

# PROBLEMS OF DRYING WESTERN HEMLOCK HEARTWOOD TO A UNIFORM FINAL MOISTURE CONTENT

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## INTRODUCTION

Drying lumber to a uniform final moisture content with minimum degrade is the goal of the kiln operator. He may be rushed, however, by sales personnel to shorten the drying time for a charge to meet an order deadline. Even with ample time to dry a charge with a given schedule, the operator still may be faced with the problem of nonuniform final moisture content, a problem that occurs regularly. Is the kiln operator using the wrong schedule? The answer is no. Many softwood species contain wet pockets or streaks in the heartwood that defy any means of drying them to an acceptable moisture content after a reasonable time in the kiln. Species included in this group are the true firs, western hemlock, sugar pine, western or Idaho white pine, redwood, and western red cedar.

I will discuss segments of several studies of the slow movement of moisture in western hemlock sinker heartwood and possible means of easing moisture problems at individual mills. Processing of western hemlock lumber

includes two difficult problems, the wide variation in moisture content after kiln drying and large losses in degrade from shake.

The problems arise in the heartwood, which includes portions of wood that have been termed wetwood or sinker or heavy wood. Sinker heartwood has a distinctive odor and darker color or wetter appearance than normal heartwood. Properties of sinker heartwood include higher initial moisture content, greater specific gravity, higher percentage of extractives, and lower drying rates than adjacent heartwood. Shake is commonly associated with sinker heartwood.

Drying to the new specification of a maximum moisture content of 19 percent, based on the ovendry weight of the wood, has caused concern to the hemlock producers. A wide range in final moisture contents from 8 to 25 percent or more has been shown in studies by Abner (1), Dedman and Van Dusen (2), Kozlik (6), and Salmon and McBride (8). Lumber with high final moisture content is attributed directly to the sinker heartwood.

First, I will report on a study that compared some of the physical and chemical properties of sinker heartwood with normal heartwood. Second, I will show that revised kiln schedules with temperatures above 212 F did not materially affect the nonuniformity of final moisture, but did reduce total kiln time. Degrade loss from shake is an unavoidable problem because shake occurs in the living tree. It can only be eliminated by proper trimming in the sawmill.

#### PROPERTIES OF HEMLOCK HEARTWOOD

All samples collected for this study were donated by Willamette Industries, Inc., Dallas, Oregon. The timber was from near Snow Peak, due east of Albany, Oregon, in the Cascade Range.

#### Methods

Samples were collected on the green chain, and 2-foot end sections were sawed from 2-inch dimension or shop lumber. Generally, vertical or near vertical grain samples were selected, because this material allows a rapid visual assessment of the amount of sinker and normal heartwood in each piece.

Fifth-four samples were collected. At least 20 samples contained a minimum width of 2.5 inches of sinker heartwood immediately adjacent to a minimum width of 2.5 inches of normal heartwood. The remainder of the samples contained similar sinker heartwood streaks, but minimum width of adjacent normal heartwood was reduced to 1 inch. Samples were protected against loss of moisture during storage. Tests on the samples were as follows:

- 1) Specific gravity and moisture content were determined on matched specimens of sinker and normal heartwood.
- 2) Matched specimens of sinker and normal heartwood were chemically analyzed by extraction of ground wood.
- 3) Determinations of pH were made on ground wood from sinker and normal heartwood.
- 4) Drying rates of matched specimens of sinker and normal heartwood were compared.
- 5) Drying rates were compared on matched specimens of sinker heartwood that were unextracted and extracted with ethanol.
- 6) Drying rates were compared on matched specimens of sinker heartwood that were unextracted, extracted with acetone, and presteamed at 212 F.

#### Moisture content

The initial moisture content averaged 66.1 percent for the normal heartwood and 153.0 percent for sinker heartwood (Figure 1). Moisture contents ranged from 32.9 to 152.4 percent for the normal heartwood and from 108.4 to 185.7 percent for sinker heartwood. The high initial moisture contents for normal heartwood may be attributed to the presence of sapwood. Only 5 of the 54 samples had moisture contents above 100 percent in normal heartwood.

