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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 676

Contribution from the Forest Service
HENRY S. GRAVES, Forester

FOREST PRODUCTS LABORATORY, Madison, Wisconsin
In Cooperation with the University of Wisconsin

Washington, D. C.

PROFESSIONAL PAPER

July 16, 1919

THE RELATION OF THE SHRINKAGE
AND STRENGTH PROPERTIES OF
WOOD TO ITS SPECIFIC GRAVITY

By

J. A. NEWLIN, in Charge, Section of Timber
Mechanics, and T. R. C. WILSON, Engineer in
Forest Products

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FOREST SERVICE.

HENRY S. GRAVES, Forester.

ALBERT F. POTTER, Associate Forester.

BRANCH OF RESEARCH.

EARLE H. CLAPP, *Assistant Forester in charge.*

FOREST PRODUCTS LABORATORY.

CARLILE P. WINSLOW, *Director.*

OVID M. BUTLER, *Assistant Director.*

SECTION OF TIMBER MECHANICS.

J. A. NEWLIN, *Engineer in Forest Products in charge.*

T. R. C. WILSON, *Engineer in Forest Products.*

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PURPOSE.

It has long been recognized that there are direct relations between the specific gravity, or density, of a wood and its strength properties.¹ By the analysis of over 200,000 tests, the Forest Products Laboratory, conducted in cooperation with the University of Wisconsin, Madison, Wis., has now definitely established these relations. It is the purpose of this bulletin to state these relations and to put the expression of them in such form as to render them easily useful (1) for estimating the properties of any particular timber; (2) for selecting timber for any given purpose; (3) for comparing the various species; and (4) for determining in what way the species are exceptional and to what uses they are best adapted.

It has usually been assumed that the strength of wood varies directly with the first power of its density; i.e., that the respective strengths of two sticks would differ in the same proportion as the densities. It was recognized that fiber stress at elastic limit in compression perpendicular to the grain, or bearing strength on side

¹ Accurate determinations made at the Forest Products Laboratory on seven species of wood, including both hardwood and coniferous species, showed a range of only about 4½ per cent in the density of the wood substance, or material of which the cell walls are composed. Since the density of wood substance is so nearly constant, it may be said that the density or specific gravity of a given piece of wood is a measure of the amount of wood substance contained in it.

surface, and work values in static bending or toughness, deviate very erratically from this relation; but the relation was supposed to hold especially true in the case of such properties as modulus of rupture, or maximum bending strength, and strength in compression parallel

FIG. 1.

FIG. 2.

to the grain, or strength as a column. It has also been supposed that the relation applied between pieces of the same species, between pieces of different species, and between average results of strength tests on different species. A study of the data at present available, which are derived from a much larger number of tests and which cover a greater

range in specific gravity and strength values than was true of the data available heretofore, made it evident that these assumptions were inaccurate and that there was a better and more correct method expressing the actual relations between specific gravity and strength.

FIG. 3.

(a) HARDNESS - END SURFACE

(b) SHEARING STRENGTH || TO GRAIN

(c) HARDNESS - SIDE SURFACE

(d) TENSION 1 TO GRAIN

FIG. 4.

In order that the relation between specific gravity and each of the various mechanical properties of wood may be easily put to practical use, the relation, both for green and for air-dry material, is given in the form of an equation (Table 1) and, in addition, in the form of a curve (figs. 1 to 4).

SPECIES-LOCALITY AVERAGES.

The specific-gravity relations given in this bulletin are derived from a study of what may be called "species-locality" averages; that is, each average represents tests of material of one species from one locality.

There are two principal reasons for using "species-locality" averages in preference to the results of individual tests. First, the number of individual tests is quite large, amounting in some instances to as many as 900 from a single "species-locality", so that an immense amount of work is saved by the use of the "species-locality" averages; second, if individual tests were used, the "species-localities" having larger trees or a larger number of trees would include a larger number of tests and would have undue weight in determining the relations.

The method of analysis used is applicable also to individual tests from a single species to determine the specific gravity relations within that species. It has been applied to a few of the properties of some of the more important species which are used for structural timbers where there was a rather large number of test pieces and a considerable range in specific gravity.

DETERMINATION OF SPECIFIC GRAVITY.

Specific gravity of wood, as used herein, is based on the volume of the specimens when tested (green or air-dry) and their weight when in an oven-dry condition; that is, it is the ratio of the weight of the specimen of wood, *oven-dry*, to the weight of a volume of water equal to the *volume of the specimen at the time of test*. Because of the shrinkage which takes place in wood when it is dried, this figure is not the true specific gravity of a piece of oven-dry wood. The method, however, is easily applied to each specimen tested, and is the standard method of the Forest Service for the determination of a specific-gravity figure for use in studying the properties of wood.

MOISTURE CONTENT OF TEST SPECIMENS.

Both green and air-dry specimens were used in the tests, and the relations between specific gravity and strength were determined separately for green and air-dry wood. Variations in the moisture content of wood have no effect on its mechanical properties so long as the wood is thoroughly green; they have considerable influence on these properties, however, as soon as the wood becomes air-dry, or partially air-dry. Accurate comparisons can not be made between the properties of two lots of air-dry specimens unless they were tested at the same moisture content or adjustments made in the strength figures for difference in moisture content.

The moisture content of the air-dry material at the time of test varied from 8 to 18 per cent. Modulus of rupture and maximum strength in compression parallel to the grain were adjusted to a moisture content of 12 per cent before determinations of the relation of these properties to the specific gravity was made. This adjustment was possible because the laws governing the variation of these properties with varying moisture content are fairly well established. However, in the case of the other strength functions their variation with varying moisture content has not been studied in detail and no such adjustment is possible with any very great degree of accuracy. Consequently, the actual moisture content values as obtained from tests have been used in the determination of the relation of these properties to specific gravity.

THE EQUATIONS.

Table 1 and figures 1 to 4 give equations which represent the average relations between specific gravity and each of the mechanical properties. All the "species-locality" averages available on any particular property were considered in deriving the equations for that property. The number of "species-locality" averages from which an equation is derived varies from 84 to 178. This variation is due to the fact that several of the tests were not used in some of the earlier testing work and to the fact that tests have not yet been completed on air-dry material for all of the "species-localities" listed.

Table 1 gives first the equations for shrinkage and for each of the strength properties of green and air-dry wood in terms of the specific gravity. These equations, as explained in the appendix, are reduced to a simple form; and the powers of gravity used are such that the equations may be solved by arithmetical operations and without the use of higher mathematics. However, to simplify even further the use of the equations, figures 1 to 4 have been prepared for their solution. Each of the curves shown in these diagrams represents the equation connecting specific gravity and one of the properties of wood. The curves representing the equations for radial, tangential, and volumetric shrinkage appear in figure 1(a). In each of the other figures, 1(b) to 4(d), appear two curves for some one mechanical property. One of these curves is for green and the other for air-dry material. If the specific gravity is known, the equation value for any one or all of the properties of the wood in question may be readily determined from the curves without computation.

