QUALITY OF HIGH-TEMPERATURE DRYING[1]

by

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and

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INTRODUCTION

The term "high-temperature drying" refers to two lumber-drying processes carried out with the dry-bulb temperature above the boiling point of water. One is the superheated steam process in which the wet-bulb temperature is maintained at 212^{o} F. and air is excluded. The other process uses a mixture of air and steam with the wet-bulb temperature below 212^{o} F.

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High-temperature drying, in this country, is a relatively recent revival of long-established commercial practice. Patents for high-temperature dry kilns were issued in 1867 and 1917. In the 1920's a few superheated steam high-temperature kilns were being used in the Pacific Northwest; however, the high maintenance and operating costs of these kilns forced their abandonment. Since that time, newly developed materials, methods, and instrumentations have largely overcome the initial obstacles, and present-day research is rapidly providing a sound base for using this drying method.

The principal advantage of high-temperature drying is that it appreciably reduces drying time--as much as 80 percent has been claimed by some European research workers. The disadvantages of high temperature drying, aside from higher initial costs and kiln maintenance, have been associated with the quality of drying as accomplished in these kilns. Lumber dried in high-temperature kilns is likely to be darker in color and less uniform in moisture content; also it may develop more seasoning degrade than lumber dried in conventional kilns at lower temperatures.

This paper discusses the results of a study designed to compare the quality of high-temperature and conventionally dried studs.

STUDY PROCEDURE

Six separate kiln runs were studied; one run of lodgepole pine and two runs of western larch were made in paired high-temperature and conventional kilns. The 8-foot studs of both species were sawed from freshly cut logs just before the kiln runs. To obtain the test material, mill run studs, sorted by species on the green chain and piled in stickered packages by the automatic stacker, were segregated by green grade and restacked into the necessary test packages for each run. The material not used in the test packages was restacked and used as fill material in the various runs.

Originally we planned to use two packages of each stud grade (Select, Construction, Standard, Utility, and Economy) for each kiln run. However, the plan had to be modified when we found that the studs of both species were of a higher grade than had been anticipated. The lodgepole pine runs had four packages of Selects, three of Construction, and one each of Standard, Utility, and Economy. The larch runs all had three packages of Selects, three of Construction, two of Utility, and one each of Standard and Economy. All test packages were located in their respective runs at random.

The drying conditions used in this study, for both high-temperature and conventional kilns, followed company practices in use at the time. The schedules were of the time-temperature type and no kiln samples were used to check drying progress during the runs.

The same schedules were used for the high-temperature drying of both species, and the drying times were approximately 25 percent of the conventional kiln drying time, or 24 hours. After the kiln was loaded and closed, the desired conditions were set on the controls, and the heat and spray lines opened. The vents were opened after about 4 hours, while the kiln was still heating; they stayed open through the remainder of the drying period. The fans were started when the recorded dry bulbs showed a temperature between 150° and 170° F.; thereafter, reversal switches automatically reversed fan direction every 2 hours.

The time-temperature schedule used in the conventional kiln, for both species, required 96 hours. The initial dry-bulb setting was 140° F., and the initial wet-bulb temperature was 130° F. During the final drying stage the dry-bulb temperature was 160° F. and the wet-bulb temperature was 140° F.

The kiln fans were started at the beginning of the runs and were reversed manually every 12 hours during drying. The recorder-controller regulated heating, spraying, and ventilation.

Temperature readings in various zones of both kilns were taken at intervals during the complete drying processes by using thermocouples and a potentiometer. Thermocouples were placed at 24 locations on the high-temperature charges, and 21 thermocouples were used on the conventional kiln charges--eight along each side of the load and five at the wet- and dry-bulb locations.

The moisture content of the green material was determined on 1- to 3-foot-long pieces of studs collected at the trim saws during the cutting operation. The moisture content sample of lodgepole pine consisted of 43 pieces; the larch sample was 19 pieces. One-inch sections were cut from these sample pieces, 6 inches from the freshly trimmed end, and were tested by the ovendry method.

The criteria used to evaluate the quality of drying achieved by the two methods included: moisture-meter and degrade data for all the test material and average moisture content, shell and core moisture content, prong test, and records of depth of end-check penetration for a randomly selected subsample of the test studs.

After all the studs were dried and surfaced, moisture content data were obtained by using a moisture meter on each of the 209 studs in each of the 10 test packages of each run. These readings were later corrected for species and temperature at the time of meter reading. Complete degrade data were also collected for each stud. However, only the degrade that could be directly or indirectly attributed to the seasoning method is considered in this report.

