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TESTS UNDER WINTER CONDITIONS IN CALIFORNIA

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PACIFIC SOUTHWEST
FOREST AND RANGE
EXPERIMENT STATION

FOREST SERVICE - U. S. DEPARTMENT OF AGRICULTURE

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PACIFIC SOUTHWEST FOREST AND RANGE EXPERIMENT STATION

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AIR DRYING OF INCENSE-CEDAR: TESTS UNDER WINTER CONDITIONS IN CALIFORNIA

by Harvey H. Smith[1/]
Charles P. Berolzheimer[2/]

INTRODUCTION

A study of air drying 3-inch-thick planks of incense-cedar (Libocedrus decurrens Torrey) for the manufacturing of pencil slats was reported in a recent paper (Smith and Berolzheimer, 1957). The experiment was made at Pioneer Station, Amador County, California (altitude 3,000 ft.) during the dry summer season of 1955. The results showed rapid drying of the test planks and squares irrespective of width of planks, pile spacing, or position in the pile. All types of wood--sapwood, light heartwood, and heavy heartwood--reached equilibrium in 8 to 15 weeks. The heavy heartwood samples, however, did not represent the extremely high moisture content typical of the difficult-to-dry material. The incidence of checks was influenced by plank width. Pile spacing and position in the pile had no significant effect on checking. The greatest incidence and severity of checking was in the tangential grain (flat-sawn) zones of the wide planks. It was concluded that the checking was serious and unavoidable under the test conditions in that region of California.

This paper reports the second phase of this cooperative study of air drying incense-cedar at Pioneer Station. The drying period was from 27 October 1956 to 24 October 1957.

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PURPOSE OF THE EXPERIMENT

The experiment sought to answer the following questions:

1. What are the winter drying rates and the time required to reach 15 percent moisture content of the sapwood, light heartwood, and heavy heartwood?

2. How does width of material affect drying rate and final moisture content?

3. How do pile spacing and vertical position in the pile affect drying rate and final moisture content?

4. How is the incidence of checks related to (a) width of material and (b) orientation of grain, i.e. whether tangential grain (flat-sawn) or radial grain (quarter-sawn) on the wide face of the piece?

5. How do pile spacing and position in the pile affect the incidence of checks?

6. Under prevailing weather conditions, can such material be dried without substantial loss from checks?

EXPERIMENTAL PROCEDURE

The test material was prepared in the same manner as in the previous experiment (Smith and Berolzheimer, 1957). The same pile foundation was used. The pile spacing was also the same, namely 0, 2, and 6 feet (fig. 1). Nine units each of random-width 3-inch-thick planks and of "squares" (actually 3 inches thick and 4 inches wide) 16 feet long composed the test material. The total volume was about 25,000 board feet.

Samples

Planks and sawmill squares (3 x 4 in.), representative of the sapwood, light heartwood, and heavy heartwood types, were selected for samples. Samples were cut 1 meter long, end-coated, and weighed. One or more sample planks and three sample squares of light and heavy heartwood were prepared and placed in each of six pile positions: the top and the bottom of the 0-, 2-, and 6-foot spacings. Samples of sapwood planks and squares were likewise prepared, but placed only at the bottom of the pile with zero spacing and at the top of the pile with 6-foot spacing. The samples were placed in the same positions as previously described (Smith and Berolzheimer, 1957), so as to be exposed to the same drying conditions as the test material (fig. 1).

