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SAPWOOD THICKNESS of douglas-fir and five other western softwoods

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Abstract

Sapwood measurements were made on increment cores extracted at breast height from Douglas-fir, western larch, lodgepole pine, ponderosa pine, western redcedar, and Engelmann spruce trees. The trees sampled were representative of the growth range of each species. Sapwood thickness measurements, of primary interest to preservative treating of forest products, showed an increase with increasing tree diameter. In addition, Douglas-fir sapwood thickness was greater in the Coast type than in the Interior type for trees of the same diameter. Also for Coast Douglas-fir, sapwood thickness decreased with increasing elevation, and trees having the most rapid diameter growth had the thickest sapwood.

SAPWOOD THICKNESS OF DOUGLAS-FIR AND FIVE OTHER WESTERN SOFTWOODS

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Introduction

Included in this report are tabulations of the average sapwood thickness at breast height by diameter class of Douglas-fir and five other species of western softwoods. Also included is a discussion of some of the sources of variation in sapwood thickness of Douglas-fir. Sapwood thickness information is primarily of interest in preservative treating forest products because sapwood generally receives preservatives better than heartwood.

Sapwood thickness was measured on increment cores bored at breast height (4.5 ft.) from living trees (3)[2] throughout the natural growth range of the species within the United States (6). This method of measurement varies from the American Wood-Preservers' Association Standards C3-68 and C4-68 (1) by which sapwood thickness is measured on an increment core bored from the midlength of piles and poles. It should be remembered that piles and poles are often mechanically shaved, a process by which some of the sapwood is removed.

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

[2] Numbers in parentheses refer to Literature Cited at the end of this Note.

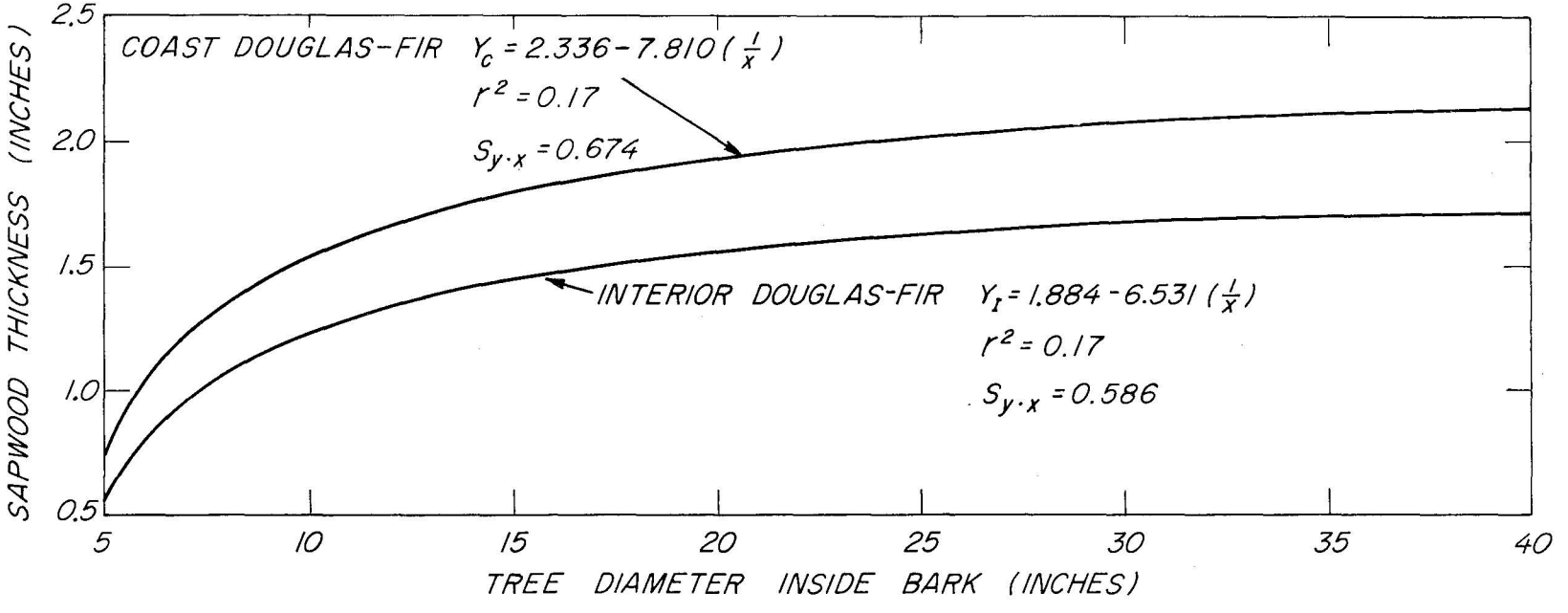

Figure 1.--Regression of diameters of Coast and Interior Douglas-fir on sapwood thickness.

