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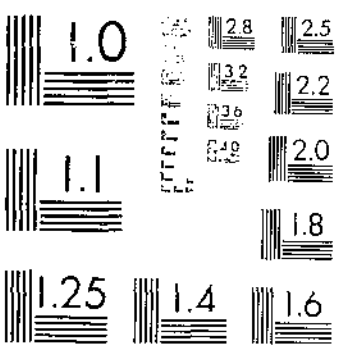

MICROCOPY RESOLUTION TEST CHART
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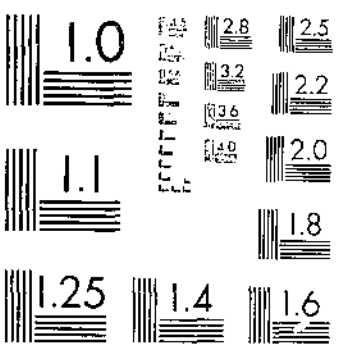

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SPECIFIC GRAVITY AND RELATED PROPERTIES OF SOFTWOOD LUMBER

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CONTENTS

INTRODUCTION

Lumber is frequently compared in terms of its weight, that is, a thousand board feet of lumber of a given species weighs so many pounds. For exact comparisons, however, a more definite term must be used. In this bulletin, therefore, the term specific gravity is used. Specific gravity as used here is based on the weight of the oven-dry wood and the volume when green.

The average specific gravity and the range in specific gravity for the wood of a species are, in the absence of actual test data, criteria of the character of the wood, and may be used to estimate the strength properties; wearing qualities; shrinkage characteristics; and woodworking, painting, gluing, and nail-holding properties; as well as the shipping weights; fuel value; heat conductivity; and pulp yields. Specific-gravity values may be converted into any other form for practical use, provided the moisture-shrinkage relation is known.

[1] Acknowledgment is made of cooperation received in this study from the National Lumber Manufacturers' Association and from various members of the Forest Products Laboratory.

[2] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

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In the past many data have been gathered on the specific gravity of wood, but usually on a small number of logs or trees. It is the purpose of this bulletin to present specific-gravity data, based on tests of sections of boards collected at sawmills throughout the United States, for the lumber of 14 of the commercially important softwood (coniferous) species. The principal difference between this study and former studies is the manner of selecting the test specimens. The data presented here are classified according to the commercial terms or designations of the lumber and not according to botanical classification, although in most instances the two are approximately the same.

In addition to presenting the specific-gravity values for lumber, an effort is made to indicate their effect on the various properties and characteristics of the wood. The effect of specific gravity on some of the properties of wood has been determined, but on many others it is still unknown.

FACTORS THAT INFLUENCE THE WEIGHT OF WOOD

WOOD SUBSTANCE

The most important of the factors that determine the specific gravity of wood is the wood substance itself. The woody structure is in the form of a honeycomb of cells, the walls of which are composed mainly of cellulose and lignin. The specific gravity of any wood, as far as the wood substance is concerned, is proportional to the relation of the volume of the cell walls to that of the cavities or voids, inasmuch as the specific gravity of the cell-wall substance is approximately the same in all woods.

SPRING WOOD AND SUMMER WOOD

In many species there is a marked difference between the wood cells that are formed early in the growing season and those that are formed later. The different types of seasonal growth are known as spring wood and summer wood. The spring-wood cells are large and thin walled, whereas the summer-wood cells are smaller and thick walled, when viewed in cross section. In some species, however, there is no strong contrast between the cells of the spring wood and those of the summer wood. In those woods having very dense summer wood the width of these bands of cells, viewed in cross section, as compared with the total width, permits a segregation of classes according to specific gravity.

MOISTURE

The weight per unit volume of wood at any given time is influenced by the amount of moisture the wood contains. At moisture-content conditions below the fiber-saturation point a change in moisture content has slight effect on the weight per unit volume because the increase or decrease in weight is to a large extent offset by a corresponding increase or decrease in volume. (The condition at which the cell cavity is empty while the cell walls are still saturated is called the "fiber-saturation point.") Above the fiber-saturation point the

weight per unit volume is greatly influenced by a change in moisture content because there is no offsetting change in volume. In all of the softwood species dealt with in this bulletin the addition of

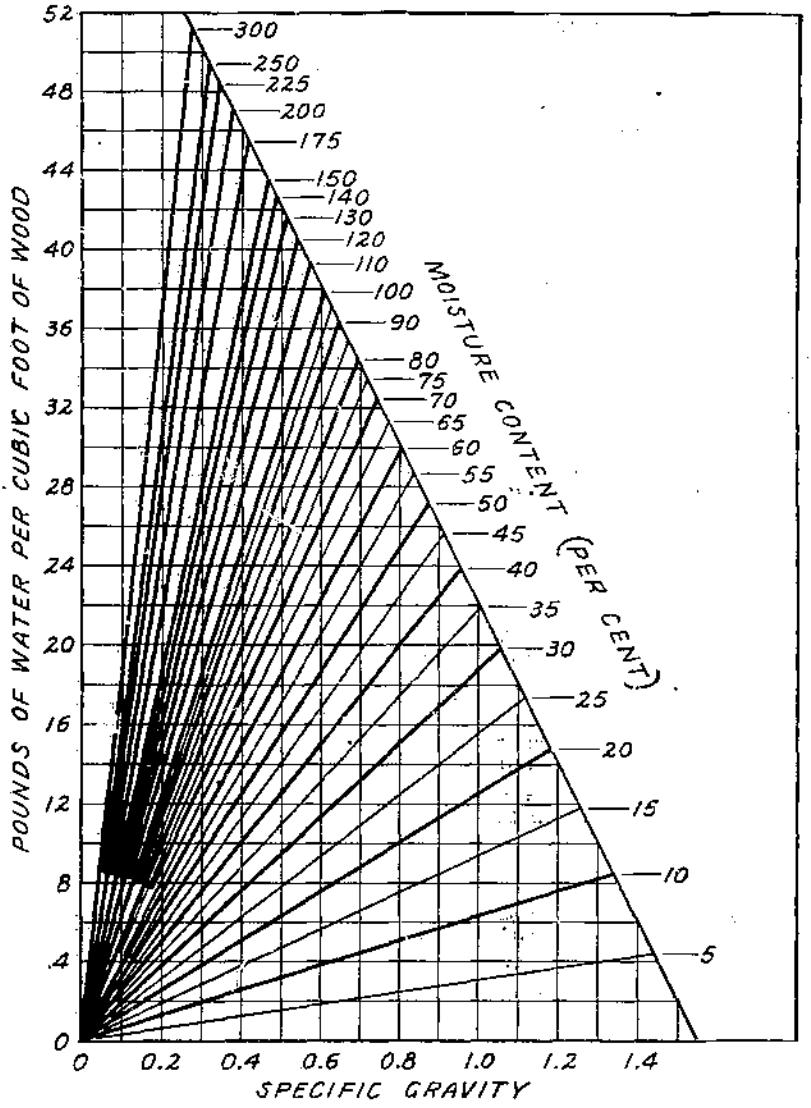

FIGURE 1.—Pounds of water per cubic foot for wood of a given specific gravity and moisture content; also the moisture content of wood at various specific gravities, when completely saturated. The specific gravity for use with this figure is always based on the weight of the oven-dry wood and the volume at whatever moisture content it may be

moisture increases the weight per unit volume because the increase in weight is greater than the corresponding increase in volume.

