EFFECT OF LOG SIZE AND JUVENILE WOOD ON DRYING

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As the forest products industry uses more small logs it is increasingly important to understand their drying characteristics if product quality is to be maintained. This is particularly true as the consumer demands a perfect product, in both the domestic and export markets.

The objectives of this study were: 1) to determine if log size has an effect on the drying characteristics, 2) determine if drying at elevated or conventional temperatures affects warp, 3) determine if, at a given dry-bulb schedule, the rate of drying affects warp, and 4) determine the degree to which warp is associated with wood factors such as juvenile wood, ring count, density, board thickness, and out-of-kiln moisture content. Meeting these objectives will enable green sorts and drying schedules to be tailored to the type of product to be dried.

Eight 160-board charges of 2x6 lumber from large and small logs were dried using four different kiln schedules. Two dry-bulb temperature schedules were used, each with two wet-bulb temperature schedules. For each board, the percentage of juvenile wood, out-of-kiln moisture content, green thickness, density, and ring count were measured so their effect on bow, crook, and twist could be determined.

PROCEDURE

The 65 large logs ranged from 16" to 27" in diameter at the lower end with an average of 21.5". Only logs from which 30 percent or more of the lumber was likely to be in the L1 structural lamination grade were selected. Logs with shake and knots were excluded as were logs with less than 6 rings per inch (rpi). The selection criteria for the small logs were much less stringent, however, knotty logs or logs with sweep were not used. The average diameter for the 342 small logs was 10.4" (top and bottom averaged together). The logs were obtained from and sawn with cooperation of the Weyerhaeuser Company in Cottage Grove, OR. The plant was ideal because it is close to Corvallis and has both a small log and a large log mill. Their assistance is appreciated.

Sawing

Before sawing, the 12 rings nearest the pith at each end of the log were marked with paint. Juvenile wood characteristics, such as high fibril angle, are at a maximum near the pith and decrease toward the bark with about 90 percent of the changes occurring in the first 12 rings[1,2]. Marking these at each end of the log allowed the percent juvenile wood in each board to be estimated. The trim saws were not used in the sawmills.

The sawing patterns in each sawmill were adjusted to give as much 16', 2-by-6 material as possible. Large logs were broken down on a carriage bandsaw followed by a rotary gang. Small logs were processed on a chip-and-saw followed by a rotary gang. All large logs were sawn on one shift as were the small logs, approximately two months later. The material was solid-piled, covered, and shipped to Corvallis for drying. The covered packages were stored under sprinklers to keep them wet and cooler than the ambient temperature.

Measurements on green boards

Prior to stacking on stickers, the percentage of juvenile wood in each board was estimated from the paint marks. The distribution of juvenile wood among the boards is shown in Figure 1. Average board properties for lumber from the two sets of logs are shown in Table 1. Thickness was measured on opposite edges one foot in from each end of the board and ring count was estimated. The average green moisture contents for the lumber from large and small logs were estimated from oven-dry samples. These were very consistent from charge to charge. The density was calculated from board weight, board dimensions, and the moisture meter readings after drying. Wane was not taken into account.

Table 1. Summary of the board properties by log size.

	Log Size		
Property	Small	Large	
Green MC	48	59	%
Ring Count	7.33	6.25	/inch
Density	24.4	26.4	lb/ft^3
Juv. Wood	47.3	27.6	%

Bow and crook were measured by placing the board on a table against two stops which were 16' apart. The deviation of the board from a straight line between the two stops was measured at two-foot intervals along the length of the board. If the pith side of the board was concave, the bow was taken to be negative. A positive value indicated the pith side was convex. Similarly for crook, the pith face was place up and positive and negative measurements were made; however, this was done only for consistency from the green to dry measurements. There was not sufficient twist in the green material to make measurements.

Drying

Eight charges, each containing 160 boards, were dried. Four entering-air schedules, each a variation on schedule #294 (Douglas-fir, 8/4, upper grades) in reference 3, were used as shown in Figure 2. Dry-bulb temperatures of 160°F and 190°F were selected to be representative of the highest temperature (considering possible strength loss) and the lowest temperature (considering drying time) at which lamstock might be dried. Wet-bulb depressions were equal in the fast schedules at 160°F and 190°F. Similarly, they are equal in the two slow schedules. The air velocity was 800 feet per minute for all schedules. For all charges a four-hour conditioning period was used.

The lumber was stacked using 0.75" laminated stickers on a spacing of 2'. The position of each board in the kiln was recorded. Top weight of 45 pounds per square foot was used so that the lab kiln would not simulate the top few layers of the commercial kiln. This loading is the equivalent of about 8 courses of green lumber.