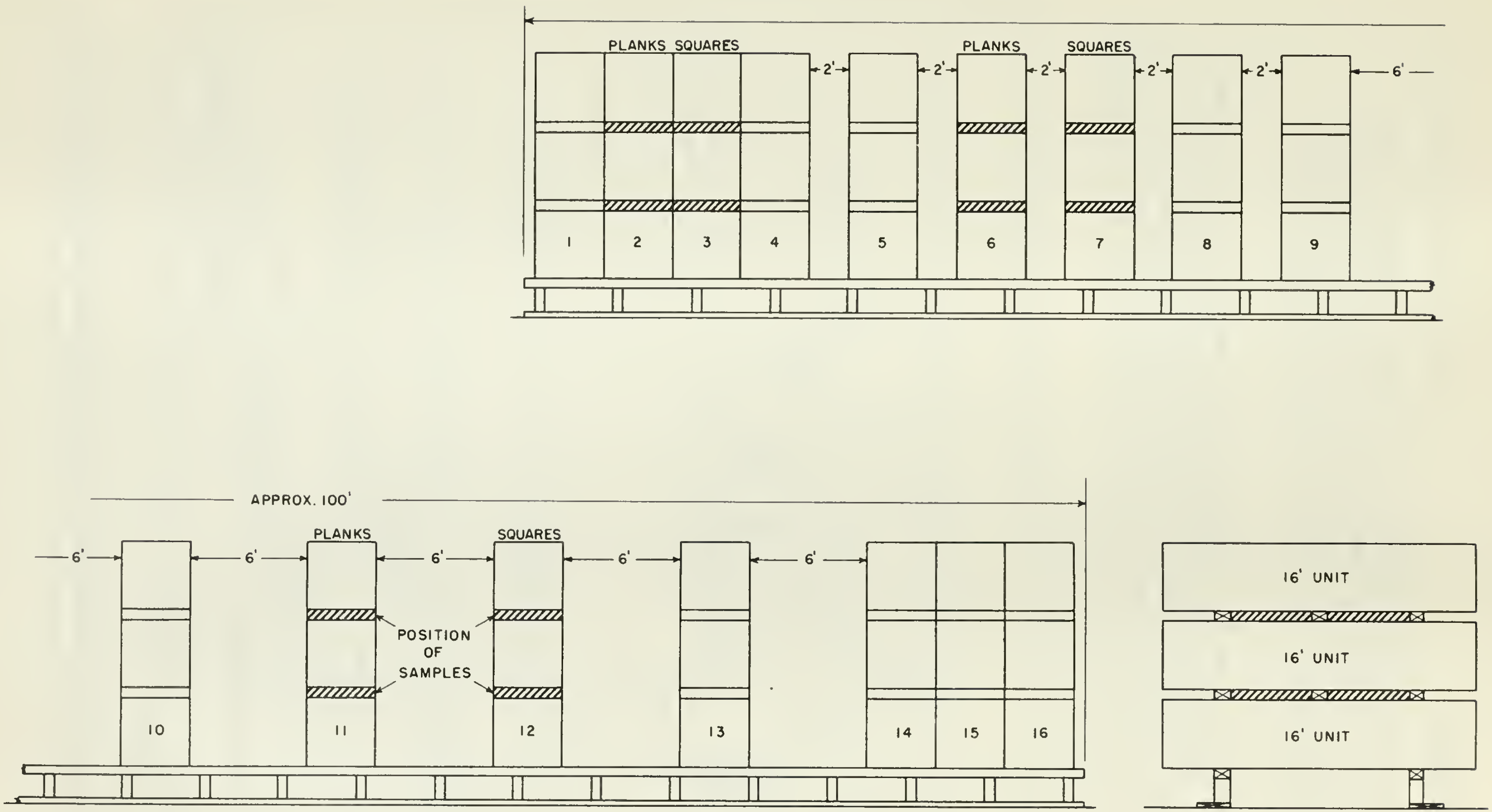

Figure 1.--Spacing of piles on continuous foundation for air drying.

Weather Records

Temperature and humidity records were recorded at the drying yard during the winter, spring, and part of the summer seasons (35 weeks), using a strip-chart hygro-thermograph. U. S. Weather Bureau records were used to supplement these readings.