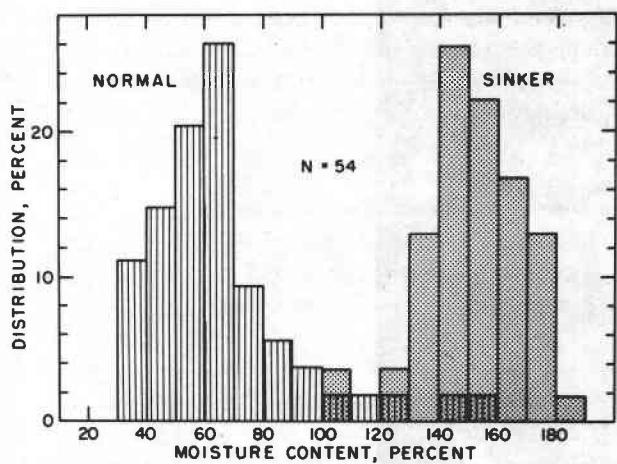


Figure 1. Distribution of unseasoned moisture contents in normal and sinker heartwood.

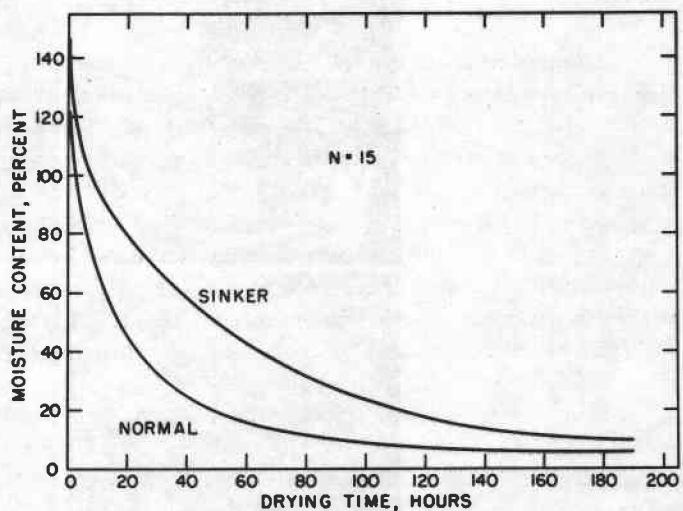


Figure 2. Drying curves for normal and sinker heartwood.

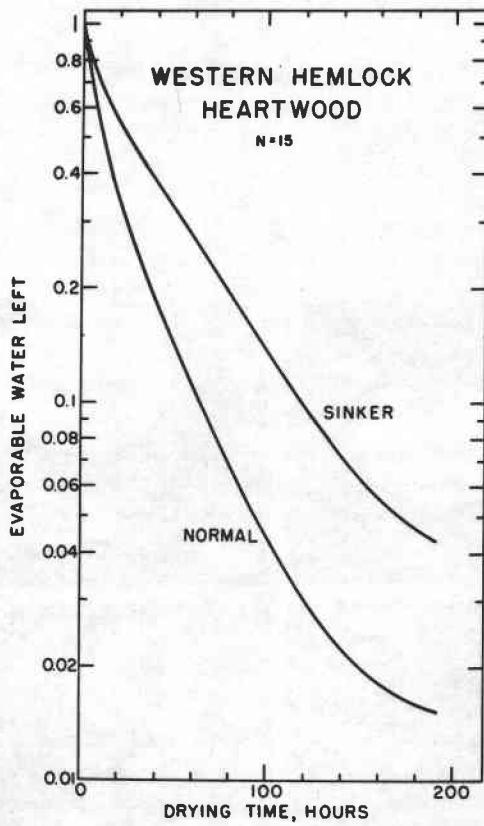


Figure 3. Comparison of evaporable water in normal and sinker heartwood.