Figure 1 shows the amount of water in pounds per cubic foot in wood of any specific gravity at any moisture content, where the

specific gravity is based on the weight of the oven-dry wood and the volume of the wood at whatever moisture content it may be.[3] Under all conditions of moisture content above about 25 per cent, the specific gravity is based on the weight of the wood when oven dry and the volume when green, and is constant. Below about 25 per cent the volume varies with varying moisture content. This diagram also indicates the maximum moisture content that may be attained by wood of various specific gravities. The point of intersection with the line from lower right to upper left gives this value.

EXTRACTIVES

Many species of wood contain materials other than wood substance and water that add considerably to the weight (*7*).[4] Among these are extractive materials such as resins, gums, and oils. These materials are present in all parts of the tree, but are usually preponderant in the heartwood and in the butt logs. These extractives affect the properties of wood, but in somewhat different ways from that in which an equal weight of wood substance affects them. In addition to the extractive materials that may be removed by the use of certain solvents, there are other substances present that are relatively insoluble. The influence of these insoluble substances on the weight of the wood is similar to that of the soluble extractives.

COMPRESSION WOOD

The discussion so far has been confined to what may be called normal wood. There is an abnormal form of wood called "compression wood" that occurs rather frequently in coniferous trees. Compression wood is considerably heavier than normal wood and is usually distinguishable by wide annual rings and lack of contrast between the spring wood and the summer wood. Wood with an appreciable amount of compression wood possesses a specific gravity that is out of keeping with its actual properties, because compression wood shrinks differently and is weaker in most strength properties than normal wood of like specific gravity.

DECAY

Decay organisms attack the wood substance; some organisms show a preference for cellulose, whereas others show a preference for lignin. These decay organisms will ultimately decrease the weight and therefore the specific gravity.

GROWTH CONDITIONS

Growth conditions have an effect on the specific gravity of the wood produced by coniferous trees. There are a number of factors included in the term "growth conditions," and it is often difficult to isolate them so that the effect of any one may be definitely demonstrated. Much research has been conducted on this subject, and in some instances it has been possible to show the effect of certain factors on specific gravity.

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[3] Figure 1 was prepared by J. D. MacLean, Forest Products Laboratory.
[4] Italic numbers in parentheses refer to Literature Cited, p. 23.

In the southern pines the wood of high specific gravity is rarely found in very wide or in very narrow growth rings, but usually in rings of medium width (*11*). Southern pine trees growing in open stands when young or in crowded stands when old usually produce wood of low specific gravity. In second-growth stands the trees with large crowns contain wood of low specific gravity, and those with smaller crowns contain wood of high specific gravity unless crowding of the stand has been continued for such a long time that the specific gravity of the wood has been decreased by suppression of the growth of the trees. Wood of the greatest specific gravity is produced by normal trees growing in normal stands. These rules apply only if the soil is of sufficient fertility and if the supply of soil water is ample, especially during the period of summer-wood formation.

POSITION IN THE BOLE

The specific gravity of the wood varies in accordance with its position in the bole of the tree. This position resolves itself into two components, height above the ground and distance from the pith. At a given height in the tree the specific gravity of the wood may remain constant, may increase, or may decrease with distance from the pith. Along the bole of the tree there is a tendency for the wood of many species to become lower in specific gravity as the distance above the ground increases. In a study of redwood (*7*) the butt logs on an average were found to contain wood the specific gravity of which, based on the volume when green and the weight of the oven-dry wood, was 15 per cent greater than that of the top logs.

GEOGRAPHICAL LOCATION

Some species that are widely distributed geographically show different characteristics in different parts of their ranges. Although these differences are due to variation in growth conditions, some of the growth conditions in turn are affected by the geographical location. With certain of the species it is possible to demonstrate the difference in the specific gravity of the wood growing in different regions.

METHOD OF EXPERIMENTATION

SCOPE

The data in this bulletin are based on specific-gravity determinations made on 22,838 sections of boards, termed specimens, collected at 49 sawmills from 14 kinds of softwood lumber. In some instances lumber of two species is included under a single commercial designation. For example, the term "shortleaf" includes the lumber from both loblolly and shortleaf pines, and the term "white fir" includes the lumber from lowland white fir as well as white fir. The term "longleaf" may apply to true longleaf and the denser pieces of the other southern-pine species. Specimens of the same kind of lumber were sometimes collected in different geographical regions. The location of the sawmills and the kinds of lumber sampled at each is shown on the map in Figure 2.

Upper and lower grades of lumber and thicknesses up to and including 2 inches were studied. The specimens were usually selected

at random so that the proportion of heartwood and sapwood would approximate that actually in the lumber. Table 1 gives the number and character of the specimens.

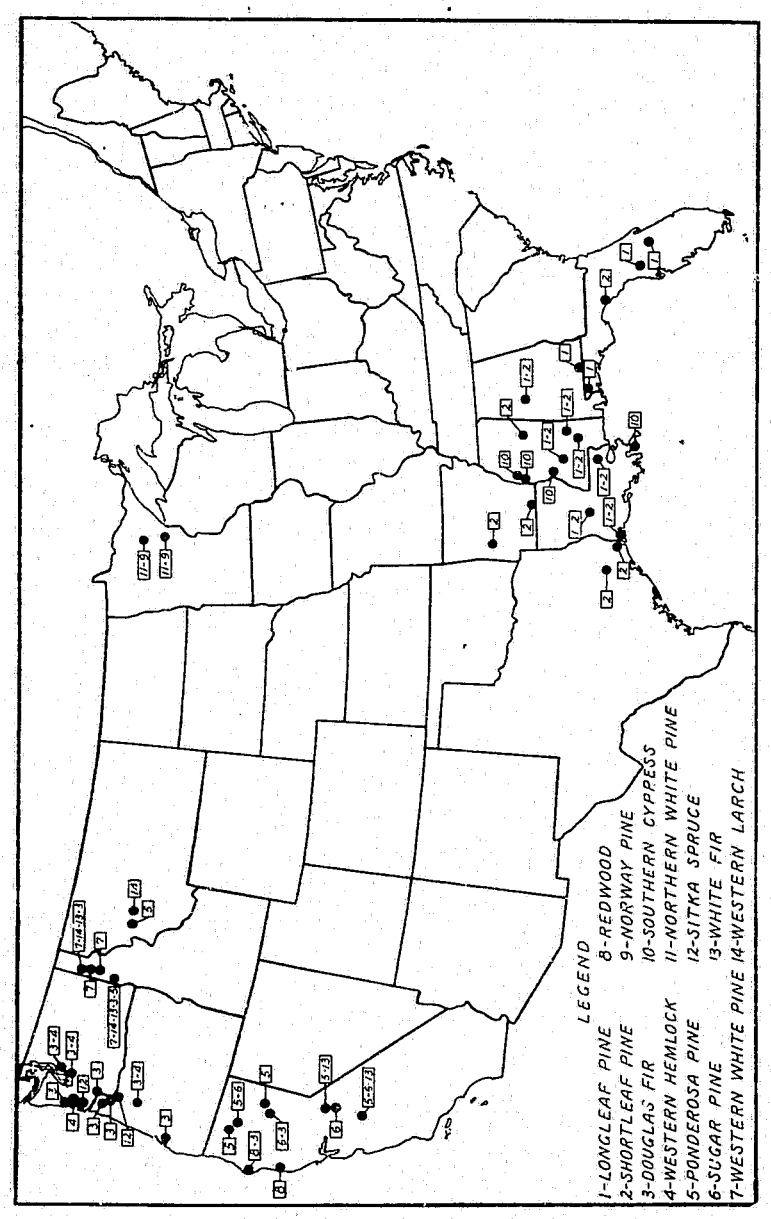

FIGURE 2.—Location of sawmills visited and the kinds of lumber studied at each

TABLE 1.—*The number and character of the specimens from which specific-gravity determinations were made*

