CHARACTERISTICS FOR PRESORTING WHITE FIR LUMBER WITH WETWOOD [1]

James C. Ward
Forest Products Laboratory
Madison, Wisconsin

Del Shedd
Roseburg Lumber Company
Anderson Division
Anderson, California

Introduction

Wetwood, or sinker heart, is an abnormal type of heartwood that frequently occurs in lumber of the western true firs and adversely affects drying. Boards containing wetwood take considerably longer to dry than normal wood and will have uneven moisture contents at the conclusion of a conventional kiln drying cycle (2, 3, 7, 8, 12, 16).[2] Furthermore, most wetwood boards will be above 19% moisture content (MC) limitation of American Softwood Lumber Standard PS 20-70 (14). Kiln drying times cannot be extended to dry wetwood boards completely, because normal stock will then be overdried and subject to serious degrade and losses from roller splitting during planing (1, 3, 7, 12, 19). Even after wet boards are dried below the required 19% MC, they may still have troublesome wet pockets that cannot be eliminated without serious overdrying (19). Common commercial practice is to sort out kiln dried boards with greater than 19% MC and redry them in a later kiln run, but the redry operation increases kiln drying costs by at least 45%. Reinking reported 13 to 19% of kiln dried white fir lumber had to be redried regardless of the kiln schedule used (19).

Presorting or segregation of wetwood boards from normal stock on the green chain has long been advocated as a practical alternative to the redry problem (1, 2, 3, 7, 8, 9, 12). Wetwood boards can then be dried for longer times under special schedules in separate charges, avoiding serious overdrying of normal stock. For best results, though, white fir should be segregated into three green drying sorts (sapwood, heartwood, and wetwood or sinker) and each sort dried separately (2, 7, 8, 12).

At the present time white fir can be presorted with good accuracy by experienced graders; yet the practice has not been widely adopted. Effective presorting requires that each board be visually examined on both surfaces during the segregation operation. Under high production mill conditions, manual presorting is generally not possible. Examination of individual

[1] The use of trade names in this article is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the U.S. Department of Agriculture of any product to the exclusion of others that may be suitable.

[2] Underlined numbers in parentheses refer to literature cited at end of report.

boards is also limited where tray and drop sorters are used. Thus, for presorting to become a commercial reality, instrumentation should be developed for automatic presorting of wetwood lumber.

This paper reports results from a series of drying tests on white fir, Abies concolor, (Gord. & Glend.) Lindl. ex Hildebr., the most important commercial species of the western true firs (6). Study objectives were to determine wetwood characteristics that could be used for a more objective method of presorting. Determination of measurable wood properties to accurately identify wetwood will help to promote wider use of presorting at high-production mills where boards flow along the green chain at 60 lugs per minute.

Methods and Materials

This study consisted of three small-scale kiln drying tests at the Forest Products Laboratory (FPL) in Madison, Wis., and one large-scale test at Anderson, Calif.[3] In conjunction with the drying tests the following wood properties were measured and evaluated with relation to drying characteristics: Green board weight or density, moisture content, specific gravity, pH, and pulsed-current resistances. Samples for the drying test and wood property evaluations were collected from 1-3/4-in.-thick dimension lumber freshly sawed from white fir timber grown in northern California on the west slope of the Cascade Range.

The green board sections were all assembled at Anderson. For the large-scale test boards 12 in. wide by 16 ft. long were preselected from the green chain after cutoff and bulk-piled under polyethylene sheets to reduce moisture loss. For the small-scale tests, green board sections 3 to 5 ft. long were individually wrapped in polyethylene and packed into opaque, covered shipping containers. These containers were trucked to Madison during the winter months.

Drying Tests

All drying tests were conducted with green board samples using the kiln schedule in Table 1.

Large-Scale Test. This large-scale test at Anderson, Calif. involved 299 flatsawn boards, 12 in. wide by 16 ft. long. The purpose was to determine if board weight and pulsed-current resistance could be applied to commercial presorting of white fir dimension lumber. Studies of western hemlock dimension lumber found that measurements of board weights and pulsed-current resistances were both necessary for identifying boards with wetwood (5, 15). For this test, sample boards were preselected from the green chain after cutoff and bulk-piled under polyethylene sheets to reduce moisture loss.