The second portion of Table 1 gives what may be termed a measure of the accuracy of the respective equations. It is not to be expected that all the "species-locality" averages will satisfy the equation exactly or even very closely. Some of the properties are more erratic than others, so that one "species-locality" may far exceed

the equation values and another "species-locality" fall far below them.

In figure 5 are plotted the curves of the equation for modulus of rupture in static bending in green material, $M=18500 \sqrt[4]{g^5}$, and of the equation for the same property in air-dry material, $M=26200 \sqrt[4]{g^5}$. In order to give a graphical idea as to the reliability of these equations, the specific gravity and the modulus of rupture of each "species-locality" have been plotted as a point. The reference number placed near each plotted point is assigned to the "species-locality" in the order of its respective specific gravity as determined from compression parallel to grain specimens of green wood. In figures 6, 7, and 8 the data are given for the curves on shrinkage in volume from green to oven-dry condition, maximum crushing strength in compression parallel to grain, and fiber strength at elastic limit in compression perpendicular to grain.

Under each property is listed in this second portion of Table 1, for both green and air-dry conditions, those percentages of the equation value above which were one-tenth of the "species-localities." Similarly, there are listed those percentages above which were one-fourth of the "species-localities," those below which were one-fourth, and those below which were one-tenth. For instance, in static bending (green), one-tenth of the "species-localities" tested had a modulus of rupture of more than 114 per cent of what the specific gravity equation indicated they should have had; one-fourth of them had a modulus of rupture greater than 108 per cent of the equation value; one-fourth of them less than 91 per cent of the equation value; and the lowest one-tenth had a modulus of rupture less than 84 per cent of what the equation indicated they should have had. It follows from these figures that one-half of the "species-localities" had a modulus of rupture of between 91 per cent and 108 per cent of the value given by the equation, and that the other one-half were evenly divided between those that were more than 108 per cent and those that were less than 91 per cent.

The third portion of Table 1 gives the actual value of each property for each "species-locality" as determined by the tests, expressed as a percentage of the value computed from the specific gravity by the use of the equation at the head of the column. For instance, it is found from the table that air-dry Biltmore ash has a modulus of rupture 98 per cent as great as that of the average wood of its specific gravity, the modulus of rupture of the average wood of this specific gravity being the figure given by the equation. These percentages are given for both green and air-dry wood.

Big sugarbark.....	Mississippi.....	135	Sumac, staghorn.....	Wisconsin.....	61
Do.....	Ohio.....	154	Sycamore.....	Indiana.....	63
Bitternut.....	do.....	139	Do.....	Tennessee.....	65
Mockernut.....	Mississippi.....	144	Umbrella, Fraser.....	do.....	45
Do.....	Pennsylvania.....	159	Willow:		
Do.....	West Virginia.....	155	Black.....	Wisconsin.....	11
Nutmeg.....	Mississippi.....	112	Western black.....	Oregon.....	43a
Pignut.....	do.....	148	Witch hazel.....	Tennessee.....	114
Do.....	Ohio.....	157			
Do.....	Pennsylvania.....	160			
Do.....	West Virginia.....	161			

CONIFERS.

Cedar:			Pine—Continued.		
Incense.....	California.....	26	Lodgepole.....	Montana, Granite County.....	41a
Western red.....	Montana.....	2	Do.....	Montana, Jefferson County.....	40a
Do.....	Washington.....	10	Do.....	Wyoming.....	34
White.....	Wisconsin.....	1	Longleaf.....	Florida.....	123
Cypress, bald.....	Louisiana.....	62	Do.....	Louisiana, Lake Charles.....	113
Douglas fir.....	California.....	45a	Do.....	Louisiana, Tangipa- hoa Parish.....	96
Do.....	Oregon.....	67a	Do.....	Mississippi.....	95
Do.....	Washington, Che- halis County.....	46a	Norway.....	Wisconsin.....	57
Do.....	Washington, Lewis County.....	75	Pitch.....	Tennessee.....	71
Do.....	Washington and Oregon.....	67	Pond.....	Florida.....	86
Do.....	Wyoming.....	48	Shortleaf.....	Arkansas.....	77
Fir:			Sugar.....	California.....	22
Alpine.....	Colorado.....	4	Table Mountain.....	Tennessee.....	82
Amabilis.....	Oregon.....	39	Western white.....	Montana.....	42
Do.....	Washington.....	18	Western yellow.....	Arizona.....	19
Balsam.....	Wisconsin.....	14	Do.....	California.....	37
Grand.....	Montana.....	36	Do.....	Colorado.....	41
Noble.....	Oregon.....	16	Do.....	Montana.....	32
White.....	California.....	17	White.....	Wisconsin.....	25
Hemlock:			Redwood.....	California, Albion.....	28
Black.....	Montana.....	47	Do.....	California, Korb.....	13
Eastern.....	Tennessee.....	52	Spruce:		
Do.....	Wisconsin.....	15	Engelmann.....	Colorado, Grand County.....	8
Western.....	Washington.....	50	Do.....	Colorado, San Miguel County.....	3
Larch, western.....	Montana.....	84	Red.....	New Hampshire.....	44
Do.....	Washington.....	64	Do.....	Tennessee.....	29
Pine:			White.....	New Hampshire.....	7
Cuban.....	Florida.....	127	Do.....	Wisconsin.....	38
Jack.....	Wisconsin.....	43	Tamarack.....	do.....	81
Jeffrey.....	California.....	33	Yew, western.....	Washington.....	134
Loblolly.....	Florida.....	88			
Lodgepole.....	Colorado.....	31			
Do.....	Montana, Gallatin County.....	35a

LIST OF SPECIES AND REFERENCE NUMBERS FOR FIGURES 5 TO 9.

HARDWOODS.