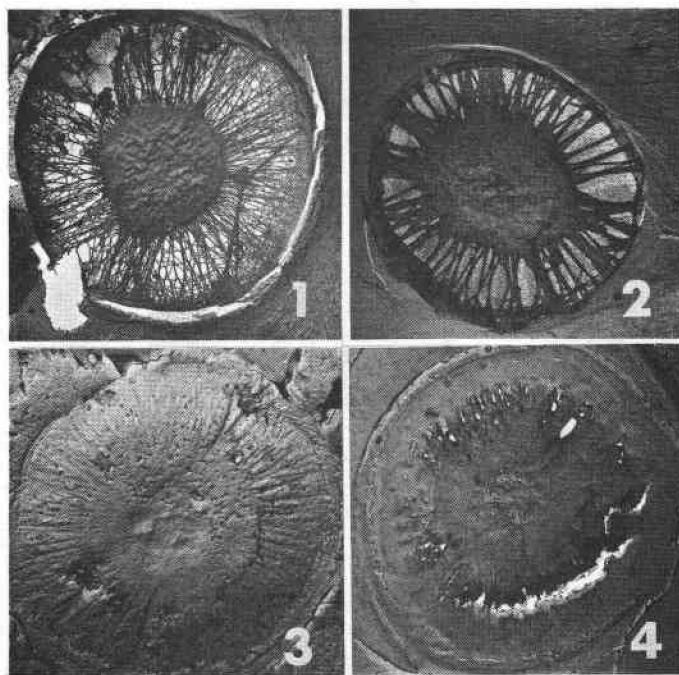


Figure 4. Normal bordered pits in hemlock sapwood (1) and heartwood (2) and in sinker heartwood (3, 4)

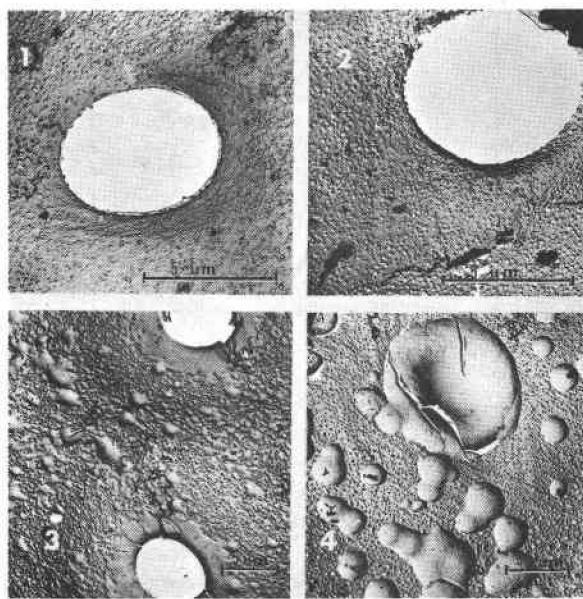


Figure 5. Extraneous deposits on the cell wall. The cell wall is well-defined in (1); deposits range from a slight coating (2) to heavily localized deposits in 3 and 4.

### Specific gravity

Specific gravity of the 54 samples, based on green volume and ovendry weight, averaged 0.426 for normal heartwood and 0.443 for sinker heartwood. The specific gravities of normal and sinker heartwood were significantly different at the 5 percent level of probability.

### Chemical analysis and pH determination.

Portions of the sample for extractive analysis and pH determinations were dried at 110 F until the moisture contents averaged 4 to 6 percent and then ovendried at 220 F. Ovendried specimens were ground in an attrition mill and placed in airtight bottles.

Determinations of pH were made with ground wood and distilled water. The average value of pH for normal heartwood was 4.8 and was 4.9 for sinker heartwood. The range in pH from 4.1 to 5.5 was similar for both sinker and normal heartwood specimens.