---

[3] At the Kimberly-Clark Corporation mill now owned by Roseburg Lumber Company.

The 299 boards were individually weighed. Pulsed-current resistance measurements were then made on both surfaces of each board at three places along the length. These three points were at the contact point that an inline dielectric moisture meter would touch to measure MC in each board after kiln drying. Forty-two resistance measurements were made in each board. Green board MC was not measured in this test.

Small-Scale Tests. An experimental dry kiln at FPL was used for the three small-scale tests. The study was initiated with two tests that compared the drying characteristics of samples containing sapwood, heartwood, wetwood, and decayed wood with their salient wood properties. These wood properties were measured from both the drying test samples and from end-matched board sections. The first test used 50 samples, 8 in. wide by 30 in. long, consisting of 16 sapwood, 16 heartwood, and 18 wetwood samples. The second test used 41 samples, 8 or 12 in. wide by 18 in. long. Five of these samples contained wood decayed by fungi, while the remaining 36 samples contained mixtures of sapwood, heartwood, and wetwood.

The third small-scale test used 38 samples, 8 to 12 in. wide by 30 in. long, that were cut from board sections 3 to 4 ft. long. These board sections were collected at the Anderson mill upon completion of the large-scale test. This third test evaluated more fully the wood properties and drying characteristics of heavy sapwood boards. Heartwood with high and low pulsed-current resistances and mixed board types containing wetwood and normal wood were also evaluated in the third small-scale test.

Wood Properties

During the small-scale tests, most measurements of wood properties were made on drying samples and on end-matched wood samples cut from the original green full-length boards.

Board Weight. All samples were weighed prior to drying, and the unit weight or density of each board was calculated in terms of pounds per board feet. Samples for the small-scale tests were weighed to the nearest gram on a platform balance (18 kg capacity) in the laboratory. Full-length boards for the large-scale test were weighed in the mill yard to the nearest pound on a portable platform scale (1,100 lb. capacity).

Moisture Content. For all green and dried samples in the small-scale tests, MC was determined gravimetrically and based on ovendry wood weight. In the large-scale test, the average MC was determined after kiln drying at three points along the length of each 16-ft. sample board with an inline, dielectric moisture meter.

Specific Gravity. The volume of small green wood samples (end-matching the drying samples) was determined by the water immersion method and specific gravity calculated on the basis of ovendry weight and green volume.

pH. Sawdust from green wood was moistened with freshly boiled and cooled distilled water. After soaking at least 30 min., the moistened wood was measured for pH with a glass electrode pH meter.

Pulsed-Current Resistances. The Shigometer, a portable ohmmeter (Northeast Electronics Corp., Concord, N.H.), was used to measure resistances to a pulsed electric current (10). Pulsed-current resistances were measured in green wood on the surface of board samples and on the end grain of small wood samples. Needle electrodes spaced 1/2 in. apart were inserted 1/4 in. into the wood.

Results and Discussion

Wood Types and Properties

The appearance of sapwood, heartwood, and wetwood dried in this study was similar to descriptions by previous investigators (2, 12). When compared to sapwood and heartwood, wetwood had a decidedly water-soaked appearance with darker hues that ranged from dull gray to purplish. The smell of a sour, sometimes rancid, odor of volatile fatty acids could always be detected in wetwood. These fatty acids are characteristic of the wetwood and can be accurately detected with gas chromatography in the laboratory, but the technique cannot currently be applied to commercial presorting of lumber.

Table 2 lists the comparative properties of sapwood, heartwood, wetwood, and decayed wood determined from small-scale test samples. Even though wetwood may appear wetter than sapwood, its moisture content is not always higher and may even be lower. Wetwood is more aptly named when compared with normal heartwood, which had the lowest moisture contents. The average specific gravity of wetwood was higher than all other wood types, even though the lowest specific gravity value was measured in wetwood. Specific gravities of sapwood were comparable to wetwood. For the white fir in this study, as in other studies (17, 18), it was not possible to distinguish wetwood from sapwood solely on the basis of specific gravity. These other studies did find that specific gravities of both sapwood and wetwood from the butt sections of white fir trees were significantly higher than comparable wood from upper logs.

