | 58 | 9.8 | 4.4 | 6.9 | 8,750 | 13,800 | 1,849 | 2.36 | 15.4 | 39.9 | 18,270 | 7.9 | 44 | 6,120 | 6,800 | 1,426 | 1,637 | 1,568 | 1,755 | 400 | 772 |
| | | | Dry | 2 | | | 10.8 | .673 | | | | | | 13,820 | 20,700 | 2,890 | 5.30 | 19.1 | 51.5 | 21,580 | 10.1 | 50 | 8,920 | 10,880 | 2,523 | 1,572 | 1,724 | 2,714 | 328 | 620 |
| 310 | Madroño, Pacific (*Arbutus menziesii*) | Douglas County, Oreg. | Green | 5 | 9.7 | | 82.9 | .583 | .705 | 59 | 17.6 | 5.5 | 11.9 | 4,700 | 7,580 | 844 | 1.49 | 11.9 | 23.4 | 10,560 | 5.1 | 42 | 2,370 | 3,340 | 817 | 1,158 | 970 | 1,456 | 440 | 788 |
| | | | Dry | 2 | | | 4.8 | .711 | | | | | | 9,300 | 13,740 | 1,485 | 3.34 | 7.7 | 8.9 | 9,930 | 3.9 | 15 | 5,210 | 11,090 | 2,710 | 2,865 | 1,967 | 2,167 | 558 | |
| 294 | do | Butte County, Calif. | Green | 1 | 10.9 | | 90.5 | .537 | .641 | 56 | 16.2 | 5.1 | 11.7 | 4,890 | 7,410 | 1,072 | 1.14 | 7.9 | 14.7 | 8,180 | 2.6 | 28 | 2,720 | 3,230 | 594 | 954 | 771 | 1,226 | 370 | 678 |
| | | | Dry | 1 | | | 4.1 | .664 | | | | | | 10,790 | 12,780 | 1,464 | 2.90 | 6.8 | 8.2 | 14,340 | 6.8 | 17 | 7,340 | 9,810 | 2,311 | 2,427 | 1,635 | | 453 | |
| 226 | Magnolia, cucumber (*Magnolia acuminata*) | Sevier County, Tenn. | Green | 5 | 13.6 | | 78.9 | .440 | .516 | 49 | 13.6 | 5.2 | 8.8 | 4,220 | 7,420 | 1,505 | .66 | 10.0 | 21.8 | 9,200 | 2.9 | 30 | 2,810 | 3,140 | 408 | 595 | 515 | 991 | 262 | 438 |
| | | | Dry | 2 | | | 8.3 | .497 | | | | | | 10,680 | 15,440 | 1,940 | 3.73 | 13.4 | 22.7 | 17,840 | 7.6 | 37 | 6,130 | 8,540 | 885 | 1,155 | 700 | 1,533 | 300 | 815 |
| 258 | Magnolia, evergreen (*Magnolia grandiflora*) | Winn Parish, La. | Green | 2 | 14.6 | | 104.8 | .460 | .530 | 59 | 12.3 | 5.4 | 6.6 | 3,610 | 6,780 | 1,106 | .67 | 15.4 | 34.8 | 8,820 | 3.2 | 54 | 2,160 | 2,700 | 570 | 785 | 738 | 1,044 | 344 | 612 |
| | | | Dry | 1 | | | 8.8 | .513 | | | | | | 7,850 | 12,540 | 1,475 | 2.20 | 12.3 | 14.3 | 15,090 | 7.5 | 25 | 3,879 | 6,600 | 1,250 | 1,452 | 1,118 | 1,703 | 464 | 997 |
| 226 | Magnolia, mountain (*Magnolia fraseri*) | Sevier County, Tenn. | Green | 5 | 15.3 | | 88.8 | .400 | .477 | 47 | 13.0 | 4.4 | 7.5 | 3,360 | 6,120 | 1,193 | .55 | 8.3 | 16.5 | 8,600 | 2.9 | 23 | 2,270 | 2,610 | 330 | 574 | 503 | 827 | 259 | 451 |
| | | | Dry | 2 | | | 6.4 | .468 | | | | | | 9,340 | 12,710 | 1,515 | 3.27 | 10.9 | 15.5 | 16,470 | 7.4 | 28 | 5,660 | 7,500 | 938 | 976 | 668 | 1,339 | 360 | 792 |
| 752 | Mangrove (*Rhizophora mangle*) | Dade County, Fla. | Green | 4 | | | 39.3 | .886 | 1.063 | 77 | 15.8 | 5.4 | | 9,700 | 15,190 | 2,300 | 2.30 | 14.6 | 38.7 | 20,520 | 8.2 | 52 | 5,200 | 6,490 | 2,456 | 2,012 | 2,236 | 1,804 | | |
| | | | Dry | 2 | | | 11.8 | .988 | | | | | | 13,970 | 21,580 | 2,947 | 3.27 | 17.8 | 31.8 | | | 32 | 6,190 | 10,840 | 3,318 | | 2,745 | 2,250 | | |
| 263 | Maple, bigleaf (*Acer macrophyllum*) | Snohomish County, Wash. | Green | 5 | 12.3 | | 71.8 | .440 | .513 | 47 | 11.6 | 3.7 | 7.1 | 4,370 | 7,390 | 1,095 | 1.02 | 8.7 | 14.2 | 8,520 | 2.8 | 23 | 2,510 | 3,240 | 554 | 762 | 624 | 1,108 | 324 | 597 |
| | | | Dry | 1 | | | 8.3 | .496 | | | | | | 7,890 | 12,050 | 1,590 | 1.93 | 7.6 | 11.2 | | | 30 | 5,840 | 7,180 | 1,115 | 1,026 | 946 | 2,018 | 432 | 526 |
| 111 | Maple, black (*Acer nigrum*) | Hendricks County, Ind. | Green | 1 | 17.1 | | 65.0 | .520 | .620 | 54 | 14.0 | 4.8 | 9.3 | 4,060 | 7,920 | 1,328 | .70 | 12.8 | 20.8 | 10,160 | 3.8 | 48 | 2,800 | 3,270 | 742 | 936 | 836 | 1,128 | 429 | 717 |
| | | | Dry | 1 | | | 10.3 | .575 | | | | | | 8,950 | 14,800 | 1,657 | 2.71 | 12.5 | 20.8 | 13,760 | 5.8 | 29 | 4,940 | 7,390 | 1,780 | 1,836 | 1,396 | 2,030 | 499 | 667 |
| 5 | Maple, red (*Acer rubrum*) | Marathon County, Wis. | Green | | 20.0 | | 69.9 | .505 | | 54 | | | | 4,450 | 8,310 | 1,445 | .78 | 9.8 | 20.4 | | | 28 | | 3,680 | 605 | 766 | 748 | 1,232 | 267 | |
| | | | Dry | | | | 12.1 | .548 | | | | | | 8,650 | 13,400 | 1,761 | 2.37 | 12.4 | 19.6 | 17,090 | 8.5 | 21 | 5,110 | 8,610 | 1,291 | 1,631 | 1,024 | 1,788 | 476 | 966 |

TABLE 21.—*Strength and related properties, by localities, of woods grown in the United States*—Continued

| Shipment no. | Species (common and botanical names) | Place of growth of material tested | Moisture condition | Trees tested | Rings per inch | Summer wood | Moisture content | Specific gravity, oven dry, based on volume— At test | Specific gravity, oven dry, based on volume— When oven-dry | Weight per cubic foot | Shrinkage from green to oven-dry condition based on dimensions when green: Volumetric | Shrinkage: Radial | Shrinkage: Tangential | Static bending: Stress at proportional limit | Static bending: Modulus of rupture | Static bending: Modulus of elasticity | Static bending: Work to proportional limit | Static bending: Work to maximum load | Static bending: Work total | Impact bending: Stress at proportional limit | Impact bending: Work to proportional limit | Impact bending: Height of drop causing complete failure (50-pound hammer) | Compression parallel to grain: Stress at proportional limit | Compression parallel to grain: Maximum crushing strength | Compression perpendicular to grain; stress at proportional limit | Hardness; load required to embed a 0.444-inch ball to ½ its diameter: End | Hardness: Side | Shear parallel to grain; maximum shearing strength | Cleavage; load to cause splitting | Tension perpendicular to grain; maximum tensile strength |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 | 28 | 29 | 30 | 31 |
| | HARDWOODS—continued | | | *Number* | *Number* | *Per cent* | *Per cent* | | | *Pounds* | *Per cent* | *Per cent* | *Per cent* | *Lb. per sq. in.* | *Lb. per sq. in.* | *1,000 lb. per sq. in.* | *In.-lb. per cu. in.* | *In.-lb. per cu. in.* | *In.-lb. per cu. in.* | *Lb. per sq. in.* | *In.-lb. per cu. in.* | *Inches* | *Lb. per sq. in.* | *Lb. per sq. in.* | *Lb. per sq. in.* | *Pounds* | *Pounds* | *Lb. per sq. in.* | *Lb. per in. of width* | *Lb. per sq. in.* |
| 197 | Maple, red (*Acer rubrum*) | Potter County, Pa. | Green | 5 | 11.5 | | 70.0 | 0.464 | 0.539 | 49 | 12.5 | 3.8 | 8.1 | 3,770 | 7,470 | 1,395 | 0.60 | 11.3 | 23.6 | 9,000 | 3.7 | 31 | 2,370 | 3,090 | 456 | 715 | 603 | 1,084 | 334 | 705 |
| | | | Dry | 1 | | | 8.5 | .520 | | | | | | 9,620 | 14,820 | 1,716 | 3.15 | 13.1 | 28.0 | 17,020 | 7.9 | 31 | 5,710 | 7,910 | 1,268 | 1,530 | 874 | 2,116 | 487 | 445 |
| 805 | do | Strafford County, N. H. | Green | 5 | 8.8 | | 51.4 | .494 | .552 | 47 | 13.7 | 4.2 | 8.3 | 3,430 | 7,410 | 1,330 | .70 | 12.9 | 20.4 | 9,030 | 2.9 | 35 | 2,100 | 3,160 | 461 | 850 | 740 | 1,154 | 250 | 635 |
| | | | Dry | 3 | | | 14.0 | .544 | | | | | | 8,160 | 12,820 | 1,518 | 3.06 | 12.5 | 33.8 | | | 33 | 3,780 | 5,540 | 1,290 | 1,437 | 928 | 1,828 | 486 | 1,047 |
| 211 | Maple, silver (*Acer saccharinum*) | Sauk County, Wis. | Green | 5 | 7.1 | | 65.7 | .439 | .500 | 45 | 12.0 | 3.0 | 7.2 | 3,120 | 5,820 | 943 | .61 | 11.0 | 22.3 | 6,830 | 2.6 | 20 | 1,930 | 2,400 | 450 | 671 | 592 | 1,053 | 302 | 564 |
| | | | Dry | 1 | | | 5.2 | .470 | | | | | | 7,690 | 10,100 | 1,296 | 2.67 | 7.6 | 11.2 | 15,000 | 9.4 | 24 | 5,640 | 5,600 | 1,181 | 1,376 | 746 | 1,714 | 358 | 480 |
| 904 | Maple, striped (*Acer pennsylvanicum*) | Hampshire County, Mass. | Green | 4 | 11.6 | | 35.3 | .438 | | 37 | 12.3 | 3.2 | 8.6 | 3,620 | 7,230 | 1,080 | .68 | 10.0 | 13.4 | 8,740 | 2.3 | 30 | 1,700 | 2,920 | 490 | 500 | | 1,140 | | |
| | | Bennington County, Vt. | Dry | 3 | | | 13.2 | .462 | | | | | | 5,110 | 10,760 | 1,352 | 1.06 | 11.3 | 16.7 | 11,310 | 5.0 | 27 | | 5,200 | 754 | 970 | 699 | | | |
| 111 | Maple, sugar (*Acer saccharum*) | Hendricks and Morgan Counties, Ind. | Green | 4 | 19.4 | | 55.4 | .553 | .649 | 54 | 14.4 | 4.9 | 9.1 | 4,780 | 9,090 | 1,490 | .92 | 12.7 | 30.3 | 12,000 | 4.8 | 35 | 3,020 | 3,780 | 631 | 1,006 | 928 | 1,373 | 447 | 742 |
| | | | Dry | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 197 | do | Potter County, Pa. | Green | 5 | 22.2 | | 67.1 | .554 | .671 | 58 | 14.7 | 4.8 | 9.2 | 5,710 | 9,490 | 1,524 | 1.25 | 13.6 | 35.6 | 12,370 | 5.3 | 42 | 3,200 | 3,870 | 704 | 1,035 | 920 | 1,380 | 430 | 790 |
| | | | Dry | 2 | | | 9.1 | .643 | | | | | | 11,760 | 16,700 | 1,736 | 4.54 | 14.6 | 22.8 | 23,270 | 11.9 | 40 | 7,620 | 9,700 | 1,893 | 2,110 | 1,584 | 2,764 | 649 | 818 |
| 904 | Maple, sugar (second growth) (*Acer saccharum*) | Bennington County, Vt. | Green | 7 | 9.5 | | 40.7 | .581 | .695 | 54 | 15.3 | 4.9 | 10.0 | 5,240 | 9,960 | 1,672 | 1.02 | 15.9 | 45.7 | 13,550 | 4.7 | 51 | 3,430 | 4,270 | 917 | 1,200 | 1,065 | 1,012 | 430 | 785 |
| | | | Dry | 4 | | | 13.7 | .644 | | | | | | 8,650 | 16,040 | 1,856 | 2.17 | 19.9 | 37.5 | | | 49 | 4,420 | 7,340 | 2,018 | 1,774 | 1,332 | 2,354 | 705 | 1,002 |
| 5 | Maple, sugar (*Acer saccharum*) | Marathon County, Wis. | Green | | 22.0 | | 62.5 | .560 | | 57 | | | | 4,020 | 8,820 | 1,437 | .85 | 9.6 | 17.1 | | | 28 | | 4,020 | 870 | 965 | | 1,434 | | |
| | | | Dry | | | | 12.5 | .621 | | | | | | 9,110 | 14,830 | 1,930 | 2.41 | 13.8 | 21.3 | 17,440 | 8.5 | 29 | 5,360 | 7,370 | 1,755 | 1,909 | 1,342 | 2,112 | 693 | |
| 752 | Mastic (*Sideroxylon foetidissimum*) | Dade County, Fla. | Green | 5 | | | 38.6 | .886 | 1.034 | 77 | 11.7 | 6.1 | 7.5 | 7,070 | 10,390 | 1,576 | 1.79 | 8.1 | 19.8 | 18,000 | 8.7 | 52 | 4,050 | 5,880 | 2,079 | 1,667 | 1,706 | 1,067 | 428 | 1,034 |
| | | | Dry | 2 | | | 10.8 | .936 | | | | | | 6,550 | 10,200 | 1,794 | 1.35 | 6.0 | 6.0 | 13,900 | 4.9 | 22 | 3,850 | 7,040 | 2,842 | 2,150 | 1,706 | 1,451 | 350 | 628 |
| 5 | Oak, black (*Quercus velutina*) | Marathon County, Wis. | Green | | 10.0 | | 84.5 | .538 | | 62 | | | | 3,720 | 7,650 | 1,121 | .71 | 13.2 | 33.4 | 12,250 | 5.0 | 35 | | 3,080 | 802 | 847 | 1,000 | 1,202 | | |
| | | | Dry | | | | 11.4 | .593 | | | | | | 8,220 | 14,630 | 1,641 | 2.31 | 14.3 | 24.3 | 15,470 | 7.3 | 30 | 4,650 | 7,120 | 1,746 | 1,508 | 1,208 | 2,118 | 488 | 894 |
| 101 | do | Stone County, Ark. | Green | 5 | 12.5 | 71 | 76.7 | .560 | .669 | 63 | 14.2 | 4.5 | 9.7 | 5,060 | 8,570 | 1,219 | 1.20 | 11.7 | 23.1 | 10,840 | 4.4 | 43 | 2,000 | 3,700 | 912 | 1,003 | 1,057 | 1,179 | 424 | 828 |
| | | | Dry | 1 | | | 11.8 | .625 | | | | | | 7,850 | 13,790 | 1,662 | 2.11 | 13.4 | 23.6 | 13,790 | 5.8 | 47 | 4,640 | 6,390 | 1,112 | 1,275 | 1,208 | 1,890 | 393 | 773 |
| 211 | Oak, bur (*Quercus macrocarpa*) | Sauk County, Wis. | Green | 5 | 12.1 | 59 | 69.6 | .583 | .671 | 62 | 12.7 | 4.4 | 8.8 | 3,640 | 7,180 | 877 | .89 | 10.7 | 20.1 | 10,020 | 4.7 | 44 | 2,380 | 3,290 | 836 | 1,168 | 1,108 | 1,354 | 423 | 804 |
| | | | Dry | 2 | | | 10.2 | .653 | | | | | | 7,000 | 10,900 | 1,060 | 2.39 | 9.6 | 16.2 | 15,340 | 8.8 | 27 | 3,810 | 6,640 | 1,072 | 1,460 | 1,419 | 1,918 | 312 | 453 |
| 294 | Oak, California black (*Quercus kelloggii*) | Butte County, Calif. | Green | 5 | 20.1 | 48 | 106.9 | .491 | .547 | 63 | 13.6 | 4.1 | 6.4 | 3,210 | 5,740 | 786 | .81 | 7.5 | 12.1 | 8,320 | 3.1 | 28 | 1,800 | 2,530 | 696 | 807 | 728 | 987 | 334 | 600 |
| | | | Dry | 1 | | | 5.3 | .585 | | | | | | 10,850 | 12,950 | 1,264 | 5.31 | 7.3 | 13.1 | 6,780 | 4.0 | 12 | 5,020 | 9,320 | 1,692 | 1,287 | 1,331 | 1,641 | 323 | 808 |
| 319 | do | Douglas County, Oreg. | Green | 5 | 11.9 | 55 | 104.7 | .529 | .608 | 68 | 10.6 | 3.1 | 6.8 | 3,640 | 6,630 | 684 | 1.25 | 10.2 | 20.0 | 8,050 | 3.6 | 31 | 1,960 | 3,070 | 1,093 | 1,020 | 950 | 1,208 | 300 | 784 |
| | | | Dry | 2 | | | 5.2 | .608 | | | | | | 5,900 | 6,160 | 1,033 | 2.14 | 4.1 | 4.2 | 9,650 | 4.5 | 12 | 4,040 | 7,520 | 2,030 | 1,460 | 1,234 | 1,762 | 412 | 644 |