Daily figures for temperature and humidity were averaged from six readings picked off the strip charts. These daily temperature and relative humidity figures were translated into equilibrium moisture content figures. Temperature and equilibrium moisture content figures were then plotted as dependent variables for the drying period (fig. 2).

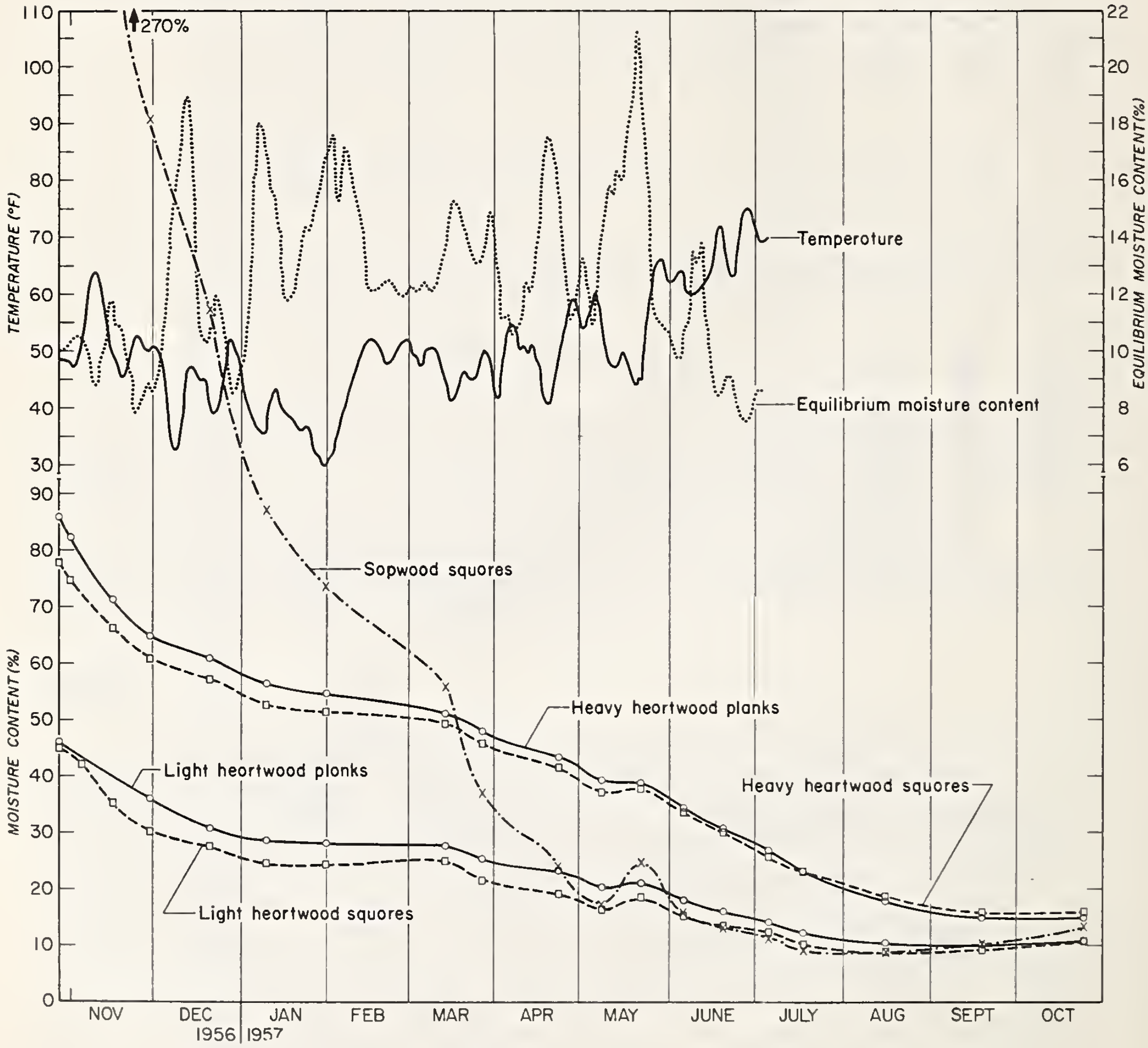

Figure 2.--Average air temperature, equilibrium moisture content, and drying curves for incense-cedar planks and squares during air drying.