Resistance to a pulsed electric current is a good property to distinguish sapwood and heartwood (to a lesser degree) from wetwood (Table 2). Generally, pulsed-current resistances less than 30,000 ohms can accurately indicate wetwood in white fir, providing the wood is otherwise sound and free of fungal decay.

White fir wetwood can have either an acid or an alkaline pH reaction (Table 3). The characteristic odors of wetwood appear to vary with pH. Wetwood emitting a rancid butyric acid odor tends to be more acid than wetwood with odors comparable to that of rumen fluid in cattle.

Lumber sorts of sapwood, wetwood, and to a lesser degree heartwood could be divided into heavy and light subtypes because of variations in the density or weight of green boards. The heavier type sapwood and wetwood boards required longer drying times than the lighter boards. Heartwood boards from butt logs tend to be more dense than heartwood boards from upper logs, but both subtypes can be dried to required MC within a standard kiln cycle. Comparative data for these subtypes are presented in Table 4.

Heavy sapwood has a higher moisture content but not necessarily higher specific gravity values. This type of sapwood is more prevalent in boards sawn from butt logs, and its occurrence appears to vary with site and possibly even season of the year. Longer drying times for heavy sapwood can often be attributed to high MC, but other factors such as incipient wetwood formation in butt logs may also be important.

The two types of wetwood in white fir appear to result from differences in normal wood types from which the wetwood developed. Most heavy wetwood appears to have formed directly from sapwood, but some examples may have formed in the denser heartwood of butt logs. Light wetwood appears to have formed in normal heartwood, particularly the corky type. Light wetwood usually has a lower MC and will dry faster than heavy wetwood.

Board Types and Drying Times

For all drying times, heartwood boards dried quickest, wetwood boards took the longest time, and sapwood boards were intermediate. These results agree with the results from other tests with white fir (1, 2, 7, 9, 12, 13). However, drying rates varied for the different types of normal wood and wetwood described in the preceding section. Heavy types of sapwood and wetwood take longer to dry than lighter types.

The problem of classifying various wood types into correct drying sorts is further compounded by mixtures of normal wood and wetwood within boards. Under commercial conditions, an appreciable number of boards often cannot be conveniently divided into pure sorts of sapwood, heartwood, and wetwood. Instead, mixtures of these sorts appear because of the configuration of these wood types in the stem and practical limitations on sawing.

Board Types. Observation of samples in the small-scale drying tests indicates that white fir can be divided into six general types, largely on appearance and odor of board surfaces (Table 4). In addition to the pure sorts (sapwood, heartwood, and wetwood), three mixed sorts can be used (mostly normal/sap and heart, 60 normal/40 wetwood, and 60 wetwood/40 normal). These six classifications were easily applied to the sorting of the 16-ft. boards in the large scale mill test, but further subdivisions were apparent in the three pure sorts.

The sapwood boards could generally be subdivided into light sapwood and heavier sapwood boards; the heavier ones often required an additional 12 to 24 hrs. to reach 19% MC. The heartwood boards could be subdivided into those with resistance measurements greater than 45 k ohms and those with low resistances often in the wetwood range of 20 to 35 k ohms. Both high- and low-resistance heartwood boards could be dried well under the required 19% MC in 3 to 4 days' drying time. Wetwood boards could be subdivided into heavy and light boards, but all heavy boards and most light wetwood required longer than normal drying times. Sapwood and wetwood subdivisions into light and heavy boards could be of greater commercial importance than the heartwood subdivisions.