| 294 | Oak, canyon live (*Quercus chrysolepis*) | Butte County, Calif. | Green | 3 | 12.9 | | 61.8 | .702 | .838 | 71 | 16.2 | 5.4 | 9.5 | 6,330 | 10,550 | 1,340 | 1.70 | 14.4 | 30.9 | 11,150 | 3.9 | 47 | 3,940 | 4,690 | 1,475 | 1,592 | 1,570 | 1,096 | 525 | 974 |
| | | | Dry | 1 | | | 5.0 | .822 | | | | | | 11,990 | 14,640 | 1,810 | 4.67 | 7.8 | 17.0 | 14,280 | 6.7 | 32 | 7,880 | 13,360 | 2,890 | 3,358 | 3,140 | 2,740 | 728 | |
| 226 | Oak, chestnut (*Quercus montana*) | Sevier County, Tenn. | Green | 5 | 23.4 | 50 | 71.8 | .573 | .674 | 61 | 16.7 | 5.5 | 9.7 | 4,630 | 8,030 | 1,372 | .90 | 9.4 | 22.4 | 12,010 | 4.0 | 35 | 2,590 | 3,520 | 657 | 971 | 894 | 1,212 | 383 | 686 |
| | | | Dry | 1 | | | 9.5 | .676 | | | | | | 10,600 | 15,940 | 1,645 | 3.85 | 11.5 | 18.6 | 21,200 | 9.0 | 42 | 4,830 | 7,540 | 1,178 | 1,336 | 1,290 | 1,600 | 352 | |
| 258 | Oak, laurel (*Quercus laurifolia*) | Winn Parish, La. | Green | 5 | 11.0 | 61 | 84.3 | .564 | .703 | 65 | 10.0 | 4.0 | 9.9 | 4,520 | 7,940 | 1,393 | .88 | 11.2 | 28.3 | 10,350 | 3.4 | 29 | 2,050 | 3,170 | 707 | 1,019 | 996 | 1,182 | 394 | 770 |
| | | | Dry | 1 | | | 9.5 | .645 | | | | | | 8,680 | 14,050 | 1,770 | 2.47 | 12.0 | 28.6 | 15,210 | 5.9 | 39 | 5,220 | 6,230 | 1,490 | 1,275 | 1,200 | 2,026 | 351 | 797 |
| 751 | Oak, live (*Quercus virginiana*) | Marion County, Fla. | Green | 5 | 8.2 | | 49.7 | .810 | .977 | 76 | 14.7 | 6.6 | 9.5 | 8,440 | 11,930 | 1,575 | 2.54 | 12.3 | 26.0 | 17,200 | 8.5 | 57 | 4,170 | 5,430 | 2,517 | 1,074 | 1,882 | 2,210 | 550 | 1,041 |
| | | | Dry | 2 | | | 13.4 | .879 | | | | | | 8,730 | 18,080 | 1,956 | 2.20 | 16.6 | 28.4 | 21,000 | 11.0 | 34 | 5,000 | 8,400 | 3,528 | 3,020 | 2,618 | 2,074 | 518 | 1,012 |
| 319 | Oak, Oregon white (*Quercus garryana*) | Douglas County, Oreg. | Green | 10 | 16.3 | 49 | 71.6 | .644 | .748 | 69 | 13.4 | 4.2 | 9.0 | 4,630 | 7,720 | 792 | 1.51 | 13.7 | 29.8 | 10,260 | 4.8 | 49 | 2,480 | 3,570 | 1,375 | 1,432 | 1,392 | 1,634 | 449 | 943 |
| | | | Dry | 4 | | | 6.8 | .760 | | | | | | 7,780 | 11,740 | 1,207 | 2.73 | 8.5 | 14.8 | 12,720 | 5.7 | 23 | 4,880 | 8,570 | 2,358 | 2,490 | 1,783 | 2,210 | 360 | 810 |
| 904 | Oak, pin (*Pinus palustris*) | Hampshire County, Mass. | Green | 5 | 9.0 | 58 | 75.2 | .577 | .677 | 63 | 14.5 | 4.3 | 9.5 | 4,000 | 8,330 | 1,318 | .71 | 14.0 | 35.2 | 11,920 | 4.2 | 48 | | 3,680 | 883 | 996 | 1,074 | 1,293 | 470 | 804 |
| | | | Dry | 5 | | | 11.4 | .629 | | | | | | 8,360 | 14,490 | 1,754 | 2.37 | 14.9 | 30.2 | 12,250 | 3.6 | 45 | 4,770 | 7,030 | 1,289 | 1,642 | 1,586 | 2,126 | 528 | 1,002 |
| 101 | Oak, post (*Quercus stellata*) | Stone County, Ark. | Green | 5 | 30.4 | 61 | 64.5 | .590 | .732 | 61 | 16.0 | 5.7 | 10.6 | 4,720 | 7,380 | 913 | 1.39 | 9.1 | 18.0 | 11,260 | 4.4 | 38 | 2,750 | 3,330 | 1,148 | 1,139 | 1,074 | 1,299 | 420 | 819 |
| | | | Dry | 1 | | | 11.2 | .677 | | | | | | 7,840 | 12,480 | 1,221 | 2.68 | 10.0 | 19.2 | 16,160 | 7.3 | 44 | 3,240 | 6,660 | 1,970 | 1,364 | 1,286 | 1,688 | 454 | 690 |
| 258 | do | Winn Parish, La. | Green | 5 | 21.2 | 47 | 73.6 | .602 | .745 | 65 | 16.5 | 5.2 | 8.9 | 5,230 | 8,780 | 1,250 | 1.23 | 13.0 | 32.8 | 10,570 | 3.7 | 49 | 2,930 | 3,020 | 964 | 1,172 | 1,182 | 1,256 | 405 | 756 |
| | | | Dry | 1 | | | 11.2 | .683 | | | | | | 7,810 | 14,800 | 1,770 | 1.99 | 16.6 | 63.9 | 19,400 | 10.0 | 48 | 4,280 | 7,120 | 1,820 | 1,385 | 1,489 | 1,902 | 418 | 734 |
| 75 | Oak, red (*Quercus borealis*) | Richland Parish, La. | Green | 5 | 10.4 | 70 | 90.7 | .564 | | 67 | | | | 4,370 | 8,120 | 1,474 | .75 | 9.8 | 27.6 | 10,250 | 3.3 | 40 | 2,680 | 3,450 | 682 | 924 | 892 | 1,053 | 388 | 735 |
| | | | Dry | 1 | | | 11.2 | .706 | | | | | | 9,550 | 15,050 | 2,070 | 2.42 | 14.5 | 40.0 | 23,500 | 12.7 | 49 | 6,190 | 7,910 | 870 | 1,620 | 1,450 | 1,800 | 554 | |
| 101 | do | Stone County, Ark. | Green | 5 | 11.1 | 62 | 83.3 | .566 | .662 | 65 | 14.5 | 4.2 | 8.3 | 3,890 | 8,100 | 1,248 | .70 | 12.7 | 32.6 | 10,800 | 4.2 | 43 | 2,550 | 3,440 | 844 | 1,139 | 1,042 | 1,220 | 406 | 770 |
| | | | Dry | 1 | | | 10.5 | .610 | | | | | | 10,500 | 14,400 | 2,000 | 3.26 | 12.6 | 16.0 | 16,800 | 7.8 | 34 | 4,490 | 8,150 | 1,386 | 1,605 | 1,448 | 1,945 | 417 | 982 |
| 211 | do | Hendricks and Marion Counties, Ind. | Green | 6 | 10.7 | 64 | 79.9 | .567 | .660 | 64 | 13.1 | 3.7 | 8.3 | 3,490 | 7,780 | 1,268 | .60 | 11.4 | 25.6 | 10,580 | 4.2 | 36 | 2,310 | 3,210 | 807 | 1,107 | 1,011 | 1,164 | 425 | 756 |
| | | | Dry | 1 | | | 11.9 | .612 | | | | | | 6,340 | 12,300 | 1,675 | 1.38 | 11.7 | 25.3 | 16,100 | 8.1 | 29 | 3,100 | 5,740 | 1,260 | 1,350 | 1,188 | 1,748 | 342 | 474 |
| 226 | do | Sevier County, Tenn. | Green | 5 | 11.5 | 52 | 84.5 | .529 | .627 | 61 | 15.8 | 3.7 | 8.3 | 3,210 | 6,790 | 1,170 | .54 | 12.1 | 32.9 | 10,020 | 3.8 | 47 | 1,870 | 2,700 | 554 | 892 | 854 | 1,020 | 388 | 693 |
| | | | Dry | 1 | | | 9.8 | .621 | | | | | | 8,500 | 15,100 | 1,760 | 2.41 | 14.9 | 38.8 | 18,100 | 8.0 | 45 | 6,020 | 8,000 | 1,300 | 1,490 | 1,191 | 1,638 | 390 | 690 |
| 534 | do | Grafton County, N. H. | Green | 7 | 11.0 | 63 | 72.9 | .564 | .649 | 61 | 13.2 | 4.4 | 7.8 | 4,920 | 9,160 | 1,514 | .94 | 15.3 | 41.4 | 11,380 | 4.0 | 48 | 2,330 | 3,730 | 806 | 1,021 | 1,006 | 1,338 | 456 | 740 |
| | | | Dry | 7 | | | 10.9 | .635 | | | | | | 9,350 | 14,330 | 1,816 | 2.70 | 15.4 | 40.4 | 18,450 | 9.5 | 48 | 5,210 | 6,730 | 1,547 | 1,605 | 1,230 | 1,957 | 374 | 824 |
| 805 | do | Strafford County, N. H. | Green | 5 | 7.1 | 67 | 72.1 | .591 | .688 | 63 | 11.7 | 3.8 | 8.2 | 4,310 | 9,680 | 1,397 | .76 | 17.6 | 45.9 | 10,030 | 3.2 | 54 | 2,450 | 4,010 | 829 | 1,265 | 1,223 | 1,448 | 470 | 837 |
| | | | Dry | 3 | | | 12.5 | .632 | | | | | | 7,370 | 15,330 | 1,746 | 2.01 | 18.8 | 39.9 | 14,040 | 5.3 | 53 | 4,460 | 6,970 | 1,420 | 1,320 | 1,404 | 2,110 | 455 | |
| 463 | Oak, Rocky Mountain white (*Quercus utahensis*) | Coconino County, Ariz. | Green | 3 | 23.8 | | 61.0 | .617 | .701 | 62 | 12.5 | 4.1 | 7.2 | 3,220 | 5,900 | 480 | 1.23 | 11.3 | 27.2 | 8,080 | 4.3 | 80 | 1,330 | 2,940 | 1,100 | 1,213 | 1,278 | 1,531 | 374 | 749 |
| | | | Dry | 3 | | | 10.3 | .753 | | | | | | 5,830 | 9,140 | 724 | 2.63 | 8.8 | 11.4 | 14,360 | 5.2 | 22 | | 5,640 | 2,419 | 2,260 | 1,483 | | | |
| 904 | Oak, scarlet (*Quercus coccinea*) | Franklin County, Mass. | Green | 5 | 13.5 | 52 | 65.1 | .603 | .709 | 62 | 13.8 | 4.6 | 9.7 | 4,540 | 10,420 | 1,470 | .81 | 15.0 | 41.9 | 11,880 | 4.0 | 54 | 2,840 | 4,090 | 1,030 | 1,171 | 1,200 | 1,411 | 419 | 700 |
| | | | Dry | 4 | | | 11.4 | .676 | | | | | | 10,360 | 18,040 | 1,950 | 3.21 | 21.0 | 44.0 | 16,406 | 6.3 | 52 | 5,740 | 8,040 | 1,401 | 1,734 | 1,417 | 1,964 | 452 | 900 |
| 258 | Oak, southern red (*Quercus rubra*) | Winn Parish, La. | Green | 4 | 20.4 | 46 | 89.7 | .521 | .624 | 62 | 16.3 | 4.5 | 8.7 | 4,220 | 6,920 | 1,141 | .93 | 8.0 | 16.5 | 9,100 | 3.1 | 29 | 2,220 | 3,030 | 675 | 912 | 862 | 934 | 285 | 476 |
| | | | Dry | 1 | | | 10.1 | .599 | | | | | | 8,400 | 11,810 | 1,500 | 1.55 | 9.7 | 15.8 | 16,520 | 8.3 | 26 | 3,040 | 6,800 | 1,125 | 1,048 | 1,100 | 1,532 | 365 | 523 |
| 258 | Oak, swamp red (*Quercus rubra pagodaefolia*) | do | Green | 3 | 6.6 | 63 | 78.4 | .607 | .708 | 68 | 16.4 | 5.2 | 10.8 | 6,490 | 10,850 | 1,790 | 1.32 | 14.7 | 38.0 | 12,300 | 3.8 | 54 | 3,820 | 4,620 | 944 | 1,207 | 1,244 | 1,321 | 456 | 795 |
| | | | Dry | 1 | | | 10.0 | .692 | | | | | | 12,970 | 19,370 | 2,355 | 3.45 | 18.6 | 34.2 | 25,200 | 12.2 | 49 | 6,910 | 9,720 | 1,730 | 1,840 | 1,538 | 2,183 | 394 | 858 |
| 258 | Oak, swamp chestnut (*Quercus prinus*) | do | Green | 4 | 11.7 | 58 | 76.0 | .595 | .756 | 65 | 19.4 | 5.9 | 9.2 | 4,850 | 8,490 | 1,350 | 1.00 | 12.8 | 32.2 | 10,400 | 3.2 | 45 | 3,000 | 3,540 | 707 | 1,101 | 1,106 | 1,202 | 396 | 672 |
| | | | Dry | 1 | | | 14.3 | .679 | | | | | | 7,460 | 14,470 | 1,811 | 1.75 | 11.9 | 20.3 | 19,240 | 8.1 | 41 | 4,500 | 7,580 | 1,470 | 1,318 | 1,257 | 2,187 | 365 | 696 |
| 111 | Oak, swamp white (*Quercus bicolor*) | Hendricks County, Ind. | Green | 1 | 15.5 | 71 | 74.1 | .637 | .792 | 69 | 17.7 | 5.5 | 10.6 | 5,380 | 9,860 | 1,593 | 1.05 | 14.5 | 34.7 | 13,270 | 4.8 | 50 | 3,580 | 4,360 | 943 | 1,205 | 1,158 | 1,296 | 482 | 863 |
| | | | Dry | 1 | | | 13.2 | .711 | | | | | | 9,910 | 17,210 | 2,020 | 2.74 | 18.9 | 47.9 | 21,720 | 10.7 | 49 | 5,550 | 8,030 | 1,406 | 1,600 | 1,530 | 1,998 | 476 | 836 |
| 258 | Oak, water (*Quercus nigra*) | Winn Parish, La. | Green | 5 | 9.5 | 61 | 81.1 | .556 | .685 | 63 | 16.4 | 4.2 | 9.3 | 5,560 | 8,910 | 1,552 | 1.14 | 11.1 | 32.5 | 11,030 | 3.8 | 39 | 3,260 | 3,740 | 766 | 1,046 | 1,006 | 1,240 | 446 | 816 |
| | | | Dry | 1 | | | 10.5 | .641 | | | | | | 9,300 | 15,900 | 2,000 | 2.36 | 22.0 | 33.4 | 19,445 | 8.6 | 44 | 4,040 | 7,200 | 1,315 | 1,452 | 1,215 | 2,014 | 470 | 932 |

**Table 21.**—*Strength and related properties, by localities, of woods grown in the United States*—Continued

| Shipment no. | Species (common and botanical names) | Place of growth of material tested | Moisture condition | Trees tested | Rings per inch | Summer wood | Moisture content | Specific gravity, oven dry, based on volume— At test | Specific gravity— When oven-dry | Weight per cubic foot | Shrinkage from green to oven-dry condition based on dimensions when green: Volumetric | Shrinkage: Radial | Shrinkage: Tangential | Static bending: Stress at proportional limit | Static bending: Modulus of rupture | Static bending: Modulus of elasticity | Static bending: Work— Proportional limit | Static bending: Work— Maximum load | Static bending: Work— Total | Impact bending: Stress at proportional limit | Impact bending: Work to proportional limit | Impact bending: Height of drop causing complete failure (50-pound hammer) | Compression parallel to grain: Stress at proportional limit | Compression parallel to grain: Maximum crushing strength | Compression perpendicular to grain; stress at proportional limit | Hardness; load required to embed a 0.444-inch ball to ½ its diameter: End | Hardness: Side | Shear parallel to grain; maximum shearing strength | Cleavage; load to cause splitting | Tension perpendicular to grain; maximum tensile strength |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 | 28 | 29 | 30 | 31 |
| | HARDWOODS—continued | | | *Number* | *Number* | *Per cent* | *Per cent* | | | *Pounds* | *Per cent* | *Per cent* | *Per cent* | *Lb. per sq. in.* | *Lb. per sq. in.* | *1,000 lb. per sq. in.* | *In.-lb. per cu. in.* | *In.-lb. per cu. in.* | *In.-lb. per cu. in.* | *Lb. per sq. in.* | *In.-lb. per cu. in.* | *Inches* | *Lb. per sq. in.* | *Lb. per sq. in.* | *Lb. per sq. in.* | *Pounds* | *Pounds* | *Lb. per sq. in.* | *Lb. per in. of width* | *Lb. per sq. in.* |
| 75 | Oak, white (*Quercus alba*) | Richland Parish, La. | Green | 5 | 16.0 | 67 | 78.5 | 0.596 | 0.708 | 66 | 10.0 | 4.8 | 9.2 | 4,410 | 7,760 | 1,194 | 0.94 | 8.9 | 20.2 | 11,750 | 5.2 | 35 | 3,000 | 3,490 | 1,004 | 1,183 | 1,155 | 1,252 | 422 | 805 |
| | | | Dry | 1 | | | 11.4 | .722 | | | | | | 9,060 | 15,580 | 1,795 | 2.50 | 15.6 | 30.0 | 17,750 | 8.0 | 44 | 5,160 | 7,580 | 1,065 | 1,590 | 1,529 | 2,048 | 488 | 673 |
| 101 | do | Stone County, Ark. | Green | 5 | 22.1 | 65 | 58.0 | .591 | .704 | 58 | 15.8 | 6.2 | 8.3 | 4,320 | 8,090 | 1,137 | .95 | 12.1 | 31.4 | 9,860 | 3.8 | 40 | 2,980 | 3,520 | 820 | 1,113 | 986 | 1,194 | 420 | 686 |
| | | | Dry | 1 | | | 10.5 | .646 | | | | | | 7,450 | 13,900 | 1,505 | 2.02 | 11.2 | 22.3 | 14,600 | 6.4 | 28 | 4,620 | 7,580 | 1,486 | 1,622 | 1,275 | 2,000 | 494 | 818 |
| 111 | do | Hendricks, Marion, and Morgan Counties, Ind. | Green | 5 | 15.6 | 60 | 62.5 | .603 | .696 | 61 | 14.3 | 4.9 | 9.0 | 4,780 | 8,640 | 1,311 | 1.18 | 13.3 | 31.4 | 10,980 | 4.3 | 45 | 3,130 | 3,630 | 727 | 1,087 | 1,048 | 1,306 | 424 | 814 |
