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TESTS OF WESTERN YELLOW PINE CAR SILLS, JOISTS, AND SMALL CLEAR PIECES.

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CONTENTS.

INTRODUCTION.

Western yellow pine, *Pinus ponderosa*, is distributed over the greater part of the western United States, but reaches it best development in California. A variety of the species, known as *scopulorum*, occurs in the Rocky Mountains. It is a smaller tree but has the same botanical structure. Western yellow pine is long lived, attaining an age of from 350 to 500 years. The wood is camparatively weak, light, soft, and fine-grained. The heartwood is reddish-yellow, and the sapwood almost white. In some regions the wood is quite resinous; in others it is so free from resin that it is marketed as "white pine."

The tests described in the following pages were made for the purpose of gaining a definite knowledge of the mechanical properties of the wood. They began early in 1912, at the Seattle laboratory of the Forest Service, U. S. Department of Agriculture, and have been carried on in cooperation with the University of Washington. The Western Pine Manufacturers' Association contributed the test material. The tests were similar to those made by the Forest Service on Douglas fir, western hemlock, western larch, and various other species, so that a direct comparison of mechanical properties can be made.

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MATERIAL TESTED.

The logs from which the test material was taken were cut near Springdale, Stevens County, Wash., during September, 1911, and sawed into car sills and joists at a mill at Spokane, Wash., during the same month. Representatives of the Forest Service selected the sills and joists; and, upon the arrival of the selected timbers at the Seattle laboratory, an inspector of the Pacific Coast Lumber Manufacturers' Association graded the sills in accordance with the association's export rules for 1911.

The material tested was of two classes:

(1) Car sills and joists representative of the various commercial grades found on the market. The car sills were 5 by 8 inches by 16 feet; and the joists, 2 by 10 inches by 16 feet.

(2) Small, clear pieces cut from the uninjured portions of the tested beams. Tests on these were made to determine the relative strength of wood free from knots and other natural defects, as compared to that of the various grades of market material.

METHODS OF TEST.[1]

BENDING.

Two methods of applying the load were used in these tests: "Third-point" loading was used for testing the large beams and center-loading for the small, clear sticks. In the "third-point" method the load is applied at two points, each one-third the length of the span from the end supports. This method of loading represents as nearly as practicable the conditions to which the beam will be subjected in structural use. Plate I shows the method of loading and of preventing buckling in the joist tests.

COMPRESSION PARALLEL TO THE GRAIN.

In the tests in compression parallel to the grain the load was applied to the upright specimens. The specimens were of two sizes, 5 by 5 by 24 inch sticks taken from the car sills and 2 by 2 by 8 inch sticks taken from both car sills and joists.

COMPRESSION AT RIGHT ANGLES TO THE GRAIN.

The tests in compression at right angles to the grain consisted in applying the load to an iron plate 4 inches in width and extending across the upper side of 5 by 8 by 20 inch specimens lying horizontal on the platform of the machine.

MOISTURE DETERMINATIONS.

From each test piece a moisture disk 1 inch in thickness was cut and dried to a constant weight at 100° C. The moisture disks taken

[1] The methods of making the various tests on western yellow pine and the definitions of the different strength factors referred to are fully discussed in Forest Service Circular 38, "Instructions to Engineers in Timber Tests."

from the large beams were cut into a number of sections, in order to determine the distribution of the moisture in the timber. The proportion of moisture was found by multiplying the difference between the original and dry weights by 100 and dividing the result by the dry weight of the wood.

WEIGHT PER CUBIC FOOT OVEN DRY.

The weight per cubic foot oven dry is based on the volume when tested and the weight oven dry. It does not represent the actual weight of wood in any condition of seasoning, and is used merely as an indication of the density of the material tested.

TABLE 1.—*Results of tests of 5-inch by 8-inch by 16-foot car sills, western yellow pine, 15-foot span, third-point loading. Green.*

Grade. (Pacific Coast Lumber Manufacturers Association Rules for 1911.)	Number of tests.	Rings per inch.	Moisture.	Weight per cubic foot.		Fiber stress at elastic limit per square inch.	Modulus of rupture per square inch.	Modulus of elasticity per square inch.
				As tested.	Oven dry.			
			Per cent.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Thousands of pounds.*
Select:								
Average	6	18.0	50.7	38.0	25.2	3,167	4,910	1,455
Maximum	1	21.5	62.0	43.8	28.2	3,850	5,840	1,808
Minimum	1	14.2	33.5	33.3	22.4	2,400	4,055	1,140
Merchantable:								
Average	11	15.3	37.1	36.1	26.4	2,828	4,745	1,224
Maximum	1	21.0	56.9	43.7	32.0	3,740	5,750	1,436
Minimum	1	9.7	26.2	29.3	23.2	2,040	3,830	990
Common:								
Average	9	14.4	34.4	33.6	25.1	2,432	4,100	1,125
Maximum	1	17.5	54.3	35.8	26.9	3,110	4,935	1,240
Minimum	1	10.7	26.9	30.2	21.9	1,805	3,060	866
All grades:								
Average	26	15.6	39.3	35.7	25.7	2,769	4,560	1,243
Maximum	1	21.5	62.0	43.8	32.0	3,850	5,840	1,808
Minimum	1	9.7	26.2	29.3	21.9	1,805	3,060	866
					Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Select, average					100	100	100	100
Merchantable, average					105	89	97	84
Common, average					100	77	84	77

TABLE 2.—*Results of tests of 5-inch by 8-inch by 16-foot car sills, western yellow pine, 15-foot span, third-point loading. Air seasoned.*

Grade.	Number of tests.	Rings per inch.	Moisture.	Weight per cubic foot.		Fiber stress at elastic limit per square inch.	Modulus of rupture per square inch.	Modulus of elasticity per square inch.
				As tested.	Oven dry.			
			Per cent.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Thousands of pounds.*
Select:								
Average	3	16.6	12.7	29.9	26.5	4,020	6,260	1,614
Maximum	1	21.2	13.4	30.7	27.2	5,120	7,760	1,720
Minimum	1	13.5	11.4	28.9	25.9	2,820	4,460	1,548
Merchantable:								
Average	13	14.8	12.6	30.6	27.2	4,136	6,395	1,503
Maximum	1	21.5	14.9	36.3	32.7	5,760	9,730	1,909
Minimum	1	12.1	11.0	26.6	23.7	2,713	3,895	1,191
Common:								
Average	7	15.1	12.5	30.6	27.2	3,552	5,546	1,514
Maximum	1	19.5	12.9	32.8	29.0	4,780	7,780	1,988
Minimum	1	12.0	11.6	25.1	22.5	2,610	4,495	1,245
All grades:								
Average	23	15.2	12.6	30.6	27.2	3,976	6,119	1,521
Maximum	1	21.5	14.9	36.3	32.7	5,760	9,730	1,988
Minimum	1	12.0	11.0	25.1	22.5	2,610	3,895	1,191
					Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Select, average					100	100	100	100
Merchantable, average					103	103	102	93
Common, average					103	88	89	94

GENERAL OBSERVATIONS.