Comparative Drying Times. Table 5 shows that under laboratory conditions the commercial kiln schedule (Table 1) with 4 days' drying time is essentially designed for sapwood boards. Many heartwood boards will be overdried and most wetwood boards will require a redrying operation. When this schedule was used under commercial conditions, Table 6 shows sapwood, heartwood, and mostly normal mixed boards could be dried in 4 days with good results. Sapwood boards which were still above 19% MC limit would have met this requirement if the drying time had been extended to 5 days. Most boards with wetwood would have required at least 6 days' drying time. Five- and 6-day drying times would have caused serious overdrying in most of the heartwood boards.

Internal water pockets, or wet streaks, were observed within the core of wetwood boards that required 5 days or longer to dry to 19% MC in the small-scale tests. Kozlik (4) found that water pockets in kiln dried western hemlock could be associated with the presence of sinker heart or wetwood. His tests showed that these internal water pockets will cause MC measurements with dielectric moisture meters to give values higher than the average MC determination by gravimetric methods. In the large-scale test, we did not check the final MC determinations by the dielectric inline meter (Table 6) with gravimetric or ovendrying. Thus it is possible that some boards may have an average MC under 19%, but are placed in higher MC categories.

Presorting Considerations

Visual and olfactory detection of wetwood by experienced graders would not have been practical for commercial presorting of sample boards used in the large-scale mill test. Under normal operating conditions, these 16-ft. boards travel on the green chain at 40 to 60 pieces per minute. Each board would need to be turned and observed on both surfaces, and many of the boards weigh in excess of 150 lb.

Results indicate that presorting of white fir would be a two-step procedure: Heartwood boards would first be segregated from sapwood and wetwood boards on the basis of differences in measurements of either moisture content or board weight. For the second step, sapwood boards would be segregated from wetwood boards by differences in their resistances to a pulsed-electric current.

Moisture Content. Results from the small-scale tests found that all heartwood boards could be segregated from all other types on the basis of green MC (Tables 2 and 4). No moisture meter is currently available for accurately determining MC of green lumber, so green MC values were not obtained for sample boards in the large-scale test. Under commercial operating conditions, MC determination would be more practical for presorting then weighing boards, but a suitable moisture meter for green lumber must first be developed. FPL is currently conducting tests for presorting of white fir dimension lumber with dielectric moisture meters.

Board Weights. Table 4 showed the most distinctive weight differences were between heartwood and all other board sorts; these weight comparisons were similar for samples from both the small-scale and large-scale tests.

Electrical Resistance to a Pulsed Current. Not all normal board sorts can be separated from wetwood sorts by electrical resistance measurements. Lower resistance values for sapwood and heartwood samples sometimes overlapped the higher resistance values for wetwood (Table 2). Wetwood resistance measurements did not exceed 50 k ohms while only 1-1/2% of all sapwood resistance measurements were less than 60 k ohms. Heartwood had the widest range of resistance measurements and about 32% of these measurements were less than 50 k ohm.

Presorting and Drying Procedure. From this study, 90% of the heartwood boards could be segregated in the first presorting step with a maximum weight of 3-1/2 lb/fbm. About 20% of the lighter boards with mixed sapwood and heartwood will also be included in this first segregation, and these boards will usually dry as fast as the pure heartwood boards. Also segregated by weight will be smaller percentages of the sapwood and mixed normal-wetwood boards. These lighter boards from other sorts are likely to be fast drying and will be under the 19% MC limit when included in a kiln charge of heartwood boards.

The second presorting step will be to segregate the sapwood and mixed sapwood-heartwood boards by electrical resistance measurements. Ninety percent of all wetwood resistances were below 30 k ohms, so this value was used to separate sapwood and mixed normal wood sorts from the slower drying wetwood and mixed wood sorts. Table 7 indicates that the slowest drying sorts of wetwood and mixed wood (Tables 5 and 6) might be comprised of boards with approximately 35 to 100% of the combined resistance measurements being under 30 k ohms. The faster drying sorts of sapwood and mixed wood boards would have about 65 to 100% of their total resistance measurements in excess of 30 k ohms.