Kind of lumber	Species	State where grown	Sawmills at which specimens were collected	Specimens							
				Heartwood, lumber grade				Sapwood, lumber grade			
				Select [1]	Common [2]	Flooring [3]	No designation	Select [1]	Common [2]	Flooring [3]	No designation
			Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
Longleaf pine [4]	*Pinus palustris*	Alabama	2	9	261	398	.....	122	191	335	.....
		Mississippi	3	79	357	174	.....	206	199	299	.....
		Louisiana	3	87	395	295	.....	187	289	318	.....
		Florida	3	.....	.....	.....	651	.....	.....	.....	545
Total			11	175	1,013	867	651	515	679	952	545
Shortleaf pine [4]	*Pinus echinata* and *P. taeda*	Arkansas	2	82	109	198	.....	356	321	327	.....
		Alabama	1	.....	5	.....	.....	26	74	23	.....
		Mississippi	4	14	17	37	.....	291	640	235	.....
		Florida	1	.....	.....	.....	39	.....	.....	.....	167
		Louisiana	3	5	19	85	.....	14	50	151	.....
		Texas	2	47	83	35	.....	114	441	285	.....
Total			13	148	293	355	39	801	1,526	1,021	167
Southern cypress	*Taxodium distichum*	Mississippi	3	121	.....	.....	9	25	.....	.....	11
		Louisiana	1	142	57	.....	.....	11	1	.....	.....
Total			4	263	57	.....	9	36	1	.....	11
Douglas fir	*Pseudotsuga taxifolia*	Washington	4	598	476	.....	.....	228	54	.....	.....
		Oregon	4	886	400	.....	.....	103	21	.....	.....
		California	2	204	219	.....	.....	111	82	.....	.....
		Idaho	2	52	124	.....	.....	3	9	.....	.....
Total			12	1,740	1,219	.....	.....	443	166	.....	.....
Western hemlock	*Tsuga heterophylla*	Washington	3	524	173	.....	.....	219	99	.....	.....
		Oregon	1	201	134	.....	.....	.....	9	.....	.....
Total			4	725	307	.....	.....	219	108	.....	.....

[1] Better than No. 1 Common.
[2] No. 1 Common and below.
[3] Distinction made in southern yellow pine only.
[4] Commercial designation.

TABLE 1.—*The number and character of the specimens from which specific-gravity determinations were made*—Continued

Kind of lumber	Species	State where grown	Sawmills at which specimens were collected	Specimens							
				Heartwood, lumber grade				Sapwood, lumber grade			
				Select	Common	Flooring	No designation	Select	Common	Flooring	No designation
			Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
Sitka spruce	*Picea sitchensis*	Washington	1	266	70			5			
		Oregon	1	108	162			15	32		
Total			2	374	232			20	32		
Ponderosa pine [5]	*Pinus ponderosa*	California	5	403	252			549	125		
		Idaho	1	18	94			41	156		
		Montana	1	6	109			20	103		
Total			7	427	455			610	384		
Sugar pine	*Pinus lambertiana*	California	4	381	103			381	100		
Western white pine	*Pinus monticola*	Idaho	4	252	472			126	329		
Redwood	*Sequoia sempervirens*	California	2	585				[6] 10			
White fir [4]	*Abies concolor* and *A. grandis*	Idaho	2		598						
		California	2	9	580						
Total			4	[7] 9	[7] 1,178						
Western larch	*Larix occidentalis*	Idaho	2	460	172			83	2		
		Montana	1		103						
Total			3	460	275			83	2		
Northern white pine	*Pinus strobus*	Minnesota	2	110	153			114	9		
Norway pine	*Pinus resinosa*	do	2	19	49			29	24		

[4] Commercial designation.
[5] Formerly called western yellow pine.
[6] Sapwood samples of redwood were not used in the final analysis on account of their small number.
[7] Separation of heartwood and sapwood impracticable.

COLLECTION OF SPECIMENS

Each specimen was cut approximately 2 feet from one end of a board or piece of lumber. Two crosscuts were made at this point, producing a section of the board about 1 inch in dimension along the grain. In cutting these sections serious defects, such as knots, were avoided. For each kind or item of lumber sampled, 40 or more sections were usually procured. About 300 sections from each species at each mill, representing the clear wood of all products of the log except large timbers, were obtained. The specimens that contained any appreciable quantity of compression wood were segregated from the rest. In addition, all specimens were subjected to a visual examination which resulted in the discarding of a few showing evidences of decay.

SPECIFIC-GRAVITY DETERMINATIONS

The specific-gravity values used for the comparison of species are based on the volume when green and the weight of the oven-dry wood. Since the specimens were cut from lumber that had been seasoned to some extent and consequently had shrunk, the first step was to bring them back to their green dimensions. This was accomplished by soaking them in cold water for four to five weeks. Previous experiments had demonstrated that specimens of this character would, for all practical purposes, recover their green dimensions on soaking in cold water for this length of time. The volumes of the soaked specimens were determined by displacement. In order to determine the weight of the wood when oven-dry, the specimens were placed in a drying oven and kept at a temperature of about 212° F. until a constant weight had been reached. Previous experiments had shown that leaching took place during the soaking period, but so little leaching occurred that it had no practical effect on the specific-gravity determinations.

DISCUSSION OF RESULTS

SPECIFIC-GRAVITY DATA

The specific-gravity data permit comparisons to be made in a number of ways. These fall naturally under two heads, comparison between different species and comparison within a species. The former consists of comparisons of all the lumber of a species, of heartwood alone, and of sapwood alone. Within a species comparisons are made between heartwood and sapwood, regions, mills, and lumber qualities.

In many of the softwoods studied, the average specific gravity of the heartwood was consistently greater than that of the sapwood. This is probably due largely to a greater percentage of extractive materials in the heartwood. In the consideration of specific-gravity values for those species having this difference between heartwood and sapwood, and possessing considerable sapwood, it is necessary to take into account the relative amount of heartwood and sapwood in those specimens upon which the values are based. A difference in specific gravity due to a difference in the proportion of heartwood to sapwood is a perfectly legitimate difference, but the method of collecting the test specimens gave no assurance that the percentage of heartwood and sapwood was fairly representative although it was probably

approximately so. In those species possessing considerable sapwood the percentage obtained in the specimens is affected considerably by the relative amounts of upper-grade and lower-grade lumber tested. The percentage of heartwood and sapwood is influenced greatly by the age of the timber, young timber possessing a larger percentage of sapwood than mature timber. Table 2 gives the average specific gravity for heartwood and for sapwood of each kind of lumber and also the percentage of heartwood in the specific-gravity specimens.