Before testing each specimen was weighed and measured. The proportions of sapwood and summerwood were also recorded. After the test a sketch of each specimen was made showing the failures and all natural defects. All large green beams were photographed after the test and the air-seasoned ones both before and after the test, the four sides of the timbers being shown in each case. All strength values obtained from the tests were calculated in pounds per square inch and are given in tabulated form along with the other test data.

STRENGTH VALUES SHOWN BY THE TESTS.

CAR SILLS.

Tables 1 and 2 give the average strength values of green and air-seasoned car sills of the commercial grades. These tables also include a comparison of the strength values of the different grades, the values of the merchantable and common grades being expressed in percentages of the values of the select grade.

JOISTS.

The results of the tests on green and air-seasoned joists are shown in Table 3. The average values for all grades have been grouped together.

TABLE 3.—*Results of tests of 2-inch by 10-inch by 16-foot joists, western yellow pine, 15-foot span, third-point loading.*

	Number of tests.	Rings per inch.	Moisture.	Weight per cubic foot.		Fiber stress at elastic limit per square inch.	Modulus of rupture per square inch.	Modulus of elasticity per square inch.
				As tested.	Oven dry.			
			Per cent.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Thousands of pounds.*
Green, all grades:								
Average	46	17.3	35.8	35.7	26.4	2,830	4,272	1,266
Maximum	1	28.0	123.1	55.2	35.6	4,047	6,105	1,705
Minimum	1	7.5	20.2	28.5	21.0	2,147	1,980	731
Air seasoned, all grades:								
Average	33	16.7	13.2	31.6	28.5	4,502	6,640	1,595
Maximum	1	29.0	14.8	37.7	33.2	7,025	9,520	2,148
Minimum	1	10.5	12.2	25.5	22.5	1,811	2,320	1,088

SMALL CLEAR PIECES.

Tables 4 and 6 give the results of the bending tests on the clear pieces taken from the tested car sills and joists. The results of tests in compression parallel to the grain, on both large and small specimens taken from the car sills, are contained in Table 5. The results of tests on small specimens taken from the joists are given in Table 7. Table 10 contains the results of a limited number of tests in compression at right angles to the grain made on clear pieces taken from the tested car sills.

COMPARISON OF RESULTS OF TESTS ON LARGE AND SMALL PIECES.

The ratios of the average strength values in bending of small clear pieces to the average strength values of the sills and joists from which they were taken are shown in Tables 8 and 9. These tables indicate that the difference in strength between large timbers and small clear pieces is considerably smaller for the air-seasoned than for the green material. In other words, the increase in strength as the result of seasoning is less in the structural sizes than in the clear sticks. This is due to the development of defects in the large timbers during seasoning.

In the tests in compression parallel to the grain, only a slight difference was shown between the strength values of the large pieces taken from the sills and those of the small pieces taken from both the sills and joists. This is largely due to the fact that all of the specimens used in these tests were free from defects.

TABLE 4.—*Results of bending tests of small clear sticks taken from western yellow pine car sills, 2-inch by 2-inch by 30-inch beams, 28-inch span.*

	Number of tests.	Rings per inch.	Moisture.	Weight per cubic foot.		Fiber stress at elastic limit per square inch.	Modulus of rupture per square inch.	Modulus of elasticity per square inch.
				As tested.	Oven dry.			
			Per cent.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Thousands of pounds.*
Green:								
Average	52	14.9	36.1	35.5	25.6	3,156	5,831	1,178
Maximum	1	31.0	126.1	56.8	29.4	4,240	7,615	1,680
Minimum	1	7.5	24.9	27.7	21.7	2,120	3,910	775
Air seasoned:								
Average	48	13.6	11.5	29.6	26.6	6,705	10,661	1,442
Maximum	1	28.0	13.7	39.3	34.6	9,615	14,840	1,980
Minimum	1	7.0	10.2	24.0	21.7	3,762	7,350	995

TABLE 5.—*Results of tests in compression parallel to grain on clear specimens taken from western yellow pine car sills.*

Seasoning and size of sticks.	Number of tests.	Rings per inch.	Moisture.	Weight per cubic foot.		Crushing strength at maximum load per square inch.
				As tested.	Oven dry.	
Green, 4 inch by 4 inch by 16 inch:			*Per cent.*	*Pounds.*	*Pounds.*	*Pounds.*
Average	25	14.1	43.2	35.9	25.0	2,830
Maximum	1	21.0	80.9	45.7	28.8	3,910
Minimum	1	8.0	27.4	27.4	21.4	2,195
Air-seasoned, 5 inch by 5 inch by 24 inch:						
Average	23	11.5	12.5	29.6	26.3	5,758
Maximum	1	22.0	14.4	34.4	30.5	7,002
Minimum	1	8.0	11.3	24.8	22.1	4,460
Green, 2 inch by 2 inch by 8 inch:						
Average	52	14.9	39.4	34.9	25.3	2,896
Maximum	1	31.0	130.4	57.1	29.5	3,890
Minimum	1	7.5	24.0	27.4	20.3	2,240
Air-seasoned, 2 inch by 2 inch by 8 inch:						
Average	47	13.5	11.4	29.9	26.8	6,334
Maximum	1	28.0	15.7	38.5	33.3	8,160
Minimum	1	7.0	10.0	24.2	21.5	4,770

RELATION BETWEEN STRENGTH VALUES.

The chart (fig. 1) showing the relation between strength values was made by plotting along one vertical line the various strength values for each green car sill and the corresponding air-seasoned sill. The order of succession of the pieces was obtained by first plotting the values for the modulus of rupture of the green sills, beginning with the maximum and descending in order. The other values for the same beams were then plotted on the same vertical lines. The chart shows that, with one exception, the strengths of the air-dry beams are in the same order as those of the green beams to which they are matched. However, the air-seasoned material shows a greater range in values than the green material. This is due, in part at least, to the variable moisture content of the air-dry sills. It will be observed that the pairs of pieces having the greater modulus of rupture in the green condition showed the larger increase in strength in air-seasoning. The other strength properties of the air-seasoned material are somewhat more erratic than those of the green. This also is partly due to variable moisture content.

