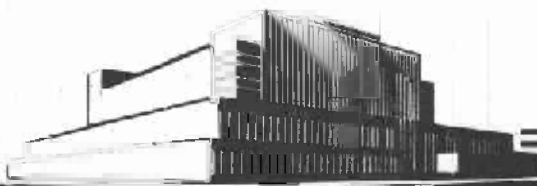


SPECIFIC GRAVITY, SHRINKAGE, AND STRENGTH OF TANOAK

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In Cooperation with the University of Wisconsin

SPECIFIC GRAVITY, SHRINKAGE, AND STRENGTH OF TANOAK

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Summary

Tanoak (Lithocarpus densiflorus (Hook. & Arn.) Rehd.) from Humboldt and Trinity Counties, California, possessed average bending and compression strength values close to those of the best oak (Quercus) species that have been tested at this Laboratory.

Specific gravity determinations of tanoak revealed no excessive variation among samples from two heights in the commercial lengths of each of five trees. Shrinkage in volume was rather high, and appeared to be associated with collapse of cells in many specimens. Transverse shrinkage was about normal for wood having the density of tanoak.

Introduction

Tanoak (Lithocarpus densiflorus) grows from the Umpqua river in southern Oregon southward through California along the Coast ranges to the Santa Inez mountains, east to Santa Barbara, and on the western slopes of the Sierra Nevada to Mariposa County. Earlier names were Quercus densiflora and Pasania densiflora.

Common names in use in California include tanbark oak and chestnut oak, while in Oregon it is often called California chestnut oak, peach oak, and live oak. Tanoak is the name now most widely accepted. It is not a true oak, but is considered the connecting link between the oaks and chestnuts. The fruit resembles that of the oak, while the flowers are nearly identical with those of the chestnut.

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

Tanoak grows chiefly in mixed stands with redwood and Douglas-fir, and occasionally with California live oak. It is readily distinguished from associated trees by the light color of its foliage. It grows to large sizes along the Coast but is a shrub at high elevations.

The form and size of the trunk and limbs depend on the surrounding conditions. In close stands, the trunks are long, rarely straight, and support a narrow pyramidal crown of ascending branches. In the open, the trunks are short and thick, and support a mass of large, horizontally spreading limbs that form a broad, dense, and symmetrically rounded crown. It is reported to reach its best development for lumber on the ridges and high ground within the redwood belt.

The bark, which varies in thickness with growth conditions and age, is pale brown tinged with red, and often has grayish areas. It is either smooth or broken by deep, narrow seams into very wide and square plates, depending also on age. The bark contains an appreciable amount of tannin, and has been the principal commercial source of tannin on the Pacific Coast for years.

Tanoak is reportedly a slow-growing species. It is apparently quite free from insect diseases but very susceptible to injury from fire. The wood is light brown faintly tinged with red, fine grained, porous, and has strongly marked medullary rays. The annual rings are often difficult to distinguish.

The bark of tanoak has been used extensively for tanning purposes, and the wood has been sold for heating purposes, burned in logging operations, or left to rot in the forest. Little information is available on the strength of tanoak or its utilization by the lumber trade.

In the early 1900's a series of tests were made on tanbark oak (Quercus densiflora) from California, and a report² was prepared to emphasize the possibilities of using tanbark oak lumber. This report included:

- I. Tanbark Oak and the Tanning Industry (Jepson)
- II. Utilization of the Wood of Tanbark Oak (Betts)
- III. Distribution of Tannin in Tanbark Oak (Mell)

In spite of the conflict in names, both common and botanical, the Bulletin is believed to concern tanoak (Lithocarpus densiflorus). Details of the selection of the test specimens and the origin of growth of the material are not clear, but the methods of testing are believed to be comparable to present standard procedures.

The deterioration of old producing areas, the development of second-growth stands, and the accessibility of new locations of supply leave some

²Jepson, Betts, and Mell. California Tanbark Oak, U. S. Department of Agriculture, Forest Service, Bulletin No. 75, 1911.

questions about the strength of existing tanoak. With this in mind, a brief series of exploratory tests was undertaken.