(M 136 899)

Because sapwood thickness was measured on a single increment core from each tree, the tabulations do not reflect within-tree thickness variation with circumference, height, age, or tree vigor. Previous research on the extent of these variations is limited, but some information is available.

For example, Wellwood and Jurazs (8), reporting on variation in sapwood thickness with circumference, found no significant difference in sapwood thickness for western redcedar (Thuja plicata Donn) determined by a single radial measurement versus the average of four quadrant measurements. For variation with height, they noted that sapwood thickness was greatest at the stump, decreased to the end of the first 16-foot log, and then increased gradually. For Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco), Wellwood (7) and Smith et al. (5) recorded that sapwood was thickest at the base of the tree and narrowed with height.

These workers also found for both western redcedar and Douglas-fir that the thickest sapwood was associated with the most vigorously growing trees. Based on the previous research sapwood thickness generally increased with tree diameter, rate of growth, bark thickness, and relative crown size.

Douglas-fir Sapwood Thickness

Poles and piles are a major grouping of wood products that requires preservative treatment. Of the western species Douglas-fir is by far the most used for these products; therefore it receives more emphasis in this report than do the other species (2).

The Pacific Coast (var, menziesii) Douglas-fir differs from the Interior (var. glauca) (4) in external form and in woodproperties and characteristics. Because of these varietal differences, sapwood data were segregated into Coast and Interior groupings (tables 1, 2) and examined for differences.

In figure 1 regression curves show the relationship between sapwood thickness and tree diameters (inside bark) for the two groupings; sapwood thickness rapidly increases as diameter increases. After the trees reach 10 to 15 inches in diameter, the sapwood thickness increases only slightly. Figure 1 also shows an apparently greater sapwood thickness in Coast trees than in Interior trees of the same diameter. A statistical test for a common regression indicates the slopes of the regressions differ significantly ($P = .01$).

A further test of sapwood thickness differences between Coast and Interior Douglas-fir was made by segregating all trees under 40 inches in diameter into