Table 11 is a summary of the averages of all the preceding tables. It gives, in condensed form, the corresponding values of green and air-seasoned material of each size tested, and also the percentage of increase of those values in seasoning.

RELATION BETWEEN PHYSICAL CHARACTERISTICS AND MECHANICAL PROPERTIES.

DEFECTS.

The natural defects found in timber have an important influence on its strength values. In order to secure a more specific knowledge of this influence the timber was graded before being tested.

TABLE 6.—*Results of bending tests of small clear sticks taken from western yellow pine joists, 2-inch by 2-inch by 30-inch beams, 28-inch span.*

Seasoning.	Number of tests.	Rings per inch.	Moisture.	Weight per cubic foot.		Fiber stress at elastic limit per square inch.	Modulus of rupture per square inch.	Modulus of elasticity per square inch.
				As tested.	Oven dry.			
			Per cent.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Thousands of pounds.*
Green:								
Average	91	16.5	33.4	35.8	26.9	3,530	5,560	1,149
Maximum	1	41.0	133.7	58.3	40.8	6,080	8,530	1,765
Minimum	1	5.5	19.0	26.6	21.0	1,910	3,630	583
Air seasoned:								
Average	58	17.1	11.7	30.9	27.6	6,622	11,045	1,611
Maximum	1	27.0	13.5	38.3	34.2	10,270	15,960	2,236
Minimum	1	8.0	10.6	24.8	22.1	2,890	6,670	964