Material Tested

Samples of five tanoak trees supplied by the California Forest and Range Experiment Station and the Trinity National Forest were studied to determine the specific gravity, shrinkage, and certain mechanical properties of the wood. The trees grew in Humboldt and Trinity Counties, California, at elevations ranging from 1,000 to 3,000 feet. The trees were selected as representative of the species.

Data on the trees and samples are given in table 1.

Growth

Growth of the trees in diameter ranged from fairly rapid to slow. Growth rings per radial inch ranged between 6 and 28 and averaged 14. None of the trees sampled were listed as dominant, which indicates that tanoak occupies a subordinate position in the forest. Rings-per-inch data for specific gravity specimens appear in table 2.

Samples

Sample cross sections 32 inches long were taken from each tree at heights of 14 feet 8 inches and 30 feet 8 inches above the stump. At the 14-foot level, the trees ranged from about 12 to 18 inches in diameter. Height in the tree from which the bolts were taken is indicated in the tables by the letter "d" for the 14-foot level and the letter "h" for the 30-foot level.

Specific Gravity and Shrinkage in Volume

Specific gravity specimens approximately 2 by 2 inches in cross section and 4 inches long were cut from flitches extending across the sample bolts from bark to bark through the pith. Shrinkage in volume was determined from the specific gravity specimens. Specimens extending in opposite directions from the pith were indicated by the letters "H" and "K", and were numbered consecutively from the pith outward.

Specific gravity and volumetric shrinkage data are presented in table 2. Specific gravity based on weight when oven-dry and volume when green ranged from a high of 0.632 to a low of 0.542, and averaged 0.588. Average values at the 14- and 30-foot levels were about the same. The specific gravity of tanoak from lumber used in kiln-drying studies in 1946 was 0.56 on the same basis.²

Shrinkage in volume was variable, and in some cases appeared to be associated with cell collapse. The range in volumetric shrinkage was between 12 and 25 percent of the volume when green, and averaged 17.3 percent.

Transverse Shrinkage

Tangential and radial shrinkage specimens were cut from cross-sectional disks 1 inch thick. The tangential shrinkage specimens were about 1 inch in size in the radial direction and 2 to 4 inches in the tangential direction, and were cut along the growth rings. No specimens were taken closer than 2-1/2 inches from the pith because of extreme curvature of the growth rings closer to the pith.

Average transverse shrinkage values for individual trees from the green to air-dry and oven-dry conditions are listed in table 3. The tangential shrinkage from the green to the oven-dry condition ranged between 7.5 and 18.1 percent, and averaged 11.7 percent.

Radial shrinkage specimens also were cut from a 1-inch-thick disk. They extended radially from the center approximately 4 inches, and were 1 inch in the tangential direction. Due to the small diameters of the bolts, only 1 or 2 specimens were taken from opposite sides of the pith at each height in the trees. Average radial shrinkage values from green to air-dry and oven-dry conditions also appear in table 3. The air-dry moisture content of the specimens at equilibrium at 65 percent relative humidity and 80° F. was about 13 percent. Transverse shrinkage of boards in the 1946 drying study² amounted to 12 percent in thickness and 13 percent in width when dried from green to 6 percent moisture content. Total radial shrinkage ranged between 4.1 and 5.6 percent of the dimension when green, and averaged 4.9 percent.

Shrinkage Along the Grain

Longitudinal shrinkage was measured on specimens 1 by 1 inch in cross section and up to 9 inches long from both sides of the flitch that extended through the pith. The length of individual specimens depended

²Torgeson, O. W. Kiln Drying Schedules for 1-Inch Laurel, Madrone, Tanoak, and Chinquapin. Forest Products Laboratory Rept. No. 1684, 1950.

upon the presence or absence of defects in the flitch. Only specimens with clear wood were used.

In general, shrinkage along the grain was not excessive. Of 97 specimens, 17 exceeded 0.30 percent in total shrinkage from the green to the oven-dry condition. Values of shrinkage along the grain for individual specimens dried to air-dry and oven-dry conditions are listed in table 4.