Species.	Locality.	Reference No.	Species.	Locality.	Reference No.
Alder, red	Washington.	30	Hickory—Continued.		
Ash:			Shagbark.	Mississippi	140
Biltmore.	Tennessee.	91	Do.	Ohio.	152
Black.	Michigan.	60	Do.	Pennsylvania.	143
Do.	Wisconsin.	70	Do.	West Virginia.	153
Blue.	Kentucky.	90	Water.	Mississippi.	141
Green.	Louisiana.	93	Holly, American.	Tennessee.	87
Do.	Missouri.	100	Hornbeam.	do.	149
Pumpkin.	do.	79	Laurel, mountain.	do.	145
White.	Arkansas.	106	Locust:		
Do.	New York.	128	Black.	do.	158
Do.	West Virginia.	83	Honey.	Indiana.	162
Aspen.	Wisconsin.	23	Madrona.	California.	101
Large-tooth.	do.	20	Do.	Oregon.	128a
Basswood.	Pennsylvania.	12	Magnolia.	Louisiana.	66
Do.	Wisconsin.	5	Maple:		
Beech.	Indiana.	110	Oregon.	Washington.	58
Do.	Pennsylvania.	98	Red.	Pennsylvania.	69
Birch:			Do.	Wisconsin.	92
Paper.	Wisconsin.	73	Silver.	do.	56
Sweet.	Pennsylvania.	129	Sugar.	Indiana.	104
Yellow.	do.	107	Do.	Pennsylvania.	108
Do.	Wisconsin.	103	Do.	Wisconsin.	124
Buckeye, yellow.	Tennessee.	9	Oak:		
Buckthorn, cascara.	Oregon.	84a	Bur.	do.	125
Butternut.	Tennessee.	27	California black.	California.	80
Do.	Wisconsin.	21	Canyon live.	do.	103
Chinquapin, western.	Oregon.	46b	Chestnut.	Tennessee.	121
Cherry:			Cow.	Louisiana.	133
Black.	Pennsylvania.	72	Laurel.	do.	116
Wild red.	Tennessee.	24	Post.	Arkansas.	130
Chestnut.	Maryland.	46	Do.	Louisiana.	137
Do.	Tennessee.	40	Red.	Arkansas.	119
Cottonwood, black.	Washington.	6	Do.	Indiana.	118
Cucumber tree.	Tennessee.	59	Do.	Louisiana.	117
Dogwood:			Do.	Tennessee.	97
Flowering.	do.	151	Highland Span-	Louisiana.	94
Western.	Oregon.	125a	ish.		
Elder, pale.	do.	69a	Lowland Spanish.	do.	142
Elm:			Swamp white.	Indiana.	150
Cork.	Wisconsin, Marathon County.	126	Tanbark.	California.	115
Do.	Wisconsin, Rusk County.	120	Water.	Louisiana.	111
Slippery.	Indiana.	102	White.	Arkansas.	132
Do.	Wisconsin.	74	Do.	Indiana.	138
White.	Pennsylvania.	55	Do.	Louisiana, Richland Parish.	136
Do.	Wisconsin.	53	Do.	Louisiana, Winn Parish.	131
Greenheart.		165	Willow.	Louisiana.	109
Gum:			Yellow.	Arkansas.	122
Black.	Tennessee.	68	Do.	Wisconsin.	105
Blue (Eucalyptus).	California.	147	Osage orange.	Indiana.	184
Cotton.	Louisiana.	76	Poplar, yellow (tulip tree).	Tennessee.	35
Red.	Missouri.	54	Rhododendron, great.	do.	85
Hackberry.	Indiana.	90	Sassafras.	do.	51
Do.	Wisconsin.	78	Serviceberry.	do.	156
Haw, pear.	do.	146	Silverbell tree.	do.	49
Hickory:			Sourwood.	do.	89
Big shellbark.	Mississippi.	135	Sumac, staghorn.	Wisconsin.	61
Do.	Ohio.	154	Sycamore.	Indiana.	63
Bitternut.	do.	139	Do.	Tennessee.	65
Mockernut.	Mississippi.	144	Umbrella, Fraser.	do.	45
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Douglas fir.	California.	45a	Do.	Louisiana, Tangipahoa Parish.	96
Do.	Oregon.	67a	Do.	Mississippi.	95
Do.	Washington, Chelan County.	46a	Norway.	Wisconsin.	57
Do.	Washington, Lewis County.	75	Pitch.	Tennessee.	71
Do.	Washington and Oregon.	67	Pond.	Florida.	86
Do.	Wyoming.	48	Shortleaf.	Arkansas.	77
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Black.	Montana.	47	Do.	California, Korb.	13
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Jeffrey.	California.	33	Yew, western.	Washington.	134
Loblolly.	Florida.	88			
Lodgepole.	Colorado.	31			
Do.	Montana, Gallatin County.	35a

FIG. 5.—Relation of modulus of rupture in static bending to specific gravity.

22
20
18
16
14
12

PERCENT OF VOLUME WHEN GREEN.

try conditions to specific gravity.

PERPENDIC

ession perpendicu

SHRINKAGE FROM GREEN TO O.D. CONDITION - PERCENT OF VOLUME WHEN GREEN.

Fig. 6.—Relation of shrinkage from green to oven dry conditions to specific gravity.

FIG. 7.—Maximum crushing strength in compression parallel to grain to specific gravity.

ULAR TO GRAIN-100 LBS. PER SQ. IN.

lar to grain to specific gravity.

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FIG. 8.—Relation of fiber stress at elastic limit in compression perpendicular to grain to specific gravity.

FIG. 9.

TEMPERATURE OF AIR, SPECIFIC GRAVITY

0
10
20
30
40
50
60
70
80
90
100

TEMPERATURE OF AIR

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APPLICATION OF THE EQUATIONS.

Additional data may possibly necessitate the making of some slight changes in the equations given in Table 1 and the diagrams. However, for comparing species and for determining the best utilization of timber, the value of the equations as they are now is not affected by this possibility. It is to be expected that among a large number of species of widely different structure many will be found which do not satisfy very accurately the average equations connecting the various properties with specific gravity. It is often this variation from an average relation which determines the usefulness of a species for a special purpose.

As an example of the use to which the table and diagrams may be put, suppose it is desired to obtain the strength in compression parallel to the grain of a piece of green hemlock (eastern) grown in the southern Appalachian region. Its specific gravity may be determined by any one of several means which may readily be devised, and we will say that it is found to be 0.38. In the table, the "species-locality" which is probably most nearly representative of the region in question is the eastern hemlock from Tennessee, and of this the maximum crushing strength is 29 per cent above the average for woods of the same specific gravity. To find what an average wood of a specific gravity of 0.38 will stand in compression parallel to the grain, we solve the equation $C = 6,900 \times 0.38$, or turn to figure 1 and read from the curve a maximum crushing strength of about 2,600 pounds per square inch. But since the compressive strength of the Tennessee hemlock was 29 per cent high, it is reasonable to expect that the timber in question will also run about 29 per cent high, or that the value would be about 3,300 or 3,400 pounds per square inch ($2,600 \times 1.29 = 3,354$). Any of the other properties of the hemlock under consideration may be estimated in a similar manner.