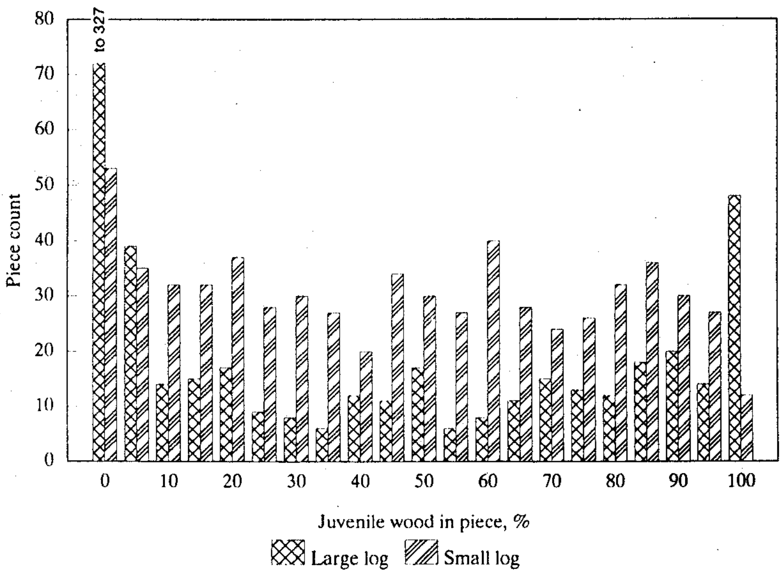

Figure 1. Distribution of juvenile wood among the boards from large and small logs. Note that the 0% column for large logs goes considerably off the scale.

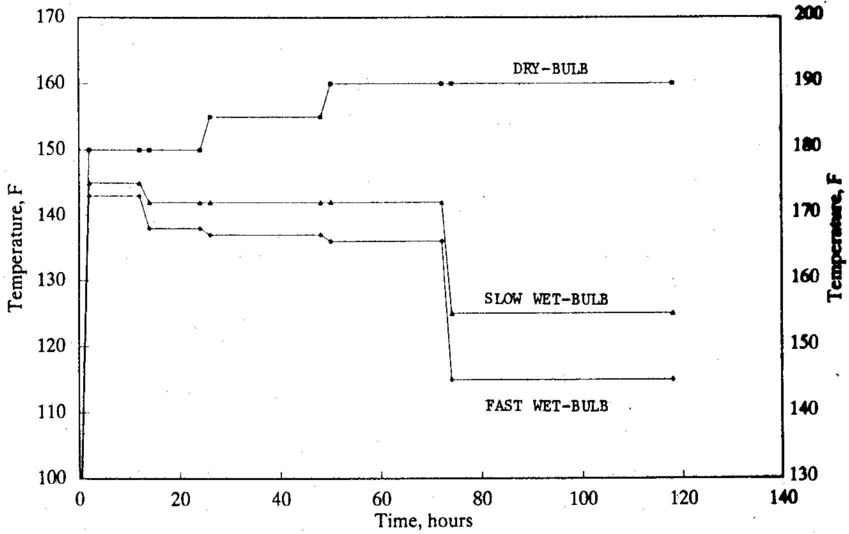

Figure 2. Four kiln schedules used in the experiment. Read the scale on the left for the conventional-temperature schedules and the scale on the right for the elevated-temperature schedules.

Measurements on dry boards

Each charge was allowed to cool to room temperature prior to unstacking. Bow and crook were remeasured using the same board orientation relative to the table and stops as in the green measurements. Twist was measured by holding three corners of the board against a flat surface and measuring the rise in the fourth corner. Bow, when present, was placed upward during the twist measurement. No attempt was made to measure the direction of the twist; however, it was generally one way. Each board was weighed and metered for moisture content using a conductance-type meter. Two measurements were taken, one four feet from each end of the board. If these differed by more than four percent (occurred in 24 out of 1280 boards), a third reading was taken at the center of the board.

DATA ANALYSIS

The maximum values reported for bow and crook were determined by fitting a third order polynomial to the seven displacement measurements. This polynomial was forced to give zero displacement at x=0' and x=16' where the board was against stops. Simply reporting the maximum of the seven measurements would give nearly identical results. The advantages of the present method will be discussed in a separate paper.