Ground wood of sinker and normal heartwood was extracted in ethanol. Extractives in normal heartwood averaged 1.9 percent and ranged from 1.0 to 3.7 percent; extractives in sinker heartwood averaged 9.7 percent and ranged from 4.1 to 14.9 percent. The ratio increase of extractives in sinker heartwood, compared to normal heartwood, averaged 5.5 and ranged from 2.7 to 9.6. Average specific gravity for normal heartwood was 0.419 and 0.455 for sinker heartwood. When corrected for extractive content, the average specific gravity, 0.411, was identical for both normal and sinker heartwood.

With various solvents, sinker heartwood showed a higher content of extractives than normal heartwood. Sinker heartwood had much more conidendrin, a lignan, than normal heartwood. Other lignans present are matairesinol and hydroxy-matairesinol.

### Drying rates

Drying rates for 15 matched specimens of sinker and normal heartwood were compared by sawing adjacent specimens across the width of the original samples. Specimens were dressed to 3/4 by 2 by 18 inches and placed in a drying chamber controlled at 110 F at conditions for equilibrium moisture content (EMC) of 3.8 percent for 190 hours. Sixteen periodic weighings were made during the drying cycle. Figure 2 shows drying curves for sinker and normal heartwood. The normal heartwood dried at a much faster rate than the sinker heartwood under equal conditions.

Another measure of drying rates is the fraction of evaporable water ( $E$ ) in the specimen at any given time ( $\theta$ ). Numerical values for  $E$  may be calculated from the following:

$$E = (w - c_1)/(c_0 - c_1),$$

where  $w$  is the actual moisture content of the specimen at any time  $\theta$ ,  $c_1$  is the equilibrium moisture content for these drying conditions, and  $c_0$  is the original moisture content of the wood.

The relation of  $E$  to  $\theta$  for sinker and normal heartwood is shown in Figure 3. Normal heartwood again dried faster.

### Unextracted and extracted

Movement of moisture through pit areas and cell walls in sinker heartwood is apparently obstructed or retarded more than in normal heartwood. Figure 4 illustrates by electron microscopy a normal bordered pit in hemlock sapwood (1) and a similar bordered pit in hemlock heartwood (2). Bordered pits in sinker heartwood (3) and (4) are completely encrusted or blocked with deposits.

Figure 5 shows, also by electron microscopy, various amounts of extraneous deposits on the cell wall adjacent

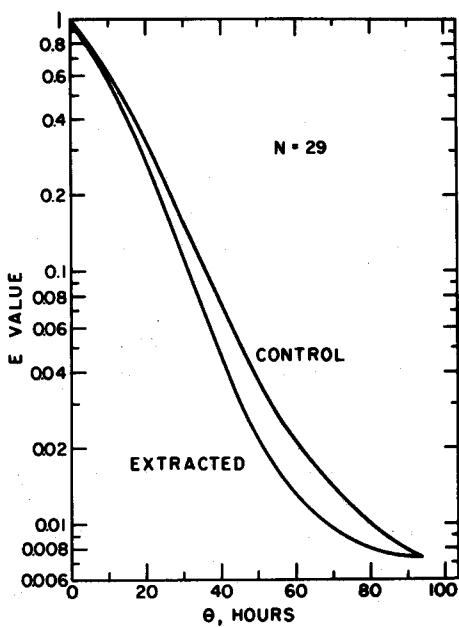


Figure 6. Comparison of evaporable water in ethanol-extracted and control specimens of sinker heartwood.

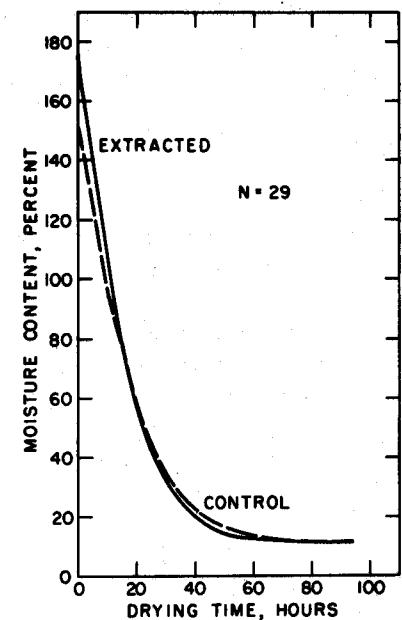


Figure 7. Drying curves for ethanol-extracted and control specimens of sinker heartwood.