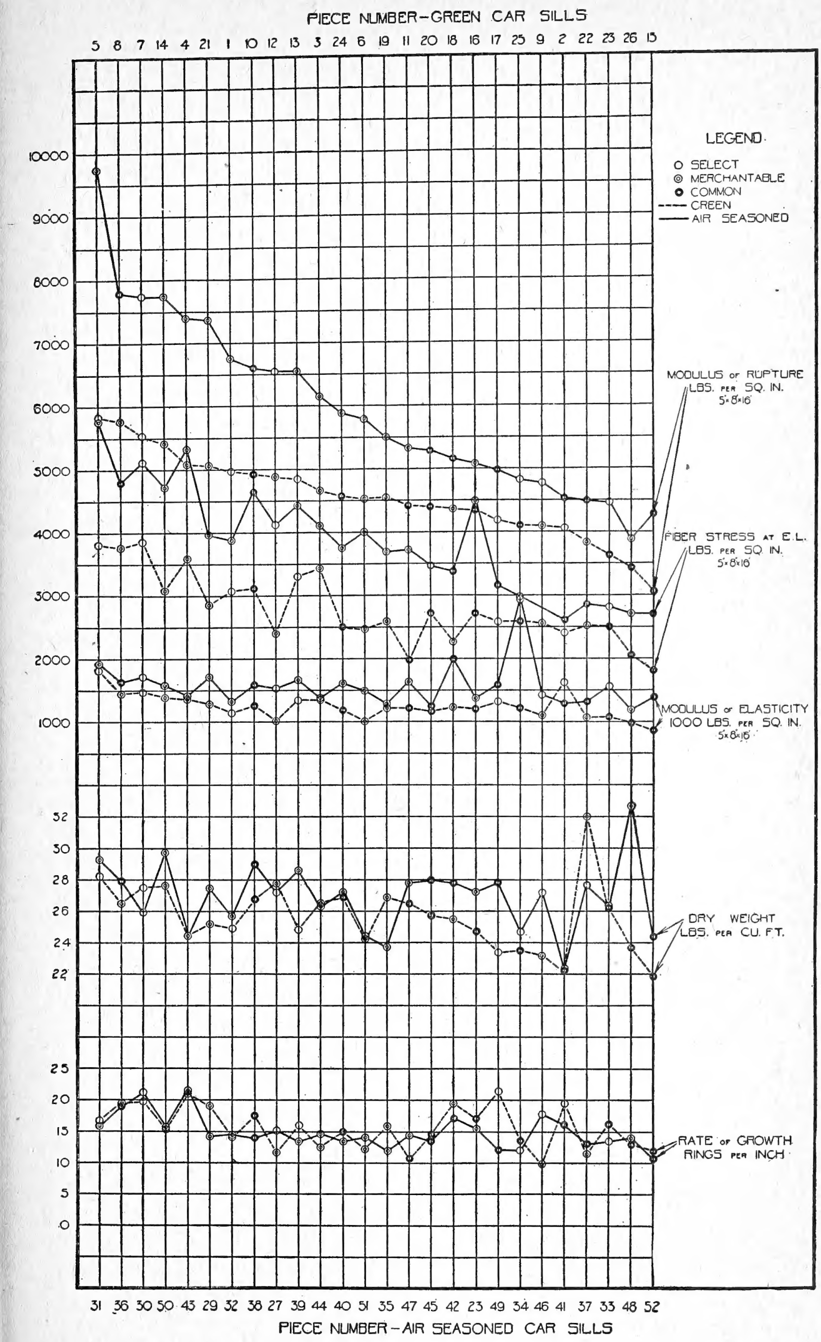


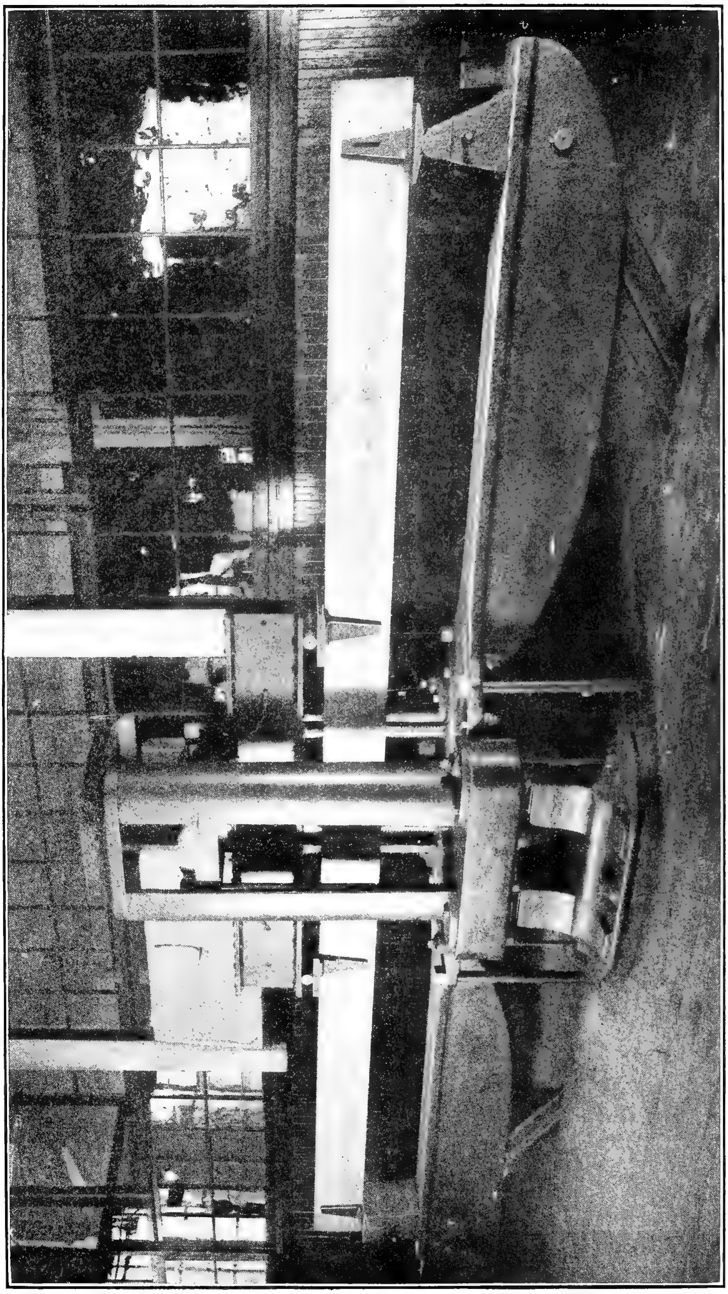
FIG. 1.—Relation between modulus of rupture and other test values for green and air-seasoned car sills.

TABLE 7.—*Results of tests in compression parallel to grain on clear specimens taken from western yellow pine joists.*

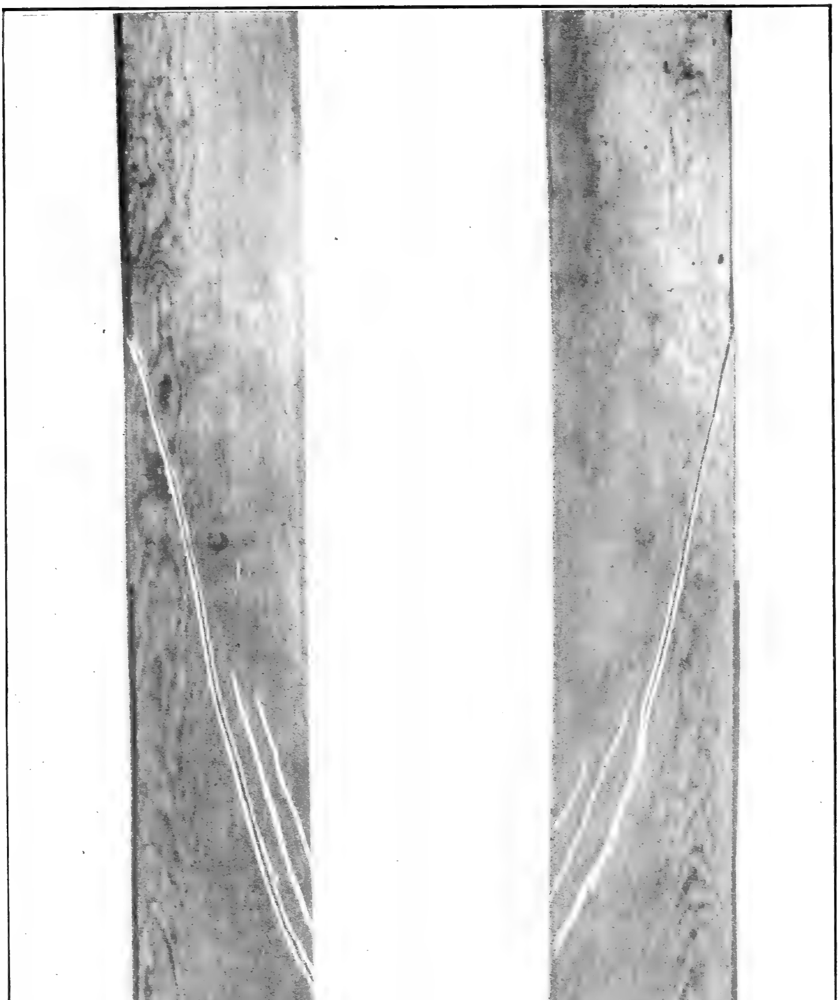
Seasoning and size of sticks.	Number of tests.	Rings per inch.	Moisture.	Weight per cubic foot.		Crushing strength at maximum load per square inch.
				As tested.	Oven dry.	
Green, 2 by 2 by 8 inches:			*Per cent.*	*Pounds.*	*Pounds.*	*Pounds.*
Average	91	16.5	36.5	35.5	26.2	2,698
Maximum	1	41.0	182.7	61.9	41.4	3,960
Minimum	1	7.0	20.2	26.2	17.2	1,870
Air seasoned, 2 by 2 by 8 inches:						
Average	57	16.5	11.0	30.3	27.5	6,559
Maximum	1	28.0	21.7	38.3	34.4	8,560
Minimum	1	8.0	6.8	22.8	20.2	4,160

TABLE 8.—*Ratio of average strength values in bending for all and separate grades of car sills to small clear pieces cut from them.*