Again, suppose it is desired to obtain a wood for a use which requires that it be very strong for its weight in its ability to resist a splitting force. Tension perpendicular to grain is the best measure of this. By looking down the column, "Tension, surface of failure radial," it is found that in ability to resist such a force, yellow buckeye is 17 per cent stronger when green and 120 per cent stronger when air-dry than is the average wood of the same specific gravity. It would appear at first that yellow buckeye is the most desirable wood for the purpose, but there is another consideration to be taken into account. Tension perpendicular to the grain varies with the square of the specific gravity; and it must be remembered that those properties (such as tension perpendicular to grain, hardness, work values, and compression perpendicular to the grain) which vary with the higher powers of specific gravity show a large increase in strength

with a comparatively small increase in specific gravity. For instance, a wood with twice the specific gravity of another would be expected to have four times as much strength in tension. Yellow buckeye is a very light wood and woods of more than double its specific gravity may easily be found. Such woods, even though they may run somewhat less in tension strength than the average wood of their weight, may have a tension strength considerably in excess of that of yellow buckeye. Thus, the red oaks, having a specific gravity of about twice that of yellow buckeye, are several times as strong in tension perpendicular to the grain, although they are very little above the average wood of their weight in this respect.

It may be seen from these examples that in comparing different timbers or species, in estimating their various properties, and in finding species with exceptional strength in some properties which may render them valuable for special uses, a knowledge of the specific-gravity strength relations is a valuable aid. It must be borne in mind, however, that such equations can never take the place of tests of species whose properties are unknown. If any particular mechanical property is known, the specific gravity may be approximated and the other properties estimated; even the properties of woods upon which no test data are available can be estimated with a fair degree of accuracy from the results of specific gravity determinations. Nevertheless, it is apparent from a study of the table and diagrams that no one kind of test can replace a complete series of tests.

APPENDIX.

METHOD OF DERIVING EQUATIONS.

In plotting the various points to a natural scale (i. e., the shrinkage or a given mechanical property vs. specific gravity) it was found that in many cases they arranged themselves in the form of a curve, or if their trend was along a straight line, this line would not pass through the origin. Assuming that the function should pass through the origin, i. e., that a piece of wood of zero weight or specific gravity should have zero strength, it was found that in practically every case a curve of the form $f=pG^n$ (where f is the strength value, G the specific gravity, and p and n are constants) would fit the points quite well. This equation is the general equation of the parabola of the n th degree passing through the origin.

In order to simplify the determination of the proper values for the constants p and n the equation was transformed into the logarithmic form, $\log f = \log p + n \log G$. This equation represents a straight line having its slope equal to n and its intercept on the y axis equal to $\log p$. Consequently, to find the constants p and n it is only necessary to plot $\log f$ against $\log G$ on ordinary cross-section paper and find the straight line which best averages the points; then n and $\log p$ are determined from the slope and intercept of this line.

To find the straight line which best averages the points in the logarithmic plot the following plan was adopted:

By successive trials the parallel lines BB and CC (see fig. 9) were so located that 25 per cent of the points were above BB and 25 per cent were below CC and at the same time the vertical distance between the two was a minimum. Two lines (not shown on the figure) were then drawn as follows: Both parallel to BB and CC, one bisecting the distance between them and the other in such a position that 50 per cent of the points were on each side of it. AA was then drawn midway between these two lines and assumed to be the line which best averages the points and best represents the relation between specific gravity and the strength property in question. This method, as can readily be seen, is very likely to produce values of n such that the resulting equations can not be handled without the use of logarithms. As the slope of the lines could in most cases be varied through a considerable angle without appreciably affecting the distance between the lines BB and CC, the slope was so taken that n would be a fraction with the denominator 1, 2, 3, or 4. The solution of the equation is then possible by using the rules for the extraction of square and cube roots. Whenever it happened that more than one direction of the lines BB and CC fulfilled the conditions outlined above, preference was given to that slope which would simplify the form of the equation. The constant p was changed at the same time, so that the new line A'A' passed as nearly through the center of gravity of the points as possible.

The analytical process known as the "method of least squares" can be applied to determining the mathematical relations between two properties of a substance as ascertained from experimental results. This method was used in one or two instances to determine the specific gravity strength relations; but it was found that the long and refined computations essential to the application of this method to so large a number of tests was not justified by the added accuracy of the final determinations. Especially is this true since it is desirable to obtain n to the nearest 0.125 only, and since undue refinement in the value of the constant p is unnecessary in view of the fact that there is a considerable variation of actual results from the values given by any equation which may be derived.

III.—MEASURE OF ACCURACY OF RESPECTIVE EQUATIONS.

[illegible]

III.—ACTUAL VALUE OF EACH PROPERTY FOR EACH "SPECIES-LOCALITY" AS DETERMINED BY TESTS—EXPRESSED IN PERCENTAGE OF EQUATION VALUE.

Alder, red (Washington):	30	119	125	117	122	119	123	139	131	102	119	127	128	117	136	117	138	98	137	119	128	108	110	125	138	139	137
Green:																											
Air-dry:																											
Ash, Baltimore (Tennessee):																											
Green:	91	88	87	80	124	116	104	142	104	88	120	110	130	86	123	114	103	135	121	121	125	124	110	119	109	106	98
Air-dry:					131	98	105	160	95	59	117	108	132	132	126	100	100	143	146	135	117	126	98	128	111	130	100
Ash, black (Michigan):																											
Green:	60	122	118	103	70	90	100	61	139	144	82	88	81	123	66	76	88	86	100	101	103	100	88	132	86	131	98
Air-dry:					128	117	131	92	180	229				174	136	105	115	114	130	114	132	148	106	144	144	124	169
Ash, black (Wisconsin):																											
Green:	70				65	84	82	53	142	162	87	69	114	99		91		92	85	92	93	95	83	112	93		
Air-dry:					80	107	94	76	135	177	83	90	88		84	90	93	81	108	102	106	122	100	156	119	144	108
Ash, blue (Kentucky):																											
Green:	99	84	77	72	120	113	92	146	121	117	102	87	117	108	115	114	86	144	135	135	138	141	128	96	108	92	101
Air-dry:					99	100	82	100	106	129	115	108	123	112	111	97	70	135	135	132	122	112	119	108	112	66	

TABLE 1.—Equations and variations—specific gravity, shrinkage, and strength relations based on tests of small clear pieces, green and air-dry—Con.