| | | | Dry | 1 | | | 12.8 | .625 | | | | | | 7,700 | 16,100 | 1,948 | 2.07 | 14.3 | 22.3 | 17,680 | 7.3 | 25 | 5,200 | 8,160 | 1,445 | 1,570 | 1,473 | 2,295 | 444 | 864 |
| 258 | do | Winn Parish, La. | Green | 5 | 14.7 | 49 | 71.8 | .591 | .732 | 63 | 10.9 | 5.4 | 9.5 | 5,430 | 8,090 | 1,344 | 1.26 | 11.9 | 29.6 | 10,390 | 3.3 | 40 | 3,250 | 3,700 | 757 | 1,083 | 1,039 | 1,243 | 416 | 762 |
| | | | Dry | 1 | | | 11.3 | .680 | | | | | | 9,000 | 15,410 | 1,790 | 2.56 | 18.2 | 30.2 | 18,760 | 8.9 | 53 | 4,710 | 7,180 | 1,310 | 1,412 | 1,100 | 1,950 | 396 | 856 |
| 258 | Oak, willow (*Quercus phellos*) | do | Green | 2 | 13.7 | 56 | 94.3 | .556 | .688 | 67 | 18.9 | 5.0 | 9.6 | 4,370 | 7,400 | 1,286 | .88 | 8.8 | 21.3 | 9,220 | 2.9 | 35 | 2,340 | 3,000 | 754 | 1,022 | 978 | 1,184 | 404 | 760 |
| | | | Dry | 1 | | | 9.8 | .724 | | | | | | 10,470 | 16,400 | 2,043 | 3.16 | 16.0 | 41.3 | 17,480 | 9.3 | 44 | 4,920 | 8,230 | 1,640 | 1,531 | 1,620 | 1,664 | | |
| 111 | Osage-orange (*Toxylon pomiferum*) | Morgan County, Ind. | Green | 1 | 6.5 | 82 | 31.2 | .761 | .838 | 62 | 8.9 | | | 7,760 | 13,660 | 1,329 | 2.53 | 37.9 | 101.7 | 15,520 | 8.0 | 120 | 3,960 | 5,810 | 2,260 | 1,838 | 2,037 | | | |
| | | | Dry | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 751 | Palmetto, cabbage (*Sabal palmetto*) | Marion County, Fla. | Green | 5 | | | 133.5 | .372 | .453 | 54 | 25.0 | | | 1,910 | 3,750 | 485 | .45 | 4.0 | 15.8 | 5,000 | 2.7 | 15 | 1,410 | 1,750 | 180 | 333 | 281 | 571 | 114 | 224 |
| | | | Dry | 2 | | | 10.6 | .389 | | | | | | 2,240 | 4,830 | 471 | 1.07 | 4.5 | 20.2 | 6,380 | 2.9 | 16 | 1,450 | 2,280 | 173 | 298 | 278 | 377 | 72 | 114 |
| 752 | Paradise-tree (*Simarouba glauca*) | Dade County, Fla. | Green | 4 | | | 81.2 | .332 | .359 | 38 | 8.6 | 2.2 | 5.2 | 1,910 | 3,490 | 696 | .40 | 1.8 | 2.4 | 5,400 | 1.0 | 7 | 1,260 | 1,810 | 265 | 349 | 245 | 711 | 149 | 308 |
| | | | Dry | 2 | | | 8.3 | .349 | | | | | | 4,320 | 5,880 | 877 | .99 | 3.4 | 4.4 | 5,510 | 1.5 | 7 | 2,550 | 3,510 | 484 | 664 | 388 | 583 | | 230 |
| 308 | Pecan (*Hicoria pecan*) | Pemiscot County, Mo. | Green | 5 | 12.1 | 63 | 62.9 | .601 | .694 | 61 | 13.6 | 4.0 | 8.9 | 5,230 | 9,770 | 1,367 | 1.18 | 14.6 | 43.4 | 12,320 | 5.0 | 53 | 3,100 | 3,990 | 950 | 1,274 | 1,308 | 1,482 | 420 | 677 |
| | | | Dry | 2 | | | 6.2 | .687 | | | | | | 11,900 | 16,210 | 1,941 | 4.33 | 13.4 | 22.2 | 20,450 | 10.4 | 41 | 6,620 | 10,890 | 2,340 | 2,370 | 2,142 | 2,436 | 656 | |
| 308 | Persimmon (*Diospyros virginiana*) | do | Green | 5 | 13.8 | | 58.5 | .639 | .776 | 63 | 18.3 | 7.5 | 10.8 | 5,600 | 10,030 | 1,367 | 1.35 | 13.0 | 31.2 | 12,120 | 4.5 | 41 | 3,160 | 4,170 | 1,110 | 1,243 | 1,279 | 1,474 | 410 | 770 |
| | | | Dry | 2 | | | 5.5 | .812 | | | | | | 15,450 | 23,700 | 2,460 | 5.70 | 18.9 | 27.4 | 22,120 | 11.7 | 35 | 9,350 | 14,050 | 3,000 | 2,730 | 2,176 | 2,606 | 719 | 1,535 |
| 752 | Pigeon-plum (*Coccolobis laurifolia*) | Dade County, Fla. | Green | 5 | | | 52.1 | .771 | .851 | 73 | 15.7 | 4.4 | 7.8 | 5,030 | 9,830 | 1,299 | 1.17 | 11.6 | 21.7 | 15,970 | 6.8 | 40 | 4,260 | 4,940 | 1,500 | 1,734 | 1,722 | 1,510 | 399 | 853 |
| | | | Dry | 2 | | | 10.6 | .787 | | | | | | 7,600 | 13,270 | 1,292 | 2.82 | 10.8 | | | | | 4,690 | 7,310 | 3,210 | | 1,907 | | | |
| 752 | Poisonwood (*Metopium toxiferum*) | do | Green | 4 | | | 70.6 | .511 | .553 | 54 | 11.6 | 4.2 | 7.2 | 3,160 | 5,120 | 407 | 1.36 | 5.6 | 7.2 | 8,070 | 3.3 | 15 | 1,220 | 2,100 | 900 | 398 | 298 | 906 | 163 | 353 |
| | | | Dry | 1 | | | 9.8 | .537 | | | | | | 5,470 | 10,840 | 1,322 | 1.25 | 5.4 | 6.5 | | | | | 5,530 | 792 | | | | | |
| 904 | Poplar, balsam (second growth) (*Populus balsamifera*) | Bennington County, Vt. | Green | 5 | 4.6 | | 121.2 | .301 | .331 | 42 | 8.0 | 2.0 | 5.4 | 2,120 | 4,040 | 799 | .32 | 4.2 | 8.1 | 6,180 | 2.3 | 18 | 1,310 | 1,720 | 157 | 261 | 250 | 523 | 140 | 183 |
| | | | Dry | 4 | | | 12.3 | .316 | | | | | | 4,020 | 6,900 | 1,033 | .96 | 5.8 | 7.1 | 7,750 | 2.9 | 14 | 2,070 | 3,750 | 268 | 404 | 318 | 853 | 204 | 233 |
| 930 | Poplar, balsam (*Populus balsamifera*) | Near Girdwood, Alaska | Green | 5 | | | 103.8 | .296 | .363 | 38 | 13.0 | 4.0 | 8.7 | 2,090 | 3,680 | 696 | .37 | 4.2 | 6.4 | 5,740 | 2.2 | 13 | 1,130 | 1,600 | 178 | 214 | 203 | 480 | 120 | 148 |
| | | | Dry | 3 | | | 10.7 | .343 | | | | | | 4,330 | 7,290 | 1,252 | 1.16 | 4.4 | 6.6 | 8,610 | 2.6 | 14 | 3,100 | 4,660 | 284 | 383 | 307 | 800 | 204 | 436 |
| 226 | Poplar, yellow (*Liriodendron tulipifera*) | Sevier County, Tenn. | Green | 5 | 14.0 | | 64.0 | .371 | .410 | 38 | 11.4 | 4.1 | 6.9 | 3,150 | 5,570 | 1,207 | .48 | 5.6 | 9.2 | 8,050 | 2.6 | 17 | 2,030 | 2,550 | 310 | 418 | 338 | 788 | 250 | 464 |
| | | | Dry | 1 | | | 6.1 | .411 | | | | | | 8,380 | 11,850 | 1,610 | 2.53 | 7.5 | 10.6 | 18,620 | 6.9 | 22 | 4,630 | 7,480 | 740 | 590 | 448 | 1,174 | 300 | 573 |
| 634 | do | Breathitt County, Ky. | Green | 6 | | | 63.9 | .381 | .434 | 39 | 13.0 | 4.0 | 7.2 | 3,570 | 5,210 | 991 | .74 | 5.3 | | 9,000 | 3.8 | 19 | | 2,310 | 351 | 359 | 341 | 710 | 202 | 442 |
| | | | Dry | 6 | | | 10.8 | .406 | | | | | | 6,280 | 9,670 | 1,600 | 1.49 | 7.0 | 12.4 | 13,190 | 5.4 | 20 | | 5,790 | 668 | 629 | 510 | 1,232 | 288 | 530 |
| 228 | Rhododendron, great (*Rhododendron maximum*) | Sevier County, Tenn. | Green | 5 | 27.0 | | 98.8 | .501 | .601 | 62 | 16.2 | 6.3 | 8.7 | 4,630 | 6,900 | 872 | 1.38 | 12.1 | 32.4 | | | 26 | | 3,470 | 880 | 1,000 | 864 | 1,240 | | |
| | | | Dry | 4 | | | 4.6 | .627 | | | | | | 8,410 | 14,390 | 1,270 | 3.00 | 12.5 | 10.0 | 9,180 | 3.3 | 10 | 5,510 | 9,360 | 1,910 | | | | 372 | 608 |
| 226 | Sassafras (*Sassafras varitfolium*) | do | Green | 5 | 19.4 | 48 | 67.4 | .424 | .473 | 44 | 10.3 | 4.0 | 6.2 | 3,580 | 5,980 | 911 | .80 | 7.1 | 22.2 | 8,470 | 3.5 | 37 | 2,400 | 2,730 | 459 | 609 | 524 | 952 | 303 | 522 |
| | | | Dry | 2 | | | 6.8 | .442 | | | | | | 7,700 | 10,450 | 1,221 | 2.71 | 9.5 | 25.9 | 11,680 | 6.1 | 31 | 3,720 | 6,050 | 1,440 | 670 | 658 | 1,290 | 302 | 611 |
| 226 | Service berry (*Amelanchier canadensis*) | do | Green | 5 | 19.4 | | 47.9 | .656 | .791 | 61 | 18.7 | 6.7 | 10.8 | 5,630 | 9,620 | 1,635 | 1.08 | 16.2 | 37.9 | 12,230 | 4.1 | 63 | 3,250 | 4,080 | 783 | 1,249 | 1,244 | 1,250 | 402 | 729 |
| | | | Dry | 2 | | | 8.4 | .774 | | | | | | 12,350 | 20,010 | 1,962 | 4.83 | 19.8 | 53.0 | 24,460 | 12.2 | 58 | 7,740 | 11,920 | 2,201 | 2,487 | 2,028 | 1,730 | | |
| 226 | Silverbell (*Halesia carolina*) | do | Green | 5 | 20.5 | | 70.3 | .418 | .475 | 44 | 12.6 | 3.8 | 7.6 | 3,510 | 6,490 | 1,163 | .62 | 8.8 | 16.1 | 9,100 | 3.3 | 27 | 2,140 | 2,830 | 428 | 552 | 470 | 931 | 282 | 464 |
| | | | Dry | 1 | | | 6.1 | .470 | | | | | | 7,310 | 9,800 | 1,465 | 2.22 | 6.2 | 19.0 | 16,650 | 6.0 | 23 | 4,020 | 6,590 | 840 | 1,057 | 648 | 1,310 | 340 | 494 |
| 226 | Sourwood (*Oxydendrum arboreum*) | do | Green | 5 | 23.8 | | 68.7 | .504 | .593 | 53 | 15.2 | 6.3 | 8.9 | 4,440 | 7,680 | 1,316 | .82 | 9.8 | 20.0 | 10,770 | 4.1 | 38 | 2,700 | 3,250 | 678 | 859 | 728 | 1,157 | 400 | 713 |
| | | | Dry | 2 | | | 6.8 | .570 | | | | | | 10,680 | 13,820 | 1,645 | 3.67 | 11.4 | 22.4 | 20,690 | 11.5 | 38 | 5,490 | 8,190 | 1,370 | 1,684 | 1,060 | 1,330 | 374 | 448 |
| 752 | Stopper, red (*Eugenia confusa*) | Dade County, Fla. | Green | 3 | | | 40.9 | .814 | .918 | 72 | 13.3 | 6.2 | 9.1 | | 14,970 | 1,942 | | 21.0 | 48.3 | | | 54 | | 6,140 | 2,450 | | | 1,816 | | 915 |
| | | | Dry | 2 | | | 11.6 | .871 | | | | | | | 18,170 | 2,040 | | 10.4 | 18.8 | | | 34 | | 9,945 | 2,793 | | 2,590 | 1,963 | | |
| 368 | Sugarberry (*Celtis laevigata*) | Pemiscot County, Mo. | Green | 5 | 17.2 | 38 | 61.6 | .473 | .545 | 48 | 12.7 | 5.0 | 7.3 | 3,190 | 6,550 | 813 | .78 | 12.0 | 30.7 | 8,220 | 3.2 | 33 | 1,990 | 2,800 | 685 | 842 | 739 | 1,049 | 377 | 658 |
| | | | Dry | 3 | | | 5.6 | .529 | | | | | | 9,840 | 12,900 | 1,403 | 4.23 | 10.7 | 22.1 | 14,140 | 7.4 | 27 | 5,050 | 8,450 | 2,006 | 1,642 | 1,106 | 1,450 | 374 | |
| 211 | Sumach, staghorn (*Rhus hirta*) | Sauk County, Wis. | Green | 5 | 8.0 | 61 | 44.7 | .449 | | 41 | | | | 3,030 | 5,840 | 809 | .67 | 10.8 | 42.4 | | | | | 2,680 | 477 | 671 | 590 | | | |
| | | | Dry | 3 | | | 8.0 | .481 | | | | | | 10,450 | 12,110 | 1,250 | 4.50 | 7.8 | 15.6 | | | | 5,660 | 7,750 | 1,308 | 945 | 719 | | | |
| 111 | Sycamore (*Platanus occidentalis*) | Hendricks County, Ind. | Green | 5 | 19.2 | | 81.1 | .454 | .526 | 51 | 13.5 | 4.9 | 7.3 | 2,820 | 6,300 | 964 | .51 | 7.1 | 14.2 | 8,180 | 3.2 | 24 | 2,310 | 2,790 | 433 | 604 | 580 | 1,001 | 345 | 600 |
| | | | Dry | 1 | | | 11.5 | .484 | | | | | | 5,880 | 9,350 | 1,305 | 1.41 | 6.4 | 8.8 | 11,050 | 4.6 | 17 | 5,260 | 5,340 | 685 | 857 | 614 | 1,544 | 420 | 760 |
| 226 | do | Sevier County, Tenn. | Green | 5 | 14.5 | | 84.9 | .458 | .552 | 53 | 14.8 | 5.2 | 7.9 | 3,730 | 6,640 | 1,166 | .70 | 7.9 | 17.6 | 9,420 | 3.4 | 20 | 2,460 | 3,060 | 468 | 729 | 638 | 990 | 319 | 603 |
| | | | Dry | 1 | | | 6.0 | .524 | | | | | | 5,400 | 13,180 | 1,650 | 3.00 | 11.9 | 20.6 | 10,500 | 3.4 | 30 | 5,790 | 7,220 | 1,142 | 992 | 800 | | | |
| 380 | Walnut, black (*Juglans nigra*) | Kentucky | Green | 5 | 12.2 | | 81.1 | .513 | .562 | 58 | 11.3 | 5.2 | 7.1 | 5,360 | 9,490 | 1,420 | 1.16 | 14.6 | 35.9 | 11,860 | 4.5 | 37 | 3,620 | 4,300 | 601 | 956 | 899 | 1,216 | 358 | 571 |
| | | | Dry | 1 | | | 4.8 | .574 | | | | | | 14,400 | 17,940 | 1,616 | 6.45 | 9.2 | 12.9 | 19,450 | 11.3 | 33 | 7,760 | 10,460 | 1,965 | 1,110 | 1,063 | 1,476 | 306 | 781 |
| 463 | Walnut, little (*Juglans rupestris*) | Coconino County, Ariz. | Green | 1 | | | 66.8 | .532 | .613 | 55 | 10.7 | 4.4 | 4.6 | 3,420 | 7,960 | 914 | .74 | 12.8 | 46.4 | 9,920 | 4.5 | 46 | | 3,020 | 758 | | | | | |
| | | | Dry | 1 | | | 8.2 | .582 | | | | | | 10,120 | 10,250 | 1,450 | 3.46 | 10.9 | 10.9 | 11,410 | 4.5 | 17 | | 8,720 | | | | | | |
| 211 | Willow, black (*Salix nigra*) | Sauk County, Wis. | Green | 5 | 4.2 | | 143.4 | .330 | .400 | 51 | 13.3 | 2.2 | 8.2 | 1,360 | 3,340 | 489 | .27 | 12.9 | 25.3 | 4,090 | 1.8 | 44 | 860 | 1,320 | 193 | 305 | 334 | 562 | 210 | 424 |
| | | | Dry | 2 | | | 8.2 | .350 | | | | | | 5,020 | 7,720 | 640 | 2.64 | 9.9 | 11.6 | 8,410 | 4.8 | 18 | 2,480 | 4,280 | 633 | 576 | 443 | 1,340 | 221 | 443 |
| 368 | do | Pemiscot County, Mo. | Green | 5 | 6.3 | | 129.1 | .345 | .406 | 40 | 14.3 | 2.8 | 7.4 | 2,170 | 4,240 | 637 | .46 | 8.7 | 14.4 | 6,170 | 2.2 | 27 | 1,000 | 1,710 | 237 | 391 | 384 | 686 | 248 | 431 |
| | | | Dry | 2 | | | 4.6 | .393 | | | | | | 6,200 | 7,550 | 1,006 | 2.26 | 3.7 | 5.7 | 9,940 | 4.7 | 12 | 3,220 | 5,780 | 784 | 794 | 548 | 1,242 | 371 | |
| 319 | Willow, western black (*Salix lasiandra*) | Douglas County, Oreg. | Green | 5 | 5.3 | | 104.7 | .394 | .473 | 50 | 13.8 | 2.9 | 9.0 | 3,120 | 5,630 | 1,027 | .58 | 10.8 | 27.6 | 7,640 | 2.5 | 33 | 1,810 | 2,340 | 333 | 488 | 501 | 866 | 210 | 357 |
| | | | Dry | 2 | | | 4.0 | .473 | | | | | | 8,050 | 11,140 | 1,544 | 2.39 | 8.4 | 21.0 | 13,900 | 7.1 | 30 | 4,490 | 7,120 | 925 | 1,230 | 730 | 1,410 | 350 | 604 |
| 226 | Witch-hazel (*Hamamelis virginiana*) | Sevier County, Tenn. | Green | 5 | 14.1 | | 70.2 | .558 | .714 | 59 | 18.8 | | | 5,000 | 8,280 | 1,112 | 1.29 | 19.5 | 56.8 | 12,440 | 6.3 | 40 | | 3,400 | 619 | 1,013 | 977 | 1,118 | | |
| | | | Dry | 5 | | | 5.1 | .646 | | | | | | 12,050 | 20,319 | 1,664 | 4.85 | 21.8 | | | | | 6,410 | 10,000 | 2,172 | 2,555 | 1,946 | | | |