Seasoning, size, and grade.	Number of tests.	Rings per inch.	Moisture.	Weight per cubic foot.		Fiber stress at elastic limit per square inch.	Modulus of rupture per square inch.	Modulus of elasticity per square inch.
				As tested.	Oven dry.			
Green:								
Select—			*Per cent.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Thousands of pounds.*
5″ x 8″ x 16′	6	18.0	50.7	38.0	25.2	3,167	4,910	1,455
Per cent						98	80	114
2″ x 2″ x 30″	12	15.5	38.9	38.4	25.9	3,229	6,108	1,281
Per cent						100	100	100
Merchantable—								
5″ x 8″ x 16′	11	15.3	37.1	36.1	26.4	2,828	4,745	1,224
Per cent						89	82	106
2″ x 2″ x 30″	22	15.0	36.3	35.5	26.0	3,172	5,815	1,156
Per cent						100	100	100
Common—								
5″ x 8″ x 16′	9	14.4	34.6	33.6	25.1	2,432	4,100	1,125
Per cent						79	72	99
2″ x 2″ x 30″	18	14.3	33.6	33.3	24.9	3,089	5,704	1.142
Per cent						100	100	100
All grades—								
5″ x 8″ x 16′	26	15.6	39.3	35.7	25.7	2,769	4,560	1,243
Per cent						88	78	106
2″ x 2″ x 30″	52	14.9	36.1	35.5	25.6	3,156	5,831	1,178
Per cent						100	100	100
Air dry:								
Select—								
5″ x 8″ x 16′	3	16.6	12.7	29.9	26.5	4,020	6,260	1,614
Per cent						59	61	112
2″ x 2″ x 30″	6	14.2	12.0	28.5	25.4	6,791	10,200	1,434
Per cent						100	100	100
Merchantable:								
5″ x 8″ x 16′	13	14.8	12.6	30.6	27.2	4,136	6,395	1,503
Per cent						62	58	103
2″ x 2″ x 30″	22	14.4	11.6	30.3	27.1	6,722	10,944	1,474
Per cent						100	100	100
Common—								
5″ x 8″ x 16′	7	15.1	12.5	30.6	27.2	3,552	5,546	1,514
Per cent						54	52	105
2″ x 2″ x 30″	14	13.1	11.2	29.6	26.6	6,584	10,687	1,448
Per cent						100	100	100
All grades—								
5″ x 8″ x 16′	23	15.2	12.6	30.6	27.2	3,976	6,119	1,521
Per cent						59	57	104
2″ x 2″ x 30″	42	13.9	11.5	29.9	26.7	6,681	10,751	1,459
Per cent						100	100	100



METHOD OF LOADING AND OF HOLDING JOISTS TO PREVENT BUCKLING.



TYPICAL SPIRAL GRAIN FAILURE IN GREEN WESTERN YELLOW PINE JOISTS.

VIEW OF SIDES OF JOIST.

TABLE 9.—*Ratio of average strength values in bending for joists to small clear pieces cut from them.*

Seasoning and size.	Number of tests.	Rings per inch.	Moisture.	Weight per cubic foot.		Fiber stress at elastic limit per square inch.	Modulus of rupture per square inch.	Modulus of elasticity per square inch.
				As tested.	Oven dry.			
			Per cent.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Thousands of pounds.*
Green:								
2″ x 10″ x 16′	46	17.3	35.8	35.7	26.4	2,830	4,272	1,266
Per cent						80	77	110
2″ x 2″ x 30″	91	16.5	33.4	35.8	26.9	3,530	5,560	1,149
Per cent						100	100	100
Air seasoned:								
2″ x 10″ x 16′	33	16.7	13.2	31.6	28.5	4,502	6,640	1,595
Per cent						68	60	99
2″ x 2″ x 30″	58	17.1	11.7	30.9	27.6	6,622	11,045	1,611
Per cent						100	100	100

TABLE 10.—*Results of tests in compression perpendicular to grain on clear specimens, 5-inch by 8-inch by 20-inch, taken from western yellow pine car sills.*

	Number of tests.	Rings per inch.	Moisture.	Weight per cubic foot.		Compressive strength at elastic limit per square inch.
				As tested.	Oven dry.	
Green:			*Per cent.*	*Pounds.*	*Pounds.*	*Pounds.*
Average	25	15.6	42.9	36.8	25.6	299
Maximum	1	21.5	69.8	45.8	28.7	413
Minimum	1	9.7	26.9	31.2	21.1	179
Air seasoned:						
Average	26	13.3	13.0	30.5	27.0	701
Maximum	1	20.0	17.4	40.7	34.6	1,110
Minimum	1	8.0	11.5	24.1	21.5	315

TABLE 11.—*Average strength values for green and air-seasoned western yellow pine in structural sizes and small pieces without defects.*

Cross section.	Bending.							Compression parallel to grain.				Compression perpendicular to grain.			
	Number of tests.	Rings per inch.	Moisture.	Weight per cubic foot, oven dry.	Fiber stress at elastic limit per square inch.	Modulus of rupture per square inch.	Modulus of elasticity per square inch.	Size of specimen.	Number of tests.	Moisture.	Crushing strength at maximum load per square inch.	Size of specimen.	Number of tests.	Moisture.	Compressive strength at elastic limit per square inch.
GREEN MATERIAL.															
Inches.			*Per cent.*	*Lbs.*	*Lbs.*	*Lbs.*	*1,000 lbs.*	*Inches.*		*Per cent.*	*Lbs.*	*Inches.*		*Per cent.*	*Lbs.*
5 x 8	26	15.6	39.3	25.7	2,769	4,560	1,243	4 x 4 x 16	25	43.2	2,830	5 x 8 x 20	25	42.9	299
2 x 10	46	17.3	35.8	26.4	2,830	4,272	1,266	....	....	......	......	....	....	......	......
2 x 2	143	15.9	34.4	26.4	3,394	5,659	1,159	2 x 2 x 8	143	37.6	2,770	....	....	......	......
AIR-SEASONED MATERIAL.															
5 x 8	23	15.2	12.6	27.2	3,976	6,119	1,521	5 x 5 x 24	23	12.5	5,758	5 x 8 x 20	26	13.0	701
2 x 10	33	16.7	13.2	28.5	4,502	6,640	1,595	....	....	......	......	....	....	......	......
2 x 2	106	15.5	11.6	27.1	6,660	10,871	1,534	2 x 2 x 8	104	11.2	6,457	....	....	......	......
RATIO—AIR-SEASONED TO GREEN.															
5 x 8	....	......	......	......	144	134	122	4 x 4 x 16 and 5 x 5 x 24	....	......	204	5 x 8 x 20	....	......	234
2 x 10	....	......	......	......	159	156	126	....	....	......	......	....	....	......	......
2 x 2	....	......	......	......	196	192	132	2 x 2 x 8	....	......	233	....	....	......	......

The results of tests on green car sills (Table 1) show the weakening effect of knots to be directly proportional to their size and quantity, the lower grades of timber having larger knots and a greater number of them. Table 2, in which the air-seasoned sills are given, shows a greater increase in strength through air seasoning in the lower grades than in the clear sills.

The material tested contained no shakes. The checking in air seasoning was practically the same as that which usually occurs in Douglas fir, western hemlock, and western larch.