Species and locality.	Reference number.		Specific gravity, oven-dry, based on volume at time of test.		Per cent.		Moisture content.		Shrinkage from green to oven-dry condition.			Static bending.								Impact bending, 50-pound hammer.				Compression parallel to grain.				Hardness: load required to embed a 0.444-inch ball one-half its diameter.				Shear.		Cleavage.		Tension.																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																								
	In volume.	Radial.	Tangential.	Per cent of dimensions when green.	Lbs. per sq. in.	Lbs. per sq. in.	 	L

III.—ACTUAL VALUE OF EACH PROPERTY FOR EACH "SPECIES-LOCALITY" AS DETERMINED BY TESTS—EXPRESSED IN PERCENTAGE OF EQUATION VALUE—Continued.

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
Ash, green (Louisiana):																													
Green.....	93				80		99	110	102	94	94	77	112	90	137	86	108	113	101	117	107	105	106	118	102	119	99	119	100
Air-dry.....							98	106	97	104	104	97	91	95	90	90	91	92	95	95	124	121	107	111	93	90	100	111	79
Ash, pumpkin (Missouri):																													
Green.....	100				87	78	128	118	110	139	104	92	103	98	102	92	126	115	101	139	114	118	124	120	109	103	98	100	87
Air-dry.....							100	105	99	100	106	80	108	108	108	83	105	97	104	135	125	130	112	135	120	159	126	114	57
Ash, white (Missouri):																													
Green.....	79				88	80	107	101	86	130	94	69	90	82	101	92	103	100	80	180	121	119	112	124	112	124	121	125	101
Air-dry.....							79	88	81	81	67	60	98	93	117	76	85	89	66	172	122	114	107	134	105	174	114	182	98

Ash, white (Arkansas):	106	80	82	69	104	111	101	100	151	112	105	95	109	79	109	111	97	119	114	109	117	119	106	100	89	111	98
Green.....					105	114	106	102	101	122	78	88	69	81	103	98	88	76	130	128	110	120	101	161	100	132	74
Ash, white (West Virginia):	83	92	87	79	107	108	103	111	130	115	119	101	140	111	105	99	104	114	123	125	124	121	86	111	117	113	
Air-dry.....					106	100	102	119	113	120	115	99	145	111	98	92	100	130	140	126	124	135	100	118	58	150	
Ash, white (New York):	128	82	96	88	116	113	111	108	111	92	114	102	115	99	111	115	103	96	106	112	111	129	119	103	105	112	
Green.....					118	105	102	130	104	76	116	108	121	99	137	103	94	106	121	117	126	125	111	109	80	142	
Air-dry.....																										98	
Aspen (Wisconsin):	23	106	96	113	98	99	90	135	117	125	100	96	121	144	86	87	75	72	69	92	93	87	89	72	68	70	
Green.....																										55	
Air-dry.....																											
Aspen, largetooth (Wisconsin):	20	114	92	132	109	111	129	106	106	86	112	107	135	96	115	111	124	96	132	121	124	114	120	130	135	144	
Green.....					117	107	135	128	104	128	131	122	166	146	143	110	121	106	114	100	98	104	121	100	131	101	
Air-dry.....																										100	
Basswood (Pennsylvania):	12	171	215	176	105	108	133	98	97	108	106	112	130	104	120	107	152	98	94	95	96	97	100	106	105	103	
Green.....					135	115	127	177	177	172	140	136	180	137	165	102	128	85	93	90	97	104	105	161	149	71	
Air-dry.....																										123	
Basswood (Wisconsin):	5	162	206	156	101	101	106	126	135	102	97	97	122	114	73	84	113	96	103	96	93	101	103	115	120	117	
Green.....					113	90	157	108	64	91	62	108	51	55	75	93	185	117	108	123	115	150	158	159	194	108	
Air-dry.....																										144	
Beech (Indiana):	110	105	87	111	90	96	96	86	106	81	103	90	108	98	107	91	91	77	104	104	106	98	108	97	130	102	
Green.....					78	108	99	67	110	123	92	94	87	98	67	93	97	52	87	98	94	98	96	128	123	132	
Air-dry.....																										140	
Beech (Pennsylvania):	98	105	101	118	95	91	84	100	88	69	83	87	74	92	76	84	80	83	102	95	96	97	100	104	117	106	
Green.....					93	90	83	104	73	71	105	101	110	73	90	87	84	82	83	97	94	103	101	90	110	106	
Air-dry.....																										50	
Birch, paper (Wisconsin):	73	116	147	109	70	78	84	59	151	146	82	82	77	137	62	68	71	61	56	77	76	78	78	87	83	92	66
Green.....																											
Air-dry.....																											
Birch, sweet (Pennsylvania):	129	90	113	76	86	91	102	62	107	86	81	97	62	94	76	88	101	61	88	84	90	94	98	83	86	73	84
Green.....					119	105	109	121	102	53	132	117	128	106	109	109	150	83	110	103	107	134	120	96	152		
Air-dry.....																											
Birch, yellow (Pennsylvania):	107	106	131	94	100	99	107	90	144	125	110	100	115	106	91	92	95	62	83	85	86	93	91	88	88	76	74
Green.....					105	104	106	102	144	88	119	118	114	142	129	102	82	83	93	104	101	103	118	66	123	55	88
Air-dry.....																											
Birch, yellow (Wisconsin):	103	111	152	97	86	97	117	59	112	85	96	107	80	81	81	90	123	59	87	91	88	93	86	83	71	72	72
Green.....					127	118	129	123	119	119	97	109	88	130	121	110	108	76	90	104	97	73	73	76	96	121	142
Air-dry.....																										123	