Three separate kiln schedules would be necessary to dry the sample boards used in this study. The heartwood sort and the light sapwood and mixed wood boards from the first segregation step would be dried in 3 days. The largely sapwood sort from the second segregation step will require 4 to 5 days' drying time. At least 6 days, and possibly longer, will be required to dry the wetwood and mixed wood boards with 60% of total resistance measurements 30 k ohms or less. It is possible that presteaming lumber in the slow-drying wetwood and mixed wood sorts will reduce the number of boards that may not meet the minimum 19% MC requirement even after extended drying times. Simpson (11) tested white fir boards from the same source as the samples in the first small-scale test and found that presteaming will increase the drying rate of wetwood boards but not sapwood. This might speed up drying wetwood without increasing the risk of overdrying normal stock.

Summary and Conclusions

Boards containing wetwood generally need to be redried after a conventional kiln run. Redrying increases processing costs, but kiln drying times should not be extended to accommodate drying of wetwood boards, because the normal boards will then be overdried. Overdried white fir boards are subject to breakage during the planing operation.

Presorting, or segregation of wetwood boards from normal stock on the green chain, will reduce processing losses incurred when mixed charges of normal and wetwood lumber are kiln dried. Experimental results from this study suggest that a commercial presorting system for white fir dimension lumber will require a two-step system that begins at the green chain. The first step separates fast-drying heartwood boards from slower drying sapwood and wetwood boards by measuring either moisture content or board weight. Most of the sapwood and mixed sap-heartwood boards are then separated from the slowest drying boards with 35% or more wetwood by a series of pulsed-current resistance measurements.

Three board sorts (heartwood, sapwood, and wetwood) will result, and each sort needs to be dried under a special schedule. Mixed-wood boards with wetwood volumes greater than 35% will probably need to be dried under the schedule used to dry pure board sorts of wetwood. It is possible that presteaming green lumber will increase the drying rates of wetwood, and this aspect needs to be tested when developing kiln schedules for pure and mixed board sorts containing wetwood.

Literature Cited

1. Anderson, B. G. 1954. Study of change in grade and footage loss in kiln dried white fir lumber from the green chain to the car. Report presented at Meeting of Eastern Oregon-Southern Idaho Dry Kiln Club, La Grande, Oreg., Nov. 19, 1954. 4 p. Corvallis, Oreg.

2. Knight, E. 1955. Identification of white fir drying sorts. Western Pine Assoc. Res. Note No. 4.213. 5 p. (Jan. 15.)

3. Knight, E. 1970. Kiln-drying western softwoods. Bull. No. 7004. Moore Dry Kiln Co. of Oregon, North Portland, Oreg. 77 p.

4. Kozlik, C. J. 1971. Electrical moisture meter readings in western hemlock dimension lumber. For. Prod. J. 21 (6):34-35.

5. Kozlik, C. J., and J. C. Ward. 1981. Properties and kiln-drying characteristics of young-growth western hemlock dimension lumber. For. Prod. J. 31(6):45-53.

6. Markstrom, D. C., and J. R. Jones. 1975. White fir--an American wood. USDA For. Ser. Publ. FS-237. U.S. Gov. Print. Off., Washington, D.C. 9 p.

7. Pong, W. Y. 1971. Changes in grade and volume of central California white fir lumber during drying and surfacing. USDA For. Ser. Res. Note PNW-156. Pac. Northwest For. and Range Exp. Stn., Portland, Oreg. 20 p.

8. Pong, W. Y., and W. W. Wilcox. 1974. Spatial distribution of lumber degrade in white fir trees. USDA For. Ser. Res. Pap. PNW 184. Pac. Northwest For. and Range Exp. Stn., Portland, Oreg. 18 p.

9. Reinking, G. 1971. Kiln drying lumber to the moisture provisions of the new lumber standards. Forest Prod. Res. Soc. News Digest File J-1.1, 2 p., Madison, Wis.

10. Shigo, A. L., and A. Shigo. 1974. Detection of discoloration and decay in living trees and utility poles. USDA For. Ser. Res. Pap. NE-294. Northeast For. Exp. Stn., Broomall, Pa. 11 p.