TABLE 2.—*Average specific gravity of heartwood and of sapwood for the various kinds of lumber studied, and the percentage of heartwood*

Kind of lumber	Average specific gravity		Comparative figure [1]		Heartwood [2]
	Heartwood	Sapwood	Heartwood	Sapwood	
			Points	*Points*	*Per cent*
Longleaf pine [3]	0.507	0.477	100	100	50
Shortleaf pine [3]	.510	.460	90	96	19
Western larch	.449	.430	79	90	90
Douglas fir	.440	.426	78	89	83
Western hemlock	.394	.395	69	83	76
Norway pine	.394	.376	69	79	56
Southern cypress	.388	.355	68	74	88
Ponderosa pine	.377	.359	66	75	47
Western white pine	.363	.360	64	75	61
Sitka spruce	.363	.333	64	70	82
Redwood	.358		63		98
Northern white pine	.348	.338	61	71	68
White fir [3]	.328	.328			(4)
Sugar pine	.326	.324	57	68	50

[1] The species of highest specific gravity has been designated 100 points, so that the comparison with other species can be made at a glance.
[2] These values are based on the proportion of heartwood specimens to the total number.
[3] Commercial designation.
[4] Heartwood and sapwood not distinguishable.

SPECIES AND REGIONAL COMPARISONS

Figures 3 to 8 show specific-gravity comparisons based on various factors. These figures show the average specific gravity and the variability in specific gravity. The average specific gravity is shown in each diagram by the vertical line that extends slightly above the top of the horizontal bar. The plain central area in each diagram shows points between which 50 per cent of the specific-gravity values fall, while the limits of the diagram show the approximate total range (99.95 per cent) of the values (*12*, *18*). In most of these charts the species are arranged in order of the magnitude of their average specific gravities.

The data shown in Figure 3 are based on tests on all of the specimens of each species. Each diagram for each species includes the specimens from different regions, different sawmills, heartwood, sapwood, and different lumber grades and sizes. Table 3 summarizes these data so that a comparison of species may readily be made, both with respect to the average specific gravity and range in specific gravity.

Figures 4 and 5 show that the average specific gravity of the heartwood of the different species varies more than the average specific gravity of the sapwood of the different species. For example, the difference between the average specific gravity of the heart-

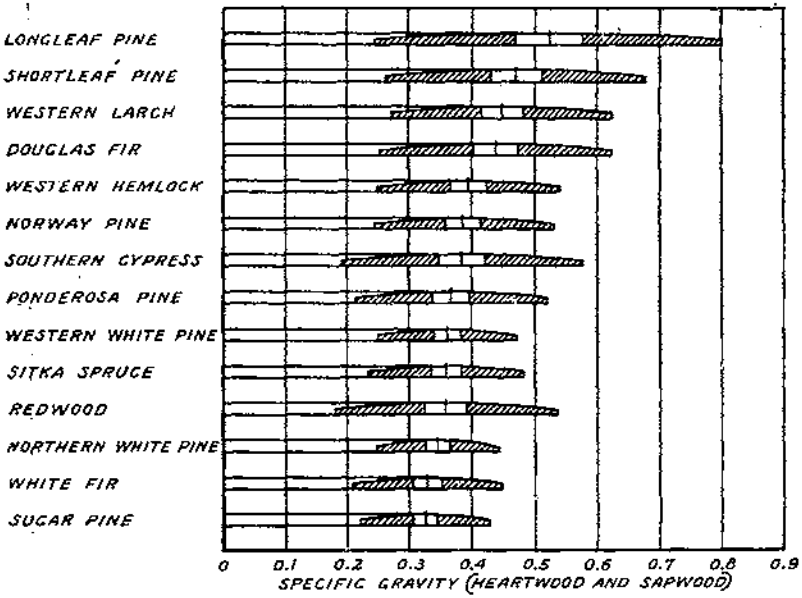

FIGURE 3.—Specific-gravity averages and ranges of the lumber of the various softwood species

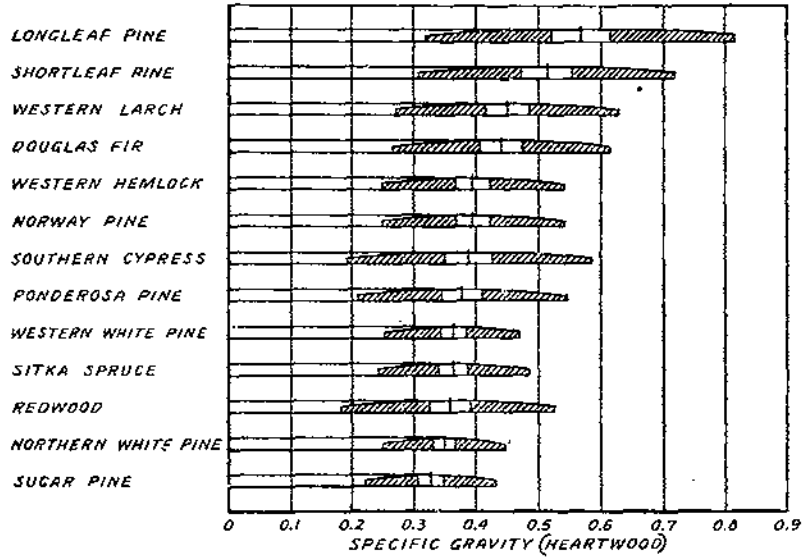

FIGURE 4.—Specific-gravity averages and ranges of the heartwood of the various softwood species

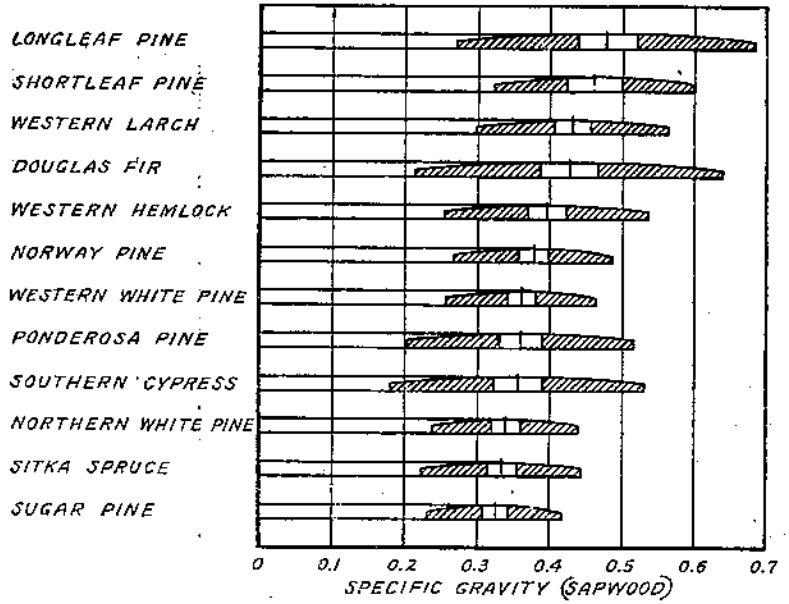

FIGURE 5.—Specific-gravity averages and ranges of the sapwood of the various softwood species