Butternut (Wisconsin):	21	93	107	95	108	113	110	130	149	177	107	110	123	121	115	106	123	90	112	121	121	114	115	154	145	159	159
Green:					144	111	111	210	117		130	117	183	130		117	92	130	97	106	110	131	134	121	135	116	125
Air-dry:																											
Chinquapin, western (Oregon):	468	112	116	105	119	110	95	169	123	106	110	100	128	126	85	105	128	125	135	137	114	119	124	108	110	137	121
Green:																											
Cherry, black (Pennsylvania):	72	87	82	89	103	111	111	102	135	125	110	105	123	107	111	109	114	86	117	121	112	115	117	119	128	114	130
Green:					133	104	101	193	106	71	95	109	86	94	133	111	111	90	134	114	139	110	128	138	81	92	87
Air-dry:																											
Cherry, wild red (Tennessee):	24	124	81	168	99	96	115	100	110	137	98	107	105	118	96	87	103	90	110	108	112	93	101	109	106	104	106
Green:					126	95	115	174	144	270	106	110	125	196	132	90	100	96	139	119	112	109	106	125	132	87	90
Air-dry:																											
Chestnut (Maryland):	46	90	86	97	97	100	93	110	104	114	106	110	108	102	100	97	86	105	108	93	100	117	100	128	125	149	132
Green:					112	104	103	142	82	79	90	100	97	85	115	128	102	119	101	108	105	95	85	112	93	113	94
Air-dry:																											
Chestnut (Tennessee):	40	118	92	103	90	93	94	100	106	103	104	98	124	107	91	83	86	107	116	105	110	103	89	130	111	123	112
Green:					104	87	97	137	86	132	99	87	132	96	108	94	89	104	106	99	96	103	94	133	111	110	127
Air-dry:																											
Cottonwood, black (Washington):	6	109	120	161	117	111	135	121	118	149	119	124	144	139	111	99	126	93	101	103	106	100	105	125	146	117	132
Green:																											
Air-dry:																											
Cucumber tree (Tennessee):	59	109	124	118	112	110	140	94	119	101	109	127	100	111	114	103	133	90	93	93	90	105	117	110	112	107	106
Green:					133	106	129	144	137	128	126	137	130	144	132	101	143	86	103	93	95	99	111	117	99	123	182
Air-dry:																											
Dogwood, flowering (Tennessee):	151	111	116	104	82	84	74	77	121	94	52	43	56	99		83		95	104	118	115	102	103				
Green:					87	76	74	90	83	61	76	75	68	60	76	60	67	87	105	123	114		96	71	101	137	
Air-dry:																											
Dogwood, western (Oregon):	125a	106	116	97	80	88	75	77	117	89	82	87	71	119	66	91	93	106	112	110	106	98	105	78	86	104	102
Green:																											
Air-dry:																											
Elder, pale (Oregon):	69a	116	99	115	87	94	78	96	97	149	85	88	85	120	95	95	111	99	124	135	135	115	105	139	96	126	108
Green:																											
Air-dry:																											
Elm, cork (Wisconsin, Marathon County):	126				83	101	85	77	137	111	101	79	128	101		94		83	89	93	94	99	101	76	87		
Green:					75	105	93	59	131	113	94	94	91	120	79	94		88	90	98	93	107	103	103	114	121	120
Air-dry:																											

TABLE 1.—Equations and variations—specific gravity, shrinkage, and strength relations based on tests of small clear pieces, green and air-dry—Con.

Species and locality.	Reference number.	Specific gravity, oven-dry, based on volume at time of test.	Per cent. Moisture content.	Shrinkage from green to oven-dry condition.	Static bending.										Impact bending, 50-pound hammer.				Compression parallel to grain.				Hardness: load required to embed a 0.444-inch ball one-half its diameter.				Shear.		Cleavage.		Tension.																																																																																																																																																																																																																																																																					
					In volume.					Radial.					Tangential.					Per cent of dimensions when green.	Lbs. per sq. in.	Modulus of rupture.	Modulus of elasticity.	Work to elastic limit.	Inch lbs. per cu. in.	Work to maximum load.	Total work.	Fiber stress at elastic limit.	Lbs. per sq. in.	Modulus of elasticity.	Fiber stress at elastic limit.	Maximum crushing strength.	Modulus of elasticity.	Compression perpendicular to grain, fiber stress at elastic limit.	Lbs. per sq. in.	End surface.	Lbs.	Radial surface.	Tangential surface.	Lbs. per sq. in.	Surface of failure radial.	Lbs. per sq. in.	Surface of failure tangential.	Lbs.	Surface of failure radial.	Lbs. per sq. in.	Surface of failure tangential.	Lbs. per sq. in.	Surface of failure radial.	Lbs. per sq. in.	Surface of failure tangential.	Lbs. per sq. in.	 

III.—ACTUAL VALUE OF EACH PROPERTY FOR EACH "SPECIES-LOCALITY" AS DETERMINED BY TESTS—EXPRESSED IN PERCENTAGE OF EQUATION VALUE—Continued.

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	
Elm, cork (Wisconsin, Rusk County):																														
Green.....	120					89	89	84	102	80	100	139	122	90	92	78	108	86	97	84	95	100	108	108	97	97	104	88	97	83
Air-dry.....																														
Elm, slippery (Indiana):																														
Green.....	102					103	99	107	118	113	98	170	95	126	109	99	115	102	108	106	94	92	112	104	94	110	99	128	115	142
Air-dry.....								84	103	95	76	111	150	92	86	97	105	82	97	83	77	100	112	89	112	109	142	121	127	120
Elm, slippery (Wisconsin):																														
Green.....	74					100	108	108	92	105	101	90	164	172	94	95	94	156	102	97	95	80	106	108	111	120	106	151	131	143
Air-dry.....								109	100	95	132	154	207	112	100	135	147	111	94	99	108	101	93	104	110	102	95	83	81	45

Elm, white (Pennsylvania):	55	112	101	129	103	104	93	121	132	128	96	97	102	93	109	106	110	101	106	132	132	135	138
Green:					120	107	98	166	137	161	116	88	70	85	120	109	114	121	120	121	117	121	98
Air-dry:																							
Elm, white (Wisconsin):	53				79	107	97	67	149	142	109	81	146	112	69	96	93	100	94	87	96	112	126
Green:					95	118	110	94	162	166	108	97	135	147	77	102	106	102	100	110	135	137	
Air-dry:																							
Greenheart:	165	57	76	62	179	132	142	174	45	23	131	139	95	44	88	69	85	83	87	100	61	51	50
Green:					126	105	128	100	55	35	96	117	64	56	116	67	49	72	65	62	51		
Air-dry:																							
Gum, black (Tennessee):	68				101	98	88	117	85	77	105	95	117	94	94	112	106	102	105	116	119	123	121
Green:					108	78	80	154	51	77	110	96	132	64	82	83	81	122	114	100	90	115	76
Air-dry:																							
Gum, blue (California):																							
Green:	147	130	127	143	129	107	126	114	81	68	107	128	79	71	129	121	128	100	102	123	114	98	88
Air-dry:																							
Gum, cotton (Louisiana):																							
Green:	76				104	100	87	122	79	80	83	92	73	77	86	108	94	81	113	106	117	103	152
Air-dry:					76	80	84	76	53	58	74	83	73	61	80	99	85	79	114	106	103	98	122
Gum, red (Missouri):																							
Green:	54				95	99	105								113	90							
Air-dry:																							
Hackberry (Indiana):																							
Green:	90				74	96	97	59	174	166	109	96	123	146	95	96	74	92	104	114	110	111	142
Air-dry:					81	109	87	79	156	149	105	98	115	193	83	97	90	100	121	126	121	104	104
Hackberry (Wisconsin):																							
Green:	78				69	84	76	71	136	129	77	74	80	137	71	76	67	81	103	106	108	106	121
Air-dry:					77	83	75	85	97	130	95	79	117	113	82	78	58	100	92	90	97	103	94
Haw, pear (Wisconsin):																							
Green:	146				70	76	63	66	142	114						72		100	95	108	104	96	
Air-dry:					76	85	67	79	130	69	62	76	46	39	68	78	52	85	104	101	105	88	
Hickory, big shell-bark (Mississippi):																							
Green:	135				117	113	103	114	156	164	111	98	114	156	100	87	97	108				88	
Air-dry:					85	100	96	70	112	128	116	107	125	137		85	106					107	
Hickory, big shell-bark (Ohio):																							
Green:	154				77	89	66	79	190	161	101	74	117	210	48	73	68	96				74	
Air-dry:					68	96	90	40	100			88		138		96	117					92	
Hickory, bitternut (Ohio):																							
Green:	139				96	100	90	88	120	142	130	94	162	135	120	110	94	108				91	
Air-dry:							90	74	94	152	123	120	122	132		107						95	