High longitudinal shrinkage in hardwoods is frequently associated with tension wood, a form of wood structure characterized by gelatinous fibers. These fibers have been found in large numbers on the upper sides of leaning broadleaved trees, particularly cottonwood.

Three of the five tanoak trees were reported to lean as they stood in the forest. However, the high longitudinal shrinkage was not confined to these three trees. More information on the occurrence of high shrinkage along the grain of leaning hardwood trees is desirable.

Exploratory observations of the microscopic structure of specimens with high and low longitudinal shrinkage from opposite sides of two trees indicated many more gelatinous fibers in the specimens with high shrinkage. A microscopic examination revealed many gelatinous fibers in a section of stick 1dH2, and none in stick 1dK2. These sticks came from opposite sides of tree No. 1. Similarly in tree No. 5, stick 5dH4 contained many gelatinous fibers, while none were present in a comparative section from stick 5dK4 (fig. 1).

Longitudinal shrinkages on the basis of the dimensions of the green sticks, were:

1dH2 -- 0.358 percent, 1dK2 -- 0.100 percent
5dH4 -- 0.533 percent, 5dK4 -- 0.116 percent

Mechanical Tests

Because of the limited size of the sample bolts, specimens 1 inch square in cross section were used for both bending and compression tests. Sticks were cut from a 1-1/4-inch flitch across the diameter of each bolt. Each 1-inch growth increment from pith to bark was represented by 1 stick. Even-numbered pieces were taken from one side of the pith, and odd-numbered pieces from the other. Knots, checks, heart rot, and decay caused shifting of area representations, since some of the pith area was unsuited for testing.

Static bending specimens were 16 inches long and were loaded at the center of a 14-inch span on the side toward the pith. Tests were made only to maximum load, because work values (total work) beyond that point are not

directly comparable for beams of varying size. Specimens tested in compression parallel to the grain were 4 inches long, and the compression was measured with an extensometer over the center 2 inches of length. The two types of test specimens were matched end to end in the flitch.

Procedures

Testing procedures conformed to the standards established by the American Society for Testing Materials, Part II, Secondary Methods, "Methods of Testing Small Clear Specimens of Timber, D143-52." These methods permit direct comparison of results with previous and future tests.

Results of Mechanical Tests

Average test results, as presented in tables 5 and 6 for bending and compressive strength, respectively, indicate only a slight difference between the 2 tree heights examined.

While tanoak is not in the genus *Quercus*, which includes the widely distributed species in the white and red oak groups, the characteristics and uses of tanoak lumber are very similar to those of the true oaks, and ⁴ comparisons can best be made with them. There are numerous oak species which considerably exceed tanoak in specific gravity, including live oak (0.81), canyon live oak (0.70), Oregon white oak (0.64), and swamp white oak (0.64). Among all the true oaks, however, only live oak exceeds tanoak in average maximum crushing strength. Modulus of rupture and modulus of elasticity in static bending are also outstanding in tanoak in comparison with the true oaks, including those species of higher specific gravity.

There appeared to be no consistent trend as to the location of the better material in the tree cross section. There were areas in the various sections, however, that did not show normal relationship between specific gravity and either modulus of rupture or maximum crushing strength. The modulus of elasticity was also found to be deficient in many of these scattered areas, especially in some inner pieces.

Static bending failures were mostly compression followed by splintering tension, the type most commonly encountered. There were a few failures in tension with no visible evidence of compression, and there was some evidence of slight spiral grain.

⁴Markwardt, L. J., and Wilson, T. R. C. Strength and Related Properties of Woods Grown in the United States. U. S. Dept. of Agriculture Tech. Bull. No. 479, 1935.

Strength-density relations were quite variable, with some pieces showing lower strength properties than would be expected from their specific gravity. That variation, together with the nature of some bending failures and the behavior of the material when drying, is attributed to the presence of extractives and abnormal growth, such as tension wood. The presence of excessive amounts of tension wood would be expected to cause warping.

Data from the early tests of tanoak are included in tables 5 and 6 for comparison with the recent test data. Specific gravity data were not reported, but calculations of specific gravity based on reported weights per cubic foot and the associated moisture content values indicate that the early test material may have been slightly lower in density than the present test samples. Only the values for green wood, of course, can be compared with the present test data.