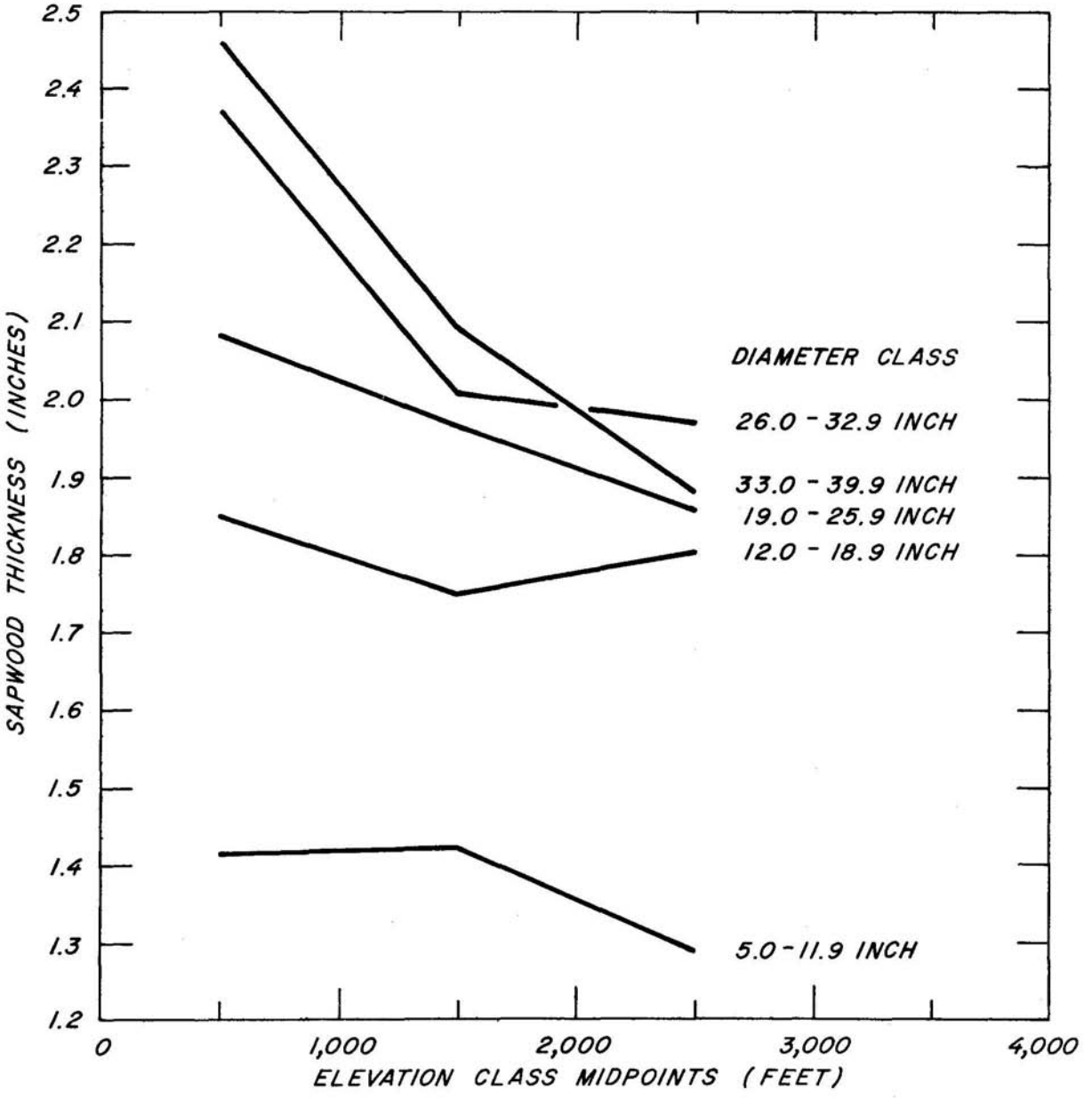

Figure 2.--Relationship of sapwood thickness by five diameter classes of Coast Douglas-fir to three elevation levels.

(M 136 901)

five diameter classes and testing for differences within each diameter class. Highly significant differences (P = .01) were found between sapwood thickness of Coast and Interior trees for each diameter class except the largest (table 3).

Because Coast Douglas-fir generally grows more rapidly than Interior Douglas-fir to attain a given diameter, the results here will agree with Wellwood (7) and Smith et al. (5) who found that the most rapidly growing trees have the widest sapwood bands.

On the Coast, the greatest concentrations of Douglas-fir occur from sea level to 3,000 feet in elevation. The average sapwood thickness from Coast trees growing within three arbitrarily chosen elevational ranges is plotted in figure 2. Sapwood thickness in each diameter class decreased from the lowest elevation to the highest elevation. An analysis of variance revealed significant differences in sapwood thickness among elevations within each diameter class except within the 12.0- to 18.9-inch class. Again, because growth rate generally slows with increasing elevation, these results agree with the trend that sapwood thickness decreases as growth rate decreases.

Further evidence that sapwood thickness is influenced by growth rate can be seen from a multiple regression analysis of data of Coastal trees in which:

Y = sapwood thickness
X_1 = elevation
X_2 = d.b.h. (diameter at breast height), o.b. (outside bark)
X_3 = bark thickness at breast height
X_4 = radial growth for the 10 growth rings nearest the bark
X_5 = age at breast height

All the independent variables made a significant stepwise reduction (P = .05) in the sapwood thickness variation associated with regression. Radial growth and d.b.h., o.b. were the most important individual variables, and all five independent variables were associated with 37 percent of the sapwood thickness variation.

Similar analysis of elevational effects was not made with the Interior Douglas-fir because the sample was taken over an area so vast that the elevational effects would be confounded by changing environmental relationships.

Sapwood Thickness of Five Other Species

The sapwood thickness of western larch (*Larix occidentalis* Nutt.), lodgepole pine (*Pinus contorta* Dougl.), ponderosa pine (*P. ponderosa* Laws), western redcedar, and Engelmann spruce (*Picea engelmannii* Parry) are plotted against tree diameters (i.b.) in figure 3 and are listed in tables 4 to 8.

Summary

1. Sapwood thickness of the Coast Douglas-fir sampled is greater than that of the Interior Douglas-fir trees of the same diameter (inside bark).

2. Sapwood of the Coast Douglas-fir tends to decrease in thickness as elevation increases.

3. Coast Douglas-fir trees with the most rapid growth in diameter have the thickest sapwood.

4. Sapwood thickness increases as tree diameter increases in the Douglas-fir and five other western softwoods sampled. It increases most rapidly in the species that have the widest sapwoodbands and, in general, increases most rapidly during the first 15 to 20 years of growth.