TABLE 1.—Equations and variations—specific gravity, shrinkage, and strength relations based on tests of small clear pieces, green and air-dry—Con.

Species and locality.	Reference number.	Specific gravity, oven-dry, based on volume at time of test.	Per cent.	Moisture content.	Shrinkage from green to oven-dry condition.		Static bending.						Impact bending, 50-pound hammer.						Compression parallel to grain.				Hardness: load required to embed a 0.444-inch ball one-half its diameter.				Shear.		Cleavage.		Tension.																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																			
					In volume.	Radial.	Tangential.	Lbs. per sq. in.	Fiber stress at elastic limit.	Modulus of rupture.	1,000s of lbs. per sq. in.	Modulus of elasticity.	Inch lbs. per cu. in.	Work to elastic limit.	Inch lbs. per cu. in.	Work to maximum load.	Total work.	Lbs. per sq. in.	Fiber stress at elastic limit.	1,000s of lbs. per sq. in.	Modulus of elasticity.	Maximum crushing strength.	Lbs. per sq. in.	Modulus of elasticity.	Lbs. per sq. in.	Compression perpendicular to grain.	End surface.	Radial surface.	Tangential surface.	Lbs. per sq. in.	Surface of failure radial.	Surface of failure tangential.	Lbs. per sq. in.	Surface of failure radial.	Surface of failure tangential.	Lbs. per sq. in.	Surface of failure radial.	Surface of failure tangential.																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																												

III.—ACTUAL VALUE OF EACH PROPERTY FOR EACH "SPECIES-LOCALITY" AS DETERMINED BY TESTS—EXPRESSED IN PERCENTAGE OF EQUATION VALUE—Continued.

Magnolia (Louisiana): Green.	66	95	122	85	92	96	90	88	167	154	100	102	103	186	86	85	98	112	119	128	125	110	115	113	157	121	156
Air-dry.					96	96	97	104	121	72	101	95	118	90	83	85	127	100	132	135	132	124	100	190	119	135	138
Maple, Oregon (Washington): Green.	58																										
Air-dry.		91	89	95	117	110	98	146	103	72	99	110	93	84	98	107	99	121	130	121	121	122	123	126	144	132	151
Maple, red (Pennsylvania): Green.	69	95	86	103	94	103	118	76	120	96	110	107	118	104	97	97	119	90	114	108	110	109	120	119	139	122	132
Air-dry.					113	104	109	130	121	135	107	110	112	100	114	97	91	98	117	102	99	122	135	139	149	66	104
Maple, red (Wisconsin): Green.	92																										
Air-dry.					100	104	113	85	88	55	119	95	146	83	104	101	98	100	90	85	85	106	115	99	94		135
Maple, silver (Wisconsin): Green.					93	106	104	84	98	80	103	97	113	94	98	101	98	98	114	101	102	104	106	135	130	102	102
Maple, silver (Wisconsin): Green.	56																										
Air-dry.					112	82	85	133	86	91	110	86	171	100	128	87	68	106	145	100	109	118	129	132	137	69	125
Maple, sugar (Indiana): Green.	104																										
Air-dry.					100	103	100	103	85	81	84	95	76	74	87	100	95	59	123	112	114	111	130	100	95	52	108
Maple, sugar (Pennsylvania): Green.	108																										
Air-dry.					107	95	90	122	89	64	116	112	116	89	117	101	80	98	114	114	116	132	132	108	154	104	74
Maple, sugar (Wisconsin): Green.	124																										
Air-dry.					89	95	99	72	63	38	120	94	142	63	103	101	98	104	89	85	85	109	115	95	104		
Oak, bur (Wisconsin): Green.					86	104	103	70	90	62	94	94	94	73	90	101	98	92	112	104	107	108	110	140	138		
Oak, bur (Wisconsin): Green.	125																										
Air-dry.					68	75	59	71	72	67	79	66	85	85	68	82	52	102	100	108	110	98	101	95	97	100	106
Oak, California black (California): Green.					62	63	54	71	56	45	74	66	79	56	53	76	59	79	72	94	94	80	95	43	72	48	83
Oak, chestnut (Tennessee): Green.	80																										
Air-dry.					77	75	63	92	71	42	84	84	83	80	64	75	66	116	106	108	106	96	91	108	113	109	119
Oak, canyon live (California): Green.	163																										
Air-dry.					95	88	76	94	67	46	75	86	55	71	93	97	73	110	96	108	105	100	109	81	100	83	108
Oak, chestnut (Tennessee): Green.	121																										
Air-dry.					106	101	100	90	87	53	99	101	80	73	86	91	94	77	90	96	92	93	94	81	102	86	102
Oak, cow (Louisiana): Green.					93	81	82	97	66	53	101	119	83	87	79	81	98	53	67	81	77	65	79	45	95		
Air-dry.	133																										
Green.					114	104	91	90	88	91	80	85	76	61	90	87	87	77	96	110	109	91	98	83	102	85	93
Air-dry.					65				87	90	44	68	49	38	105	66	38	92	115	64	85	79	98	86	45	71	68

TABLE 1.—Equations and variations—specific gravity, shrinkage, and strength relations based on tests of small clear pieces, green and air-dry—Con.

Species and locality.		Reference number.	Specific gravity, oven-dry, based on volume at time of test.		Per cent.	Moisture content.		Shrinkage from green to oven-dry condition.			Static bonding.						Impact bending, 50-pound hammer.						Compression parallel to grain.				Hardness: load required to embed a 0.444-inch ball one-half its diameter.				Shear.		Cleavage.		Tension.	