The modulus of rupture, modulus of elasticity, and work to proportional limit determined from the early data are nearly the same as those determined from the recent test samples (table 5). The maximum crushing strength in compression parallel to the grain is also at about the same level as in the recent tests (table 6).

The similarity of the two series of tests in static bending and compression indicates that the early tests may also provide a reasonable estimate of the other properties included in that study: compression perpendicular to grain and shear parallel to grain. Table 7 shows the values obtained for those properties in the early tests.

The early tests included both air-dried and kiln-dried material. Since the kiln-drying practices then prevalent are not specifically known, data on the kiln-dried material cannot be evaluated accurately. Tables 5, 6, and 7 include the average values obtained in the early tests on tanoak in an "air-dry" condition of 13.3 to 14.4 percent average moisture content. For convenience, these data have also been adjusted to the standard moisture content, 12 percent. These adjusted data provide a basis for comparing dry tanoak with other species, although it must be emphasized that the data are quite old and should not be considered as reliable as the more carefully standardized data reported for other species.⁴ The ratio of strength at 12 percent moisture content to that at the green condition does correspond very closely to published ratios⁴ for hardwoods, however, except for fiber stress and work to proportional limit in static bending and compression perpendicular to grain. Hence, it appears that the adjusted dry values are probably quite reasonable.

Conclusions

The limited tests included in this work yielded an average specific gravity (based on volume when green and weight when oven-dry) of 0.588 for 5 representative trees of tanoak. That value is quite similar to the average obtained in early Forest Service tests on the species, and places tanoak on the same general density level as the true oaks (Quercus spp.).

Tests in bending and compression showed that tanoak has strength properties close to those of the best Quercus species. The average shrinkage in volume was rather high, 17.3 percent, and appeared to be associated with cell collapse in many specimens. Transverse shrinkage, which averaged 4.9 percent in the radial direction and 11.7 percent in the tangential direction, could be considered normal for dense wood.

More than 17 percent of the longitudinal shrinkage specimens showed particularly high shrinkage. Microscopic observations confirmed the presence of gelatinous fibers in specimens with abnormally high longitudinal shrinkage. Direct correlations between occurrence of gelatinous fibers and lean in trees were not made, but it was shown that specimens with and without gelatinous fibers occurred in opposite sides of the same tree.

Table 1.--Growth data on tanoak trees and samples

Tree No.	Elevation	Aspect	Tree class	Lean, amount and direction	Diameter, breast height	Approximate age	Total height	Merchantable length	Height of samples above stump	Diameter, inside bark	Length of samples
				Degrees	Inches	Years	Feet	Feet	Feet	Inches	Inches
1	2,000	East	Suppressed	10° W	20	150	95	60	14	14.8	32
2	3,000	Ridge	Codominant	0	22	120	115	80	30	12.9	32
3	1,000	North	Intermediate	2° SW	16	75	65	42	14	18.1	32
4	1,000	West	Codominant	2° W	22	75	108	72	30	15.6	32
5	1,000	West	Codominant	0	20	60	96	68	14	12.2	32
									30	9.5	32
									14	14.8	32
									30	12.0	32
									14	14.3	32
									30	12.5	32

Table 2.--Rings per inch, specific gravity, and volumetric shrinkage¹ of tanoak (*Lithocarpus densiflorus*)