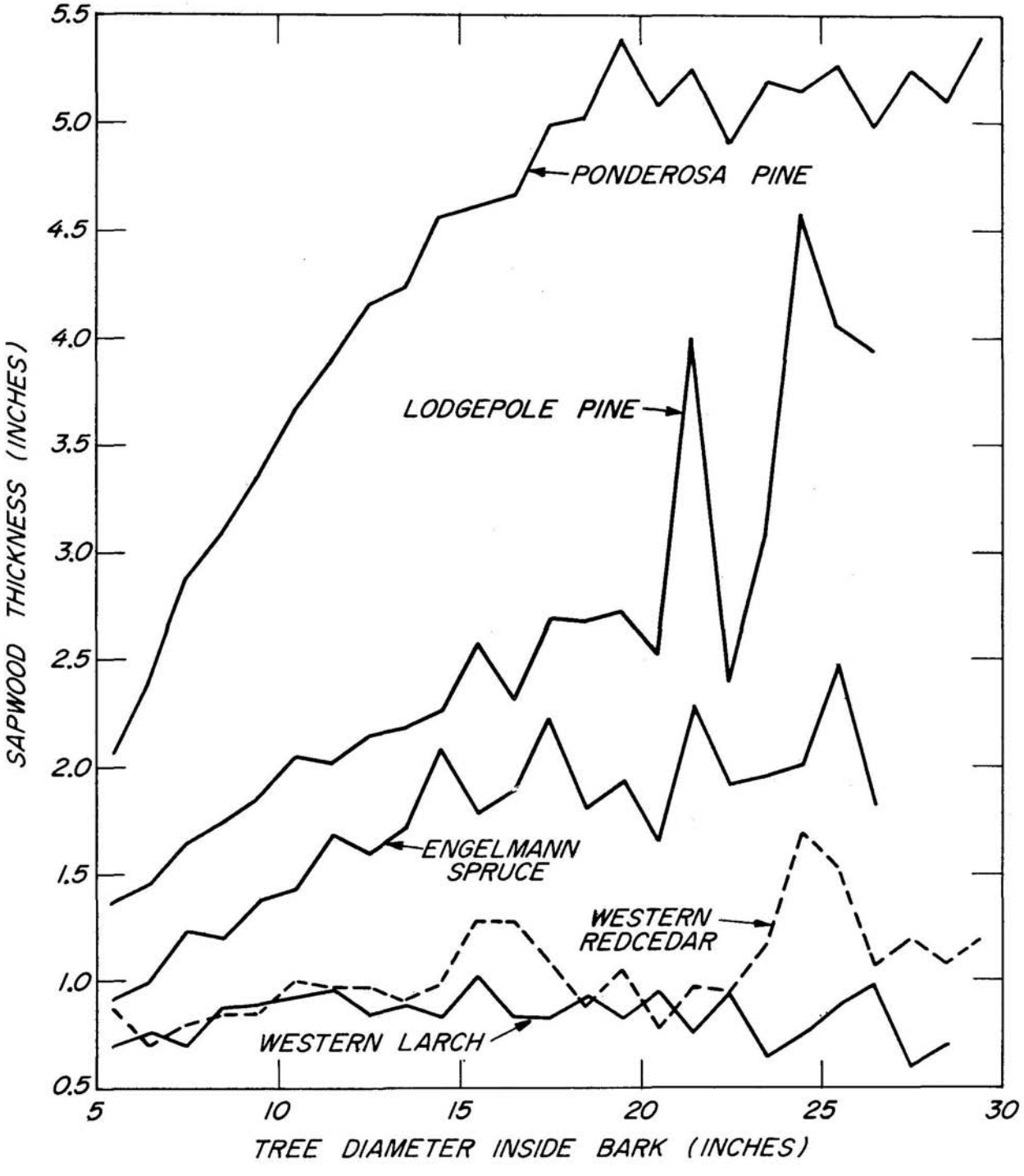

Figure 3.--Relationship of sapwood thickness of five western softwood species to tree diameter.