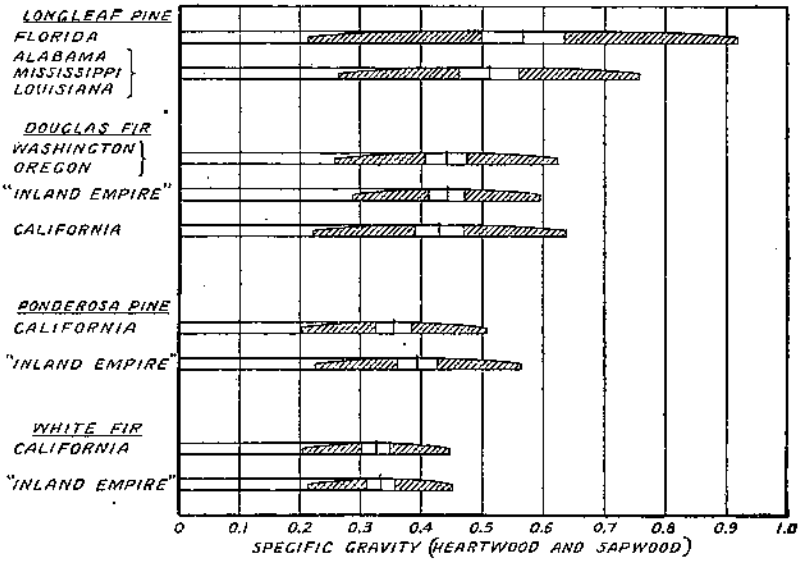

FIGURE 6.—Specific-gravity averages and ranges of the lumber of various softwood species from different regions. The "Inland Empire" region comprises northwestern Montana, Idaho north of the Salmon River, Washington east of the Cascade Mountains, and the northeastern tip of Oregon

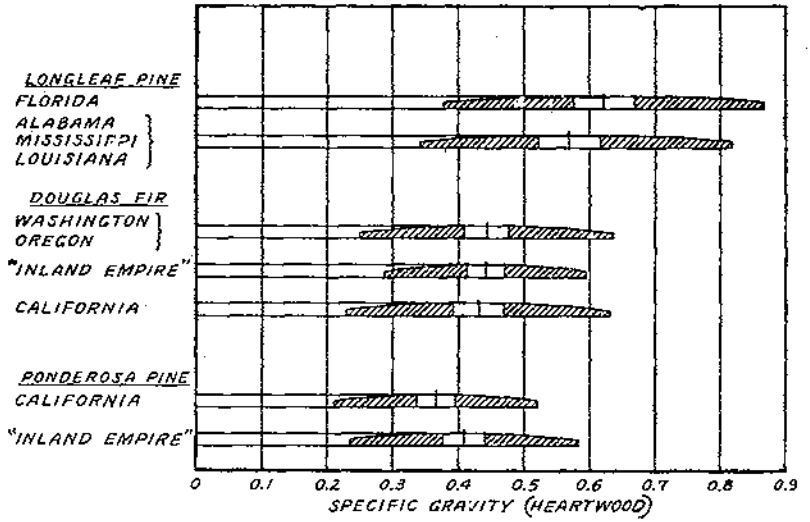

FIGURE 7.—Specific-gravity averages and ranges of the heartwood of several softwood species from different regions

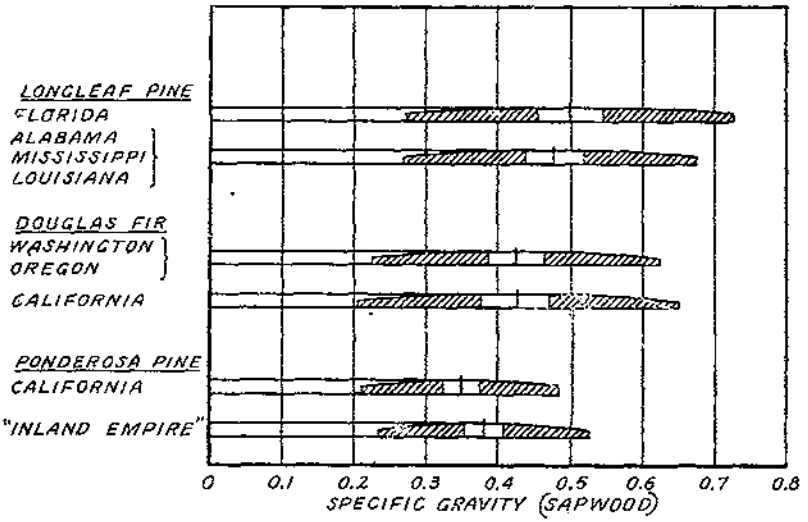

FIGURE 8.—Specific-gravity averages and ranges of the sapwood of several softwood species from different regions

wood of longleaf pine, which has the highest average specific gravity, and that of the heartwood of sugar pine, which has the lowest average specific gravity, is 0.241, whereas the difference between the average specific gravity of the sapwood of longleaf pine and that of sugar pine is 0.153. Since the heartwood in most softwoods contains more extractives than the sapwood, the greater differences in specific-gravity values of the heartwood may be largely attributed to these extractives.

TABLE 3.—*Comparison of the various kinds of softwood lumber studied with respect to the specific gravity*

Kind of lumber	Average value		Range in values	
	Actual	Comparative figure [1]	Difference between maximum and minimum [2]	Comparative figure [3]
		Per cent		*Per cent*
Longleaf pine [4]	0.522	100	0.556	100
Shortleaf pine [4]	.470	90	.416	82
Western larch	.448	86	.352	74
Douglas fir	.438	84	.368	79
Western hemlock	.394	75	.290	69
Norway pine	.386	74	.286	69
Southern cypress	.384	74	.384	93
Ponderosa pine	.366	70	.300	79
Western white pine	.361	69	.224	58
Sitka spruce	.359	69	.250	65
Redwood	.358	69	.354	93
Northern white pine	.345	66	.196	53
White fir [4]	.320	63	.240	68
Sugar pine	.325	62	.208	60

[1] Based on the average specific gravity of longleaf pine.
[2] The approximate total range, that is, 99.95 per cent of the specific-gravity values will fall within this range.
[3] Ratio of the range to the mean within each species, compared with that of longleaf pine, which is taken as 100.
[4] Commercial designation.

MILL COMPARISONS

There is considerable difference in the specific gravity of lumber of the same species cut at different sawmills. These differences may be caused by climatic factors, site factors, or characters or type of the timber stand. The timber may be quite different because of differences in exposure, rainfall, or soil. Moreover, one mill may be logging virgin timber, while another mill in the same locality may be logging young open-grown timber with a large percentage of sapwood. The effect of all of these various factors that influence specific gravity is manifested in the product of a sawmill. Table 4 gives the average specific gravity of the heartwood and of the sapwood separately for the lumber studied at the individual mills. If the heartwood and sapwood values were combined the mill averages would be influenced by the relative amounts of heartwood and sapwood in the specimens collected, which proportion might or might not be similar to that of the product of the mill as a whole.

TABLE 4.—*Average specific gravity of lumber, heartwood and sapwood separately, at the individual mills*[1]