Measuring Moisture Content

The samples were weighed immediately after their preparation and again at intervals of about 3 weeks during the next 12 months. In July 1957, after about 9 months of air-drying, the moisture content of each sample was measured with a resistance-type moisture meter having a range of 7 to 60 percent. The electrodes were placed in the shell, about 1/4 inch deep, and in the core, about 1 inch deep. In October 1957, after one year on the yard, the air-drying was terminated, and the final moisture content of each sample was determined by the oven-dry method. The moisture content of each sample was then calculated for each time of weighing during the air-drying.

The final moisture content in the shell and core of 12 representative samples was also measured with an electric moisture meter.

The moisture content of these same 12 samples was also determined by the solvent extraction method (McMillen, 1956), to correct for the volatile extractive components.

Additional cross sections of all samples were weighed and placed in a room at 35 percent relative humidity at 70 degrees F., or a 7 percent equilibrium moisture content of wood (Smith, 1956). In February 1959, or after one year in the room, they were weighed again and their oven-dry weights computed on the assumption that they had reached the known equilibrium moisture content. The oven-dry weights of the original samples and their moisture contents during the experiment were then computed.

Measuring Drying Defects

Each sample was inspected for drying defects (checks) when weighed during the 12 months of air drying.

All the 25,000 board feet of test material was left in piles during the winter of 1957-1958, then trucked to the pencil slat factory of California Cedar Products Company, Stockton, California, for final evaluation. All the test pieces, i.e., wide planks, narrow planks, and sawmill squares, were ripsawn to squares 2-13/16 inches wide by the usual remanufacturing procedure.

The new, remanufactured squares resulting from each of these three widths were sorted according to orientation of grain: tangential and radial in relation to the wider surface of the original test piece. The squares were kept separate according to the original pile spacing but not to the position in the pile. This procedure yielded the following 18 categories of remanufactured squares: grain - 2 (radial and tangential); width - 3 (wide planks, narrow planks, and squares); pile spacing - 3 (0, 2, and 6 feet).

The remanufactured squares in each of the 18 categories were cut into blocks 7-1/4 inches long and ripsawn into pencil slats 0.20 x 2.6 x 7.25 inches by the usual slat-manufacturing procedure. Knotty or other worthless blocks were discarded; badly checked blocks, but otherwise suitable for remanufacture, were saved and counted as constituting ten checked slats each. All the sawn slats were assorted into usable and cull, the usable being divided into slats free of checks and with checks. Although some of the slats with checks could be partially saved by ripping or cross-cutting to smaller sizes, all slats with checks were counted lost in the subsequent analysis.

Statistical Analysis of Loss from Checks

The realized number of seven-ply slats as a proportion of potentially available seven-ply slats was the measurement chosen to express the effect of drying--as reflected in piling, board width, and type of sawing--upon the incidence of checking. A standard statistical analysis of variance was run. In addition, a co-variable, the ratio of natural loss to the total potentially available slats, was introduced into the analysis. This co-variable had no significant effect upon the proportion of realized slats and was therefore dropped.