Failure because of spiral grain was quite frequent in the green joists. This grain is very difficult to detect, the surface grain often appearing straight and the resin ducts indistinct. Plate II is an excellent illustration of this.

Both the joists and the car sills contained an unusual amount of sapwood, but this in no way altered the strength of the material under consideration. However, because of its lack of durability, sapwood is undesirable in timbers used under conditions favorable to decay.

RATE OF GROWTH.

The effect of the rate of growth on strength was studied in small, clear pieces, for there are so many factors which influence the strength of material in structural sizes that it is impossible to draw any conclusions regarding the effect of rate of growth from the results of tests on such timbers.

Figure 2 shows the relation of the strength values obtained from the various tests to the number of rings per inch. The small number at each circle on the curve indicates the number of tests used to obtain that average. It will be observed that the maximum strength values are reached in pieces having a rate of growth approximately 20 rings to the inch.

The modulus of rupture varies considerably with the rate of growth, while the remaining factors are influenced to a less degree.

The dry weight increases with the number of rings per inch until it reaches its maximum at 26 rings per inch and remains about constant thereafter.

DRY WEIGHT.

Without question, the dry weight of wood, all other things being equal, is the best criterion of its strength. But in order to obtain reliable and definite results it was deemed advisable to study the effect of this factor in small, clear pieces only, as in the case of the rate of growth. Figure 3, in which the results of the tests are given, shows that the various strength factors increase with the dry weight of the wood, the greatest increase being in the modulus of rupture.

SEASONING.

The results of moisture determinations made on the car sills and joists tested are indicated in figure 4. The green car sills show an average moisture content for the entire section of 39.2 per cent; the green joists, an average moisture content of 35.7 per cent. In the case of both car sills and joists the outer portion of the green beams showed a smaller moisture content than the intermediate portions. This variation was doubtless caused by slight surface seasoning before testing. The air-seasoned car sills showed an average moisture content for the whole section of 12.6 per cent and the joists 13.3 per cent. The moisture content within the sections varied but slightly, increasing from the minimum in the outer portion to the maximum in the inner portion. The material tested was all air seasoned under cover, the car sills for about 16 months and the joists for 14 months.

EFFECT OF SEASONING UPON STRENGTH.

Seasoning, as a rule, increases the strength of wood. Although a lowering of the moisture content is accompanied by an increase

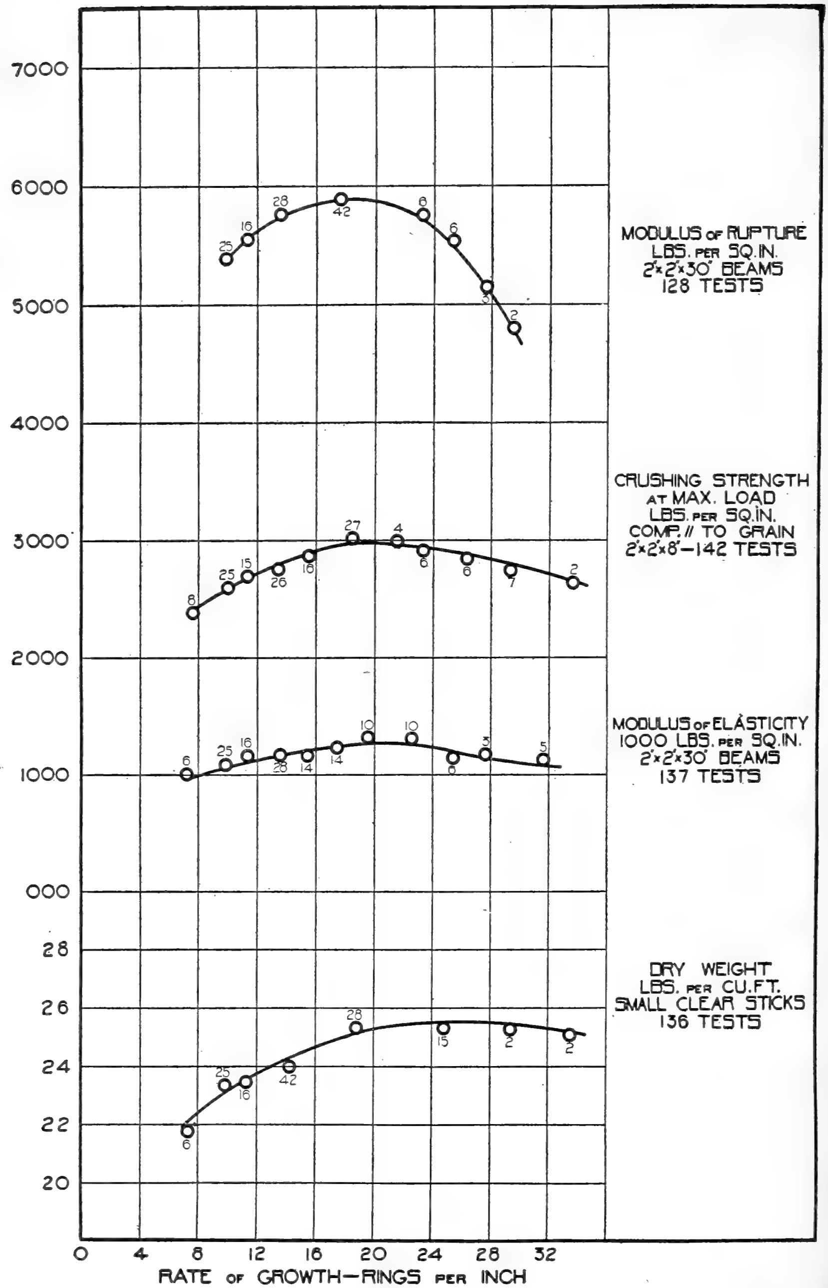


FIG. 2.—Relation of density and strength values to rate of growth in small, clear pieces of green western yellow pine.