Kind of lumber	State where grown	Average specific gravity	
		Heartwood	Sapwood
Longleaf pine[2]	Florida	0.611	0.511
		.636	.501
		.578	.483
	Mississippi	.535	.465
		.555	.476
		.544	.481
	Louisiana	.552	.459
		.573	.500
		.554	.468
	Alabama	.545	.465
		.527	.467
Weighted average		.567	.477
Western hemlock	Washington	.393	.383
		.403	.406
		.414	.414
	Oregon	.371	[3].370
Weighted average		.394	.395
Southern cypress	Louisiana	.400	.350
	Mississippi	.372	
		.377	.360
		.365	.360
Weighted average		.388	.355
Sitka spruce	Washington	.366	.332
	Oregon	.359	.334
Weighted average		.363	.333
Western larch	Idaho	.475	.431
		.436	[3].416
	Montana	.415	
Weighted average		.449	.430
Sugar pine	California	.332	.326
		.340	.334
		.326	[3].316
		.310	.312
Weighted average		.326	.324
Western white pine	Idaho	.340	.347
		.370	.362
		.363	.373
		.367	.348
Weighted average		.363	.360
Shortleaf and loblolly pine[2]	Florida	[3].504	.473
	Mississippi	[3].500	.476
Shortleaf and loblolly pine[2]	Mississippi		0.448
		0.504	.464
		[3].514	.447
	Arkansas	.494	.441
		.508	.455
	Texas	.521	.480
		[3].528	.496
	Louisiana	[3].490	.452
		[3].553	.475
		.533	.480
	Alabama	[3].413	.459
Weighted average		.510	.460
Norway pine	Minnesota	.384	[3].349
		.407	.378
Weighted average		.394	.376
Ponderosa pine	California	.409	.359
		.376	.353
		.347	.354
		.368	.350
		.349	.326
	Idaho	.405	.371
	Montana	.410	.386
Weighted average		.377	.359
Northern white pine	Minnesota	.345	.333
		.357	.339
Weighted average		.348	.338
Douglas fir	Washington	.436	[3].450
		.440	.443
		.460	.418
		.450	.425
	Oregon	.425	.396
		.448	.417
		.425	[3].395
		.474	[3].418
	Idaho	.464	[3].442
		.431	[3].451
	California	.396	.370
		.467	.464
Weighted average		.440	.426
Redwood	California	.361	
		.356	
Weighted average		.358	

[1] Separation of heartwood and sapwood in white fir is impracticable. The average specific gravity of the white fir from two California mills was 0.320 and 0.324 and from two "Inland Empire" mills, 0.325 and 0.338; the weighted average for the species was 0.328.
[2] Commercial designation.
[3] Inadequate number in sample.

COMPARISON OF AVERAGE SPECIFIC GRAVITY OF DIFFERENT QUALITIES OF LUMBER OF THE SAME SPECIES

The upper grades of lumber are obtained primarily from the outer portions of the logs, which contain the clear wood, and more from lower logs than from top logs. In most softwood species, the specific gravity of the sapwood is lower than that of the heartwood. In

mature or overmature timber the outer portion of the tree is made up of fine ringed wood that is often of low specific gravity. All of these things tend to cause a difference in specific gravity between upper and lower grade lumber within a species.

Table 5 gives a comparison of the average specific gravity of the upper and the lower grades of lumber studied. In some species the Select, or upper-grade, lumber is higher in average specific gravity than the Common, or lower-grade, lumber, whereas in others it is lower. The data are inadequate to offer an explanation of these differences.

TABLE 5.—*Average specific gravity and percentage of heartwood in Select and Common lumber* [1]

Kind of lumber	Select				Common			
	Heartwood	Sapwood	All wood	Heartwood	Heartwood	Sapwood	All wood	Heartwood
				Per cent [2]				*Per cent* [2]
Longleaf pine [3] [4]	0.559	0.468	0.499	33.5	0.540	0.469	0.508	57.6
Shortleaf pine [3] [5]	.515	.467	.474	15.5	.498	.448	.450	16.5
Southern cypress	.383	.351	.379	88.0	.406	.376	.401	84.5
Douglas fir (Washington and Oregon)	.449	.425	.444	82.0	.433	.424	.432	92.0
Western hemlock	.397	.401	.398	77.0	.383	.384	.383	72.0
Sitka spruce	.410	.337	.406	94.0	.364	.331	.360	88.0
Ponderosa pine (California)	.367	.347	.356	44.5	.365	.350	.358	53.5
Ponderosa pine ("Inland Empire")	.422	.393	.402	29.0	.406	.378	.390	43.5
Sugar pine	.318	.316	.317	49.0	.331	.325	.330	51.0
Western white pine	.375	.375	.375	66.5	.351	.351	.351	59.5
Western larch	.443	.405	.443	98.5	.451	.430	.448	97.5
Northern white pine	.357	.338	.346	43.0	.342	.332	.341	44.5
Norway pine	.426	.382	.399	39.5	.382	.369	.377	57.0

[1] Where specimens of one quality only were collected at a sawmill, they were not used in computing this table.

[2] Based on proportion of heartwood specimens to the total number.

[3] Commercial designation.

[4] The specific-gravity values of the heartwood, sapwood, and all wood, and percentage of heartwood of longleaf pine flooring were 0.559, 0.475, 0.513, and 47.7, respectively.

[5] The specific-gravity values of the heartwood, sapwood, and all wood, and percentage of heartwood of shortleaf pine flooring were 0.521, 0.470, 0.484, and 28.0, respectively.

COMPARISON OF PRESENT DATA WITH PREVIOUSLY PUBLISHED DATA

Many data have been published previously on the specific gravity of various species. The chief difference between the previously published data and those presented in this bulletin is that the present data were obtained by a different method of sampling. Table 6 affords a comparison of the present data, based on specimens obtained from lumber, with that based on specimens obtained from the top of the butt log of selected trees (*9*). For most of the species the data based on the lumber designation represent wood from a greater number of trees more widely distributed over the geographical range of the species than do the botanical data. There are some relatively small differences between these sets of data, which is not surprising considering the different method of collecting the specific-gravity specimens and differences in the method of making the tests. Such small differences may or may not be important, depending on the use to which the wood is put.

TABLE 6.—*Comparison of lumber data with botanical data*

Kind of lumber	Lumber data		Botanical data [1]		
	Average specific gravity	Specimens	Average specific gravity	Trees tested	Specimens
		Number		*Number*	*Number*
Longleaf pine	[2] 0.52	5,397	0.55	34	806
Loblolly pine	[2] .47	4,350	.50	10	1,190
Shortleaf pine			.49	12	
Western larch	.45	820	.48	13	214
Douglas fir (Washington and Oregon)	.44	2,704	.45	34	1,020
Douglas fir ("Inland Empire")	.44	186	.41	10	113
Western hemlock	.39	1,359	.38	18	689
Norway pine	.39	121	.44	5	126
Southern cypress	.38	377	.42	26	479
Ponderosa pine	.37	1,676	.38	31	579
Western white pine	.36	1,179	.36	14	211
Sitka spruce	.36	658	.37	25	1,392
Redwood	.36	585	.39	16	504
Northern white pine	.35	386	.34	18	269
White fir	[2] .33	1,157	.35	45	278
Sugar pine	.33	965	.35	9	191

[1] Markwardt, L. J. (*9*).

[2] Species unknown, based on commercial designation.

RELATION BETWEEN SPECIFIC GRAVITY AND VARIOUS PROPERTIES

The specific gravity of wood through its effect on the properties has to a large degree controlled the uses to which wood has been put. There are other properties besides specific gravity that determine the suitability of a wood for specific purposes but specific gravity is a very important one. Considerable information concerning the effect of specific gravity on some properties exists, but for many others it is lacking.

MECHANICAL PROPERTIES

The mechanical properties of wood are related to its specific gravity and increase with an increase in specific gravity (*9*, *10*). For uses where it is important that the wood be hard, stiff, or resistant to breaking it is important that the specific gravity be high. In a number of softwood species the pieces of wood of high specific gravity may be separated from those of low specific gravity by a visual inspection. Where it is necessary to select wood for maximum-strength properties it is usually sufficient merely to discard those pieces showing a small percentage of summer wood. (P. 2.) Figure 9 shows the relation of specific gravity to the modulus of rupture for 114 species of hardwoods and 48 species of softwoods (*8*). The correlation within a species of specific gravity and modulus of rupture is closer than among species.