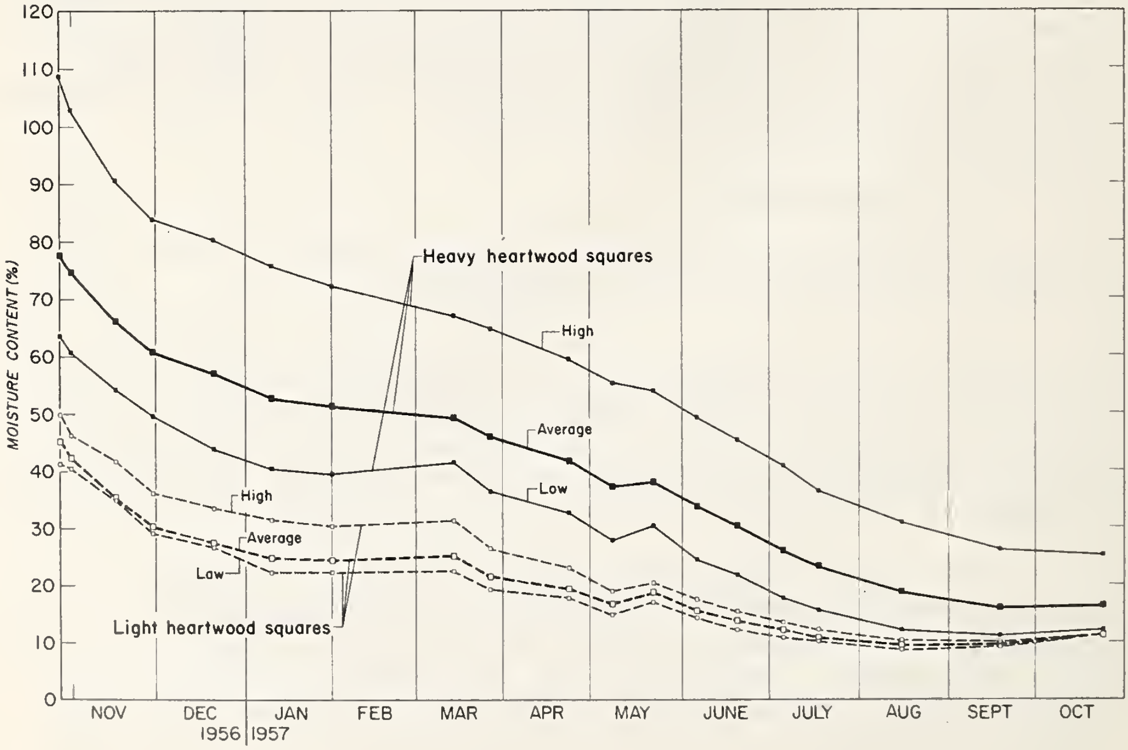

Figure 3.--Range of moisture content of heavy heartwood and light heartwood squares with air drying conditions as in Figure 2.

RESULTS

Rate of Drying

The sapwood squares dried rapidly, even during the coldest and wettest months (fig. 2). Except for a few weeks in May 1957, they also dried continuously from an initial moisture content of 270 percent to a final 15 percent by early June, after 7½ months. The sapwood planks (not plotted) exhibited a lower initial moisture content than the squares and reached equilibrium at about the same time. The lower initial moisture of the planks can be explained by the inclusion of zones near the bark which may have dried partially in the log, or by small zones of heartwood adjacent to the true sapwood. The samples of sapwood squares, because of their uniformity of dimensions, drying characteristics, and high initial moisture, can well serve as controls, to which the other types may be compared.

The light heartwood planks (initial moisture 46.0 percent) and squares (46.1 percent) dried slowly and continuously, except during some humid intervals when drying was retarded or briefly reversed. All the light heartwood samples reached 15 percent moisture in June, after 7½ months.

The heavy heartwood planks (initial moisture 85.8 percent) and squares (77.8 percent) dried more slowly, reached 15 percent at the end of September, after 11 months of drying, including the 3 summer months of favorable drying weather.

The drying rate of individual samples of light heartwood squares was fairly uniform (fig. 3). Heavy heartwood samples, however, showed large differences in drying. There is not a distinct segregation of light and heavy heartwood; the heavy heartwood samples with low moisture content are similar to the light heartwood samples with high moisture content, and their drying rates are similar. The rate of drying and the final moisture content of all heartwood samples seem to depend on their green moisture content.