Tree	Bolts ²	Specimens taken increasing distances from pith												All sticks		
		1 (closest to pith)			2			3			4 (farthest from pith)					
		Rings per inch	Specific gravity	Volu- metric shrinkage	Rings per inch	Specific gravity	Volu- metric shrinkage	Rings per inch	Specific gravity	Volu- metric shrinkage	Rings per inch	Specific gravity	Volu- metric shrinkage	Rings per inch	Specific gravity	Volu- metric shrinkage
1	d & h	18.0	0.616	16.4	20.8	0.593	18.8	24.0	0.589	16.7	19.0	0.582	12.2	20.4	0.595	16.0
2	d & h	9.0	.615	18.5	16.0	.614	21.6	18.7	.595	20.3	20.5	.590	13.4	16.0	.604	18.4
3	d & h	7.8	.555	15.6	12.8	.578	17.0	23.5	.574	14.4				14.7	.569	15.7
4	d & h	9.5	.596	16.0	8.8	.580	17.2	12.0	.587	16.4				10.1	.588	16.5
5	d & h	6.8	.578	16.4	7.0	.568	20.1	9.0	.582	19.8	11.0	.592	19.9	8.4	.580	19.0
Average		10.2	.592	16.6	13.1	.587	18.9	17.4	.585	17.5	16.8	.588	15.2	14.1	.586	17.3

¹Shrinkage is expressed as percent of the volume when green.

²The letters "d" and "h" refer to the heights in the trees, 14 and 30 feet, respectively, from which the bolts were taken.

³Average of all individual values.

Table 3.--Tangential and radial shrinkage¹ of tanoak from green to air-dry and oven-dry conditions

Tree No.	Tangential shrinkage		Radial shrinkage	
	Air-dry	Oven-dry	Air-dry	Oven-dry
	Range	Average	Range	Average
1	d & h : 6.4 - 9.2	7.9	10.0 - 13.0	11.6
			2.2 - 3.1	2.6
				4.4 - 5.4
2	d & h : 5.8 - 9.3	7.7	9.6 - 13.3	11.5
			1.9 - 2.7	2.3
				4.1 - 5.2
3	d & h : 4.4 - 11.8	7.9	7.5 - 14.9	11.2
			2.5 - 3.2	2.8
				4.7 - 5.2
4	d & h : 4.8 - 8.9	6.8	8.7 - 12.6	10.8
			2.2 - 2.8	2.5
				4.3 - 5.3
5	d & h : 6.7 - 14.5	9.9	10.1 - 18.1	13.4
			2.7 - 3.4	3.1
				5.0 - 5.6
Average		8.0		11.7
				2.7
				4.9

¹Shrinkage is expressed as percent of the volume when green.

²The letters "d" and "h" refer to the heights in the trees, 14 and 30 feet, respectively, from which the bolts were taken.

Table 4.--Longitudinal shrinkage¹ of tanoak from green to
air-dry and oven-dry conditions

Tree	Bolt ²	Direction ³	Shrinkage of specimens taken increasing distances from the pith								
			1	2	3	4	5	6	7	8	
			Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	
<u>Air-Dry Sticks</u>											
1	d	H	0.327	0.169	0.095	0.032					
		K	.168	.067	.053	.053	0.042	0.042			
		h	.047	.012	.059	.012	.012				
2	d	H	.028	.105	.109	.147	.084	.063	0.063		
		K	.012	.012	.035	.012	.035	.024	.059	0.031	
		h	.084	.084	.116	.085	.063	.079			
3	d	H	.190	.137	.063	.053					
		K	.100	.128	.100	.114	.142				
		h									
4	d	H	.095	.221	.147	.053	.000				
		K	.000	.000	.000	.011	.053	.053			
		h	.000	.116	.126	.084	.021				
5	d	H	.059	.106	.282	.295	.341				
		K	.084	.074	.063	.032	.021				
		h	.143	.132	.132	.103					
6	d	H	.059	.094	.059	.047					
		K									
		h									
<u>Oven-dry Sticks</u>											
1	d	H	.527	.358	.242	.169					
		K	.337	.100	.158	.169	.137	.148			
		h	.176	.167	.200	.118	.118				
2	d	H	.152	.270	.279	.337	.253	.221	.211		
		K	.071	.106	.153	.141	.153	.141	.176	.138	
		h	.232	.242	.306	.231	.205	.237			
3	d	H	.348	.295	.190	.200					
		K	.256	.299	.270	.228	.313				
		h									
4	d	H	.200	.400	.274	.158	.105				
		K	.084	.095	.084	.095	.147				
		h	.084	.253	.263	.211	.105				
5	d	H	.165	.235	.482	.533	.597				
		K	.169	.190	.169	.116	.105				
		h	.314	.294	.278	.265					
6	d	H	.153	.200	.176	.141					
		K									
		h									

¹Shrinkage is expressed as percent of the volume when green. Shrinkage exceeding 0.15 percent when air-dry and 0.30 percent when oven-dry is considered excessive.