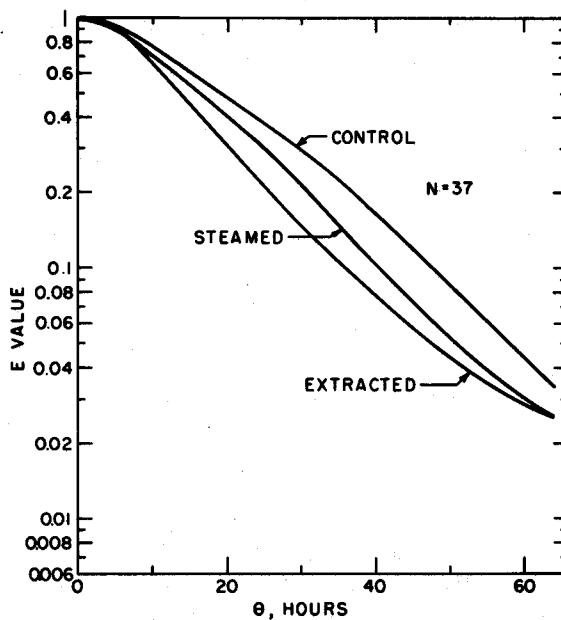


Figure 8. Comparison of acetone-extracted, steamed, and control specimens of sinker heartwood.

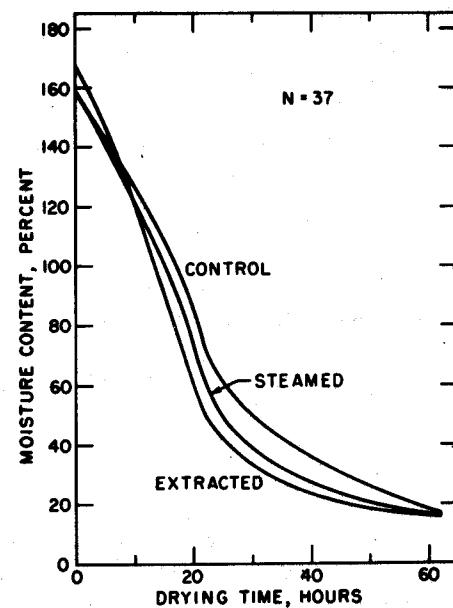


Figure 9. Drying curves for acetone-extracted, steamed, and control specimens of sinker heartwood.

to the lumen. The wart-like surface on the cell wall is well-defined in (1), but the severity of extractive deposits increases from a slight coating (2) to heavy localized deposits in (3) and (4).

If deposits in the cell walls and pit membranes were removed, rate of drying in the sinker heartwood should improve.

Drying rates were compared on matched specimens of sinker heartwood, unextracted (control), extracted with ethanol or acetone, and steamed. Adjacent specimens were sawed across the thickness of the original sample and dressed to 1/4 by 2 by 18 inches. Twenty-nine specimens were extracted with ethanol in a pressure vessel held at 125-130 F at atmospheric pressure for 140 hours. Thirty-seven specimens were extracted with acetone in a pressure vessel at 145 F at 4 to 5 psig for 168 hours. The solvent was changed after 80 hours in each extraction process. After each extraction, specimens were stickered and fan-dried for 10 days to remove excess solvent.

Thirty-seven matched specimens, dressed to 1/4 by 2 by 18 inches, were steamed in a small kiln at 212 F and 99 percent relative humidity for 6 hours. Control, extracted, and steamed specimens were placed in a pressure vessel, treated with water at a vacuum of 29.9 inches of mercury for 3 hours, and then held at 100 psi pressure for 18 hours. The water treatment was intended to restore the original moisture content of the extracted and steamed specimens. Original weight and weight after water treatment were compared and the differences were not significant at the 5 percent level of probability. Before the water-treated specimens were weighed, excess surface moisture was removed.