11. Simpson, W. T. 1975. Effect of steaming on the drying rate of several species of wood. Wood Sci. 7(3):247-255.

12. Smith, H. H., and J. R. Dittman. 1960. Moisture content in kiln-dried lumber. For. Prod. J. 10(7):353-357.

13. Steel, J. 1953. Kiln drying white fir. Wood Drying Committee News Digest (Aug.) 3 p. Forest Prod. Res. Soc., Madison, Wis.

14. U.S. Department of Commerce. 1970. American softwood lumber standard. Product Standard PS 20.

15. Ward, J. C., and C. J. Kozlik. 1975. Kiln drying sinker heartwood from young-growth western hemlock: preliminary evaluation. Proc. 26th Annu. Meet. Western Dry Kiln Clubs, Oregon State Univ., Corvallis. p. 44-63.

16. Ward, J. C., and W. Y. Pong. 1980. Wetwood in trees--overview of a timber resource problem. USDA For. Serv. Gen. Tech. Res. Pap. PNW 112. 56 p. Pac. Northwest For. and Range Exp. Stn., Portland, Oreg.

17. Wilcox, W. W. 1968. Some physical and mechanical properties of wetwood in white fir. For. Prod. J. 18(120):27-31.

18. Wilcox, W. W., and W. Y. Pong. 1971. The effects of height, radial position, and wetwood on white fir wood properties. Wood and Fiber 3(1):47-55.

19. Williston, E. M. 1971. Drying West Coast dimension to meet the new lumber standards. For. Prod. J. 21(3): 44-48.

Table 1.--Kiln schedule for all 7/4-in. white fir dimension lumber and samples dried in this study

Hours	Kiln temperatures		Relative humitity	Equilibrium moisture content
	Dry bulb	Wet bulb		
	°F	°F	Pct	Pct
0 - 24	180	170	79	11.1
24 - 48	180	165	70	9
48 - 72	180	157	57	7
72 - Final MC[1/]	180	140	37	4.4

1/ Maximum times required for samples to reach 19% MC in the small-scale tests were: heartwood 83 hr, sapwood 114 hr, and wetwood 164 hr.

Table 2.--Green moisture content, specific gravity, and resistance to a pulsed electric current of 386 small samples[1/] from green white fir lumber

Wood type	Number of samples	Green moisture content				Specific gravity (green volume)				Pulsed-current resistance[2/]			
		Mean	CV[3/]	Range		Mean	CV[3/]	Range		Mean	CV[3/]	Range	
				Minimum	Maximum			Minimum	Maximum			Minimum	Maximum
		Pct	Pct	Pct	Pct					k ohms	Pct	k ohms	k ohms
Sapwood	96	177	19	91	272	0.36	14	0.28	0.57	110	71	32	305
Heartwood	111	59	23	32	108	.33	11	.25	.43	51	44	22	122
Wetwood	152	157	27	80	312	.39	18	.15	.56	15	38	4	47
Fungal[4/]	27	136	51	42	278	.34	12	.28	.42	19	49	5	36

1/ Most samples measured 1-1/2 in. thick by 1 to 3 in. wide and 2 in. along the grain.

2/ Pulsed-current resistances measured on end surfaces of freshly cut samples with needle electrodes spaced 1/2 in. apart and inserted 1/4 in. into the wood.

3/ CV = coefficient of variation or the ratio of the standard deviation to the mean expressed in percent.

4/ All wood which contained fungi and appeared to be visibly degraded or altered by these microorganisms. Included are wounded and discolored sapwood, decayed wetheart, and drier heart rots.

Table 3.--The pH of normal wood and wetwood or sinker heart from California white fir

Sample	pH	
	Range	Mode
This study1/		
Normal wood		
Sapwood	4.0-7.4	2/5.3, 6.8
Heartwood	4.5-6.5	5.5
Wetwood		
Rumen, phenolic odors	5.5-7.4	6
Rancid, butyric odors	4.5-6.8	5.5
Wood adjacent to wetwood		
Sapwood	4.5-8	2/4.8, 7
Heartwood	4.5-6.7	5.5
Wilcox (1968)		
Expressed liquid3/		
Sapwood--butt logs	--	5.7
--top logs	--	5.7
Wetwood--butt logs	--	5
--top logs	--	5.4
Wood4/		
Sapwood--butt logs	--	5.5
--top logs	--	5.5
Wetwood--butt logs	--	5
--top logs	--	6

1/ Freshly ground green wood in minimum distilled water measured with a glass electrode pH meter.
2/ Bimodal distribution.
3/ Measured by an electronic method.
4/ Green wood measured with Triplex pH indicator.