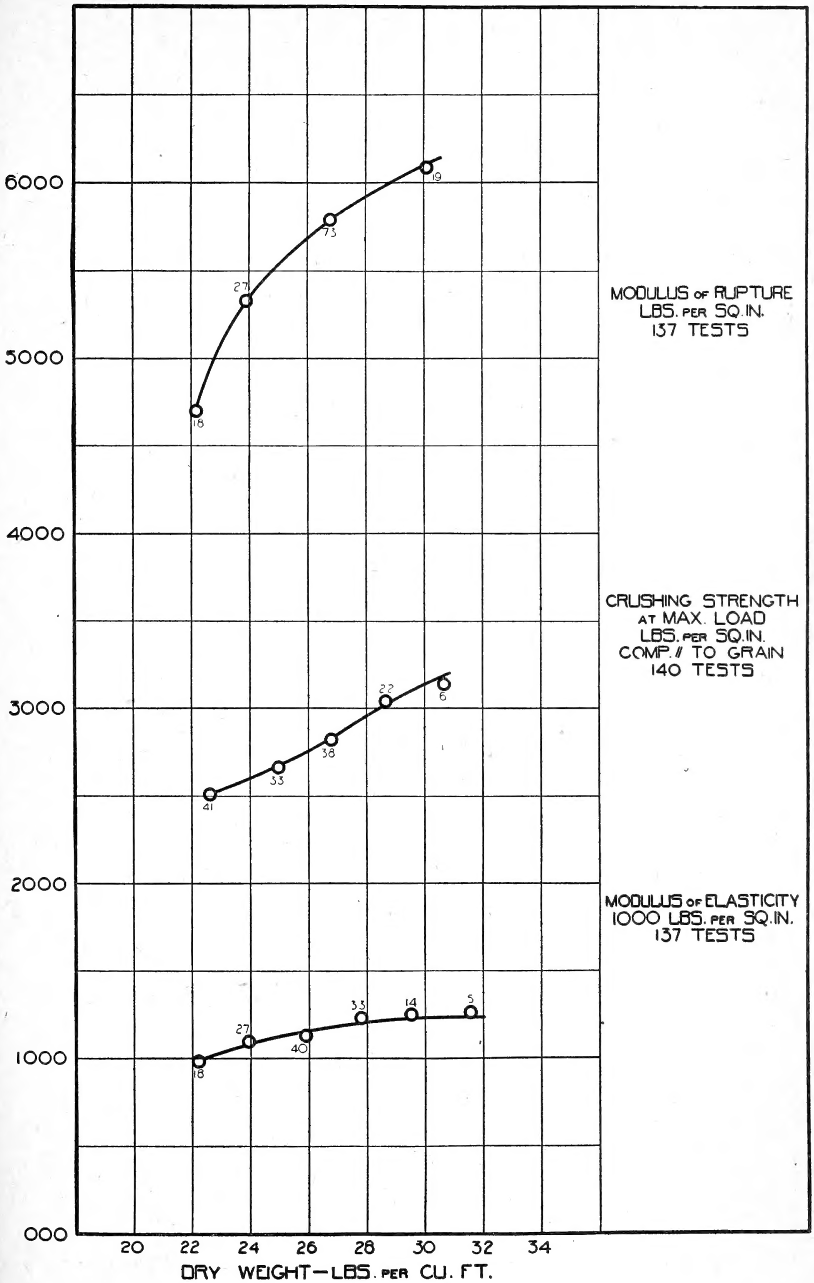


Fig. 3.—Relation of strength values to dry weight in small, clear sticks of green western yellow pine.

in strength in any wood, the gain is somewhat greater for small, clear pieces than for timbers in structural sizes. Seasoning does not, as a rule, cause any appreciable defects in small pieces, but in large beams often develops defects in the form of checks which counter-

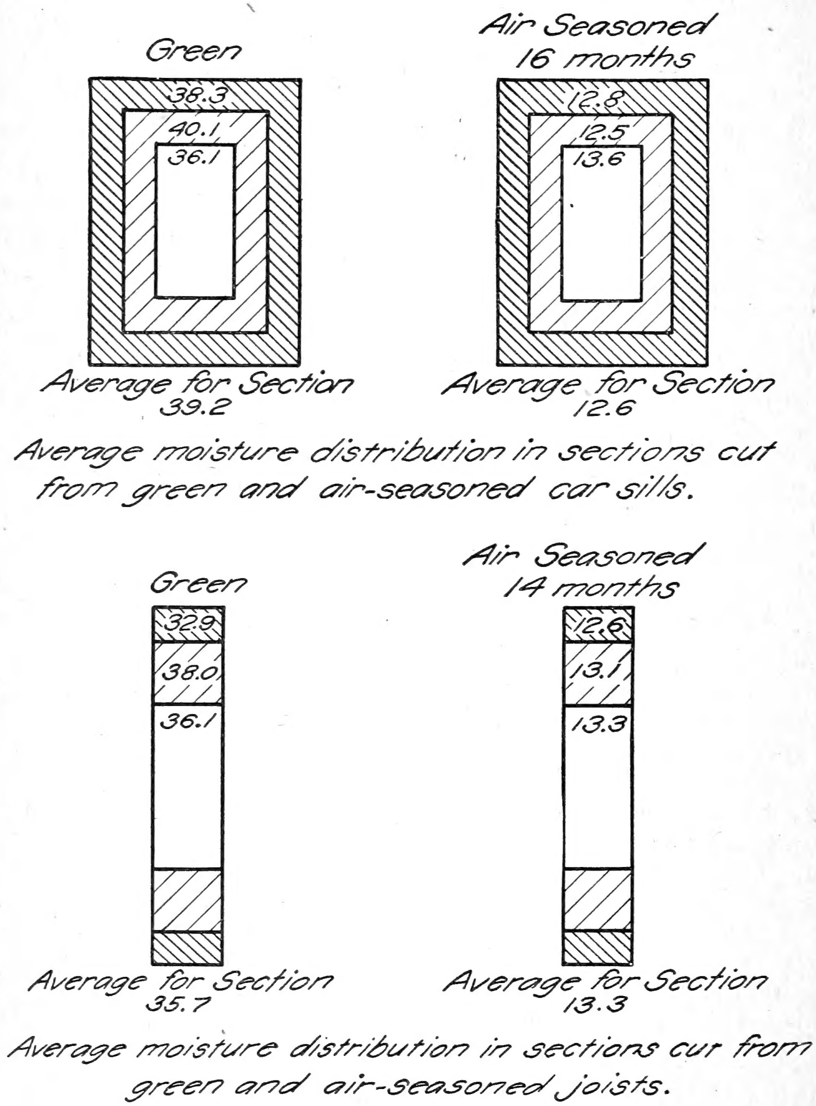


FIG. 4.—Summary of moisture determinations made upon green and seasoned joists and car sills of western yellow pine.

balance the strength gained in seasoning. A comparison of the strength values of green and air-seasoned car sills is given in figure 1. The effect of seasoning upon the strength of test material of various sizes is indicated in Table 12.