A definite improvement in drying rates for specimens extracted with ethanol is shown in the relation of E to  $\theta$  (Figure 6) and the moisture content-time curve (Figure 7). The specimens were dried 94 hours at 70 F at conditions for equilibrium moisture content of 11 percent, then were ovendried.

A similar improvement in drying rates for acetone-extracted and steamed specimens is illustrated by the E-to- $\theta$  relation in Figure 8 and moisture content-time curve in Figure 9. The specimens were dried 64 hours at 70 F at conditions for equilibrium moisture content of 11.3 percent, then were ovendried. Removal of extractive material with acetone or ethanol provided freer movement of moisture. Perhaps steaming caused sufficient removal of hot-water-soluble extractives from the pit structure to increase the drying rate. Extracted specimens increased in drying rates more than steamed specimens. Studies by Ellwood (3, 4) have shown that presteaming increased permeability in redwood and southern pine.

#### HIGH-TEMPERATURE DRYING

High-temperature drying, above 212 F, will not solve the problem of nonuniformity of final moisture content. Kiln time can be reduced without additional degrade with high-temperature drying, however.

Our current study of drying above 212 F of 2 by 4, 2 by 6, and 2 by 8-inch dimension lumber clearly shows a reduction of kiln time without additional degrade. One problem generally occurring in high-temperature drying is a slight darkening. Brown stain tended to appear in western hemlock, however, if 5 F or less wet-bulb depression was held during the warming period to wet-bulb temperatures of 200-212 F in our schedules. This problem was eliminated if a wet-bulb depression not exceeding 10 F was maintained during the warming period. This spread between wet and dry bulb did not induce additional degrade.

Table 1 shows a comparison between typical commercial kiln schedules and experimental high-temperature schedules. Lumber collected for this study was obtained from several mills and the kiln schedule of each mill was compared to the experimental schedule. Three factors were sought in comparing the kiln charges: total kiln time, degrade, and uniformity of final moisture content. Total kiln time was reduced and degrade was similar between the control and est charges. Final moisture content determined with a resistance meter was not uniform for all charges and the average moisture content and percentage of boards with moisture content over 19 percent was lower in charges dried at high temperatures than in charges dried at normal temperatures. This is illustrated in Figure 10 for 2 by 4-inch lumber, in Figure 11 for 2 by 6-inch dimension lumber, and in Figure 12 for 2 by 8-inch dimension lumber. In these figures, the distribution of moisture contents represents the percentages of boards that had a given moisture content, except that the entries for 30 percent moisture content also included all

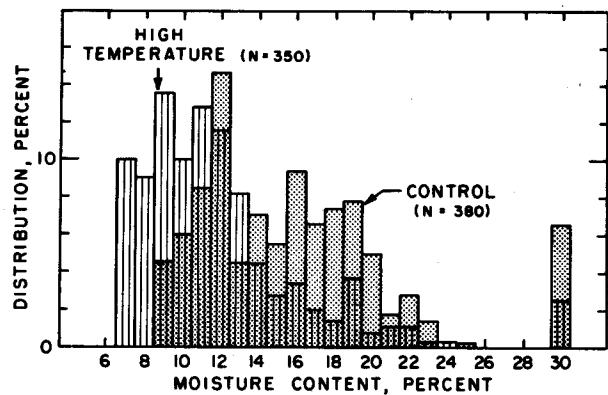


Figure 10. Distribution of moisture content in 2 by 4-inch studs.