Table 4.--Classification and characteristics of green, white fir sample boards used in kilndrying tests at Forest Products Laboratory and at the Anderson, Calif. mill

Test		Number of boards	Board surface appearance: Normal, Sapwood	Board surface appearance: Normal, Heartwood	Board surface appearance: Wetwood	Board moisture content: Mean	Board moisture content: Range, Minimum	Board moisture content: Range, Maximum	Board weight: Mean	Board weight: Range, Minimum	Board weight: Range, Maximum
			- - - -Pct- - - -			- - - -Pct- - - -			- - - -Lb/fbm- - - -		
Laboratory (small-scale)	Pure sorts										
	Sapwood	38	90	6	4	167	128	216	4.8	4.0	5.8
	Heartwood	32	3	90	7	57	45	81	2.7	2	3.4
	Wetwood	32	11	--	89	162	114	262	5.4	4.2	6
	Mixed sorts										
	Mostly sapwood and heartwood	4	38	55	7	102	92	114	3.7	3.1	4.4
	60 normal/40 wetwood	9	33	26	41	123	90	234	4	2.9	5.5
	60 wetwood/40 normal	9	22	17	61	130	98	222	4.3	3.1	5.6
	With decayed heartwood	5	7	(70)	23	78	43	96	3.3	2.6	3.6
	Total FPL sample	129									
Mill (large-scale)	Pure sorts										
	Sapwood sorts										
	Light sapwood	21	76	19	5	--	--	--	4.2	3.04	4.7
	Heavy sapwood	33	90	2	8	--	--	--	5.3	4.93	6.3
	Total sapwood	54	84	9	7	--	--	--	4.8	3.04	6.3
	Heartwood sorts										
	High resistance	63	9	87	4	--	--	--	3.0	2.28	4.29
	Low resistance	23	6	87	7	--	--	--	3.1	2.18	3.93
	Total heartwood	86	8	87	5	--	--	--	3.1	2.18	4.29
	Wetwood sort	52	11	11	78	--	--	--	4.5	3.5	5.61
	Mixed sorts										
	Mostly normal sapwood and heartwood	34	44	49	7	--	--	--	3.9	2.71	4.79
	60 normal/40 wetwood	41	27	34	39	--	--	--	4.2	3.25	5.29
	60 wetwood/40 normal	32	18	23	59	--	--	--	4.5	3.75	5.86
	Total mixed	107									
	Total mill sample	299									

Table 5.--Drying times and final moisture contents for 7/4-in. white fir sample boards[1] used in experimental kilndrying tests at the Forest Products Laboratory

Board sort and subtype	Number of boards	Board MC after kiln-drying for 96 hr			Total kilndrying times to reach					
					19% av. MC			15% av. MC		
		Mean	Range		Mean	Range		Mean	Range	
			Min.	Max.		Min.	Max.		Min.	Max.
		- - - -Pct- - - -			- - - -Hr - - - -			- - - -Hr - - - -		
Pure sort										
Sapwood--light[2]	20	13.6	11.2	16	80	74	86	90	84	99
--heavy	18	18.9	13.2	27	103	94	114	113	101	129
Total sapwood sort	38	16.1	11.2	27	96	74	114	105	84	129
Heartwood	32	9.2	6	14	60	33	83	74	40	93
Wetwood	32	37.6	19	57.9	135	116	164	152	130	194
Mixed sort										
Mostly sapwood and heartwood	4	12.1	9	16	80	66	89	89	75	112
60 normal/40 wetwood	9	13.7	10	23	78	56	106	90	67	128
60 wetwood/40 normal	9	18.9	15	24	98	83	111	112	95	128
With decayed heartwood	5	13.6	9	18.5	80	61	95	90	70	107

1/ Green sample boards were end-sealed before drying. Lengths were 18 in. or 30 in. and widths were 8 in. or 12 in.