The moisture content of each sample represents the entire piece and not the distribution of moisture within it. Measurements with the electrical moisture meter showed a rather uniform distribution of moisture in the sapwood and light heartwood samples after 9 months drying. On the other hand, the heavy heartwood samples had a steep moisture gradient between the shell and the core (table 1).

Table 1.--Moisture content of squares after 9 months, according to oven-scale and to moisture-meter

Type of wood	Oven-scale	Moisture-meter
	Percent	Percent
Sapwood		
Lowest	7.6	7 - 8
Average	9.9	7 - 8.3
Highest	10.8	7 - 9.5
Light heartwood		
Lowest	9.8	7 - 11
Average	10.7	8.6 - 13.4
Highest	12.6	10 - 19.5
Heavy heartwood		
Lowest	13.3	10 - 18
Average	23.1	10.9 - 27.6
Highest	38.2	14 - 40

Records were kept of the position of the 4 samples cut from each 16-foot plank or square. These records show that the green moisture content of sapwood and light heartwood is rather uniform. The heavy heartwood, on the contrary, has a large difference in green moisture content between longitudinally adjacent pieces (table 2). These data are similar to other evidence that wood of coniferous trees exhibits a vertically variable moisture content (Wangaard, 1950) and that the heartwood of "butt-cuts" has a high moisture content. The outer heartwood of incense-cedar butt logs is known to contain more than 20 percent of extractive components.[3/] The presence of these extractive components associated with a high initial moisture content of the wood helps to explain the slow drying rate.

Width of the samples (planks and squares) did not appreciably affect the drying rate. Neither did the pile spacing nor the position in the pile (fig. 2). The type of wood was the only significant variable affecting the drying rate (table 3).

3/ Zavarin, Eugene. Incense-cedar extractives. Progress Report VI. Forest Products Laboratory, University of California, Berkeley. (Unpublished.)

It is interesting to compare these results with experiments in drying redwood (Sequoia sempervirens Endlicher). The California Redwood Association (2) found that pile spacings up to 8 feet accelerated the drying of 1-inch-thick heavy heartwood and 2-inch-thick light heartwood lumber piled in the humid area near Humboldt Bay in Northwestern California (Clauson, 1953). This result may be attributed to the larger volume of air passing through the piles and to the large surface area presented by the test pieces of the given thickness. Drying 3-inch-thick incense-cedar in a drier climate is not limited by the capacity of the air to carry away the moisture, but by the rate of diffusion of the moisture from the interior to the surface of the planks.

Table 2.--Gradation of green moisture content along the length of original 16-foot pieces from which samples were cut

Type of wood and number of original 16-foot piece	Position in 16-foot pieces 1/			
	1	2	3	4
	Percent			
Sapwood				
1	259	254	--	--
2	267	265	--	--
3	288	285	--	--
Light heartwood				
11	46	43	43	45
16	48	47	41	--
17	50	48	45	--
Heavy heartwood				
5	105	100	84	68
6	109	83	68	61
9	96	77	76	68
10	--	72	68	67

1/ Position 1 is probably the lower end of each 16-foot piece in the standing tree.

Table 3.--Moisture content of sample planks and squares of the three types of wood at beginning, after 6 months, and after 12 months, according to pile spacing and position in the pile

Samples	Drying period	Spacing--0 ft.		Spacing--2 ft.		Spacing--6 ft.	
		Top	Bottom	Top	Bottom	Top	Bottom
	Months			Percent			
SAPWOOD							
Squares	0	-	269.7	-	-	269.8	-
	6	-	26.7	-	-	21.0	-
	12	-	13.7	-	-	13.6	-
LIGHT HEARTWOOD							
Planks	0	26.3	48.6	43.0	36.6	82.7	39.0
	6	17.3	21.9	21.1	21.7	35.6	21.0
	12	10.2	10.8	12.1	10.6	12.1	11.9
Squares	0	46.6	48.5	45.3	43.3	43.0	44.0
	6	18.9	22.1	18.9	19.1	18.9	18.6
	12	10.8	11.2	12.1	11.7	11.2	10.9
HEAVY HEARTWOOD							
Planks	0	82.8	81.6	89.9	81.8	88.6	88.8
	6	36.4	39.2	45.2	45.9	48.0	44.8
	12	13.1	13.7	15.6	15.7	17.1	14.9
Squares	0	78.9	75.6	76.6	76.9	78.8	80.0
	6	39.7	42.3	40.4	40.8	43.3	42.9
	12	16.2	14.5	16.2	18.2	16.5	16.0