| | SOFTWOODS | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 939 | Cedar, Alaska (*Chamaecyparis nootkatensis*) | Near Ketchikan, Alaska | Green | 3 | 22.8 | | 34.7 | .442 | .509 | 37 | 11.4 | 4.2 | 7.7 | 4,110 | 6,890 | 1,418 | .77 | 8.8 | 30.0 | 9,890 | 3.3 | 27 | 2,800 | 3,330 | 468 | 574 | 504 | 879 | 214 | 432 |
| | | | Dry | 2 | | | 11.0 | .469 | | | | | | 8,640 | 12,850 | 1,730 | 2.26 | 13.4 | 16.5 | 12,660 | 4.2 | 30 | 6,330 | 7,080 | 865 | 988 | 710 | 1,412 | 236 | 382 |
| 318 | do | Lane County, Oreg. | Green | 5 | 30.6 | | 39.9 | .399 | .439 | 35 | 7.9 | 1.9 | 5.0 | 3,560 | 6,180 | 965 | .77 | 9.5 | 23.9 | 8,640 | 3.2 | 27 | 2,320 | 2,880 | 409 | 617 | 408 | 820 | 142 | 264 |
| | | | Dry | 1 | | | 5.5 | .434 | | | | | | 8,960 | 12,750 | 1,431 | 3.37 | 8.5 | 11.7 | 14,580 | 7.9 | 29 | 7,030 | 6,000 | 964 | 806 | 481 | 1,117 | | 426 |

TABLE 21.—*Strength and related properties, by localities, of woods grown in the United States*—Continued

| Shipment no. | Species (common and botanical names) | Place of growth of material tested | Moisture condition | Trees tested | Rings per inch | Summer wood | Moisture content | Specific gravity, oven dry, based on volume—At test | Specific gravity, oven dry, based on volume—When oven-dry | Weight per cubic foot | Shrinkage from green to oven-dry condition based on dimensions when green: Volumetric | Shrinkage: Radial | Shrinkage: Tangential | Static bending: Stress at proportional limit | Static bending: Modulus of rupture | Static bending: Modulus of elasticity | Static bending, Work: Proportional limit | Static bending, Work: Maximum load | Static bending, Work: Total | Impact bending: Stress at proportional limit | Impact bending: Work to proportional limit | Impact bending: Height of drop causing complete failure (50-pound hammer) | Compression parallel to grain: Stress at proportional limit | Compression parallel to grain: Maximum crushing strength | Compression perpendicular to grain; stress at proportional limit | Hardness; load required to embed a 0.444-inch ball to ½ its diameter: End | Hardness: Side | Shear parallel to grain; maximum shearing strength | Cleavage; load to cause splitting | Tension perpendicular to grain; maximum tensile strength |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 | 28 | 29 | 30 | 31 |
| | SOFTWOODS—continued | | | Number | Number | Percent | Percent | | | Pounds | Percent | Percent | Percent | Lb. per sq. in. | Lb. per sq. in. | 1,000 lb. per sq. in. | In.-lb. per cu. in. | In.-lb. per cu. in. | In.-lb. per cu. in. | Lb. per sq. in. | In.-lb. per cu. in. | Inches | Lb. per sq. in. | Lb. per sq. in. | Lb. per sq. in. | Pounds | Pounds | Lb. per sq. in. | Lb. per in. of width | Lb. per sq. in. |
| 318 | Cedar, incense (*Libocedrus decurrens*) | Lane County, Oreg. | Green | 4 | 17.4 | 30 | 135.8 | 0.332 | 0.365 | 40 | 7.7 | 3.3 | 5.2 | 3,920 | 6,460 | 926 | 0.94 | 6.4 | 8.8 | 7,320 | 2.4 | 17 | 2,940 | 3,270 | 393 | 670 | 389 | 834 | 100 | 284 |
| | | | Dry | 2 | | | 5.1 | .345 | | | | | | 7,370 | 9,410 | 1,290 | 2.31 | 4.9 | 7.9 | 11,120 | 5.2 | 17 | 6,290 | 7,200 | 841 | 1,037 | 521 | 905 | | 288 |
| | do | Weed, Calif. | Green | | 16.0 | | 80.0 | .300 | | | | | | 3,950 | 6,040 | 754 | | | | | | | | 3,030 | 518 | | | | | |
| | | | Dry | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 319 | Cedar, Port Orford (*Chamaecyparis lawsoniana*) | Douglas County, Oreg. | Green | 5 | 23.6 | 25 | 52.0 | .411 | .470 | 39 | 10.7 | 5.2 | 8.1 | 3,920 | 6,800 | 1,407 | .50 | 7.8 | 24.1 | 9,330 | 2.7 | 25 | 2,980 | 3,290 | 385 | 655 | 475 | 881 | 164 | 240 |
| | | | Dry | 1 | | | 9.6 | .454 | | | | | | 8,880 | 14,510 | 2,039 | 2.25 | 12.1 | 23.6 | 17,600 | 7.2 | 33 | 7,350 | 7,750 | 1,025 | 948 | 696 | 1,496 | 338 | 631 |
| 532 | do | Coos County, Oreg. | Green | 9 | 22.4 | 39 | 38.2 | .392 | .423 | 34 | 9.7 | 4.2 | 6.3 | 3,080 | 5,840 | 1,375 | .68 | 7.2 | | 9,080 | 3.2 | 19 | 2,650 | 3,040 | 332 | 414 | 354 | 808 | 78 | 142 |
| | | | Dry | 9 | | | 10.1 | .400 | | | | | | 7,970 | 10,090 | 1,634 | 2.20 | 6.9 | | 12,300 | 4.4 | 23 | | 7,240 | 931 | 707 | 528 | 924 | 215 | 390 |
| 904 | Cedar, eastern red (*Juniperus virginiana*) | Bennington County, Vt. | Green | 5 | 12.0 | | 35.1 | .442 | .492 | 37 | 7.8 | 3.1 | 4.7 | 3,430 | 7,030 | 649 | 1.08 | 15.0 | 34.7 | 6,990 | 2.7 | 35 | 2,540 | 3,570 | 864 | 760 | 646 | 1,008 | 176 | 331 |
| | | | Dry | 3 | | | 15.3 | .464 | | | | | | 3,070 | 8,280 | 812 | 1.03 | 9.7 | | 8,040 | 4.0 | 25 | | 5,210 | 1,046 | 860 | | | 234 | |
| 751 | Cedar, southern red (*Juniperus* sp.) | Marion County, Fla. | Green | 5 | 13.4 | | 25.0 | .421 | .453 | 33 | 7.0 | 2.2 | 4.0 | 5,050 | 8,350 | 929 | 1.57 | 8.8 | 10.7 | 10,640 | 5.4 | 18 | 3,910 | 4,360 | 911 | 809 | 580 | 1,188 | 208 | 393 |
| | | | Dry | 2 | | | 12.9 | .440 | | | | | | 7,290 | 9,450 | 1,169 | 1.88 | 5.4 | 6.6 | 10,270 | 4.3 | 17 | 5,980 | 6,370 | 998 | 1,017 | 646 | 758 | | |
| 224 | Cedar, western red (*Thuja plicata*) | Missoula County, Mont. | Green | 5 | 20.9 | 42 | 32.8 | .294 | .327 | 24 | 7.6 | 2.5 | 4.6 | 2,890 | 4,750 | 586 | .54 | 4.5 | 7.1 | 6,360 | 2.0 | 10 | 2,380 | 2,630 | 278 | 394 | 240 | 698 | 132 | 216 |
| | | | Dry | 1 | | | 7.3 | .319 | | | | | | 5,440 | 8,080 | 1,220 | 1.37 | 4.9 | 7.6 | 9,980 | 3.8 | 10 | 5,020 | 6,090 | 554 | 620 | 327 | 848 | 99 | 196 |
| 263 | Cedar, western (*Thuja plicata*) | Snohomish County, Wash. | Green | 5 | 19.5 | 31 | 45.2 | .326 | .360 | 30 | 8.6 | 2.5 | 5.6 | 3,620 | 5,730 | 1,021 | .74 | 5.6 | 10.3 | 7,820 | 2.9 | 18 | 2,700 | 3,050 | 351 | 462 | 272 | 742 | 131 | 195 |
| | | | Dry | 1 | | | 7.5 | .356 | | | | | | 6,670 | 9,520 | 1,281 | 1.98 | 7.9 | 11.1 | 9,150 | 3.1 | 21 | 5,720 | 6,540 | 850 | 875 | 428 | 985 | 148 | |
| 930 | do | Near Ketchikan, Alaska | Green | 5 | 17.6 | | 34.0 | .311 | .340 | 26 | 7.0 | 2.2 | 4.6 | 3,040 | 4,850 | 850 | .62 | 4.9 | 12.0 | 6,650 | 2.5 | 17 | 2,330 | 2,660 | 376 | 430 | 280 | 691 | 158 | 279 |
| | | | Dry | 2 | | | 8.8 | .330 | | | | | | 6,200 | 8,500 | 1,061 | 2.07 | 5.7 | 13.1 | 8,320 | 3.6 | 19 | 4,890 | 5,580 | 794 | 796 | 414 | 998 | 132 | 303 |
| 185 | Cedar, northern white (*Thuja occidentalis*) | Shawano County, Wis. | Green | 5 | 23.4 | 36 | 55.0 | .293 | .315 | 28 | 7.0 | 2.1 | 4.7 | 2,000 | 4,250 | 643 | .60 | 5.7 | 8.9 | 5,290 | 2.0 | 15 | 1,400 | 1,990 | 288 | 321 | 225 | 610 | 144 | 238 |
| | | | Dry | 2 | | | 11.2 | .311 | | | | | | 5,100 | 6,720 | 811 | 1.84 | 4.7 | 5.9 | 7,200 | 2.8 | 12 | 2,710 | 4,140 | 289 | 466 | 338 | 902 | 150 | 244 |
| 805 | Cedar, southern white (*Chamaecyparis thyoides*) | Rockingham County, N. H. | Green | 5 | 20.0 | | 37.1 | .320 | .360 | 27 | 7.5 | 3.2 | 5.0 | 2,090 | 4,490 | 641 | .45 | 6.3 | 15.6 | 5,220 | 1.8 | 20 | 1,160 | 2,220 | 275 | 413 | 300 | 699 | 114 | 150 |
| | | | Dry | 5 | | | 11.8 | .323 | | | | | | 3,920 | 5,830 | 852 | 1.14 | 3.8 | 4.7 | 7,050 | 2.8 | 14 | 2,600 | 4,370 | 587 | 587 | 372 | 758 | 136 | 230 |
| 891 | do | Pasquotank County, N. C. | Green | 5 | 11.8 | | 33.4 | .299 | .345 | 25 | 9.4 | 2.5 | 5.4 | 2,940 | 4,980 | 863 | .57 | 5.4 | 11.4 | 6,730 | 2.5 | 16 | 2,100 | 2,560 | 326 | 394 | 278 | 690 | 131 | 208 |
| | | | Dry | 5 | | | 13.9 | .320 | | | | | | 5,180 | 7,380 | 1,000 | 1.54 | 4.5 | 6.1 | 7,810 | 2.9 | 14 | 2,630 | 4,640 | 560 | 488 | 326 | 848 | 130 | 233 |
| 175 | Cypress, southern (*Taxodium distichum*) | St. John the Baptist Parish, La. | Green | 4 | 24.8 | 38 | 79.4 | .452 | .513 | 51 | 11.5 | 3.8 | 6.0 | 4,430 | 7,110 | 1,378 | .96 | 6.1 | 14.3 | 8,290 | 2.7 | 23 | 3,440 | 3,960 | 548 | 460 | 354 | 818 | 100 | 246 |
| | | | Dry | 1 | | | 12.1 | .473 | | | | | | 8,400 | 11,240 | 1,725 | 2.73 | 7.8 | 18.0 | 11,070 | 4.6 | 24 | 5,160 | 7,560 | 715 | 755 | 534 | 994 | 100 | 212 |
| 368 | do | Pemiscot County, Mo. | Green | 6 | 9.6 | 26 | 92.4 | .386 | .439 | 40 | 10.1 | | | 3,770 | 6,600 | 1,061 | .70 | 7.3 | 19.7 | 7,800 | 2.8 | 25 | 2,750 | 3,170 | 424 | 474 | 403 | 822 | 188 | 310 |
| | | | Dry | 2 | | | 6.9 | .425 | | | | | | 8,840 | 11,220 | 1,411 | 3.22 | 7.8 | 12.0 | 11,230 | 4.7 | 27 | 6,000 | 7,770 | 1,034 | 830 | 584 | 1,124 | 178 | 338 |
| 553 | do | St. Bernard Parish, La. | Green | | 23.9 | 52 | 89.6 | .443 | .510 | 52 | 10.7 | 3.0 | 6.2 | 4,230 | 6,420 | 1,181 | .93 | 5.4 | 12.9 | 9,340 | 3.8 | 28 | | 3,710 | 509 | 448 | 408 | 782 | 164 | 276 |
| | | | Dry | | | | 12.8 | .484 | | | | | | 7,080 | 10,780 | 1,455 | 1.98 | 8.7 | 9.9 | 16,740 | 3.8 | 25 | | 6,130 | 947 | 848 | 529 | 1,044 | 166 | 304 |
| 734 | do | Ascension Parish, La. | Green | | 22.9 | 26 | 98.3 | .415 | .457 | 51 | 10.0 | 3.7 | 6.4 | 4,470 | 6,750 | 1,182 | .96 | 9.0 | 9.8 | 9,240 | 3.5 | 25 | | 3,510 | 513 | 399 | 370 | 848 | 194 | 380 |
| | | | Dry | | | | 12.8 | .441 | | | | | | 6,050 | 9,610 | 1,299 | 1.64 | 7.9 | 8.6 | 9,310 | 3.3 | 22 | | 5,770 | 941 | 563 | 448 | 848 | 184 | 314 |
| 315 | Douglas fir (coast type) (*Pseudotsuga taxifolia*) | Lewis County, Wash. | Green | 8 | 12.3 | 32 | 36.0 | .474 | .544 | 40 | 12.3 | 5.0 | 8.3 | 5,320 | 8,040 | 1,627 | .98 | 6.8 | 21.3 | 9,470 | 2.8 | 28 | 3,780 | 4,130 | 558 | 510 | 480 | 900 | 162 | 232 |
| | | | Dry | 2 | | | 6.6 | .540 | | | | | | 12,920 | 15,840 | 2,392 | 3.45 | 9.4 | 30.2 | 15,320 | 5.8 | 37 | 10,620 | 12,100 | 1,190 | 946 | 668 | 1,340 | 200 | |
| 318 | do | Lane County, Oreg. | Green | 5 | 19.8 | 36 | 35.2 | .401 | .536 | 39 | 43.2 | 5.7 | 7.6 | 4,800 | 7,860 | 1,679 | .80 | 7.0 | 20.4 | 9,850 | 3.1 | 27 | 3,440 | 4,080 | 541 | 538 | 514 | 882 | 102 | 161 |
| | | | Dry | 2 | | | 6.0 | .526 | | | | | | 11,370 | 15,250 | 2,186 | 3.38 | 9.2 | 30.0 | 16,720 | 6.0 | 42 | 9,290 | 10,940 | 1,334 | 904 | 778 | 1,181 | | 206 |
| 325 | do | Chehalis County, Wash. | Green | 5 | 8.8 | 39 | 39.7 | .414 | .473 | 36 | 12.5 | 4.4 | 7.4 | 4,280 | 7,010 | 1,407 | .74 | 6.1 | 15.7 | 8,890 | 2.7 | 22 | 2,780 | 3,410 | 485 | 484 | 427 | 940 | 150 | 202 |
| | | | Dry | 1 | | | 5.9 | .436 | | | | | | 7,540 | 10,900 | 1,954 | 1.67 | 5.3 | 11.0 | 10,090 | 3.2 | 18 | 7,530 | 8,160 | 1,144 | 888 | 776 | 1,258 | 232 | |
| 351 | do | Humboldt County, Calif. | Green | 5 | 10.1 | 38 | 45.7 | .444 | .503 | 40 | 10.7 | 4.9 | 7.7 | 4,550 | 7,500 | 1,508 | .79 | 6.8 | 19.6 | 10,710 | 4.1 | 25 | 3,520 | 3,830 | 540 | 582 | 524 | 981 | 176 | 294 |
| | | | Dry | 1 | | | 4.8 | .500 | | | | | | 10,720 | 14,740 | 1,991 | 3.31 | 11.0 | 31.0 | 15,100 | 6.1 | 41 | 8,270 | 10,290 | 924 | 950 | 865 | 1,285 | 183 | 357 |
| 523 | do | Clatsop County, Oreg. | Green | | 17.2 | 47 | 29.2 | .429 | .490 | 35 | 10.9 | | | 4,640 | 7,400 | 1,452 | .88 | 7.4 | 15.4 | 9,630 | 3.1 | 22 | 3,200 | 3,770 | 490 | 440 | 449 | 858 | 134 | 172 |
| | | | Dry | | | | 12.2 | .461 | | | | | | 7,680 | 11,530 | 1,741 | 1.92 | 8.4 | | 12,650 | 4.7 | 25 | | 6,990 | 953 | 758 | 642 | 1,064 | 185 | 354 |
| 720 | do | Washington County, Oreg. | Green | 4 | 15.2 | 28 | 29.8 | .460 | .533 | 37 | 12.8 | | | 4,840 | 7,720 | 1,704 | .81 | 7.4 | | 9,980 | 3.0 | 24 | | 4,200 | 481 | 481 | 472 | 1,144 | 187 | 321 |
| | | | Dry | 4 | | | 11.9 | .486 | | | | | | 7,520 | 12,240 | 2,042 | 1.56 | 10.2 | | 11,700 | 2.8 | 28 | | 7,040 | 912 | 787 | 670 | 1,114 | 178 | 334 |
| 606 | do | Clark County, Wash. | Green | 3 | 15.1 | 37 | 30.4 | .429 | .477 | 35 | 11.5 | 4.8 | 7.5 | 4,540 | 6,890 | 1,411 | .85 | 6.0 | 9.8 | 11,060 | 4.5 | 23 | | 3,470 | 471 | 508 | 440 | 849 | 190 | 334 |
| | | | Dry | 3 | | | 11.4 | .452 | | | | | | 7,840 | 11,450 | 1,663 | 2.48 | 10.0 | 11.1 | 14,220 | 6.1 | 24 | | 6,550 | 997 | 701 | 540 | 1,102 | 234 | 486 |
| 973 | Douglas fir (intermediate type) (*Pseudotsuga taxifolia*) | Lincoln County, Mont. | Green | 5 | 19.3 | | 48.8 | .430 | .503 | 40 | 11.2 | 4.0 | 7.7 | 3,890 | 7,110 | 1,437 | .60 | 7.2 | 15.0 | 9,620 | 3.0 | 25 | 2,610 | 3,450 | 518 | 541 | 483 | 888 | 226 | 320 |