Poplar, yellow (tulip tree) (Tennessee):	35	110	116	110	104	103	129	97	94	66	115	122	122	86	102	99	144	100	102	96	94	102	116	125	166	128	180
Green.....					129	99	127	139	108	100	158	142	202	114	123	102	171	102	88	83	92	96	100	144	149	118	164
Air-dry.....					86	77	72	100	92	71	50	67	36	40	90	81	81	107	135	123	120	110	112	84	66	99	119
Rhododendron, great (Tennessee):	85	114	132	102	102	85	67	147	107	101	65	65	69			100											
Green.....					105	86	88	142	112	216	87	83	113	132	89	81	67	164	86	123	112	108	94	122	112	149	110
Air-dry.....					101	88	88	102	74	92	71	87	106	62	103	80	90	81	76	88	99	99	79	86	72	81	79
Sassafras (Tennessee):	156	104	107	96	95	90	102	74	92	71	87	106	62	103	80	90	81	76	88	99	99	79	86	72	81	81	79
Green.....					101	88	88	98	90	95	98	103	85	90	108	91	61	83	79	89	83	64	84				
Air-dry.....					101	88	88	98	90	95	98	103	85	90	108	91	61	83	79	89	83	64	84				
Serviceberry Tennessee):	49	109	95	107	101	104	111	100	117	103	113	111	124	109	93	98	104	108	102	98	98	112	110	128	135	117	130
Green.....					98	80	99	112	69	81	113	106	135	90	101	86	118	85	108	86	90	91	90	110	132	93	90
Air-dry.....					110	80	92	123	83	83	116	98	137	103	104	87	192	91	114	98	94	105	77	106	79	50	55
Sourwood (Tennessee):	89	108	131	104	100	96	103	90	88	68	107	104	107	106	94	93	130	104	106	101	102	106	110	128	132	131	136
Green.....					110	80	92	123	83	83	116	98	137	103	104	87	192	91	114	98	94	105	77	106	79	50	55
Air-dry.....					79	85	72	93	123	190						87		101	112	110	110						
Sumac, staghorn (Wisconsin):	61				131	89	90	203	80	95					129	99	85	132	110	120	100						
Green.....					74	91	85	71	81	61	93	86	104	85	92	89	83	88	112	107	114	102	115	116	159	137	166
Air-dry.....					71	84	91	64	66	45	62	74	54	46	77	88	95	76	86	95	98	80	88	77	126	85	110
Sycamore (Indiana):	63	106	115	95	74	91	85	71	81	61	93	86	104	85	92	89	83	88	112	107	114	102	115	116	159	137	166
Green.....					71	84	91	64	66	45	62	74	54	46	77	88	95	76	86	95	98	80	88	77	126	85	110
Air-dry.....					71	84	91	64	66	45	62	74	54	46	77	88	95	76	86	95	98	80	88	77	126	85	110
Sycamore (Tennessee):	65	112	119	102	94	100	92	86	72	101	105	101	93	96	97	100	91	106	106	104	97	105	112	125	107	146	
Green.....					109	86	103	119	107	92	62	97	44	112	103	84	106	92	87	85	101	76					
Air-dry.....					109	86	103	119	107	92	62	97	44	112	103	84	106	92	87	85	101	76					
Umbrella, Fraser (Tennessee):	45	112	115	110	100	102	117	95	118	98	112	118	119	100	104	95	115	85	118	114	121	104	103	130	132	125	135
Green.....					126	94	107	166	125	119	125	126	142	121	123	91	144	85	112	108	104	94	105	142	144	159	174
Air-dry.....					126	94	107	166	125	119	125	126	142	121	123	91	144	85	112	108	104	94	105	142	144	159	174
Willow, black (Wisconsin):	11	134	70	147	52	71	58	67	269	237	105	55	104	272	54	58	54	77	94	114	121	86	93	154	156	161	185
Green.....					89	77	57	207	174	149	80	68	130	118	73	68	46	102	110	116	110	124	128	144	161	122	143
Air-dry.....					89	77	57	207	174	149	80	68	130	118	73	68	46	102	110	116	110	124	128	144	161	122	143
Willow, western black (Oregon):	43a	120	77	134	95	95	102	102	157	154	100	110	101	144	86	86	119	92	110	128	105	112	110	101	99	106	
Green.....																											
Air-dry.....																											
Witch hazel (Tennessee):	114				100	92	79	114	144	142	104	79	123	85		88		77	100	106	111	86	88				
Green.....					94	82	76	102	104	104	104	79	123	85		88		77	100	106	111	86	88				
Air-dry.....					94	82	76	102	104	104	104	79	123	85		88		77	100	106	111	86	88				

[illegible]

47	Hemlock, black (Montana): Green. Air-dry.	90	110	100	99	95	88	123	123	172	106	93	128	139	114	100	101	94	110	99	100	106	99	87	92	83	101
	Hemlock, eastern (Tennessee): Green. Air-dry.	94	94	108	137	118	123	156	88	114	114	113	121	92	142	129	124	133	102	98	96	121	98	76	67	51	58
52	Hemlock, eastern (Wisconsin): Green. Air-dry.	92	71	87	121	114	103	166	125	110	101	100	123	102	120	117	109	164	140	121	114	128	122	126	79	119	118
15	Hemlock, western (Washington): Green. Air-dry.				126	116	135									147	117										
50	Larch, western (Montana): Green. Air-dry.				93	110	126									102											
84	Larch, western (Washington): Green. Air-dry.	93	89	96	112	98	109	113	66	64	93	108	96	67	115	113	107	90	61	66	67	91	83	53	52	40	45
64	Pine, Cuban (Florida): Green. Air-dry.				110	104	114									117											
127	Pine, jack (Wisconsin): Green. Air-dry.	76	106	76	106	92	110	90	54	72	92	105	74	76	115	111	108	71	53	65	64	86	71	46	44	40	40
43	Pine, Jeffrey (California): Green. Air-dry.	90	90	97	92	93	92	98	87	128	103	90	108	132	106	95	93	101	81	85	90	101	91	98	82	85	94
33	Pine, loblolly (Florida): Green. Air-dry.	93	124	107	103	90	102	117	76	140	103	100	123	107	104	83	106	113	77	90	98	97	96	87	94	83	90
88	Pine, lodgepole (Colorado): Green. Air-dry.	87	114	88	105	95	112	96	72	85	93	105	79	88	100	106	105	89	50	62	66	92	75	62	58	52	50
31	Pine, lodgepole (Gallatin County, Montana): Green. Air-dry.	110	119	113	106	99	112	117	91	61	97	100	109	79	118	99	115	117	69	84	86	96	98	87	76		
35a	Pine, lodgepole (Gallatin County, Montana): Green. Air-dry.	115	130	108	100	102	122	93	85	112	108	116	117	125	98	104	135	95	74	86	93	99	90	81	72	69	64

[illegible]

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