(M 136 900)

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Table 1.--Douglas-fir (Coast) sapwood thickness by tree diameters

Tree diameter inside bark at breast height	Average sapwood thickness	Standard deviation	Range of sapwood thickness	Number of trees sampled	Average tree diameter outside bark at breast height
Inches	Inches		Inches		Inches
5.0- 5.9	1.05	0.38	0.3-2.0	131	6.1
6.0- 6.9	1.19	.44	.2-2.6	146	7.2
7.0- 7.9	1.27	.49	.2-2.9	137	8.4
8.0- 8.9	1.30	.50	.2-2.6	146	9.6
9.0- 9.9	1.54	.51	.4-3.2	167	10.6
10.0-10.9	1.64	.59	.4-3.9	186	11.7
11.0-11.9	1.64	.58	.3-3.2	167	12.9
12.0-12.9	1.78	.74	.4-5.3	180	14.0
13.0-13.9	1.74	.65	.3-3.6	166	15.1
14.0-14.9	1.80	.58	.2-4.0	147	16.1
15.0-15.9	1.85	.77	.4-5.3	125	17.5
16.0-16.9	1.91	.73	.5-4.0	140	18.7
17.0-17.9	1.96	.77	.2-5.0	156	19.7
18.0-18.9	2.11	.78	.3-4.5	132	21.0
19.0-19.9	1.99	.86	.6-6.6	142	22.1
20.0-20.9	2.01	.91	.4-5.7	103	23.2
21.0-21.9	1.99	.85	.2-5.8	104	24.3
22.0-22.9	2.02	.78	.5-5.1	100	25.4
23.0-23.9	2.05	.71	.3-4.8	98	26.7
24.0-24.9	2.18	.97	.5-5.7	89	27.9
25.0-25.9	2.07	.75	.7-4.5	85	29.2
26.0-26.9	2.21	.86	.7-6.2	87	30.3
27.0-27.9	1.83	.64	.4-3.8	75	31.4
28.0-28.9	2.14	1.09	.5-7.5	66	32.1
29.0-29.9	2.38	1.07	.5-6.5	72	33.4
30.0-34.9	2.10	.84	.3-5.6	316	36.9
35.0-39.9	2.17	.95	.3-5.1	222	42.5
40.0-44.9	2.17	.91	.3-7.9	183	48.5
45.0-49.9	2.13	.94	.5-5.3	124	54.1
50.0-54.9	2.34	1.08	.7-6.2	81	59.7
55.0-59.9	2.08	.98	.6-5.0	43	64.4
60.0-64.9	1.86	.96	.5-3.8	29	70.4
65.0-69.9	2.34	1.04	.6-5.3	17	74.7
70.0-74.9	2.09	.67	1.4-3.7	10	80.0
75.0-79.9	1.65	.56	1.3-2.0	6	84.0
Total			0.2-7.9	4,178	

Table 2.--Douglas-fir(Interior) sapwood thickness by tree diameters

Tree diameter inside bark at breast height	Average sapwood thickness	Standard deviation	Range of sapwood thickness	Number of trees sampled	Average tree diameter outside bark at breast height
Inches	Inches		Inches		Inches
5.0- 5.9	0.80	0.23	0.1-1.6	303	6.2
6.0- 6.9	.92	.38	.1-2.9	321	7.3
7.0- 7.9	1.00	.43	.1-2.3	322	8.4
8.0- 8.9	1.06	.44	.1-2.3	349	9.6
9.0- 9.9	1.16	.37	.1-3.2	324	10.6
10.0-10.9	1.21	.51	.2-3.9	342	11.8
11.0-11.9	1.22	.50	.1-2.8	307	13.0
12.0-12.9	1.28	.47	.3-2.7	287	14.1
13.0-13.9	1.33	.53	.1-3.3	234	15.2
14.0-14.9	1.46	.64	.3-4.6	242	16.4
15.0-15.9	1.32	.59	.1-3.2	195	17.5
16.0-16.9	1.49	.65	.2-4.0	209	18.6
17.0-17.9	1.45	.51	.2-3.1	166	19.8
18.0-18.9	1.53	.71	.2-5.8	151	20.8
19.0-19.9	1.62	.83	.3-6.5	110	21.9
20.0-20.9	1.80	1.21	.4-8.3	106	23.1
21.0-21.9	1.55	.67	.4-3.3	89	24.3
22.0-22.9	1.65	1.02	.3-7.8	72	25.2
23.0-23.9	1.59	.77	.2-4.6	63	26.7
24.0-24.9	1.75	.54	.4-3.5	72	27.5
25.0-25.9	1.83	.90	.4-4.8	58	28.7
26.0-26.9	1.83	.63	.9-3.3	31	29.8
27.0-27.9	1.71	.75	.8-3.8	38	31.1
28.0-28.9	1.74	.58	.9-3.0	25	31.8
29.0-29.9	1.79	.78	.9-3.8	25	32.9
30.0-34.9	1.98	.72	.6-4.3	71	35.7
35.0-39.9	1.79	.80	.3-4.0	28	41.6
40.0-44.9	1.92	.93	.8-3.6	6	46.0
45.0-49.9	.85	--	.5-1.2	2	50.8
Total			0.1-8.3	4,548	