| | | | Dry | 4 | | | 9.7 | .473 | | | | | | 8,920 | 13,500 | 1,782 | 2.53 | 10.6 | 15.8 | 13,470 | 5.1 | 32 | 6,830 | 8,250 | 1,068 | 812 | 715 | 1,341 | 200 | 302 |
| 974 | do | Shoshone County, Idaho | Green | 5 | 10.6 | | 35.9 | .390 | .450 | 33 | 10.6 | 4.2 | 7.6 | 3,290 | 6,390 | 1,239 | .50 | 6.5 | 11.5 | 7,810 | 2.5 | 19 | 2,310 | 3,040 | 485 | 513 | 448 | 859 | 224 | 344 |
| | | | Dry | 3 | | | 9.8 | .420 | | | | | | 7,860 | 11,370 | 1,549 | 2.22 | 7.2 | 15.3 | 11,480 | 4.6 | 24 | 6,240 | 7,120 | 1,054 | 740 | 628 | 1,184 | 171 | 304 |
| 334 | do | Plumas County, Calif. | Green | 5 | 19.4 | 34 | 60.5 | .401 | .462 | 40 | 11.7 | 4.5 | 6.9 | 4,340 | 6,980 | 1,376 | .78 | 6.2 | 12.3 | 8,610 | 2.7 | 21 | 2,790 | 3,420 | 447 | 485 | 423 | 781 | 111 | 222 |
| | | | Dry | 1 | | | 6.2 | .460 | | | | | | 9,410 | 13,850 | 1,872 | 2.73 | 11.2 | 22.9 | 12,730 | 5.4 | 29 | 7,810 | 9,370 | 1,165 | 830 | 814 | 1,164 | 248 | 276 |
| 24 | Douglas fir (Rocky Mountain) (*Pseudotsuga taxifolia*) | Johnson County, Wyo. | Green | 5 | 17.3 | 22 | 32.0 | .418 | .456 | 34 | 10.9 | 3.7 | 6.6 | 3,570 | 6,340 | 1,242 | .59 | 7.0 | 14.9 | 8,870 | 2.8 | 20 | 2,410 | 2,920 | 427 | 415 | 408 | 856 | 133 | |
| | | | Dry | 1 | | | 12.0 | .435 | | | | | | 5,950 | 9,320 | 1,392 | 1.48 | 6.3 | 13.5 | 11,870 | 3.9 | 27 | 4,770 | 6,050 | 744 | 723 | 616 | 1,180 | 172 | |
| 370 | do | Missoula County, Mont. | Green | 5 | 26.2 | 32 | 45.0 | .392 | .433 | 35 | 10.3 | 3.5 | 5.7 | 3,730 | 6,410 | 1,125 | .71 | 6.5 | 12.0 | 9,260 | 3.3 | 20 | 2,660 | 3,090 | 472 | 482 | 393 | 897 | 195 | 346 |
| | | | Dry | 1 | | | 8.8 | .428 | | | | | | 7,910 | 11,410 | 1,529 | 2.18 | 6.7 | 11.6 | 14,720 | 7.2 | 28 | 5,740 | 8,130 | 1,148 | 782 | 696 | 983 | 190 | 294 |
| 25 | Fir, alpine (*Abies lasiocarpa*) | Grand County, Colo. | Green | 5 | 15.0 | | 47.0 | .306 | .321 | 28 | 9.0 | 2.5 | 7.1 | 2,300 | 4,450 | 881 | .39 | 4.4 | 5.2 | 5,280 | 1.6 | 9 | 1,690 | 2,060 | 307 | 284 | 219 | 614 | 132 | |
| | | | Dry | 2 | | | 15.9 | .321 | | | | | | 4,820 | 5,960 | 897 | 1.73 | 3.6 | 4.0 | 6,460 | 2.1 | 14 | 2,890 | 3,400 | 504 | 421 | 245 | 1,006 | 148 | |
| 300 | Fir, balsam (*Abies balsamea*) | Sauk County, Wis. | Green | 5 | 12.0 | 26 | 117.0 | .335 | .414 | 45 | 10.8 | 2.8 | 6.6 | 2,980 | 4,900 | 964 | .52 | 4.7 | 6.9 | 6,900 | 2.3 | 10 | 2,080 | 2,400 | 210 | 289 | 291 | 612 | 130 | 176 |
| | | | Dry | 2 | | | 4.6 | .354 | | | | | | 7,310 | 9,000 | 1,435 | 2.11 | 5.4 | 13.4 | 8,460 | 2.9 | 23 | 5,860 | 6,640 | 530 | 744 | 504 | 788 | | 190 |
| 1082 | Fir, corkbark (*Abies arizonica*) | Taos County, N. Mex. | Green | 10 | 13.9 | | 62.5 | .285 | .316 | 29 | 9.0 | 2.6 | 6.9 | 2,520 | 4,220 | 847 | .43 | 4.2 | 5.1 | 5,640 | 2.0 | 12 | 1,030 | 2,010 | 194 | 279 | 210 | 595 | 154 | 296 |
| | | | Dry | 9 | | | 11.2 | .305 | | | | | | 4,540 | 5,960 | 1,043 | 1.12 | 4.5 | 5.3 | 8,290 | 2.7 | 13 | 4,010 | 4,280 | 491 | 502 | 394 | 679 | 172 | 275 |
| 224 | Fir, lowland white (*Abies grandis*) | Missoula County, Mont. | Green | 5 | 29.2 | 36 | 56.8 | .376 | .431 | 37 | 10.9 | 3.5 | 6.8 | 3,560 | 6,090 | 1,311 | .57 | 6.2 | 17.0 | 7,900 | 2.5 | 25 | 2,510 | 3,030 | 316 | 448 | 375 | 735 | 146 | 222 |
| | | | Dry | 1 | | | 7.4 | .422 | | | | | | 7,340 | 12,050 | 1,938 | 1.55 | 10.7 | 30.7 | 14,780 | 5.8 | 30 | 5,170 | 6,720 | 614 | 754 | 600 | 1,022 | 310 | 154 |
| 319 | do | Douglas County, Oreg. | Green | 5 | 7.4 | 24 | 130.2 | .363 | .407 | 52 | 10.2 | 2.9 | 7.5 | 3,620 | 5,930 | 1,280 | .59 | 5.0 | 12.1 | 8,270 | 2.7 | 19 | 2,760 | 3,020 | 355 | 387 | 348 | 756 | 154 | 248 |
| | | | Dry | 2 | | | 6.2 | .396 | | | | | | 6,840 | 9,890 | 1,646 | 1.47 | 5.9 | 20.8 | 13,220 | 4.9 | 32 | 5,910 | 7,280 | 1,070 | 882 | 522 | 963 | 119 | 218 |
| 270 | Fir, noble (*Abies nobilis*) | Multnomah County, Oreg. | Green | 5 | 22.9 | 17 | 41.2 | .350 | .400 | 31 | 13.6 | 4.9 | 9.1 | 3,420 | 5,690 | 1,281 | .53 | 6.2 | 14.8 | 7,890 | 2.0 | 20 | 2,390 | 2,700 | 309 | 305 | 254 | 698 | 126 | 182 |
| | | | Dry | 1 | | | 8.4 | .390 | | | | | | 7,660 | 11,950 | 1,750 | 1.92 | 8.4 | 16.4 | 12,470 | 4.8 | 27 | 6,260 | 7,210 | 848 | 860 | 489 | 1,097 | 155 | 182 |
| 616 | do | do | Green | 4 | 8.3 | 42 | 28.5 | .353 | .396 | 28 | 11.2 | 4.0 | 7.2 | 3,940 | 5,920 | 1,254 | .71 | 5.8 | | 9,430 | 3.3 | 18 | | 2,780 | 374 | 305 | 328 | 806 | 176 | 205 |
| | | | Dry | 4 | | | 10.9 | .379 | | | | | | 6,940 | 10,100 | 1,528 | 1.80 | 9.0 | | 11,140 | 3.6 | 21 | | 5,600 | 678 | 753 | 428 | 1,014 | 154 | 226 |

TABLE 21.—*Strength and related properties, by localities, of woods grown in the United States*—Continued

| Shipment no. | Species (common and botanical names) | Place of growth of material tested | Moisture condition | Trees tested | Rings per inch | Summer wood | Moisture content | Specific gravity, oven dry, based on volume— At test | Specific gravity, oven dry, based on volume— When oven-dry | Weight per cubic foot | Shrinkage from green to oven-dry condition based on dimensions when green: Volumetric | Shrinkage: Radial | Shrinkage: Tangential | Static bending: Stress at proportional limit | Static bending: Modulus of rupture | Static bending: Modulus of elasticity | Static bending: Work: Proportional limit | Static bending: Work: Maximum load | Static bending: Work: Total | Impact bending: Stress at proportional limit | Impact bending: Work to proportional limit | Impact bending: Height of drop causing complete failure (50-pound hammer) | Compression parallel to grain: Stress at proportional limit | Compression parallel to grain: Maximum crushing strength | Compression perpendicular to grain; stress at proportional limit | Hardness; load required to embed a 0.444-inch ball to ½ its diameter: End | Hardness: Side | Shear parallel to grain; maximum shearing strength | Cleavage; load to cause splitting | Tension perpendicular to grain; maximum tensile strength |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 | 28 | 29 | 30 | 31 |
| | SOFTWOODS—continued | | | *Number* | *Number* | *Per cent* | *Per cent* | | | *Pounds* | *Per cent* | *Per cent* | *Per cent* | *Lb. per sq. in.* | *Lb. per sq. in.* | *1,000 lb. per sq. in.* | *In.-lb. per cu. in.* | *In.-lb. per cu. in.* | *In.-lb. per cu. in.* | *Lb. per sq. in.* | *In.-lb. per cu. in.* | *Inches* | *Lb. per sq. in.* | *Lb. per sq. in.* | *Lb. per sq. in.* | *Pounds* | *Pounds* | *Lb. per sq. in.* | *Lb. per in. of width* | *Lb. per sq. in.* |
| 551 | Fir, California red (*Abies magnifica*) | Plumas County, Calif. | Green | 5 | 10.8 | 39 | 108.1 | 0.372 | 0.421 | 48 | 11.8 | 3.8 | 6.9 | 4,140 | 5,080 | 1,065 | 0.95 | 6.7 | 12.0 | 8,650 | 2.8 | 22 | | 2,830 | 441 | 387 | 380 | 923 | 191 | 340 |
| | | | Dry | 4 | | | 10.0 | .391 | | | | | | 6,410 | 9,850 | 1,481 | 1.64 | 8.8 | 13.9 | 12,000 | 4.4 | 22 | 4,830 | 5,870 | 886 | 991 | 514 | 1,060 | 199 | 358 |
| 263 | Fir, silver (*Abies amabilis*) | Snohomish County, Wash. | Green | 6 | 12.5 | 26 | 65.8 | .351 | .415 | 30 | 14.1 | 4.5 | 10.0 | 3,540 | 5,600 | 1,257 | .60 | 6.0 | 12.6 | 7,830 | 2.2 | 21 | 2,380 | 2,070 | 280 | 382 | 310 | 674 | 146 | 238 |
| | | | Dry | 1 | | | 9.3 | .392 | | | | | | 7,010 | 10,370 | 1,665 | 1.73 | 10.3 | 24.6 | 11,830 | 5.3 | 24 | 5,430 | 6,540 | 578 | 716 | 471 | 1,180 | 210 | |
| 142 | Fir, white (*Abies concolor*) | Madera County, Calif. | Green | 5 | 9.9 | 30 | 150.5 | .350 | .388 | 56 | 10.3 | 3.4 | 7.0 | 3,880 | 5,970 | 1,131 | .77 | 5.2 | 15.7 | 7,230 | 2.2 | 18 | 2,010 | 2,800 | 445 | 381 | 328 | 732 | 166 | 258 |
| | | | Dry | 1 | | | 9.6 | .375 | | | | | | 7,630 | 9,860 | 1,499 | 1.84 | 5.5 | 13.6 | 8,400 | 3.2 | 14 | 6,070 | 6,150 | 720 | 775 | 404 | 1,454 | 178 | 248 |
| 465 | do | San Miguel County, N. Mex. | Green | 5 | 10.6 | 20 | 122.8 | .312 | .360 | 43 | 9.0 | 3.1 | 6.0 | 2,940 | 4,920 | 918 | .54 | 5.1 | 7.6 | 7,000 | 2.9 | 18 | 1,810 | 2,210 | 290 | 369 | 278 | 734 | 150 | 252 |
| | | | Dry | 2 | | | 9.6 | .346 | | | | | | 6,240 | 9,440 | 1,211 | 1.83 | 8.8 | 7.4 | 10,410 | 4.3 | 15 | | 5,660 | 778 | 766 | 483 | 1,301 | | 236 |
| 571 | do | Plumas County, Calif. | Green | 10 | 12.0 | 37 | 90.7 | .365 | .420 | 43 | 9.3 | | | 4,290 | 5,050 | 1,043 | 1.02 | 5.1 | | 9,510 | 3.3 | 25 | | 2,920 | 390 | 381 | 366 | 766 | 181 | 326 |
| | | | Dry | 10 | | | 11.4 | .388 | | | | | | 6,710 | 9,430 | 1,425 | 1.79 | 7.4 | | 11,220 | 4.5 | 22 | | 5,830 | 559 | 784 | 460 | 919 | 146 | 274 |
| 105 | Hemlock, eastern (*Tsuga canadensis*) | Marathon County, Wis. | Green | 5 | 24.4 | 31 | 120.0 | .340 | .394 | 40 | 9.2 | 2.3 | 6.0 | 3,410 | 5,770 | 917 | .73 | 6.0 | 12.7 | 6,330 | 2.2 | 17 | 2,140 | 2,750 | 420 | 463 | 344 | 802 | 160 | 297 |
| | | | Dry | 1 | | | 9.5 | .368 | | | | | | 5,380 | 7,510 | 1,048 | 1.05 | 5.0 | 8.9 | 8,220 | 3.6 | 12 | 3,570 | 5,740 | 776 | 789 | 460 | 1,148 | 119 | |
| 220 | do | Sevier County, Tenn. | Green | 5 | 16.6 | 36 | 80.8 | .426 | .501 | 48 | 11.6 | 3.8 | 7.8 | 4,900 | 7,600 | 1,330 | 1.02 | 6.9 | 23.4 | 9,490 | 3.4 | 24 | 3,350 | 3,790 | 574 | 518 | 468 | 951 | 160 | 217 |
| | | | Dry | 1 | | | 7.9 | .465 | | | | | | 8,070 | 11,230 | 1,657 | 2.99 | 6.7 | 15.0 | 10,710 | 8.3 | 36 | 7,370 | 8,350 | 1,400 | 910 | 581 | 1,164 | 109 | |
| 805 | do | Strafford County, N. H. | Green | 5 | 17.8 | 36 | 119.3 | .358 | .398 | 49 | 8.6 | 3.0 | 7.1 | 3,400 | 5,910 | 1,014 | .64 | 5.2 | 14.6 | 7,240 | 2.4 | 20 | 2,540 | 2,830 | 382 | 485 | 432 | 800 | 142 | 206 |
| | | | Dry | 2 | | | 8.8 | .380 | | | | | | 5,440 | 8,280 | 1,115 | 1.46 | 7.4 | 10.7 | 11,300 | 5.1 | 18 | 3,600 | 5,600 | 918 | 892 | 516 | 842 | | |
| 904 | Hemlock, eastern (second growth) (*Tsuga candensis*) | Bennington County, Vt. | Green | 5 | 10.8 | | 114.1 | .392 | .431 | 52 | 9.5 | 3.0 | 7.4 | 3,460 | 6,390 | 1,032 | 0.66 | 8.2 | 16.7 | 8,600 | 3.4 | 23 | 2,350 | 2,970 | 396 | 476 | 361 | 838 | 144 | 204 |
| | | | Dry | 5 | | | 12.1 | .400 | | | | | | 6,010 | 9,600 | 1,150 | 1.79 | 7.8 | 9.9 | 9,270 | 3.6 | 19 | 3,580 | 5,070 | 752 | 912 | 562 | 1,234 | 206 | 344 |
| 224 | Hemlock, mountain (*Tsuga mertensiana*) | Missoula County, Mont. | Green | 5 | 22.6 | 45 | 70.1 | .418 | .480 | 44 | 10.8 | 4.4 | 7.1 | 3,490 | 6,030 | 936 | .78 | 9.4 | 30.8 | 8,770 | 3.6 | 36 | 2,550 | 2,890 | 399 | 579 | 464 | 884 | 200 | 302 |
| | | | Dry | 1 | | | 8.0 | .480 | | | | | | 7,440 | 11,440 | 1,186 | 2.74 | 9.1 | 12.6 | 15,600 | 7.9 | 36 | 6,460 | 7,510 | 1,419 | 1,280 | 690 | 1,243 | 165 | 236 |
| 939 | do | Near Girdwood, Alaska | Green | 5 | 20.3 | | 54.1 | .450 | .531 | 43 | 11.9 | 4.4 | 7.6 | 4,080 | 7,150 | 1,217 | .80 | 9.8 | 25.6 | 9,380 | 3.4 | 28 | 2,530 | 3,410 | 545 | 611 | 544 | 930 | 201 | 203 |
| | | | Dry | 3 | | | 12.1 | .495 | | | | | | 6,500 | 12,580 | 1,522 | 2.70 | 8.4 | 13.6 | 14,820 | 5.9 | 25 | 5,340 | 7,720 | 1,078 | 1,252 | 652 | 1,285 | 156 | 304 |
| 325 | Hemlock, western (*Tsuga heterophylla*) | Chehallis County, Wash. | Green | 5 | 10.3 | 27 | 71.1 | .376 | .431 | 49 | 11.6 | 4.5 | 7.0 | 3,450 | 6,070 | 1,192 | .58 | 6.0 | 13.5 | 7,800 | 2.4 | 20 | 2,320 | 2,890 | 350 | 543 | 432 | 508 | 168 | 258 |
| | | | Dry | 2 | | | 5.4 | .417 | | | | | | 8,010 | 10,600 | 1,524 | 2.48 | 6.1 | 16.1 | 13,630 | 6.6 | 28 | 7,730 | 7,010 | 833 | 1,020 | 621 | 1,173 | | 170 |
| 930 | do | Near Cordova, Alaska | Green | 5 | 21.0 | | 78.6 | .360 | .417 | 40 | 11.4 | 3.9 | 7.9 | 2,970 | 5,650 | 1,117 | .48 | 7.0 | 17.0 | 7,700 | 2.7 | 21 | 2,460 | 2,780 | 388 | 440 | 370 | 760 | 191 | 334 |