Drying Defects

Small, hair-line checks appeared on tangential surfaces, particularly of the heavy heartwood planks, during the first 2 months of drying, and became more numerous and larger during the remainder of the winter. New checks appeared until the end of June (8 months of drying), especially in the heavy heartwood planks and squares. The vertical position in these well-roofed test piles did not seem to affect the incidence of checking. Vertical position has been shown in other studies to affect the incidence of checks, especially in unroofed piles, but less so in roofed piles (Clark and Headles, 1958). The effect of vertical position in the pile on surface checking was not considered in the final analysis of the data.

The statistical analysis of the loss of pencil slats due to drying checks showed a significant difference at the 97 percent level between planks (both wide and narrow) and squares, but no significant difference between wide and narrow planks (table 4). The loss of slats cut from planks was greater than the loss from squares. The analysis also showed a significant difference (at the 99 percent level) in the loss of slats cut from pieces with tangential grain compared to flat grain. The loss was greater in the tangential sawn material than in radially sawn material. Other apparent differences (spacing) were not statistically significant and were attributable to sampling variation.

Table 4.--Loss of pencil slats due to checks; percent of checked slats from the test material

Type of material	Loss when pile spacing was:		
	0 feet	2 feet	6 feet
		Percent	
Wide planks			
Tangential grain	12.6	14.0	14.8
Radial grain	5.4	6.7	8.4
Total	18.0	20.7	23.2
Narrow planks			
Tangential grain	13.0	14.9	12.2
Radial grain	6.4	4.3	10.5
Total	19.4	19.2	22.7
Squares			
Tangential grain	3.7	4.5	7.9
Radial grain	3.8	3.0	3.2
Total	7.5	7.5	11.1

CONCLUSIONS

1. Three-inch-thick planks of incense-cedar piled for air drying at Pioneer Station, Amador County, California (altitude 3,000 feet) in October 1956 dried at various rates, depending on the type of wood. Sapwood and light heartwood dried to a uniform final moisture content of 15 percent in $7\frac{1}{2}$ months. Heavy heartwood dried to a final moisture content of 15 percent in 11 months. However, this moisture content was not uniform throughout the cross-section of individual samples or between different samples. The final moisture content of heavy heartwood was greatly affected by its initial moisture content.

2. Width of material had no appreciable effect on drying rate or final moisture content.

3. Pile spacing and position in the pile had no appreciable effect on the drying rate or final moisture content. Wide planks checked twice as much as squares.

4. Flat-sawn material checked about twice as much as quarter-sawn.

5. Pile spacing had no significant effect on the incidence of checks in planks. A very narrow spacing, however, appeared to reduce checking of squares.

6. Under the conditions of the experiment, incense-cedar planks and squares cannot be dried without a significant loss from checks. The greatest incidence of checks was on the tangential faces of the wider pieces, especially of heavy heartwood.

7. To develop a procedure for air-drying 3-inch-thick incense-cedar lumber to a more uniform moisture content with fewer checks, some additional questions seem worth investigating:

    a. What is the comparative loss because of checks in the three types of wood, especially heavy heartwood?

    b. What is the green moisture content of incense-cedar heartwood at different vertical positions in the trees?

    c. Which methods are effective to retard the drying of any categories likely to check?

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