In general, wood of high specific gravity will resist wearing better than wood of low specific gravity; therefore dense wood is the more suitable for flooring. Species in which there is a marked difference between the heavy summer wood and the light spring wood usually possess a greater tendency to sliver than do other species. Edge-grained material wears more uniformly than flat-grained material, especially in woods with a great contrast between the summer wood and spring wood.

The nail-holding properties of wood are closely related to its specific gravity, the denser the wood the greater its nail-holding power (*15*).

Although there is relatively little information on nail splitting, such experiments as have been made indicate that the denser woods have a greater tendency to split in nailing. It is also general opinion

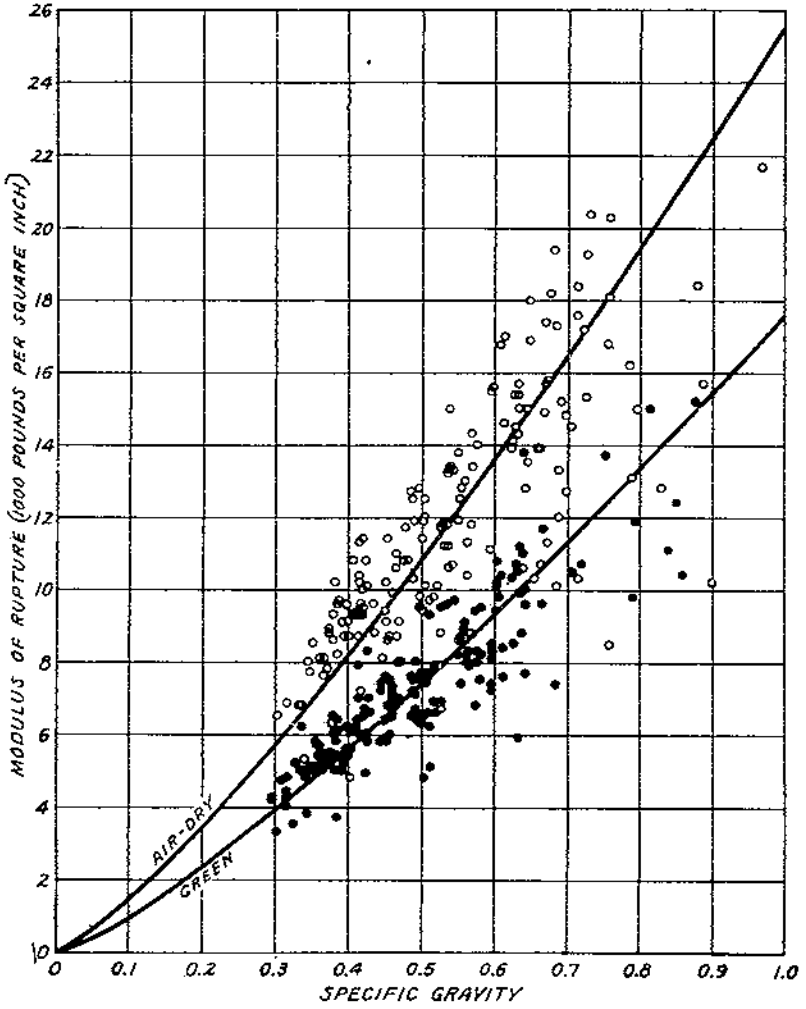

FIGURE 9.—Relation of modulus of rupture to specific gravity in hardwoods of 114 species and softwoods of 48 species, both green and air dry

that of two woods with similar specific gravities the one having the greater contrast between the summer wood and the spring wood has a greater tendency to split (*4*).

DRYING RATE

As far as is known, no information exists concerning the effect of specific gravity alone on the rate of percentage moisture loss from

wood. The differences in the drying rates of the various softwood species are probably due to factors other than specific gravity. A dense wood loses more moisture, in an absolute sense, than a light wood in losing the same percentage of moisture, since in the dense wood each percentage of moisture content represents a greater amount of moisture. If a piece of wood is heavy because it has a large amount of extractive material the drying will probably be hindered somewhat by the presence of the extractives.

EQUILIBRIUM MOISTURE CONTENT

For practical purposes it has always been maintained that wood, regardless of the species, heartwood or sapwood, specific gravity, and the like, comes to a constant moisture-content condition when exposed to a given temperature and relative humidity for a prolonged period. Indications that there are some deviations from this general rule have been found, especially with respect to the influence of different quantities of extractives. Experiments with the heartwood of longleaf and of shortleaf pine indicate that the moisture-content equilibrium values for resinous woods are lower than for wood that is not so resinous (*19*).

SHRINKAGE

In general, woods of high specific gravity shrink in volume more than woods of low specific gravity, although this relation is subject to considerable irregularity both among different species and among individual pieces of the same species. When the shrinkage of wood is resolved into its three components—tangential, radial, and longitudinal—the relationship with specific gravity becomes more complex. In the plane perpendicular to the axis of the tree, dense wood shrinks more than light wood; in the plane parallel to the axis of the tree dense wood shrinks less than light wood. Compression wood, which is very dense abnormal wood, has a much greater shrinkage in a longitudinal direction than normal wood, and a smaller shrinkage in the other two directions than normal wood. Various investigators (*3*, *13*) have found that thick-walled cells shrink more tangentially and radially than do thin-walled cells. This would explain why dense woods, which possess a large proportion of thick-walled cells, ordinarily shrink more than light woods.

WOODWORKING PROPERTIES

Specific gravity plays an important part in the ease with which a wood may be cut, planed, shaped, or otherwise worked. Light woods are more easily worked than heavy woods. Other properties besides specific gravity also affect the workability of wood. A light wood with lack of contrast between summer wood and spring wood works more easily than one with great contrast between summer wood and spring wood. Straightness of grain is also necessary if wood is to be easily worked.

Among the softwood species dealt with in this bulletin there is a slight contrast between the summer wood and spring wood in northern white pine, sugar pine, and western white pine; in Sitka spruce, western hemlock, white fir, redwood, and southern cypress there is a moderate contrast between the summer wood and spring

wood; in ponderosa pine there is a pronounced contrast between spring wood and summer wood, but the width of the summer wood varies greatly; and in Norway pine, Douglas fir, western larch, shortleaf pine, and longleaf pine there is a great contrast between the summer wood and spring wood.

PAINTING PROPERTIES

As a general rule woods of low specific gravity are more satisfactory for painting purposes than woods of high specific gravity (*2*). Besides specific gravity, however, the width of the bands of dense summer wood is important. Two woods might have the same average specific gravity, but the one of faster growth would have wider bands of summer wood and would therefore be less satisfactory for painting. In exterior painting the paint fails first on the summer wood of wide-ringed wood, especially on the tangential faces where there are larger areas of summer wood than on the radial ones. For interior painting a light wood with slight contrast between the summer wood and spring wood is preferable to a wood with marked contrast, because the grain in the latter will often show through an enameled surface.

GLUING PROPERTIES

In general specific gravity affects the gluing properties of softwoods, but gluing of wood is such a complicated matter that it is impossible to state any simple relation (*14*). A light wood with slight contrast between summer wood and spring wood is easier to glue than a heavy wood with great contrast between summer wood and spring wood because it is difficult to make the glue adhere satisfactorily to the hard, dense summer-wood bands. The denser woods are preferred for strong glued joints because in joints made under proper gluing conditions failure is usually in the wood and not in the glue; consequently the denser woods make the strongest glued joints. It is possible, however, under proper gluing conditions to make joints in practically all softwoods as strong as the wood itself. Special care must be taken with the dense woods.