| | | | Dry | 2 | | | 11.6 | .394 | | | | | | 6,030 | 9,340 | 1,398 | 1.58 | 7.4 | 13.6 | 12,180 | 5.4 | 23 | 4,890 | 5,810 | 636 | 916 | 527 | 1,178 | 207 | 357 |
| 930 | do | Near Ketchikan, Alaska | Green | 6 | 21.0 | | 65.8 | .407 | .472 | 42 | 12.5 | 4.5 | 7.8 | 3,750 | 6,580 | 1,316 | .62 | 7.3 | 21.0 | 8,510 | 3.0 | 28 | 2,640 | 3,240 | 458 | 559 | 454 | 840 | 207 | 331 |
| | | | Dry | 2 | | | 11.2 | .444 | | | | | | 8,190 | 11,380 | 1,645 | 2.25 | 8.9 | 17.0 | 13,700 | 6.2 | 31 | 6,120 | 7,390 | 806 | 1,073 | 587 | 1,358 | 202 | 341 |
| 503 | do | Oregon | Green | 2 | 11.8 | 40 | 91.5 | .380 | .430 | 46 | 11.8 | | | 3,760 | 6,180 | 1,273 | .62 | 6.0 | | 8,090 | 3.1 | 20 | | 3,010 | 323 | 507 | 395 | 798 | 168 | 303 |
| | | | Dry | 2 | | | 11.6 | .414 | | | | | | 7,440 | 9,970 | 1,535 | 2.04 | 7.4 | | 13,150 | 5.0 | 24 | | 6,270 | 662 | 842 | 597 | 1,004 | 196 | 370 |
| 403 | Juniper, alligator (*Juniperus pachyphloea*) | Coconino County, Ariz. | Green | 3 | | | 39.6 | .477 | .545 | 42 | 7.8 | 2.7 | 3.6 | 3,640 | 6,560 | 450 | 1.07 | 13.4 | 16.4 | 6,810 | 3.0 | 21 | 2,490 | 3,730 | 1,020 | 963 | 823 | 1,281 | | |
| | | | Dry | 1 | | | 9.1 | .518 | | | | | | 5,740 | 6,750 | 480 | 2.94 | 5.9 | | 5,380 | 2.4 | 11 | | 4,220 | 1,644 | 1,330 | 1,200 | | | |
| 276 | Larch, western (*Larix occidentalis*) | Missoula County, Mont. | Green | 8 | 36.2 | 37 | 66.2 | .496 | .587 | 51 | 13.2 | 4.2 | 8.1 | 4,870 | 7,630 | 1,369 | 1.01 | 7.1 | 18.2 | 8,380 | 3.7 | 24 | 3,300 | 3,870 | 559 | 400 | 432 | 917 | 168 | 229 |
| | | | Dry | 1 | | | 8.3 | .545 | | | | | | 10,080 | 13,540 | 1,830 | 3.06 | 8.2 | 18.6 | 17,000 | 8.6 | 34 | 8,170 | 9,640 | 1,250 | 1,385 | 564 | 1,537 | 165 | 236 |
| | do | Stevens County, Wash. | Green | 5 | 20.0 | | 40.0 | .450 | | 42 | | | | 4,270 | 7,250 | 1,310 | | | | | | | 3,030 | 3,700 | | | | | | |
| | | | Dry | | | | 14.8 | .490 | | | | | | 5,890 | 10,230 | 1,545 | | | | | | | 4,170 | 5,910 | | | | | | |
| 300 | Pine, jack (*Pinus banksiana*) | Barron County, Wis. | Green | 6 | 7.1 | 30 | 105.0 | .394 | .461 | 50 | 10.4 | 3.4 | 6.5 | 3,000 | 5,440 | 921 | .55 | 5.9 | 21.0 | 7,850 | 3.3 | 30 | 2,180 | 2,580 | 378 | 378 | 356 | 769 | 176 | 308 |
| | | | Dry | 1 | | | 6.1 | .445 | | | | | | 6,540 | 9,670 | 1,445 | 1.81 | 5.1 | 8.8 | 13,190 | 5.6 | 37 | | 7,770 | 1,150 | 566 | 736 | | 218 | 440 |
| 294 | Pine, jeffrey (*Pinus jeffreyi*) | Plumas County, Calif. | Green | 5 | 18.3 | 23 | 101.1 | .371 | .425 | 47 | 9.9 | 4.4 | 6.7 | 3,170 | 4,900 | 982 | .60 | 4.7 | 14.1 | 7,150 | 2.0 | 21 | 2,050 | 2,370 | 353 | 319 | 342 | 694 | 156 | 258 |
| | | | Dry | 1 | | | 8.7 | .410 | | | | | | 6,620 | 10,890 | 1,313 | 2.42 | 7.1 | 10.9 | 14,250 | 6.2 | 25 | 5,190 | 6,960 | 908 | 742 | 552 | 1,452 | 278 | 410 |
| 465 | Pine, limber (*Pinus flexilis*) | San Miguel County, N. Mex. | Green | 2 | 14.4 | 24 | 67.8 | .374 | .420 | 39 | 8.2 | 2.4 | 5.1 | 3,860 | 5,250 | 795 | 1.08 | 5.2 | 8.3 | 7,140 | 2.6 | 18 | 1,960 | 2,410 | 316 | 299 | 312 | 737 | 170 | 268 |
| | | | Dry | 2 | | | 7.8 | .410 | | | | | | 8,030 | 11,240 | 1,240 | 2.76 | 7.5 | 8.8 | 13,000 | 6.3 | 19 | | 7,000 | 917 | 619 | 488 | 826 | 288 | 300 |
| 314 | Pine, loblolly (*Pinus taeda*) | Nassau County, Fla. | Green | 10 | 8.6 | 42 | 71.8 | .504 | .593 | 54 | 12.6 | 5.5 | 7.5 | 4,680 | 7,620 | 1,431 | .89 | 8.0 | 26.0 | 9,490 | 3.1 | 32 | 2,870 | 3,070 | 548 | 405 | 452 | 904 | 186 | 294 |
| | | | Dry | 4 | | | 8.5 | .570 | | | | | | 11,700 | 15,620 | 2,130 | 3.70 | 9.0 | 16.9 | 14,800 | 5.9 | 29 | 8,275 | 11,300 | 1,535 | 1,079 | 836 | 1,725 | 236 | 270 |
| 1010 | do | Wicomico County, Md. | Green | 10 | 8.5 | 32 | 88.2 | .455 | .536 | 53 | 12.9 | 4.9 | 8.0 | 4,000 | 7,440 | 1,415 | .66 | 8.8 | 25.2 | 8,580 | 2.8 | 29 | 2,760 | 3,560 | 478 | 434 | 457 | 874 | 173 | 161 |
| | | | Dry | 18 | | | 11.3 | .514 | | | | | | 9,010 | 14,360 | 1,848 | 2.52 | 11.7 | 17.6 | 12,790 | 4.3 | 33 | 5,550 | 7,690 | 1,018 | 746 | 729 | 1,340 | 316 | 336 |
| 1016 | do | Beaufort County, N. C. | Green | 10 | 9.5 | 36 | 108.6 | .465 | .545 | 61 | 12.6 | 4.8 | 7.4 | 3,810 | 7,610 | 1,405 | .59 | 8.5 | 28.3 | 10,120 | 3.9 | 31 | 2,450 | 3,670 | 421 | 439 | 474 | 956 | 154 | 166 |
| | | | Dry | 18 | | | 12.1 | .517 | | | | | | 8,280 | 13,590 | 1,827 | 2.16 | 10.9 | 17.8 | 11,120 | 3.5 | 31 | 4,080 | 7,500 | 1,029 | 816 | 749 | 1,382 | 276 | 518 |
| 1060 | do | Greenwood County, S. C. | Green | 6 | 9.6 | 31 | 81.3 | .463 | .533 | 52 | 11.3 | 5.0 | 7.0 | 4,280 | 7,330 | 1,382 | .76 | 8.4 | 24.4 | 9,510 | 3.3 | 34 | 2,300 | 3,410 | 592 | 436 | 447 | 798 | 222 | 386 |
| | | | Dry | 6 | | | 12.4 | .501 | | | | | | 7,100 | 12,840 | 1,835 | 1.56 | 11.0 | 17.8 | 12,310 | 4.0 | 34 | 4,240 | 6,840 | 833 | 688 | 675 | 1,246 | 260 | 400 |
| 1321 | do | Nansemond County, Va. | Green | 10 | 9.8 | 32 | 75.3 | .468 | .539 | 51 | 12.0 | 4.6 | 6.8 | 3,980 | 7,220 | 1,412 | .64 | 8.3 | 22.0 | 8,170 | 2.4 | 29 | 2,450 | 3,410 | 457 | 412 | 440 | 790 | 188 | 325 |
| | | | Dry | 10 | | | 11.4 | .502 | | | | | | 7,440 | 13,390 | 1,850 | 1.70 | 11.2 | 17.8 | 11,210 | 3.5 | 31 | 4,590 | 7,160 | 905 | 741 | 702 | 1,348 | 293 | 348 |
| 1326 | do | Bertie County, N. C. | Green | 10 | 8.7 | 32 | 60.9 | .448 | .517 | 45 | 11.9 | 4.3 | 7.2 | 3,720 | 6,830 | 1,322 | .59 | 7.0 | 10.3 | 7,920 | 2.3 | 23 | 2,310 | 3,200 | 424 | 414 | 415 | 750 | 181 | 304 |
| | | | Dry | 10 | | | 11.8 | .477 | | | | | | 6,610 | 11,620 | 1,651 | 1.50 | 9.4 | 14.3 | 10,250 | 3.1 | 27 | 4,180 | 6,510 | 677 | 756 | 628 | 1,310 | 228 | 421 |
| 23 | Pine, lodgepole (*Pinus contorta*) | Johnson County, Wyo. | Green | 5 | 30.3 | 14 | 53.3 | .371 | .407 | 37 | 10.1 | 3.6 | 5.9 | 2,750 | 5,170 | 972 | .45 | 5.3 | 10.6 | 6,410 | 2.1 | 16 | 1,990 | 2,400 | 332 | 316 | 318 | 714 | 226 | |
| | | | Dry | 2 | | | 12.0 | .390 | | | | | | 6,500 | 8,730 | 1,176 | 2.09 | 5.2 | 5.7 | 10,850 | 4.4 | 20 | 4,100 | 5,230 | 824 | 492 | 403 | 874 | 134 | |
| 27 | do | Grand County, Colo. | Green | 5 | 21.0 | 29 | 41.0 | .370 | .415 | 33 | 11.3 | 4.2 | 7.1 | 3,060 | 5,130 | 1,015 | .54 | 5.1 | 7.3 | 6,870 | 2.3 | 10 | 2,200 | 2,530 | 364 | 288 | 312 | 710 | 141 | |
| | | | Dry | 2 | | | 11.0 | .393 | | | | | | 7,210 | 9,210 | 1,219 | 2.34 | 6.3 | 7.9 | 7,600 | 2.6 | 15 | 4,530 | 5,520 | 779 | 536 | 484 | 972 | 161 | |
| 323 | do | Jefferson County, Mont. | Green | 8 | 26.0 | 20 | 59.6 | .388 | .462 | 39 | 12.0 | 5.0 | 6.9 | 3,170 | 5,800 | 1,142 | .50 | 6.3 | 14.5 | 7,350 | 2.3 | 21 | 2,180 | 2,770 | 285 | 349 | 347 | 666 | 140 | 229 |
| | | | Dry | 5 | | | 4.9 | .446 | | | | | | 10,930 | 13,630 | 1,466 | 4.15 | 6.6 | 18.9 | 10,580 | 4.4 | 19 | 5,840 | 8,870 | 1,506 | 740 | 554 | 1,040 | 237 | 335 |
| 332 | do | Gallatin County, Mont. | Green | 5 | 17.4 | 25 | 100.2 | .372 | .418 | 47 | 11.9 | 4.6 | 6.8 | 2,970 | 5,430 | 1,128 | .45 | 4.9 | 15.1 | 7,560 | 2.5 | 25 | 1,970 | 2,670 | 299 | 300 | 323 | 680 | 130 | 196 |
| | | | Dry | 2 | | | 4.1 | .432 | | | | | | 9,920 | 12,260 | 1,455 | 3.87 | 9.6 | 13.4 | 14,750 | 7.5 | 24 | 5,000 | 8,100 | 1,118 | 424 | 548 | 927 | 206 | |
| 333 | do | Granite County, Mont. | Green | 5 | 23.8 | 22 | 66.6 | .392 | .453 | 41 | 11.8 | 5.0 | 6.5 | 3,170 | 5,720 | 1,081 | .53 | 6.0 | 10.7 | 7,440 | 2.4 | 22 | 2,160 | 2,600 | 290 | 344 | 350 | 670 | 138 | 224 |
| | | | Dry | 3 | | | 4.8 | .447 | | | | | | 9,350 | 12,200 | 1,556 | 3.23 | 7.9 | 14.2 | 10,260 | 4.5 | 20 | 6,740 | 7,720 | 1,148 | 770 | 618 | 1,056 | 266 | |
| 176 | Pine, longleaf (*Pinus palustris*) | Tangipahoa Parish, La. | Green | 5 | 16.5 | 37 | 63.3 | .528 | .599 | 54 | 12.8 | 6.0 | 7.6 | 5,080 | 8,630 | 1,662 | .88 | 8.1 | 36.3 | 9,680 | 3.0 | 35 | 3,470 | 4,280 | 491 | 574 | 512 | 1,006 | 184 | 269 |
| | | | Dry | 1 | | | 12.0 | .562 | | | | | | 10,040 | 14,300 | 2,022 | 2.76 | 12.4 | 22.2 | 15,200 | 6.2 | 31 | 6,910 | 8,140 | 1,413 | 924 | 796 | 1,698 | 210 | 374 |
| 308 | do | Near Hattiesburg, Miss. | Green | | 17.3 | 34 | 30.2 | .522 | .594 | 42 | 11.0 | 4.8 | 7.5 | 4,730 | 7,730 | 1,406 | .96 | 7.0 | 25.3 | 9,950 | 3.4 | 31 | 3,540 | 4,020 | 513 | 466 | 520 | 1,034 | 172 | 274 |
| | | | Dry | | | | 11.0 | .540 | | | | | | 8,520 | 12,770 | 1,834 | 2.43 | 9.1 | 14.4 | 15,020 | 6.2 | 28 | 5,740 | 8,180 | 1,425 | 968 | 650 | 1,423 | 182 | 388 |
| 309 | do | Near Lake Charles, La. | Green | | 16.1 | 39 | 29.0 | .557 | .642 | 45 | 12.8 | 5.4 | 7.8 | 5,810 | 8,930 | 1,653 | 1.06 | 8.1 | 29.4 | 10,560 | 3.3 | 31 | 3,990 | 4,550 | 628 | 524 | 595 | 1,002 | 174 | 298 |
| | | | Dry | | | | 12.8 | .574 | | | | | | 9,010 | 13,800 | 1,841 | 2.32 | 10.3 | 19.5 | 14,890 | 5.7 | 29 | 5,080 | 7,990 | 1,492 | 1,010 | 906 | 1,378 | 196 | 355 |

TABLE 21.—*Strength and related properties, by localities, of woods grown in the United States*—Continued

| Shipment no. | Species (common and botanical names) | Place of growth of material tested | Moisture condition | Trees tested | Rings per inch | Summer wood | Moisture content | Specific gravity, oven dry, based on volume—At test | Specific gravity, oven dry, based on volume—When oven-dry | Weight per cubic foot | Shrinkage from green to oven-dry condition based on dimensions when green—Volumetric | Shrinkage—Radial | Shrinkage—Tangential | Static bending—Stress at proportional limit | Static bending—Modulus of rupture | Static bending—Modulus of elasticity | Static bending—Work—Proportional limit | Static bending—Work—Maximum load | Static bending—Work—Total | Impact bending—Stress at proportional limit | Impact bending—Work to proportional limit | Impact bending—Height of drop causing complete failure (50-pound hammer) | Compression parallel to grain—Stress at proportional limit | Compression parallel to grain—Maximum crushing strength | Compression perpendicular to grain; stress at proportional limit | Hardness; load required to embed a 0.444-inch ball to ½ its diameter—End | Hardness—Side | Shear parallel to grain; maximum shearing strength | Cleavage; load to cause splitting | Tension perpendicular to grain; maximum tensile strength |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 | 28 | 29 | 30 | 31 |
| | SOFTWOODS—continued | | | *Number* | *Number* | *Percent* | *Percent* | | | *Pounds* | *Percent* | *Percent* | *Percent* | *Lb. per sq. in.* | *Lb. per sq. in.* | *1,000 lb. per sq. in.* | *In.-lb. per cu. in.* | *In.-lb. per cu. in.* | *In.-lb. per cu. in.* | *Lb. per sq. in.* | *In.-lb. per cu. in.* | *Inches* | *Lb. per sq. in.* | *Lb. per sq. in.* | *Lb. per sq. in.* | *Pounds* | *Pounds* | *Lb. per sq. in.* | *Lb. per in. of width* | *Lb. per sq. in.* |
| 314 | Pine, longleaf (*Pinus palustris*) | Nassau County, Fla. | Green | 10 | 23.6 | 43 | 41.6 | 0.574 | 0.607 | 51 | 12.2 | 5.1 | 6.9 | 5,410 | 8,580 | 1,016 | 1.02 | 7.6 | 20.3 | 11,160 | 3.6 | 33 | 3,860 | 4,340 | 576 | 542 | 602 | 1,060 | 177 | 274 |
| | | | Dry | 4 | | | 6.9 | .648 | | | | | | 13,400 | 18,540 | 2,422 | 4.20 | 11.8 | 24.6 | 18,620 | 7.5 | 34 | 9,030 | 12,720 | 1,926 | 1,350 | 1,220 | 1,886 | 248 | 418 |
| 343 | do. | Washington Parish, La. | Green | 9 | 14.4 | 38 | 63.8 | .550 | .650 | 56 | 12.4 | 5.6 | 7.8 | 5,050 | 9,400 | 1,752 | 1.03 | 8.9 | 34.1 | 11,490 | 3.8 | 39 | 3,880 | 4,620 | 707 | 597 | 664 | 1,150 | 222 | 324 |
| | | | Dry | 2 | | | 7.3 | .627 | | | | | | 14,120 | 19,340 | 2,488 | 4.47 | 11.8 | 25.4 | 16,210 | 6.5 | 35 | 10,400 | 13,210 | 1,740 | 1,194 | 1,010 | 1,618 | 312 | — |
| 1059 | do. | St. Tammany Parish, La. | Green | 5 | 13.0 | 41 | 70.8 | .564 | .661 | 60 | 12.3 | 5.5 | 7.7 | 5,360 | 9,230 | 1,717 | .95 | 11.2 | 38.8 | 10,400 | 3.1 | 40 | 3,390 | 4,710 | 714 | 597 | 641 | 992 | 248 | 428 |