Four test studs, selected at random from each test package, were sectioned for average and distribution moisture tests by the ovendry method. The studs included in this subsample were cut so that three sections, each 1 inch long the grain, were obtained from a zone approximately 36 inches from one end. Two of these 1-inch sections were used for determining average and distribution (shell and core) moisture content by the ovendry method; the third section was designated for stress analysis. The 36-inch end trim was used to determine the depth of end-check penetration (see fig. 1).

The stress analysis section was cut into a U-shaped specimen. This specimen was then placed in a right-angle jig, and the deflection of the prong showing greater deflection was measured to the nearest .05 inch.

The final quality criterion for which data were obtained was the depth of penetration of the end checks. The 36-inch end sections mentioned above were used to obtain information on the effect of the drying method on the development of end checks. These sections were cut back about 1 inch from the trimmed end and examined for checks. If checks were found, additional cuts of 1 inch or less were made until the checks disappeared. The distance of penetration from the end was then recorded.

RESULTS AND DISCUSSION

Since speed and uniformity of drying are governed by the relation of temperature and relative humidity conditions, only a small range in entering-air temperatures along the length of the kiln is desired. When the dry-bulb temperatures are consistently low, the drying rate is slow because of both the lower temperature and the higher equilibrium moisture content. Such zones could be expected to produce stock having higher final moisture content values. Where dry-bulb temperature is consistently high, the conditions are undesirably severe; drying defects may develop and the lumber may become too dry.

Variation of Kiln Temperatures

During the lodgepole pine high-temperature run, the sidewall and booster coil plenums had a temperature variation of 6° F., which could not be considered excessive.

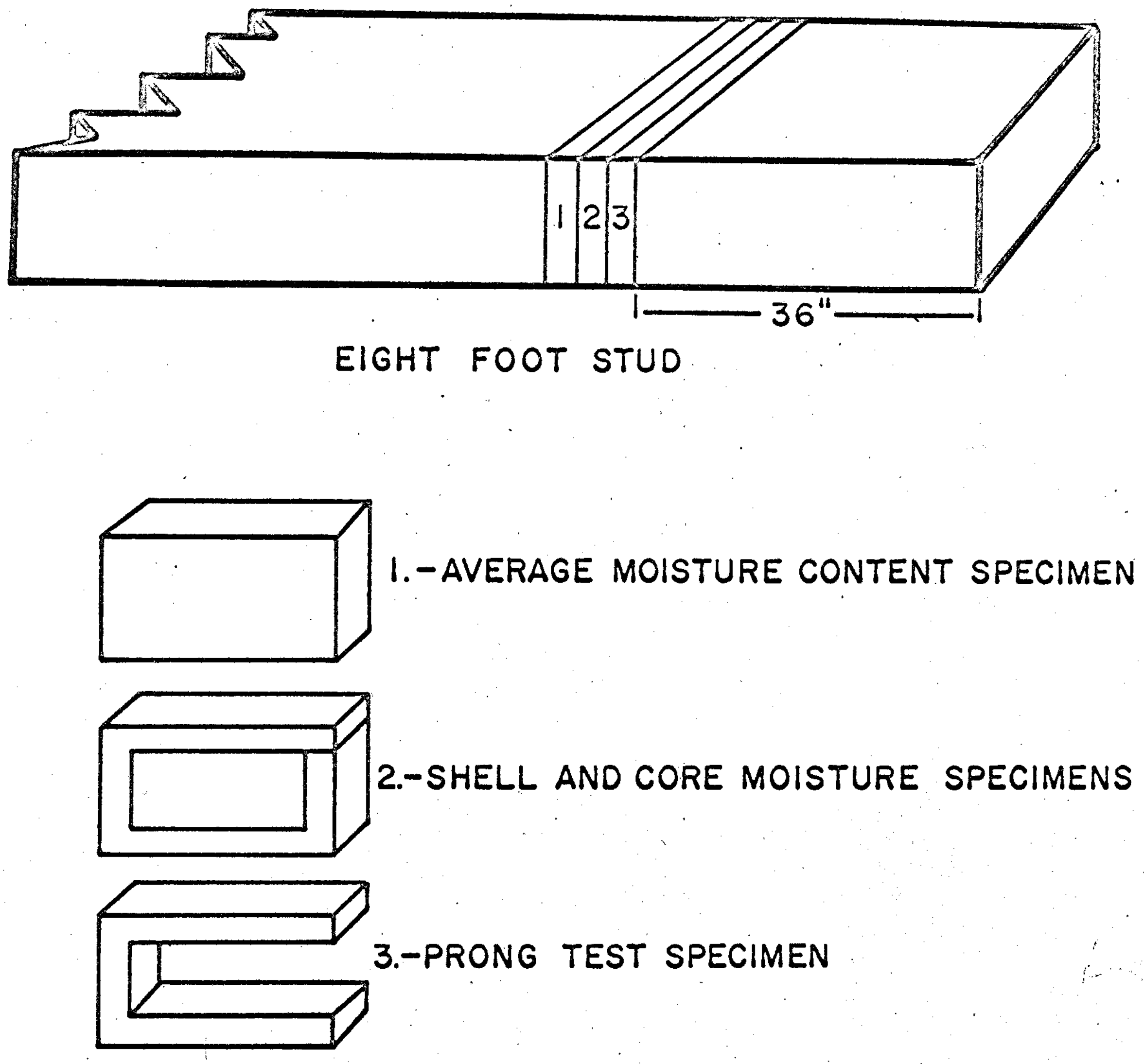
In the two high-temperature larch runs, temperature variations in the two entering-air plenums were much greater. The sidewall plenum variation in one run was 3° F. but was 20° F. in the second run. The temperature variation in the booster coil plenum was 11° F. in the first run and 22° F. in the second run.