RAISED GRAIN

Raised grain results in the corrugated appearance of the surfaces of lumber and is caused by the summer wood either projecting above or being depressed below the level of the spring wood. This may be brought about either by the pounding of the harder summer wood into the softer spring wood in the process of surfacing in the manufacture of lumber or by the differential shrinkage of the spring wood and summer wood (*6*). Raised grain usually occurs where there is a marked contrast between summer wood and spring wood, but it is not influenced by the specific gravity of the wood as a whole.

SHIPPING WEIGHTS

The weight of a given quantity of lumber depends on the amount of wood substance plus extractives and the amount of water present. At a definite moisture content the lumber that has the highest specific-gravity value will weigh the most. Another factor that contributes to this difference in weight is the fact that a certain percent-

age of moisture in a heavy wood represents more absolute water than the same percentage in a lighter wood. Table 7 gives the actual weight per thousand board feet as well as that based on one standard commercial size of the softwood lumber studied. To obtain the weight of any pattern or size of lumber at 12 per cent moisture content it is necessary only to find the ratio of the actual cross section of the lumber to the cross section on which the lumber scale is based, and multiply the values in the next-to-the-last column of Table 7 by this ratio. For the 1 by 8 inch boards given in Table 7 this ratio is 0.732, determined in the following manner:

$$\frac{\frac{25}{32}\times 7\frac{1}{2}}{1\times 8}=\frac{0.781\times 7.5}{1\times 8}=\frac{5.85}{8.0}=0.732$$

where $\frac{25}{32}$ by $7\frac{1}{2}$ inches are the actual cross-sectional dimensions and 1 by 8 inches are the cross-sectional dimensions on which the lumber scale is based.

TABLE 7.—*Weight of lumber in pounds per thousand board feet at 12 per cent moisture content*

Kind of lumber	Specific gravity	Calculated weight of dry wood in 1 cubic foot of green wood [1]	Calculated weight of dry wood in 1,000 board feet of green wood [2]	100 per cent minus shrinkage [3]	Weight of 1,000 board feet of dry wood at 12 per cent moisture content [4]	Values in preceding column plus 12 per cent for the weight of water [5]	Calculated weight of 1,000 board feet of 1 by 8 inch lumber [6]
		Pounds	*Pounds*	*Per cent*	*Pounds*	*Pounds*	*Pounds*
Longleaf pine [7]	0.522	32.57	2,714	93.5	2,903	3,251	2,380
Shortleaf pine [7]	.470	29.33	2,444	93.5	2,614	2,928	2,143
Western larch	.448	27.96	2,330	94.0	2,479	2,776	2,032
Douglas fir	.438	27.32	2,277	94.0	2,422	2,713	1,986
Western hemlock	.394	24.59	2,049	94.0	2,180	2,442	1,788
Norway pine	.386	24.09	2,007	94.0	2,135	2,391	1,750
Southern cypress	.384	23.96	1,997	95.0	2,102	2,354	1,723
Ponderosa pine	.366	22.84	1,903	95.0	2,003	2,243	1,642
Western white pine	.361	22.53	1,877	94.5	1,986	2,224	1,628
Sitka spruce	.359	22.40	1,867	94.0	1,986	2,224	1,628
Redwood	.353	22.34	1,862	96.5	1,930	2,162	1,583
Northern white pine	.345	21.53	1,794	96.0	1,869	2,093	1,532
White fir [7]	.329	20.53	1,711	95.0	1,801	2,017	1,476
Sugar pine	.325	20.28	1,690	96.0	1,760	1,971	1,443

[1] Specific gravity times 62.4.
[2] Value in preceding column times 83.3. There are 83.3 cubic feet in a thousand 1 by 1 by 12 inch board feet.
[3] One hundred per cent minus approximately one-half of the total volumetric shrinkage.
[4] Weight of wood per thousand board feet divided by 100 minus percentage shrinkage.
[5] Weight of wood per thousand board feet divided by 100 minus percentage shrinkage, plus weight of water.
[6] Values in preceding column multiplied by 0.732, which is the ratio of the actual cross-sectional area of the boards to the cross-sectional area on which the lumber scale is based.
[7] Commercial designation.

The figures in Table 7 are based on the average specific-gravity values obtained in the present study. Because there is considerable variation in specific gravity among pieces of the same species, the weight of any particular thousand board feet of lumber at a moisture content of 12 per cent will seldom be the same as that given in Table 7 but, in the absence of actual weighing, will be a close approximation of the weight and may be used for most practical purposes.

TREATING PROPERTIES

In the treating of wood for preservative purposes the effect of specific gravity, if any, is completely obscured by other more important factors.

FUEL VALUE

The heating value of a given volume of dry wood is in direct relation to its specific gravity (*5*). A given weight of one wood has approximately the same value as a like weight of another wood, although the presence of certain extractives alters this relation by increasing the fuel value.

HEAT CONDUCTIVITY

Wood depends for its heat-insulating properties on its cellular structure (*1*, *16*). Wood is composed of small cells which, when dry, contain air in the cavities. In general the efficiency of an insulating material depends on the percentage of air space and the distribution of this air space. One large air space is not nearly so effective as a large number of small spaces. Wood has naturally a very advantageous distribution of the air space. The greater the percentage of air space, provided it is advantageously distributed, the better the insulation. Light wood contains a greater proportion of air space than dense wood; therefore, the insulating property of wood varies inversely as its specific gravity.

PULP YIELD

When calculating the yield of pulp from a given volume of wood, such as a cord, the yield is related to the specific gravity of the wood (*17*). Extractive materials, although contributing to the specific gravity of wood, contribute nothing to the pulp yield, as this is made up chiefly of the stable cellulose originally in the wood.

SUMMARY

In classifying softwood lumber with respect to specific gravity three things should be considered: (1) The average specific gravity, (2) the lack of uniformity among individual pieces, and (3) the contrast between the spring wood and the summer wood. Longleaf pine, shortleaf pine, western larch, and Douglas fir are heavy woods; western hemlock, Norway pine, southern cypress, ponderosa pine, western white pine, Sitka spruce, and redwood are moderately heavy woods; and northern white pine, white fir, and sugar pine are light woods. Longleaf pine, southern cypress, redwood, shortleaf pine, Douglas fir, ponderosa pine, and western larch have a great range in specific gravity; western hemlock and Norway pine have a moderate range; and white fir, Sitka spruce, sugar pine, western white pine, and northern white pine have a small range. In longleaf pine, shortleaf pine, western larch, Douglas fir, and Norway pine there is a strong contrast between the spring wood and the summer wood; in ponderosa pine also there is a pronounced contrast between spring wood and summer wood, but the width of the summer wood varies greatly; in southern cypress, Sitka spruce, western hemlock, white fir, and redwood there is a moderate contrast; in western white pine,

northern white pine, and sugar pine there is only a slight contrast between the spring wood and the summer wood.

The range in specific gravity is wide in different kinds of softwood lumber and also in individual pieces of lumber of the same species. In most softwood species an appreciable difference is found between the specific gravity of heartwood and of sapwood.

As an index to the usefulness or suitability of lumber for definite purposes, not only is it important to know the average specific gravity but also the range in specific gravity. With such knowledge it is often possible to select individual pieces of a weak species exceeding in strength the average of a stronger one, and to segregate the lumber of a species into specific-gravity classes, so that each class may be directed to the uses for which it is best suited. It is also important to take into consideration the contrast between the summer wood and the spring wood.

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