Table 3.--Comparison of sapwood thickness of Coast Douglas-fir with Interior variety

Diameter class (inside bark)	Average sapwood thickness		Significant differences
	Coast	Interior	
Inches	Inches	Inches	
5.0-11.9	1.40	1.06	P = 0.01
12.0-18.9	1.87	1.40	P = .01
19.0-25.9	2.04	1.68	P = .01
26.0-32.9	2.12	1.83	P = .01
33.0-39.9	2.16	1.90	Not significant

Table 4.--Western larch sapwood thickness by tree diameters

Tree diameter inside bark at breast height	Average sapwood thickness	Standard deviation	Range of sapwood thickness	Number of trees sampled	Average tree diameter outside bark at breast height
Inches	Inches		Inches		Inches
5.0- 5.9	0.70	0.26	0.2-1.3	56	6.4
6.0- 6.9	.76	.25	.4-1.5	51	7.5
7.0- 7.9	.70	.29	.1-1.2	56	8.7
8.0- 8.9	.88	.30	.2-1.5	64	9.9
9.0- 9.9	.89	.50	.3-3.5	38	11.0
10.0-10.9	.93	.36	.3-2.0	49	12.1
11.0-11.9	.96	.55	.3-4.0	43	13.3
12.0-12.9	.84	.35	.3-1.8	34	14.4
13.0-13.9	.89	.36	.3-1.8	31	15.5
14.0-14.9	.83	.21	.5-1.2	18	16.6
15.0-15.9	1.02	.27	.7-1.6	23	18.1
16.0-16.9	.83	.36	.3-1.6	22	18.7
17.0-17.9	.82	.28	.3-1.3	19	20.4
18.0-18.9	.93	.64	.3-3.0	17	21.5
19.0-19.9	.83	.36	.3-1.8	23	22.6
20.0-20.9	.95	.41	.4-2.0	15	24.0
21.0-21.9	.75	.30	.4-1.4	9	25.2
22.0-22.9	.95	.32	.5-1.3	9	26.7
23.0-23.9	.64	.21	.4-1.0	7	26.3
24.0-24.9	.75	.26	.4-1.0	4	27.5
25.0-25.9	.89	.36	.5-1.7	10	29.2
26.0-26.9	.97	.78	.1-1.6	3	30.0
27.0-27.9	.60	.17	.5- .8	3	31.3
28.0-28.9	.70	.20	.5- .9	3	33.4
Total			.1-4.0	607	

Table 5.--Lodgepolepine sapwood thickness by tree diameters

Tree diameter inside bark at breast height	Average sapwood thickness	Standard deviation	Range of sapwood thickness	Number of trees sampled	Average tree diameter outside bark at breast height
Inches	Inches		Inches		Inches
5.0-5.9	1.38	0.36	0.2-3.1	492	5.7
6.0-6.9	1.46	.52	.1-3.7	550	6.8
7.0-7.9	1.65	.61	.2-3.5	522	7.8
8.0-8.9	1.74	.65	.2-4.3	395	8.8
9.0-9.9	1.86	.74	.1-5.2	327	9.8
10.0-10.9	2.05	.80	.3-4.2	260	10.8
11.0-11.9	2.02	.87	.3-5.0	201	11.8
12.0-12.9	2.15	.95	.3-5.8	152	12.9
13.0-13.9	2.19	1.01	.3-5.4	110	13.9
14.0-14.9	2.26	1.00	.3-4.8	94	15.0
15.0-15.9	2.58	1.30	.8-8.0	61	16.0
16.0-16.9	2.32	.98	1.0-4.5	33	16.9
17.0-17.9	2.70	1.15	.5-5.4	28	18.1
18.0-18.9	2.69	1.56	.7-6.6	22	19.1
19.0-19.9	2.73	1.77	1.0-4.5	12	20.0
20.0-20.9	2.51	.89	.8-3.8	7	20.9
21.0-21.9	4.00	2.09	1.6-5.4	3	22.0
22.0-22.9	2.40	1.24	.8-4.3	6	22.9
23.0-23.9	3.07	1.30	1.6-4.6	6	24.1
24.0-24.9	4.60	--	4.4-4.8	2	25.2
25.0-25.9	4.05	1.33	3.2-6.0	4	26.0
26.0-26.9	3.93	2.10	1.9-6.1	3	27.6
Total:			0.1-8.0	3,290	