Temperature measurements in the conventional kiln during the lodgepole pine run varied 23° F. at the start of the run and 2° F. near the end of the drying period. In the first larch run, the entering-air temperatures varied only 4° F.; in the second run, variation was 5° F.

No air-velocity measurements were made in the high-temperature unit but the kiln manufacturer indicated that the airspeed through the load was approximately 450 feet per minute. Measurements made at three locations in the conventional kiln recorded an average velocity of about 350 feet per minute.

Moisture Content

Results of determination of initial moisture content by the oven-dry method indicated that lodgepole pine had an average moisture content of 59 percent, with a variation from 29 to 184 percent. The 19 pieces of western larch showed an average moisture content of 53 percent. The samples varied from a low of 31 percent to a high of 94 percent.



SCHEMATIC DRAWING OF SAMPLING METHOD AND TEST SPECIMENS

At the completion of drying, the moisture content of all test studs was measured with a moisture meter. After these readings had been corrected for species and temperature, at the time of the reading the data were analyzed statistically to determine the effects of (1) the different drying processes, (2) the different species and runs within processes, and (3) the different locations of packages in the several kilns.

These analyses showed that high-temperature drying did not produce material as dry as the conventional process did. Even though the difference in final average moisture content of the lodgepole pine was small (13.0 percent in the high-temperature kiln compared with 11.7 percent in a conventional kiln), the difference was significant at the 1-percent level. The two runs of larch dried at high temperatures averaged 20.1 percent; at conventional temperatures the average was 18.4 percent. This difference also was significant at the 1-percent level.

A comparison of the data by species and runs within processes showed that the final average moisture content values were very significantly different. In the high-temperature runs the average moisture content of the lodgepole pine was 13 percent while the two runs of larch averaged 21.1 and 19.2 percent. In the conventional kiln, the average for the lodgepole pine was 11.7; for the larch runs the averages were 18.7 and 18.1 percent. These varied moisture contents indicate that the two species dry at different rates.

There was also a significant difference at the 1-percent level in average moisture content of the larch dried in the high-temperature unit but no significant difference in the material dried in the conventional kiln. In other words, the conventional kiln dried material more consistently than did the high-temperature kiln.

Seasoning Degrade

All test studs, 2,090 from each run, were examined for degrade after surfacing. Only 44 percent of these studs remained on grade. Of the 56 percent degraded, approximately 11 percent could be charged directly to seasoning, while an additional 18 percent may have been aggravated somewhat by the drying operation.

On a percentage basis, there was practically no difference between the losses due to degrade of the lodgepole pine studs dried by the two seasoning methods. The high-temperature method had 10.29 percent of the pieces degraded while the conventional process had 10.19 percent. Warp was the greatest single cause of degrade in both processes. The high-temperature process produced about two-thirds the warp degrade found in the conventional process. The superimposed loading of the high-temperature charge probably contributed to this reduction in warp. However, five times as many pieces were degraded for surface checks in the high-temperature method as were degraded by the conventional method.

When the degrade losses for the four runs of larch are combined, the total percentages of degrade show a slight advantage for the conventional process (11.48 percent) over the high-temperature process (12.56 percent). For individual degrade causes, surface checking accounted for about 58 percent of the total degrade in the high-temperature process and about 31 percent in the conventional method. Warp was a greater cause of degrade in the conventional process (63 percent) than in the high-temperature method (36 percent). End splits were about the same for both drying methods.

In addition to the losses directly attributable to the seasoning method, there were other degrading factors, such as thinness, knot checking, and knot dropout that may have been aggravated by the seasoning method. When all degrade factors are considered, the high-temperature drying method caused less degrade (20.29 percent) in the lodgepole pine than did conventional drying (27.32 percent). Larch losses were reversed: conventional drying produced less (30.40 percent) than the high-temperature method did (36.27 percent).