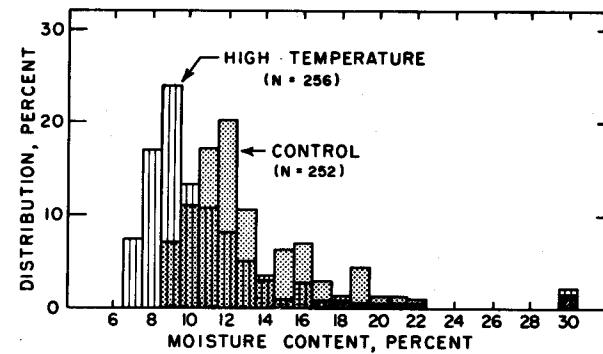


Figure 11. Distribution of moisture content in 2 by 6-inch dimension lumber.

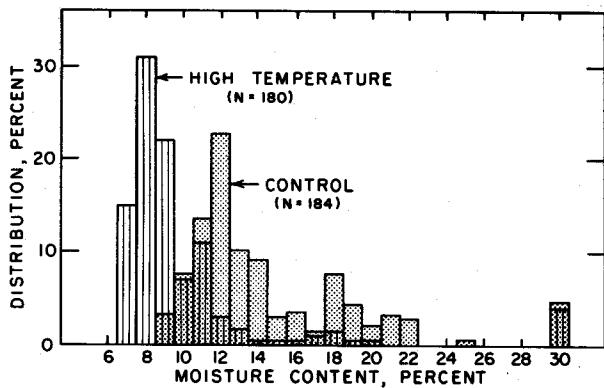


Figure 12. Distribution of moisture content in 2 by 8-inch dimension lumber.

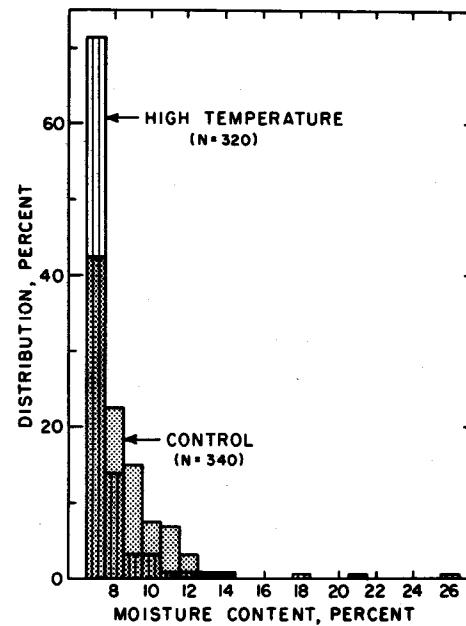


Figure 13. Distribution of moisture content in 4/4 vertical-grain shop lumber.

boards with moisture contents of more than 30 percent.

Table 1. High Temperature and Commercial Kiln Schedules Used to Compare Drying Time, Degrade, and Final Moisture Content.

Commercial			High-temperature		
Time	Dry Bulb	Wet Bulb	Time	Dry Bulb	Wet Bulb
Hr	F	F	Hr	F	F
2 By 4-INCH STUDS					
0 - 4	Warm-up		0 - 4	Warm-up	
4 - 28	170	162	4 - 22	225	210
28 - 52	170	157	22 - 46	230	210
52 - 84	170	150	46 - 52	235	210
			52 - 55	218 Steam	212
2 By 6-INCH DIMENSION					
0 - 3	Warm-up		0 - 4	Warm-up	
3 - 21	160	150	4 - 22	225	210
21 - 33	164	150	22 - 50	230	210
33 - 45	170	150	50 - 70	235	210
45 - 81	174	150	70 - 73	218 Steam	212
81 - 105	180	150			
105 - 116	Steam at 180				
2 By 8-INCH DIMENSION					
0 - 3	Warm-up		0 - 4	Warm-up	
3 - 23	160	150	4 - 24	180	170
23 - 35	164	150	24 - 48	180	165
35 - 47	170	150	48 - 90	230	205
47 - 83	174	150	90 - 94	218 Steam	212
83 - 107	180	150			
107 - 119	Steam at 180				
4/4 VERTICAL GRAIN SHOP					
0 - 4	Warm-up		0 - 4	Warm-up	
4 - 18	160	145	4 - 18	225	210
18 - 30	170	150	18 - 30	230	205
30 - 74	180	150	30 - 54	240	205
74 - 120	190	150	54 - 60	225 Steam	212

A similar comparison was made on 4/4 vertical-grain shop lumber. The commercial schedule and high-temperature experimental schedules are given in Table 1. The only degrade in both charges was shake. Moisture content distribution for two matched charges is shown in Figure 13.