2/ Light boards weighed ≤4.8 lb/fbm, while heavy boards >4.8 lb/fbm.

Table 6.--Moisture content distribution in 7/4 white fir dimension lumber after 96 hours of commercial kilndrying in the large-scale mill test at Anderson, Calif.[1/]

Board sort and wood type	Total boards		Yield of kilndried boards					
			Board MC = 19% or less		Board MC between 19.5% and 25%		Board MC grea than 25%	
	Number of boards	Percent of total sample	Number of boards	Percent of total sample	Number of boards	Percent of total sample	Number of boards	Perc of t sam
Pure sort								
Sapwood[2/]								
Light boards	21	7.0	16	5.4	1	0.3	4	1.
Heavy boards	33	11.1	12	4	8	2.7	13	4.
Total sapwood sort	54	18.1	28	9.4	9	3.0	17	5.
Heartwood[3/]								
High resistance boards	63	--	56	18.7	5	1.6	2	.
Low resistance boards	23	--	23	7.7	--	--	--	.
Total heartwood	86	28.7	79	26.4	5	1.6	2	0.
Wetwood (sinker)[4/]								
Light boards	32	11	2	.7	8	2.7	22	7.
Heavy boards	20	6	--	--	--	--	20	6.
Total wetwood sort	52	17.4	2	0.7	8	2.7	42	14.
Mixed sort								
Mostly normal (sapwood and heartwood)	34	11.4	24	8.1	10	3.3	--	-
60 normal/40 wetwood	41	13.7	9	3	17	5.7	15	5
60 wetwood/40 normal	32	10.7	1	.3	6	2.	25	8.
Total board sample	299	100.0	143	47.8	55	18.4	101	33.:

1/ Boards 12 in. wide and 16 ft long with moisture content measured in each dried board at 4, 8, and 13 ft along the length with an inline electronic, high-frequency, power-loss moisture meter on the dry lumber chain.

2/ Light boards ≤4.8 lb/fbm; heavy boards >4.8 lb/fbm.

3/ Subtypes based on total pulsed-current resistances in each green board. Low resistance boards had 28% or more resistance measurements less than 30,000 ohms.

4/ Light boards <4.6 lb/fbm; heavy boards ≥4.6 lb/fbm.

Table 7.--Pulsed-current resistance measurements of green white fir dimension lumber according to board sort. All were 7/4-in. boards, 12-in. wide surfaces, and 16 ft long

Board sort	Number of boards	Combined number of pulsed-current resistance measurements on both surfaces of each board[1/]					
		Total		Over 30 k ohms		Under 30 k ohms	
		No.	Pct	No.	Pct	No.	Pct
Pure sorts							
Sapwood[2/]							
Light boards	21	882	(100)	816	(92.5)	66	(7.5)
Heavy boards	33	1,386	(100)	1,281	(92.4)	105	(7.6)
Combined sapwood	54	2,268	100	2,097	92.5	171	7.5
Heartwood							
High resistance boards	63	2,646	(100)	2,399	(90.7)	247	(9.3)
Low resistance boards	23	966	(100)	457	(47.3)	509	(52.7)
Combined heartwood	86	3,612	100	2,856	79.1	756	20.9
Wetwood	52	2,184	100	588	26.9	1,596	73.1
Mixed sorts							
Mostly normal (sapwood and heartwood)	34	1,428	100	1,287	90.1	141	9.9
60 normal/40 wetwood	41	1,722	100	1,160	67.4	562	32.6
60 wetwood/40 normal	32	1,344	100	496	36.9	848	63.1
Total	299	12,558					

1/ 42 resistance measurements were made on each board with 21 measurements on each opposing face. Total measurements for each board were divided and grouped according to numbers over and under 30 k ohms.

2/ Light boards ≤4.8 lb/fbm; heavy boards >4.8 lb/fbm.