| | | | Dry | 5 | | | 11.9 | .624 | | | | | | 10,010 | 16,470 | 2,161 | 2.59 | 14.3 | 22.0 | 17,510 | 7.0 | 37 | 7,100 | 9,510 | 1,230 | [illegible] | 992 | 1,760 | 348 | 608 |
| 1063 | do. | Columbia County, Fla. | Green | 5 | 5.1 | 40 | 117.4 | .483 | .554 | 60 | 10.6 | 4.1 | 7.0 | 4,430 | 7,770 | 1,336 | .84 | 9.0 | 30.0 | 8,100 | 2.7 | 34 | 2,370 | 3,640 | 547 | 562 | 562 | 990 | 254 | 448 |
| | | | Dry | 5 | | | 11.7 | .529 | | | | | | 7,040 | 12,990 | 1,558 | 1.79 | 12.5 | 18.2 | 13,590 | 5.4 | 25 | 4,770 | 7,346 | 1,148 | 890 | 812 | 1,554 | 336 | 600 |
| 1065 | do. | Charleston County, S. C. | Green | 10 | 7.6 | 40 | 88.2 | .501 | .587 | 59 | 12.9 | 4.8 | 7.6 | 4,810 | 8,010 | 1,549 | .85 | 10.4 | 34.8 | 8,600 | 2.4 | 30 | 2,780 | 4,130 | 531 | 548 | 574 | 955 | 238 | 382 |
| | | | Dry | 10 | | | 13.2 | .557 | | | | | | 7,600 | 14,300 | 1,920 | 1.68 | 13.9 | 21.5 | 14,690 | 5.6 | 37 | 4,650 | 7,420 | 887 | 770 | 706 | 1,346 | 334 | 584 |
| 226 | Pine, mountain (*Pinus pungens*) | Sevier County, Tenn. | Green | 5 | 15.2 | 29 | 74.7 | .494 | .549 | 54 | 10.9 | 3.4 | 6.8 | 4,530 | 7,520 | 1,271 | .94 | 8.1 | 25.2 | 10,210 | 3.8 | 29 | 2,980 | 3,540 | 559 | 478 | 494 | 956 | 201 | 321 |
| | | | Dry | 2 | | | 8.9 | .532 | | | | | | 9,420 | 13,380 | 1,653 | 2.96 | 8.9 | 12.6 | 15,920 | 7.6 | 29 | 4,800 | 8,540 | 1,531 | 832 | 726 | 1,290 | 261 | 378 |
| 185 | Pine, northern white (*Pinus strobus*) | Shawano County, Wis. | Green | 5 | 16.2 | 31 | 73.9 | .363 | .391 | 39 | 7.8 | 2.2 | 5.9 | 3,410 | 5,310 | 1,073 | .62 | 5.9 | 13.4 | 6,490 | 2.1 | 18 | 2,430 | 2,720 | 314 | 304 | 296 | 644 | 152 | 255 |
| | | | Dry | 2 | | | 9.9 | .385 | | | | | | 7,040 | 9,020 | 1,417 | 2.04 | 6.4 | 12.6 | 9,280 | 3.3 | 18 | 5,040 | 6,300 | 757 | 611 | 449 | 1,072 | 209 | 339 |
| 615 | do. | Near Funkley, Minn. | Green | — | 13.0 | 28 | 74.7 | .343 | .371 | 37 | 8.7 | — | — | 3,210 | 4,830 | 980 | .61 | 4.9 | 6.7 | 8,020 | 3.7 | 16 | — | 2,350 | 268 | 290 | 298 | 674 | 164 | 303 |
| | | | Dry | — | | | 10.0 | .357 | | | | | | 6,540 | 9,310 | 1,298 | 1.94 | 6.4 | 6.5 | 10,540 | 5.0 | 18 | — | 5,450 | 709 | 479 | 411 | 1,034 | 155 | 377 |
| 865 | Pine, northern white (virgin growth) (*Pinus strobus*) | Strafford County, N. H. | Green | 5 | 13.4 | 28 | 52.5 | .340 | .368 | 32 | 8.7 | 2.3 | 5.8 | 3,070 | 5,160 | 1,064 | .52 | 5.3 | 11.0 | 6,810 | 2.1 | 16 | 1,870 | 2,470 | 296 | 303 | 309 | 668 | 141 | 238 |
| | | | Dry | 2 | | | 9.5 | .367 | | | | | | 6,440 | 9,700 | 1,340 | 1.82 | 7.0 | 10.1 | 10,690 | 3.9 | 20 | 3,650 | 5,280 | 656 | 578 | 416 | 834 | 142 | 268 |
| 865 | Pine, northern white (second growth) (*Pinus strobus*) | do. | Green | 5 | 10.5 | — | 75.1 | .329 | .362 | 36 | 7.8 | 2.4 | 6.3 | 2,730 | 4,760 | 934 | .46 | 4.7 | 10.5 | 5,890 | 1.5 | 16 | — | 2,380 | 257 | 318 | 322 | 653 | 132 | 158 |
| | | | Dry | 2 | | | 9.4 | .348 | | | | | | 5,040 | 9,300 | 1,222 | 1.65 | 7.9 | 10.8 | 9,660 | 4.1 | 18 | — | 4,860 | 548 | 530 | 390 | 789 | 161 | 330 |
| 185 | Pine, Norway (*Pinus resinosa*) | Shawano County, Wis. | Green | 5 | 22.1 | 41 | 54.0 | .440 | .507 | 42 | 11.5 | 4.6 | 7.2 | 3,740 | 6,430 | 1,384 | .59 | 5.8 | 28.4 | 7,480 | 2.2 | 28 | 2,410 | 3,080 | 358 | 355 | 342 | 770 | 166 | 192 |
| | | | Dry | 1 | | | 12.5 | .478 | | | | | | 9,170 | 12,200 | 1,787 | 2.68 | 9.9 | 17.1 | 15,990 | 6.3 | 25 | 5,160 | 7,080 | 833 | 600 | 507 | 1,262 | 296 | 468 |
| 226 | Pine, pitch (*Pinus rigida*) | Sevier County, Tenn. | Green | 5 | 11.7 | 30 | 85.3 | .470 | .542 | 54 | 11.7 | 4.8 | 7.4 | 3,660 | 6,080 | 1,118 | .75 | 8.5 | 30.5 | 9,120 | 3.4 | 29 | 2,370 | 3,040 | 510 | 458 | 484 | 950 | 228 | 354 |
| | | | Dry | 2 | | | 7.6 | .517 | | | | | | 7,840 | 12,430 | 1,496 | 2.56 | 8.7 | 14.0 | 17,150 | 10.7 | 28 | 4,310 | 7,000 | 1,170 | 820 | 690 | 1,566 | 258 | 576 |
| 904 | Pine, pitch (second growth) (*Pinus rigida*) | Franklin County, Mass. | Green | 5 | 11.7 | 27 | 72.3 | .431 | .504 | 46 | 10.1 | 3.3 | 6.7 | 3,540 | 6,980 | 1,281 | .60 | 9.8 | 25.3 | 8,820 | 3.1 | 26 | 1,530 | 2,860 | 390 | 378 | 459 | 772 | 151 | 202 |
| | | | Dry | 4 | | | 10.6 | .483 | | | | | | 8,040 | 11,800 | 1,500 | 1.56 | 9.6 | 12.4 | 11,290 | 4.1 | 25 | 4,770 | 6,450 | 1,255 | 742 | 634 | 1,438 | 270 | 488 |
| 314 | Pine, pond (*Pinus rigida serotina*) | Nassau County, Fla. | Green | 5 | 12.8 | 35 | 55.7 | .501 | .580 | 49 | 11.2 | 5.1 | 7.1 | 4,540 | 7,450 | 1,281 | .93 | 7.5 | 26.8 | 9,350 | 3.2 | 33 | 2,940 | 3,660 | 544 | 455 | 510 | 930 | 186 | 260 |
| | | | Dry | 2 | | | 6.2 | .556 | | | | | | 11,300 | 14,500 | 2,050 | 3.43 | 9.2 | 12.3 | 15,700 | 6.3 | 26 | 9,110 | 10,690 | 1,578 | 1,020 | 889 | 1,716 | 275 | 413 |
| 28 | Pine, ponderosa (*Pinus ponderosa*) | Douglas County, Colo. | Green | 5 | 31.9 | 40 | 92.7 | .391 | .435 | 47 | 9.0 | 3.8 | 5.8 | 3,310 | 5,460 | 1,053 | .59 | 6.0 | 11.5 | 8,010 | 2.2 | 20 | 2,240 | 2,600 | 410 | 315 | 331 | 706 | 153 | — |
| | | | Dry | 2 | | | 13.8 | .411 | | | | | | 6,220 | 8,400 | 1,262 | 1.77 | 7.0 | 8.5 | 8,020 | 2.7 | 16 | 4,210 | 4,020 | 714 | 618 | 454 | 1,030 | 200 | — |
| 31 | do. | Stevens County, Wash. | Green | — | 15.9 | — | 37.6 | .416 | — | 36 | — | — | — | 3,390 | 5,660 | 1,160 | — | — | — | | | | | 2,770 | 299 | — | — | — | — | — |
| | | | Dry | — | | | 11.2 | .436 | | | | | | 6,600 | 10,870 | 1,534 | — | — | — | — | — | — | — | 6,460 | 781 | — | — | — | — | — |
| 140 | do. | Coconino County, Ariz. | Green | 5 | 21.4 | 26 | 98.5 | .353 | .395 | 44 | 9.2 | 4.1 | 6.4 | 2,660 | 4,760 | 879 | .47 | 4.9 | 12.8 | 6,160 | 2.1 | 17 | 1,870 | 2,220 | 342 | 310 | 314 | 602 | 160 | 301 |
| | | | Dry | 1 | | | 11.6 | .384 | | | | | | 6,350 | 8,150 | 1,103 | 2.04 | 4.6 | 7.3 | 8,100 | 3.1 | 10 | 3,530 | 5,220 | 790 | 546 | 406 | 1,300 | 243 | 402 |
| 142 | do. | Madera County, Calif. | Green | 5 | 13.0 | 31 | 125.3 | .377 | .433 | 53 | 11.5 | 4.3 | 7.3 | 3,160 | 5,180 | 1,111 | .52 | 4.3 | 15.6 | 7,070 | 2.5 | 21 | 2,130 | 2,420 | 326 | 316 | 314 | 696 | 174 | 241 |
| | | | Dry | 1 | | | 9.7 | .401 | | | | | | 8,100 | 11,000 | 1,456 | 2.56 | 8.2 | 19.0 | 11,450 | 4.8 | 19 | 5,070 | 6,500 | 835 | 563 | 510 | 1,214 | 226 | 448 |
| 224 | do. | Missoula County, Mont. | Green | 5 | 17.9 | 32 | 119.4 | .371 | .425 | 51 | 9.3 | 3.6 | 5.9 | 2,930 | 4,950 | 865 | .59 | 5.2 | 15.4 | 8,600 | 2.3 | 19 | 2,050 | 2,370 | 313 | 308 | 322 | 674 | 176 | 302 |
| | | | Dry | 2 | | | 7.8 | .401 | | | | | | 7,100 | 9,020 | 1,350 | 2.14 | 6.8 | 11.7 | 12,800 | 4.0 | 19 | 4,470 | 6,740 | 802 | 567 | 486 | 1,078 | 196 | 381 |
| 655 | do. | Sierra County, Calif. | Green | 6 | 12.6 | 21 | 75.4 | .370 | .412 | 40 | 8.4 | — | — | 3,140 | 4,260 | 779 | .74 | 5.1 | 7.8 | 7,060 | 3.4 | 21 | — | 2,030 | 428 | 258 | 280 | 682 | 108 | 310 |
| | | | Dry | 6 | | | 10.5 | .396 | | | | | | 5,700 | 9,130 | 1,107 | 1.69 | 8.1 | 8.1 | 11,510 | 5.0 | 19 | — | 4,780 | 848 | 814 | 473 | 1,432 | 230 | 472 |
| 751 | Pine, sand (*Pinus clausa*) | Marion County, Fla. | Green | 5 | 6.8 | 30 | 38.1 | .451 | .506 | 38 | 10.0 | 3.9 | 7.3 | 4,120 | 7,500 | 1,024 | .95 | 9.6 | 20.6 | 9,790 | 4.6 | 25 | 2,670 | 3,440 | 556 | 465 | 477 | 1,143 | — | 376 |
| | | | Dry | 2 | | | 11.6 | .482 | | | | | | 7,580 | 12,530 | 1,525 | 2.14 | 9.6 | 16.7 | 12,920 | 5.6 | 18 | 3,950 | 7,050 | 1,145 | 1,138 | 810 | 1,953 | — | 290 |
| 41 | Pine, shortleaf (*Pinus echinata*) | Near Malvern, Ark. | Green | — | 13.4 | — | 52.0 | .477 | — | 45 | — | — | — | 4,360 | 7,710 | 1,395 | .76 | — | — | — | — | — | — | 3,570 | 400 | — | — | 708 | — | — |
| | | | Dry | — | | | 14.2 | .518 | | | | | | 7,780 | 12,120 | 1,792 | 1.90 | — | — | — | — | — | — | 6,250 | 926 | — | — | 1,135 | — | — |
| 342 | do. | Washington Parish, La. | Green | 6 | 10.0 | 40 | 75.4 | .512 | .584 | 56 | 12.6 | 5.1 | 8.2 | 4,680 | 8,210 | 1,506 | .82 | 8.7 | 36.8 | 11,210 | 4.0 | 39 | 3,660 | 4,050 | 550 | 494 | 558 | 1,071 | 214 | 330 |
| | | | Dry | 2 | | | 7.8 | .574 | | | | | | 10,470 | 15,760 | 2,140 | 3.01 | 10.1 | 16.0 | 16,590 | 6.5 | 38 | 7,160 | 10,990 | 1,683 | 944 | 884 | 1,640 | 252 | 406 |
| 1012 | do. | Burlington County, N. J. | Green | 10 | 14.8 | 26 | 70.8 | .405 | .474 | 43 | 11.4 | 3.5 | 7.2 | 3,280 | 6,140 | 1,069 | .58 | 7.3 | 20.2 | 7,000 | 2.4 | 28 | 1,810 | 2,860 | 340 | 360 | 304 | 708 | 164 | 246 |
| | | | Dry | 10 | | | 12.0 | .445 | | | | | | 6,430 | 11,420 | 1,358 | 1.78 | 10.8 | 14.6 | 11,340 | 4.2 | 28 | 4,220 | 6,890 | 790 | 594 | 563 | 1,166 | 278 | 461 |
| 1020 | do. | Iredell County, N. C. | Green | 10 | 11.4 | 31 | 90.5 | .465 | .547 | 55 | 12.0 | 4.3 | 7.6 | 3,330 | 7,500 | 1,505 | .43 | 8.8 | 24.2 | 8,300 | 2.7 | 28 | 2,140 | 3,480 | 425 | 410 | 457 | 878 | 218 | 300 |
| | | | Dry | 10 | | | 12.0 | .511 | | | | | | 8,310 | 13,390 | 1,748 | 2.22 | 12.5 | 16.3 | 12,850 | 5.0 | 24 | 5,070 | 6,730 | 948 | 602 | 650 | 1,346 | 293 | 322 |
| 1064 | do. | Jackson County, Ga. | Green | 10 | 10.7 | 32 | 101.0 | .467 | .555 | 59 | 12.8 | 4.8 | 8.0 | 4,330 | 7,450 | 1,526 | .70 | 8.2 | 27.6 | 8,780 | 2.9 | 30 | 2,840 | 3,480 | 494 | 398 | 414 | 830 | 210 | 350 |
| | | | Dry | 10 | | | 13.3 | .522 | | | | | | 7,290 | 12,860 | 1,949 | 1.54 | 10.7 | 10.7 | 15,040 | 5.7 | 34 | 5,020 | 7,230 | 955 | 744 | 720 | 1,317 | 274 | 454 |
| 314 | Pine, slash (*Pinus caribaea*) | Nassau County, Fla. | Green | 5 | 16.6 | 44 | 47.2 | .581 | .677 | 53 | 12.7 | 5.9 | 7.5 | 5,620 | 8,800 | 1,631 | 1.10 | 7.9 | 31.2 | 11,300 | 3.9 | 37 | 3,890 | 4,470 | 592 | 574 | 628 | 1,034 | 190 | 294 |
| | | | Dry | 2 | | | 8.8 | .662 | | | | | | 12,860 | 18,360 | 2,220 | 3.88 | 13.1 | 28.1 | 18,020 | 7.2 | 42 | 9,190 | 11,600 | 1,632 | 1,205 | 1,159 | 1,924 | — | 651 |
| 752 | do. | Dade County, Fla. | Green | 5 | 10.7 | 50 | 32.4 | .696 | .836 | 58 | 12.7 | 5.8 | 8.8 | 5,750 | 10,440 | 1,509 | 1.70 | 9.1 | 25.2 | 14,770 | 6.7 | 36 | 2,880 | 4,960 | 820 | 807 | 871 | 1,186 | 254 | 511 |
| | | | Dry | 2 | | | 13.2 | .717 | | | | | | 8,110 | 14,310 | 1,961 | 2.79 | 9.7 | 12.1 | 16,410 | 7.8 | 29 | 5,100 | 9,230 | 1,820 | 1,315 | 1,240 | 1,640 | — | 172 |
| 1059 | do. | St. Tammany Parish, La. | Green | 10 | 7.0 | 39 | 73.0 | .526 | .626 | 57 | 12.6 | 5.6 | 7.6 | 4,930 | 8,800 | 1,640 | .85 | 9.7 | 28.4 | 9,800 | 3.1 | 33 | 2,830 | 4,400 | 660 | 559 | 570 | 920 | 244 | 403 |
| | | | Dry | | | | 13.9 | .580 | | | | | | 9,200 | 15,140 | 2,068 | 2.30 | 13.9 | 21.9 | 14,120 | 4.6 | 37 | 6,000 | 8,000 | 1,177 | 899 | 870 | 1,582 | 296 | 554 |
| 1063 | do. | Columbia County, Fla. | Green | 10 | 6.1 | 45 | 85.1 | .521 | .601 | 61 | 11.4 | 5.0 | 7.6 | 4,610 | 8,230 | 1,515 | .81 | 10.4 | 35.1 | 9,720 | 3.2 | 37 | 2,910 | 3,900 | 675 | 551 | 572 | 958 | 236 | 390 |
| | | | Dry | | | | 12.4 | .569 | | | | | | 9,035 | 15,100 | 1,916 | 2.41 | 13.7 | 22.0 | 13,780 | 4.0 | 28 | 5,100 | 8,280 | 1,102 | 1,041 | 917 | 1,484 | 294 | 506 |
| 142 | Pine, sugar (*Pinus lambertiana*) | Madera County, Calif. | Green | 5 | 11.9 | 34 | 123.2 | .360 | .386 | 50 | 8.4 | 2.9 | 5.6 | 3,330 | 5,270 | 960 | .66 | 5.0 | 11.1 | 6,740 | 2.3 | 17 | 2,390 | 2,600 | 353 | 334 | 324 | 708 | 178 | 272 |
| | | | Dry | 1 | | | 11.4 | .369 | | | | | | 6,250 | 8,840 | 1,212 | 1.79 | 5.0 | 6.7 | 10,110 | 4.3 | 17 | 4,400 | 5,100 | 640 | 453 | 443 | 1,062 | 196 | 354 |
| 551 | do. | Plumas County, Calif. | Green | 4 | 14.5 | 20 | 154.2 | .333 | .368 | 53 | 7.3 | — | — | 3,470 | 4,850 | 904 | .76 | 5.9 | — | 8,240 | 3.0 | 18 | — | 2,450 | 349 | 294 | 266 | 640 | 186 | 276 |
| | | | Dry | 4 | | | 10.4 | .352 | | | | | | 5,420 | 8,000 | 1,249 | 1.40 | 6.1 | 9.6 | 11,840 | 4.8 | 18 | — | 4,830 | 570 | 432 | 308 | 1,149 | 198 | 348 |