CONCLUSIONS.

The comparatively small number of experiments made on western yellow pine limits the conclusions to be drawn regarding this species to the following:

(*a*) The strength values of structural timbers are influenced considerably by the defects found in them. These values vary according to the grades in the green material; but the increase in strength from air seasoning is not uniform and does not vary with the grades.

(*b*) Seasoning greatly increases the strength of the wood, the increase being greater and more uniform in small, clear sticks than in structural timbers, owing to the development of defects in the latter. Lowering the moisture content of yellow pine causes it to become more brittle.

(*c*) Western yellow pine is a lighter wood than the other western lumber species, weighing approximately 26.9 pounds per cubic foot, oven dry, in structural sizes. The dry weight of clear wood readily suggests its strength or weakness, but this factor alone can not be depended upon to indicate comparative strength when structural forms of various grades are taken into consideration, owing to the presence of defects which have an important influence on their strength.

(*d*) The table of comparison of the strengths of various western species (Table 12) is based on tests of small, clear specimens. In addition to the results of tests on western yellow pine, as previously described, there are included average values derived from similar tests on material from five trees from each of four other localities. In comparing species from data in this table it is well to base comparisons on results of tests of green material, since differences in moisture content of green material do not produce differences in strength. It must also be remembered that the figures given are averages and that the variability of timber is such that individual specimens of a species may excel the average for another species which averages considerably higher, or they may fall below the average for a species which averages considerably lower. When values from tests of air-dry materials are used for comparison careful attention should be given to the moisture content of the material compared (whether it is of two or more species or of one species from two or more localities) and the effect of differences of moisture considered. The effect of moisture and the methods for adapting strength values from one moisture content to another are gone into in Forest Service Bulletin 70, " Effect of Moisture on the Strength and Stiffness of Wood."

TABLE 12.—*Weight, shrinkage, and mechanical properties of several western species as determined from tests on small specimens free from defects and tested while green and after thorough air drying.*

Species.	Locality where grown.	Weight per cubic foot.			Shrinkage from green to oven-dry condition.			Moisture content at which tests were made.	Static bending.				Impact bending 50-pound hammer; height of drop causing complete failure.	Compression parallel to grain—crushing strength at maximum load per square inch.	Compression perpendicular to grain. Fiber stress at elastic limit per square inch.	Hardness; load required to embed a 0.444-inch ball to one-half its diameter (Jank's ball test).		Shearing strength parallel to grain per square inch.
		Kiln dry about 8 per cent moisture.	Air dry about 12 or 15 per cent moisture.	Green.	Volume.	Radial.	Tengential.		Fiber stress at elastic limit per square inch.	Modulus of rupture per square inch.	Modulus of elasticity per square inch.	Work to maximum load per cubic inch.				End.	Side.	
		Lbs.	Lbs.	Lbs.	P. ct.	P. ct.	P. ct.	P. ct.	Lbs.	Lbs.	Thousands of lbs.	Lbs.	Ins.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Port Orford cedar (*Chamæcyparis lawsoniana*)	Douglas County, Oreg.	30	31	39	10.7	5.2	8.1	52.0	3,920	6,800	1,500	7.8	25	3,280	380	560	480	880
								9.0	8,880	14,510	2,040	12.1	39	7,750	1,020	950	700	1,500
Western red cedar (*Thuja plicata*)	Snohomish County, Wash.	23	24	30	8.6	2.5	5.6	45.2	3,620	5,730	1,020	5.6	18	3,050	350	462	272	742
Amabilis fir (*Abies amabilis*)	do	26	27	36	14.1	4.5	10.0	65.8	3,540	5,660	1,260	6.0	21	2,670	290	360	310	670
Douglas fir (*Pseudotsuga taxifolia*)	Washington and Oregon.	34	35	38	12.7	5.1	7.8	35.4	4,920	7,800	1,580	6.6	25	3,910	530	510	470	870
								15.9	6,300	9,760	1,680			4,850				940
Noble fir (*Abies nobilis*)	Multnomah County, Oreg.	27	28	31	13.6	4.9	9.1	41.2	3,420	5,690	1,280	6.2	20	2,700	310	300	250	700
Western hemlock (*Tsuga heterophylla*)	Grays Harbor and Buckley, Wash.	30	31	40				52.0	4,410	7,290	1,430			3,390				
								17.0	6,330	10,370	1,670			5,400				
Western larch (*Larix occidentalis*)	Stevens County, Wash.	33	34	42				46.0	4,270	7,250	1,310			3,700				
								14.8	5,890	10,230	1,560			5,940				
Western yellow pine (*pinus ponderosa*)	Coconino County, Ariz.	25	26	44	9.2	4.1	6.4	98.0	2,660	4,760	880	4.9	17	2,220	340	310	310	660
								11.6	6,350	8,150	1,100	4.6	10	5,220	790	550	410	1,300
Do.	Madera County, Cal.	28	29	53	11.5	4.3	7.3	125.0	3,180	5,180	1,110	4.3	21	2,420	330	320	310	700
								9.7	8,160	11,060	1,460	8.2	19	6,600	800	560	510	1,210
Do.	Douglas County, Colo.	28	29	49	9.9	3.8	5.8	93.0	3,310	5,460	1,050	6.0	20	2,600	410	320	330	710
								13.8	6,230	9,400	1,260	7.0	18	4,920	710	620	450	1,030
Do.	Missoula County, Mont.	27	28	51	9.3	3.5	5.9	119.0	2,930	4,950	860	5.2	19	2,370	310	310	320	670
								7.8	7,100	9,620	1,350	6.0	19	6,740	800	570	490	1,080
Do.[1]	Stevens County, Wash.							34.4	3,390	5,660	1,160			2,770	300			
								11.6	6,660	10,870	1,530			6,460	700			
Sitka spruce (*Picea sitchensis*)	Lewis County, Wash.	25	26	32	11.2	4.5	7.4	53.0	3,020	5,490	1,180	6.4	29	2,600	330	430	370	780
Western yew (*Taxus brevifolia*)	Snohomish County, Wash.	43	45	54	9.7	4.0	5.4	44.1	6,520	10,140	990	20.2	38	4,650	1,040	1,340	1,150	1,620
								9.2	10,100	16,750	1,460	18.4	30	9,300	5,040	2,340	1,790	2,470

[1] Results taken from Table 2. NOTE.—Results opposite common name of species are from tests of green material; those opposite botanical name, from tests of air-dry material.

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