²The letters "d" and "h" refer to the heights in the trees, 14 and 30 feet, respectively, from which the bolts were taken.

³The letters "H" and "K" refer to the opposite sides of the pith from which the samples were taken.

⁴Samples lengthened slightly when dried from a green to an air-dry condition.

Table 5.--Results of static bending tests of tanoak (*Lithocarpus densiflorus*)
from Humboldt and Trinity Counties, California

Tree No. of tests	Moisture content	Specific gravity ¹	Stress at proportional limit	Modulus of rupture	Modulus of elasticity	Work to failure
	Percent	P. S. I.	P. S. I.	P. S. I.	P. S. I.	In.-lb. per cu. in.
Lower (d) Bolts ²						
1	82.0	0.589	5,420	10,350	1,583	12.46
2	73.8	.597	5,530	10,270	1,573	12.70
3	74.9	.575	6,200	10,000	1,555	12.75
4	77.7	.589	6,240	10,710	1,582	14.54
5	85.3	.562	6,490	11,010	1,615	14.50
Average	78.7	.582	5,980	10,470	1,550	13.35
Upper (h) Bolts ²						
1	71.3	.601	5,870	10,920	1,577	13.73
2	73.4	.615	6,060	10,880	1,537	16.56
3	81.5	.564	5,990	10,500	1,567	12.68
4	71.7	.586	5,680	11,110	1,641	13.74
5	75.5	.579	5,360	10,570	1,507	18.62
Average	74.7	.589	5,790	10,800	1,566	15.07
Comparative Data from Early Forest Service Tests ³						
.....	89.5	4.563	6,580	10,710	1,678	1.49
(5)	14.0	4.64	9,080	15,510	2,080	2.27
(6)	12.0	4.65	9,630	16,590	2,160	2.45

¹ Specific gravity based on volume at test and weight when oven-dry.
² Lower (d) and upper (h) bolts were taken from tree heights of 14 and 30 feet, respectively.
³ U. S. Department of Agriculture Bulletin No. 75, 1911. Test specimens were 2 inches square in cross section, and were taken from unknown heights in the trees.
⁴ Calculated from values given for weight per cubic foot as tested.
⁵ Values on this line are air-dry data published in Forest Service Bulletin No. 75.
⁶ Values on this line are data that have been adjusted to a basis of 12 percent moisture content by standard procedures.

Table 6.--Results of tests in compression parallel to the grain of tanoak (*Lithocarpus densiflorus*) from Humboldt and Trinity Counties, California

Tree No.:	Number of tests:	Moisture content:	Specific gravity ¹ :	Stress at proportional limit:	Maximum crushing strength:	Modulus of elasticity:
:	:	Percent:	:	P.s.i.:	P.s.i.:	1,000 P.s.i.:
<u>Lower (d) Bolts²</u>						
1	6	84.2	0.587	3,360	4,490	1,918
2	6	79.9	.593	3,830	4,700	1,757
3	5	84.8	.563	3,740	4,580	1,554
4	6	79.2	.584	3,680	4,780	1,822
5	4	87.2	.566	3,520	4,690	1,738
Average		83.1	.579	3,630	4,650	1,758
<u>Upper (h) Bolts²</u>						
1	5	72.2	.590	3,750	5,030	1,967
2	5	79.4	.603	3,590	4,420	1,631
3	5	80.2	.562	3,540	4,740	1,661
4	6	73.4	.582	3,950	4,890	1,610
5	5	79.0	.569	3,420	4,740	1,631
Average		76.8	.581	3,650	4,760	1,700
<u>Comparative Data from Early Forest Service Tests³</u>						
.....	237	86.8	$\frac{4}{4}$.563	4,840
(5)	406	14.4	$\frac{4}{4}$.64	8,170
(6)	406	12.0	$\frac{4}{4}$.65	9,200

¹Specific gravity based on volume when green and weight when oven-dry.