Table 6.--Ponderosa pine sapwood thickness by tree diameters

Tree diameter inside bark at breast height	Average sapwood thickness	Standard deviation	Range of sapwood thickness	Number of trees sampled	Average tree diameter outside bark at breast height
Inches	Inches		Inches		Inches
5.0-5.9	2.06	0.51	0.1-3.8	221	6.4
6.0-6.9	2.39	.56	.2-3.9	229	7.6
7.0-7.9	2.89	.60	.8-4.5	210	8.8
8.0-8.9	3.09	.77	.1-5.7	222	9.9
9.0-9.9	3.36	.83	.1-5.6	270	11.0
10.0-10.9	3.68	.83	.6-5.2	263	12.0
11.0-11.9	3.89	.92	1.0-5.9	242	13.3
12.0-12.9	4.16	1.03	.3-7.0	243	14.5
13.0-13.9	4.24	1.14	.2-6.5	258	15.4
14.0-14.9	4.57	1.31	1.1-7.4	237	16.6
15.0-15.9	4.63	1.27	1.0-7.7	236	17.8
16.0-16.9	4.66	1.36	.7-7.9	181	18.8
17.0-17.9	4.99	1.48	1.1-9.2	187	19.9
18.0-18.9	5.03	1.59	1.1-8.8	157	21.0
19.0-19.9	5.39	1.65	1.3-9.6	144	22.2
20.0-20.9	5.09	1.74	1.5-9.1	147	23.2
21.0-21.9	5.25	1.90	1.2-9.4	143	24.3
22.0-22.9	4.92	1.85	1.0-9.6	117	25.5
23.0-23.9	5.20	1.75	1.8-9.5	127	26.4
24.0-24.9	5.16	1.90	.4-9.3	91	27.3
25.0-25.9	5.27	1.77	1.7-9.2	101	28.5
26.0-26.9	4.99	1.82	.4-9.3	96	29.5
27.0-27.9	5.25	1.83	1.3-9.1	64	30.7
28.0-28.9	5.11	1.65	2.4-8.8	58	31.5
29.0-29.9	5.42	2.15	1.1-9.9	50	32.4
30.0-34.9	5.63	1.90	1.0-9.9	168	35.7
35.0-39.9	5.86	1.96	1.0-9.7	79	41.1
40.0-44.9	5.66	2.24	1.1-8.1	19	45.4
45.0-49.9	5.29	2.38	2.2-9.5	8	50.1
50.0-54.9	6.43	1.98	3.9-6.9	4	54.5
Total			0.1-9.9	4,572	

Table 7.--Western redcedar sapwood thickness by tree diameters

Tree diameter inside bark at breast height	Average sapwood thickness	Standard deviation	Range of sapwood thickness	Number of trees sampled	Average tree diameter outside bark at breast height
Inches	Inches		Inches		Inches
5.0-5.9	0.87	0.61	0.3-3.7	33	6.0
6.0-6.9	.70	.27	.2-1.5	37	6.9
7.0-7.9	.80	.28	.3-1.6	27	7.9
8.0-8.9	.85	.29	.3-1.6	21	9.8
9.0-9.9	.85	.23	.5-1.3	15	9.9
10.0-10.9	1.00	.34	.4-2.0	36	11.0
11.0-11.9	.97	.28	.6-1.7	19	12.1
12.0-12.9	.98	.20	.6-1.3	21	13.3
13.0-13.9	.88	.30	.4-1.5	18	14.1
14.0-14.9	.98	.35	.4-1.7	21	15.3
15.0-15.9	1.27	.48	.9-2.6	12	16.1
16.0-16.9	1.28	.74	.7-3.5	13	17.2
17.0-17.9	1.09	.68	.3-3.2	14	18.6
18.0-18.9	.87	.31	.5-1.4	11	19.3
19.0-19.9	1.05	.19	.8-1.3	10	20.5
20.0-20.9	.78	.10	.7- .9	4	21.8
21.0-21.9	.98	.14	.3-1.4	5	22.9
22.0-22.9	.93	.29	.4-1.4	10	23.8
23.0-23.9	1.16	.58	.6-2.7	11	24.4
24.0-24.9	1.70	1.88	.5-5.5	6	26.6
25.0-25.9	1.53	1.02	.7-2.9	4	26.6
26.0-26.9	1.08	.36	.3-1.8	12	27.5
27.0-27.9	1.20	--	--	1	28.9
28.0-28.9	1.02	.24	.8-1.4	9	29.8
29.0-29.9	1.07	.35	.8-1.6	6	30.7
30.0-34.9	1.09	.57	.4-3.8	25	33.5
35.0-39.9	1.00	.33	.2-2.7	23	39.2
40.0-44.9	.99	.43	.6-2.1	10	43.0
45.0-49.9	1.11	.59	.6-2.6	10	48.9
50.0-54.9	.86	.35	.3-1.6	11	53.4
55.0-59.9	.70	.18	.5-1.0	7	59.3
60.0-64.9	.93	.10	.7-1.3	3	64.9
65.0-69.9	.85	.26	.6-1.2	4	68.8
Total			.2-5.5	469	