Occurrence and cause of shake in western hemlock have been examined by Meyer and Leney (7). Figures on loss of volume from shake in the sawmill are not available, but an estimate of loss can be determined from degrade studies. In a study by Hunt (5), the largest value loss on 2-inch dimension lumber averaged \$1.60 per M fbm for seasoning checks and \$0.81 per M fbm for shake.

## SORTING

Because the problem of nonuniformity of final moisture content can not be remedied by altering the kiln schedule, other means must be sought. For many years, mills in the redwood, red cedar, and sugar pine areas have sorted "lights" and "heavies" for the purpose of drying to uniform final moisture contents with a reasonable time in the kiln. In 1960, Smith and Dittman (9) made a study on the sorting of white fir and red fir. The ratio in kiln time is nearly 2 to 4 to 8 for cork, sapwood, and sinker. A mill in northern California sorts 2-inch dimension white fir into three classes: light, heavy (sapwood), and sinker. To reach the same average moisture content, the lights must be dried for 48 hours, heavies for 4 days, and the sinkers for at least 9 days.<sup>1</sup>

Vertical-grain boards may be easily sorted visually into sinker and normal heartwood, because of the dark color of the wet areas. In flat-grain boards, or dimension lumber, the wet areas are not clearly defined.

At Willamette Industries in Dallas, Oregon, 384 boards of 2 by 8-inch dimension lumber were studied. The lumber was marked on the green chain as normal, sinker, or mixed normal and sinker heartwood. Lumber containing 50 percent or more of wetwood was marked as sinker.

The lumber was kiln dried on a 110-hour dimension schedule. Of the 194 boards marked as sinker, only 5 boards dried below 19 percent moisture content. Of 129 boards marked as normal heartwood, only two did not dry below 19 percent moisture content. The remainder of the boards had various amounts of wetwood, which was marked while on the green chain. Boards with wet streaks from 1/2 to 1 1/2 inches wide dried below 19 percent moisture content, but boards with wet streaks from 1 1/2 to 3 inches wide did not.

A problem now arises in sorting lumber with alternating wet streaks and normal heartwood. With visual sorting, a decision to mark boards on the basis of 50, 25, or even 10 percent sinker wood is most difficult. If a decision is made to mark on 25 percent sinker heartwood, then a 2 by 4-inch stud would only need a wet streak 1 inch wide. For a board 2 by 6 inches or more in width a 1-inch wet streak would not cause it to be classified as a sinker board. A 1-inch streak apparently would not cause drying problems, but 2 by 4-inch studs are dried on a faster schedule than wider boards, so a 1-inch streak might cause problems.

Sorting on the green chain may promote uniformity in final moisture content, but further testing will be required to determine sorting practice, especially for boards with variation in wet streaks. Another means of eliminating boards with moisture contents above 19 percent is with moisture-detecting equipment ahead of the planer. The wet boards are redried, but the extra handling and the reduction in overall kiln drying capacity increases manufacturing costs.

With the acceptance of new moisture-content specifications for kiln dried lumber, producers of hemlock and true fir dimension lumber face a tough problem. Nonuniformity of final moisture content can be reduced with better quality control, free exchange of information as in the kiln clubs, visual or electronic sorting on the green chain, and installation of moisture-detecting equipment ahead of the planer. Some of these methods are expensive and they require that kiln operators keep up with technical advances in the field.

<sup>1</sup> Minutes of the West Coast Dry Kiln Association's 165th meeting, held at Weyerhaeuser Company in Klamath Falls, Oregon, March 16, 1968.

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