²Lower (d) and upper (h) bolts were taken from tree heights of 14 and 30 feet, respectively.

³U. S. Department of Agriculture Bulletin No. 75, 1911. Test specimens were 2 inches square in cross section, and were taken from unknown heights in the trees.

⁴Computed from values given for weight per cubic foot as tested (static bending tests).

⁵Values on this line are air-dry data published in Forest Service Bulletin No. 75.

⁶Values on this line are data that have been adjusted to a basis of 12 percent moisture content by standard procedures.

Table 7.--Results of early Forest Service tests¹ of tanoak
(Lithocarpus densiflorus) in compression per-
pendicular to grain and shear parallel to grain

Compression perpendicular to grain			:	Shear parallel to grain		
Tests	Moisture	Fiber stress	:	Tests	Moisture	Maximum
:	content	at	:	:	content	shear
:	:	proportional	:	:	:	strength
:	:	limit	:	:	:	:
-----			:	-----		
<u>Number</u>	<u>Percent</u>	<u>P.s.i.</u>	:	<u>Number</u>	<u>Percent</u>	<u>P.s.i.</u>
<u>Green</u>						
244	77.9	1,350	:	221	83.1	1,410
<u>Air-Dry (As Tested)</u>						
316	13.4	1,660	:	204	13.3	1,960
<u>Air-Dry (Adjusted to 12 Percent Moisture Content)</u>						
316	12.0	1,730	:	204	12.0	2,030

¹U. S. Department of Agriculture, Forest Service Bull. No. 75,
1911.

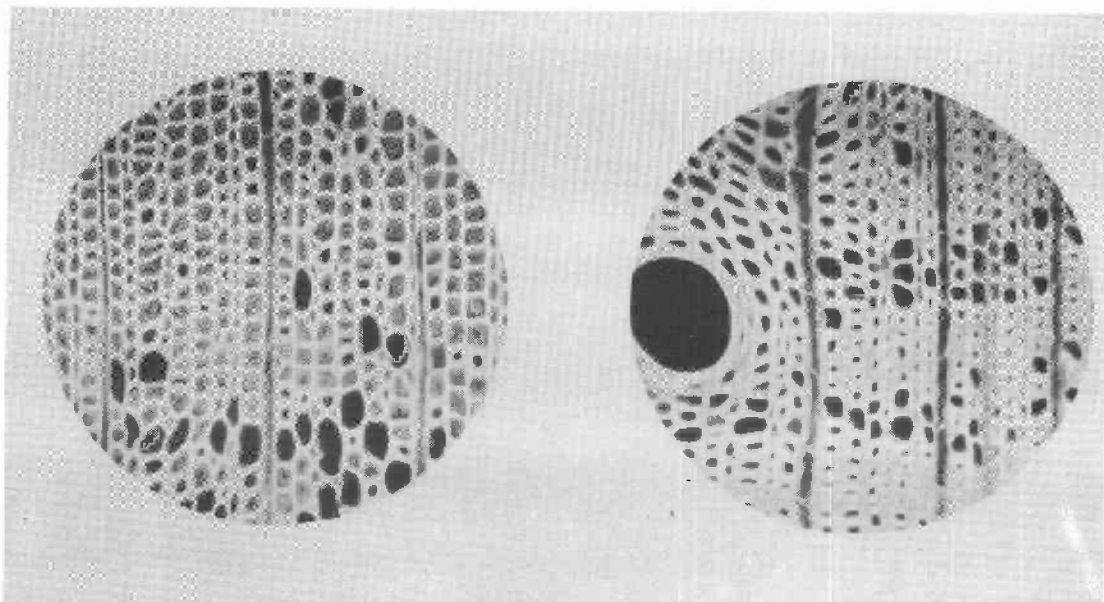


Figure 1. --Magnified cross section of sticks of high and low longitudinal shrinkage from opposite sides of tree No. 5. Section at left, with a shrinkage value of 0.533 percent, shows gelatinous fibers. These fibers are absent in section at right which has a shrinkage value of 0.116 percent. Percentages are based on dimensions when green.

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