Table 8.--Engelmann spruce sapwood thickness by tree diameters

Tree diameter inside bark at breast height	Average sapwood thickness	Standard deviation	Range of sapwood thickness	Number of trees sampled	Average tree diameter outside bark at breast height
Inches	Inches		Inches		Inches
5.0-5.9	0.91	0.39	0.2-1.8	40	5.9
6.0-6.9	.99	.50	.1-2.0	49	6.9
7.0-7.9	1.24	.55	.2-3.3	50	8.1
8.0-8.9	1.20	.62	.1-3.2	70	8.9
9.0-9.9	1.37	.63	.2-2.7	47	10.1
10.0-10.9	1.43	.81	.4-3.5	52	11.3
11.0-11.9	1.69	.86	.3-4.2	56	12.1
12.0-12.9	1.60	.73	.1-4.1	62	13.1
13.0-13.9	1.71	1.00	.3-5.3	67	14.2
14.0-14.9	2.09	1.02	.6-6.4	54	15.5
15.0-15.9	1.79	.84	.4-3.9	54	16.1
16.0-16.9	1.89	1.00	.3-6.3	62	17.2
17.0-17.9	2.23	1.14	.4-6.6	41	18.2
18.0-18.9	1.82	1.00	.3-4.4	35	19.2
19.0-19.9	1.93	.75	.7-3.5	28	20.2
20.0-20.9	1.66	.78	.4-3.6	42	21.3
21.0-21.9	2.28	1.64	.7-8.1	22	22.3
22.0-22.9	1.93	.93	.4-3.5	24	23.3
23.0-23.9	1.96	.62	.7-3.4	27	24.3
24.0-24.9	2.02	.77	.7-3.4	20	25.4
25.0-25 9	2.47	1.21	.5-5.7	14	26.5
26.0-26.9	1.65	.62	.6-3.2	17	27.4
27.0-27.9	2.78	1.72	1.3-6.5	8	28.5
28.0-28.9	1.78	.98	.3-3.4	15	29.4
29.0-29.9	2.36	2.16	.9-6.9	7	30.6
30.0-34.9	2.31	1.43	.6-7.8	31	33.1
35.0-39.9	1.71	1.28	.3-4.0	8	38.2
Total			0.1-8.1	1,002	

ABOUT THE FOREST SERVICE. . . .

As our Nation grows, people expect and need mroe from their forests--more wood; more water, fish and wildlife; more recreation and natural beauty; more special forest products and forage. The Forest Service of the U.S. Department of Agriculture helps to fulfill these expectations and needs through three major activities:

* Conducting forest and range research at over 75 locations ranging from Puerto Rico to Alaska to Hawaii.

* Participating with all State forestry agencies in cooperative programs to protect, improve, and wisely use our Country's 395 million acres of State, local, and private forest lands.

* Managing and protecting the 187-million acre National Forest System.

The Forest Service does this by encouraging use of the new knowledge that research scientists develop; by setting an example in managing, under sustained yield, the National Forest and Grasslands for multiple use purposes; and by cooperating with all States and with private citizens in their efforts to achieve better management, protection, and use of forest resources.

Traditionally, Forest Service people have been active members of the communities and towns in which they live and work. They strive to secure for all, continous benefits from the Country's forest resources.

For more than 60 years, the Forest Service has been serving the Nation as a leading natural resource conservation agency.