| 224 | Pine, western white (*Pinus monticola*) | Missoula County, Mont. | Green | 5 | 27.3 | 33 | 58.2 | .393 | .448 | 39 | 11.5 | 4.1 | 7.4 | 3,520 | 5,700 | 1,329 | .51 | 5.1 | 17.9 | 7,590 | 2.3 | 23 | 2,820 | 3,070 | 303 | 334 | 333 | 712 | 168 | 240 |
| | | | Dry | 1 | | | 7.9 | .432 | | | | | | 7,940 | 11,400 | 1,687 | 2.17 | 10.0 | 13.0 | 14,900 | 5.8 | 29 | 5,350 | 7,840 | 816 | 470 | 418 | — | 132 | — |
| 570 | do. | Near Keeler, Idaho | Green | — | 16.4 | — | 51.2 | .347 | .402 | 33 | 12.0 | 1.8 | 4.1 | 3,280 | 4,950 | 1,078 | .57 | 5.0 | — | 7,680 | 2.7 | 17 | — | 2,420 | 288 | 293 | 300 | 593 | 153 | 269 |
| | | | Dry | — | | | 9.7 | .368 | | | | | | 6,500 | 10,120 | 1,514 | 1.58 | 9.7 | — | 11,600 | 4.5 | 21 | — | 6,170 | 530 | 477 | 375 | 1,000 | 176 | 326 |

TABLE 21.—*Strength and related properties, by localities, of woods grown in the United States*—Continued

| Shipment no. | Species (common and botanical names) | Place of growth of material tested | Moisture condition | Trees tested | Rings per inch | Summer wood | Moisture content | Specific gravity, oven dry, based on volume— At test | Specific gravity, oven dry, based on volume— When oven-dry | Weight per cubic foot | Shrinkage from green to oven-dry condition based on dimensions when green: Volumetric | Shrinkage: Radial | Shrinkage: Tangential | Static bending: Stress at proportional limit | Static bending: Modulus of rupture | Static bending: Modulus of elasticity | Static bending: Work: Proportional limit | Static bending: Work: Maximum load | Static bending: Work: Total | Impact bending: Stress at proportional limit | Impact bending: Work to proportional limit | Impact bending: Height of drop causing complete failure (50-pound hammer) | Compression parallel to grain: Stress at proportional limit | Compression parallel to grain: Maximum crushing strength | Compression perpendicular to grain; stress at proportional limit | Hardness; load required to embed a 0.444-inch ball to ½ its diameter: End | Hardness: Side | Shear parallel to grain; maximum shearing strength | Cleavage; load to cause splitting | Tension perpendicular to grain; maximum tensile strength |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 | 28 | 29 | 30 | 31 |
| | SOFTWOODS—continued | | | *Number* | *Number* | *Percent* | *Percent* | | | *Pounds* | *Percent* | *Percent* | *Percent* | *Lb. per sq. in.* | *Lb. per sq. in.* | *1,000 lb. per sq. in.* | *In.-lb. per cu. in.* | *In.-lb. per cu. in.* | *In.-lb. per cu. in.* | *Lb. per sq. in.* | *In.-lb. per cu. in.* | *Inches* | *Lb. per sq. in.* | *Lb. per sq. in.* | *Lb. per sq. in.* | *Pounds* | *Pounds* | *Lb. per sq. in.* | *Lb. per in. of width* | *Lb. per sq. in.* |
| 463 | Piñon (*Pinus edulis*) | Coconino County, Ariz. | Green | 3 | 17.3 | 22 | 63.3 | 0.502 | 0.567 | 51 | 9.9 | 4.6 | 5.2 | 2,610 | 4,820 | 649 | 0.61 | 7.6 | 23.0 | 8,190 | 4.2 | 21 | 1,810 | 2,590 | 475 | 512 | 500 | 918 | | 462 |
| | | | Dry | 2 | | | 8.0 | .537 | | | | | | 6,420 | 8,580 | 1,250 | 2.28 | 4.3 | 4.8 | 8,520 | 2.6 | 11 | | 5,060 | 2,111 | 1,003 | 510 | | | |
| 550, 1265 | Redwood (*Sequoia sempervirens*) | Mendocino County, Calif. | Green | 9 | 33.0 | 28 | 104.1 | .398 | .422 | 51 | 6.7 | 2.7 | 4.1 | 5,030 | 7,040 | 1,178 | 1.33 | 7.5 | 10.3 | 9,310 | 3.4 | 22 | 3,780 | 4,290 | 524 | 509 | 422 | 798 | 157 | 248 |
| | | | Dry | 8 | | | 11.1 | .419 | | | | | | 7,410 | 10,070 | 1,372 | 2.30 | 7.5 | 8.8 | 10,800 | 2.3 | 19 | 4,710 | 6,600 | 860 | 562 | 490 | 1,016 | 186 | 246 |
| 1267 | ----do | Humboldt County, Calif. | Green | 7 | 25.2 | | 119.8 | .301 | .411 | 50 | 6.8 | 2.6 | 4.6 | 4,620 | 7,350 | 1,175 | 1.04 | 7.4 | 14.0 | 8,520 | 3.0 | 20 | 3,630 | 4,110 | 523 | 569 | 405 | 809 | 170 | 264 |
| | | | Dry | 7 | | | 11.3 | .384 | | | | | | 6,730 | 9,790 | 1,334 | 1.93 | 6.2 | 8.2 | 9,900 | 2.4 | 18 | 4,580 | 6,060 | 633 | 766 | 449 | 985 | 186 | 227 |
| 1265 | Redwood (second growth openly grown) (*Sequoia sempervirens*). | Mendocino County, Calif. | Green | 2 | 3.4 | | 90.3 | .300 | .328 | 36 | 6.9 | 2.3 | 5.0 | 3,340 | 5,530 | 801 | .80 | 6.1 | 7.2 | 6,590 | 2.6 | 14 | 2,160 | 2,740 | 444 | 448 | 304 | 716 | 179 | 283 |
| | | | Dry | 2 | | | 12.0 | .324 | | | | | | 5,220 | 7,710 | 981 | 1.64 | 5.6 | 6.0 | 8,420 | 3.3 | 13 | 3,340 | 4,600 | 616 | 690 | 381 | 1,016 | 174 | 286 |
| 1267 | ----do | Humboldt County, Calif. | Green | 4 | 2.8 | | 173.0 | .272 | .301 | 46 | 6.0 | | | 2,460 | 4,130 | 503 | .02 | 4.7 | 5.8 | 5,500 | 2.2 | 14 | 1,640 | 2,100 | 248 | 357 | 274 | 604 | 144 | 254 |
| | | | Dry | 4 | | | 11.3 | .293 | | | | | | 3,970 | 5,940 | 680 | 1.30 | 4.2 | 4.2 | 6,120 | 2.4 | 10 | 2,410 | 3,380 | 554 | 557 | 372 | 628 | 144 | 250 |
| 1265 | Redwood (second growth closely grown) (*Sequoia sempervirens*). | Mendocino County, Calif. | Green | 3 | 7.3 | | 100.0 | .347 | .396 | 43 | 8.5 | 2.6 | 5.4 | 4,030 | 6,930 | 1,208 | .78 | 6.7 | 10.7 | 8,060 | 2.8 | 19 | 3,360 | 3,780 | 376 | 522 | 384 | 704 | 178 | 271 |
| | | | Dry | 3 | | | 12.2 | .373 | | | | | | 6,240 | 9,420 | 1,340 | 1.64 | 6.6 | 10.2 | 9,570 | 3.8 | 19 | 4,430 | 5,960 | 676 | 767 | 442 | 968 | 156 | 293 |
| 1267 | ----do | Humboldt County, Calif. | Green | 5 | 6.2 | | 119.0 | .300 | .340 | 41 | 6.7 | 2.2 | 4.7 | 3,270 | 5,540 | 879 | .70 | 5.8 | 11.0 | 6,740 | 2.3 | 17 | 2,530 | 2,980 | 331 | 436 | 330 | 704 | 178 | 302 |
| | | | Dry | 5 | | | 11.6 | .327 | | | | | | 5,000 | 7,650 | 895 | 1.42 | 5.2 | 6.5 | 8,790 | 3.4 | 14 | 3,370 | 4,880 | 662 | 787 | 384 | 930 | 153 | 298 |
| 865 | Spruce, black (*Picea mariana*) | Rockingham County, N. H. | Green | 5 | 14.9 | | 37.5 | .376 | .428 | 32 | 11.3 | 4.1 | 6.8 | 2,000 | 6,360 | 1,065 | .45 | 7.4 | 20.4 | 6,800 | 1.8 | 24 | 1,540 | 2,570 | 175 | 430 | 370 | 662 | 117 | 104 |
| | | | Dry | 5 | | | 9.8 | .406 | | | | | | 5,740 | 10,290 | 1,523 | 1.33 | 10.5 | 21.4 | 13,400 | 6.2 | 22 | 5,510 | 6,010 | 1,085 | 762 | 556 | 1,096 | 170 | |
| 26 | Spruce, Engelmann (*Picea engelmannii*) | Grand County, Colo. | Green | 5 | 17.1 | 33 | 45.0 | .325 | .359 | 20 | 10.5 | 3.7 | 6.9 | 2,740 | 4,550 | 866 | .60 | 4.8 | 6.0 | 6,300 | 2.1 | 13 | 1,820 | 2,170 | 302 | 272 | 264 | 616 | 122 | |
| | | | Dry | 2 | | | 12.8 | .342 | | | | | | 5,100 | 7,740 | 1,074 | 1.37 | 5.4 | 6.2 | 8,890 | 3.5 | 16 | 2,550 | 4,360 | 589 | 484 | 334 | 1,074 | 166 | |
| 29 | ----do | San Miguel County, Colo. | Green | 5 | 11.3 | 37 | 155.5 | .299 | .335 | 48 | 10.3 | 3.0 | 6.2 | 2,160 | 3,850 | 798 | .30 | 5.0 | 6.5 | 5,350 | 1.8 | 15 | 1,530 | 1,800 | 279 | 231 | 221 | 569 | 130 | |
| | | | Dry | 2 | | | 16.8 | .244 | | | | | | 2,820 | 5,600 | 900 | .61 | 5.4 | 6.5 | 7,710 | 2.8 | 16 | 2,450 | 3,960 | 447 | 298 | 244 | 862 | 101 | |
| 1 | Spruce, red (*Picea rubra*) | Coos County, N. H. | Green | 6 | 21.4 | 27 | 34.9 | .389 | | 33 | | | | 3,550 | 5,960 | 1,166 | .63 | 7.5 | | 7,100 | 2.3 | 17 | | 2,570 | 318 | 418 | 368 | 760 | 120 | 212 |
| | | | Dry | 6 | | | 12.8 | .412 | | | | | | 6,760 | 10,260 | 1,544 | 1.64 | 8.7 | 16.1 | 11,330 | 4.4 | 22 | 5,120 | 5,790 | 523 | 633 | 502 | 1,214 | 133 | 343 |
| 320 | ----do | Sevier County, Tenn. | Green | 5 | 13.3 | 20 | 52.6 | .367 | .413 | 35 | 11.6 | 3.8 | 7.8 | 3,310 | 5,600 | 1,215 | .52 | 6.2 | 14.6 | 7,220 | 2.3 | 19 | 2,340 | 2,600 | 368 | 446 | 346 | 764 | 140 | 223 |
| | | | Dry | 2 | | | 7.9 | .407 | | | | | | 8,050 | 11,420 | 1,518 | 2.40 | 9.5 | 11.1 | 13,570 | 5.5 | 28 | 5,000 | 7,310 | 744 | 790 | 515 | 1,063 | 184 | 416 |
| 325 | Spruce, Sitka (*Picea sitchensis*) | Chehalis County, Wash. | Green | 5 | 9.0 | 24 | 53.0 | .342 | .373 | 33 | 11.2 | 4.5 | 7.4 | 3,020 | 5,490 | 1,185 | .44 | 8.4 | 21.8 | 7,940 | 2.5 | 29 | 2,270 | 2,600 | 364 | 433 | 370 | 777 | 148 | 216 |
| | | | Dry | 1 | | | 8.9 | .376 | | | | | | 7,220 | 11,250 | 1,612 | 1.78 | 10.4 | 21.6 | 13,890 | 5.2 | 25 | 5,100 | 5,770 | 1,010 | 780 | 532 | 1,216 | 165 | |
| 504 | ----do | Clatsop County, Oreg. | Green | 4 | 15.3 | | 44.6 | .340 | .379 | 31 | 10.7 | 3.8 | 7.0 | 3,160 | 4,920 | 1,092 | .53 | 5.4 | 15.3 | 7,810 | 2.7 | 20 | 1,920 | 2,180 | 222 | 350 | 280 | 696 | 108 | 172 |
| | | | Dry | 4 | | | 12.6 | .379 | | | | | | 6,180 | 8,380 | 1,366 | 1.48 | 7.4 | | 9,640 | 3.6 | 21 | | 4,570 | 553 | 602 | 442 | 1,206 | 220 | 428 |
| 563 | ----do | Oregon | Green | 3 | 13.6 | 47 | 36.1 | .384 | .444 | 33 | 12.8 | | | 3,680 | 6,020 | 1,455 | .58 | 6.2 | 11.1 | 9,040 | 3.5 | 24 | | 2,840 | 355 | 478 | 350 | 778 | 118 | 162 |
| | | | Dry | 3 | | | 10.4 | .419 | | | | | | 7,670 | 11,330 | 1,738 | 1.92 | 11.3 | | 12,850 | 5.7 | 28 | | 6,260 | 736 | 848 | 536 | 1,368 | 213 | 415 |
| 654 | ----do | ----do | Green | 3 | 9.6 | 41 | 34.0 | .368 | .412 | 31 | 11.2 | 4.4 | 7.9 | 3,640 | 5,880 | 1,311 | .60 | 6.5 | | 9,270 | 3.9 | 23 | | 2,930 | 353 | 478 | 348 | 748 | 164 | 206 |
| | | | Dry | 3 | | | 6.9 | .389 | | | | | | 6,740 | 9,060 | 1,604 | 1.61 | 8.4 | 13.2 | 12,600 | 6.0 | 24 | | 7,470 | 699 | 841 | 499 | 1,296 | 210 | 359 |
| 939 | ----do | Near Girdwood, Alaska | Green | 5 | 23.3 | | 39.2 | .394 | .456 | 34 | 11.4 | 4.4 | 7.6 | 3,350 | 5,830 | 1,136 | .56 | 6.7 | 18.1 | 8,350 | 3.1 | 23 | 2,190 | 2,710 | 420 | 395 | 334 | 758 | 150 | 326 |
| | | | Dry | 2 | | | 11.3 | .426 | | | | | | 7,040 | 11,780 | 1,662 | 1.60 | 10.3 | 14.1 | 11,100 | 3.8 | 21 | 5,170 | 6,620 | 714 | 664 | 540 | 1,160 | 252 | 346 |
| 939 | ----do | Near Ketchikan, Alaska | Green | 5 | 16.8 | | 39.1 | .384 | .431 | 33 | 11.6 | 4.0 | 7.7 | 3,340 | 5,880 | 1,295 | .51 | 6.3 | 20.8 | 8,270 | 2.9 | 23 | 2,330 | 2,810 | 375 | 405 | 390 | 778 | 190 | 298 |
| | | | Dry | 2 | | | 10.0 | .428 | | | | | | 7,700 | 11,540 | 1,632 | 2.06 | 10.1 | 19.9 | 10,250 | 3.3 | 34 | 5,310 | 6,580 | 792 | 1,050 | 617 | 1,133 | 265 | 439 |
| 1 | Spruce, white (*Picea glauca*) | Coos County, N. H. | Green | | 11.2 | 22 | 52.4 | .354 | | 34 | | | | 3,290 | 5,670 | 1,060 | .61 | 6.7 | | | | | | 2,440 | 278 | 394 | 345 | 676 | 126 | 216 |
| | | | Dry | | | | 12.6 | .387 | | | | | | 5,790 | 8,930 | 1,345 | 1.37 | 7.0 | 12.4 | 9,670 | 3.5 | 20 | 4,070 | 4,600 | 465 | 514 | 424 | 1,131 | 190 | 354 |
| 939 | ----do | Near Matanuska, Alaska | Green | 5 | 22.1 | | 50.2 | .388 | .461 | 36 | 12.6 | 5.8 | 9.1 | 3,170 | 5,660 | 1,140 | .51 | 5.8 | 17.4 | 7,580 | 2.7 | 24 | 2,230 | 2,720 | 330 | 371 | 352 | 710 | 170 | 231 |
| | | | Dry | 2 | | | 11.8 | .435 | | | | | | 6,720 | 10,640 | 1,402 | 1.56 | 8.0 | 15.4 | 11,070 | 4.2 | 22 | 3,390 | 6,310 | 752 | 548 | 504 | 1,239 | 229 | 300 |
| 300 | ----do | Rusk County, Wis. | Green | 5 | 17.1 | 29 | 48.4 | .377 | .431 | 35 | 14.8 | 3.7 | 7.3 | 3,370 | 5,410 | 988 | .69 | 5.4 | 14.2 | 6,750 | 2.0 | 20 | 2,140 | 2,550 | 267 | 290 | 278 | 691 | 134 | 198 |
| | | | Dry | 1 | | | 6.5 | .432 | | | | | | | | | | | | | | | 4,530 | 7,020 | 720 | 964 | 690 | 806 | | |
| 185, 165 | Tamarack (*Larix laricina*) | Marathon and Shawano Counties, Wis. | Green | 5 | 19.9 | 38 | 52.0 | .491 | .558 | 47 | 13.6 | 3.7 | 7.4 | 4,200 | 7,170 | 1,236 | .84 | 7.2 | 28.8 | 7,750 | 2.7 | 28 | 2,930 | 3,450 | 490 | 401 | 375 | 863 | 163 | 255 |
| | | | Dry | 2 | | | 11.0 | .531 | | | | | | 8,400 | 12,030 | 1,660 | 2.33 | 7.1 | 14.4 | 12,950 | 5.7 | 22 | 4,860 | 7,580 | 1,050 | 724 | 534 | 1,372 | 228 | 414 |
| 263 | Yew, Pacific (*Taxus brevifolia*) | Snohomish County, Wash. | Green | 5 | 26.8 | | 44.1 | .601 | .673 | 54 | 9.7 | 4.0 | 5.4 | 6,520 | 10,140 | 989 | 2.46 | 20.2 | 54.3 | 13,110 | 6.2 | 38 | 3,440 | 4,650 | 1,040 | 1,342 | 1,150 | 1,621 | 248 | 450 |
| | | | Dry | 2 | | | 9.2 | .631 | | | | | | 10,120 | 15,730 | 1,490 | 3.94 | 18.4 | 27.2 | 11,970 | 5.3 | 30 | 5,090 | 9,220 | 2,065 | 2,332 | 1,706 | 2,470 | 190 | |

END