<u>Special Test Studs</u>

The drying quality data obtained from the four randomly selected test studs from each test package included average moisture content, shell and core moisture content, deflection of the prong stress section, and depth of end-check penetration.

The differences in average, shell, and core moisture contents of the lodgepole pine were greater in the studs dried at high temperature than those dried in the conventional kiln (table 1). For larch, the differences in average, shell, and core moisture contents were greater than for the lodgepole pine in both drying methods. However, the magnitude of the differences in the larch runs was greater on the studs dried in the conventional kiln (table 2).

Table 1.-- Moisture content (percent) for the average, shell, and core test specimens of lodgepole pine.

Drying process	Average Section			Shell Section			Core Section		
	Low	Ave.	High	Low	Ave.	High	Low	Ave.	High
High temperature	8.9	15.6	27.7	7.8	12.3	19.6	9.5	19.8	36.3
Conventional	11.0	13.4	15.4	6.0	12.6	14.2	11.7	14.6	23.7

Table 2.-- Moisture content (percent) for the average, shell, and core test specimens of western larch

Drying process	Average section			Shell section			Core section		
	Low	Ave.	High	Low	Ave.	High	Low	Ave.	High
High temperature									
1	11.2	24.0	41.0	10.6	17.4	29.2	11.9	29.8	56.0
2	4.6	21.1	45.8	4.5	14.5	29.5	4.7	28.1	64.9
Conventional									
3	10.4	20.6	56.1	10.1	16.7	31.5	10.4	24.8	85.6
4	12.3	17.1	33.8	13.5	21.9	51.3	15.1	27.7	82.8

Deflection measured on the prong test specimens indicated that there was more casehardening stress in studs dried at high temperatures than in those dried at conventional temperatures. A conditioning treatment after the drying probably would have relieved some of these stresses.

End checks were more frequent and were deeper in pieces dried at high temperatures. In the lodgepole pine runs, 30 of the 40 test studs dried at high temperatures were end-checked to an average depth of 6.8 inches. Only 12 of the 40 sample studs dried in the conventional kiln were end-checked, and average penetration was only 1.17 inches.

The larch runs also showed the high-temperature process to be more severe than the conventional process. The two high-temperature runs had 31 and 30 end-checked studs, respectively. Average check penetration was to a depth of 4.4 and 6.1 inches. The conventional kiln runs had 3 and 18 end-checked studs, with an average check penetration of 2.17 and 2.25 inches, respectively.

The severe drying conditions undoubtedly caused the greater number and greater depth of penetration of end checks in the studs dried at high temperature.

CONCLUSIONS

Before summarizing, a word of caution regarding results of this study is needed. Quality is a rather nebulous term since it relates to initial and final values. For studs, the lumber item investigated in this study, values are relatively low. Quality drying of studs is probably markedly different from quality drying of shop, select, and other lumber that is to be remanufactured.

Results of this evaluation study show:

1. High-temperature drying of studs can be successfully accomplished on a commercial basis in approximately one-fourth the time required in a conventional kiln using present commercial time-temperature schedules.

2. Moisture content determinations with a moisture meter showed a significant difference for both species between the high-temperature and conventionally dried material.

3. Total degrade losses favored the high-temperature drying method for the lodgepole pine and the conventional drying method for western larch.

4. Shell and core moisture content determinations showed a steeper moisture gradient for the high-temperature dried material.

5. Prong test specimens indicated slightly greater casehardening stresses in the studs dried at high temperature.

6. End-check penetration was greater for the studs dried at high temperature, and more studs dried at high temperature developed this seasoning defect.

BIOGRAPHICAL SKETCH

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Helmuth Resch is Lecturer in Forestry and Assistant Wood Technologist on the staff of the University of California Forest Products Laboratory. He was educated in Europe and the United States and taught in forestry and wood technology at the College of Forestry in Vienna, Austria, and Utah State University prior to joining the California Forest Products Laboratory in 1962. His main interest lies in the area of physical properties of wood and the applied fields of drying and treating timber.

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Barton Ecklund earned a B. S. degree in Wood Technology from the University of Michigan in 1957 and a M. S. in Wood Technology from the University of California in 1961. During graduate work at the University of California and for three years after receiving degree, he did research in timber physics at the University of California Forest Products Laboratory. Currently he is Wood Technologist for the Research and Development Department of the Union Lumber Company in Fort Bragg, California. A member of the Forest Products Research Society, Society of Wood Science and Technology and the Redwood Seasoning Committee. Currently a trustee for the Northern California Section of the FPRS and chairman of the Redwood Seasoning Committee.