Statistically, the experimental design was a split plot with large and small logs being the whole plots, drying schedule being the subplots, and board properties as subsamples. This gives three degrees of freedom for testing the effect of temperature and drying rate resulting in a rather insensitive test. There are approximately 1270 degrees of freedom for testing effects which were measured on each board, such as percent juvenile wood, resulting in an extremely sensitive test. For these reasons, data will be presented in tabular and graphical form with only brief reference to the statistical tests.

RESULTS

No difference was evident between the drying times, shown in Table 2, for the lumber from large logs or small logs. This is especially true if one also compares the final moisture contents. For every schedule, the log size with the lower moisture content had the longer drying time.

The green lumber from small logs was about 11 percent moisture content below that of the lumber from large logs. Therefore, one could conclude that the drying rate was higher for lumber from large logs since there was a greater moisture content change per hour. There was also more pounds of water leaving the wood per hour because the density was slightly greater for the lumber from large logs. This indicates that in a given kiln, lumber from small logs may take less time to initially heat and will require less steam per hour than lumber from large logs when dried on the same schedule.

Table 2. Final average moisture content for each charge based on moisture meter readings on every board.

Final moisture content, %

Dry-bulb Temperature,F	SMALL LOG SLOW	SMALL LOG FAST	LARGE LOG SLOW	LARGE LOG FAST
160	12.2	13.4	13.4	12.8
190	12.1	13.1	13.3	13.1

Drying time not including conditioning, hours

Dry-bulb Temperature,F	SMALL LOG SLOW	SMALL LOG FAST	LARGE LOG SLOW	LARGE LOG FAST
160	117	92	102	94
190	093	77	091	78

The large difference in drying times between the two slow schedules at 160°F might be explained by one charge being nearly the driest charge while the other is the wettest. Also, at the slow drying rate, a difference in drying time would have less impact on the final moisture content than at the other conditions.

The spread of out-of-kiln moisture content was less for the lumber from small logs (standard deviation = 1.5%) than for the lumber from large logs (standard deviation = 2.2%). This might be in part because the average moisture content for the lumber from large logs was 0.45 percent higher.

Twist

The average twist for each charge is shown in Table 3. The average twist in the lumber from small logs (0.354") was greater than in lumber from large logs (0.190"). There is no evidence to suggest that dry-bulb temperature or rate of drying had any effect on twist for lumber from either size of log.

Table 3. Average twist in the dry boards by charge. Values are in inches. Each value represents 160 boards.

Dry-bulb Temperature,F	SMALL LOG SLOW	SMALL LOG FAST	LARGE LOG SLOW	LARGE LOG FAST
160	0.404	0.277	0.163	0.260
190	0.361	0.372	0.141	0.196

Bow

The average bow before and after drying are shown in Table 4. Prior to drying, the boards tend to bow with the convex side towards the pith as evidenced in the top part of Table 4 by the positive values for average green bow. This is due to the growth stresses in the tree. During drying the situation reverses so that the concave side of the board is toward the pith. Thus, in the second part of Table 4, the average values for bow have changed sign and become negative. The lumber from small logs had more positive bow prior to drying and more negative bow after drying. Although these differences are not statistically significant, the difference due to log size approaches statistical significance ($p=0.08$) for the change in bow from the green to the dry.

For both green and dry bow, of course, all of the boards do not bow in the same direction. When taking averages, positive and negative values offset each other and give a small value for the average bow. In the bottom part of Table 4, averages are presented for bow expressed as a positive number regardless of direction. These are the values with which the grader and the customer would be concerned. Statistically there are no differences in these values due to log size, dry-bulb temperature, or drying rate, although the lumber from small logs appears to have more bow.

Table 4. Average bow before and after drying. Green bow and dry bow are first presented as measured. The absolute value for bow is averaged at the bottom of the table.

Average bow in green boards, inches

Dry-bulb	SMALL LOG		LARGE LOG	
Temperature,F	SLOW	FAST	SLOW	FAST
160	0.200	0.183	0.088	0.060
190	0.222	0.193	0.063	0.081

Average bow in dry boards, inches

Dry-bulb	SMALL LOG		LARGE LOG	
Temperature,F	SLOW	FAST	SLOW	FAST
160	-0.085	-0.068	-0.083	-0.091
190	-0.203	-0.145	-0.047	-0.141

Average of absolute value of dry bow, inches

Dry-bulb	SMALL LOG		LARGE LOG	
Temperature,F	SLOW	FAST	SLOW	FAST
160	0.244	0.175	0.152	0.200
190	0.249	0.232	0.194	0.224

Bow, expressed as a positive number, did decrease slightly from the green (not shown) to the dry condition. One might expect this due to the restraining action of the stickers. This is an important point because it emphasizes the need for all kiln trucks to be the same height and bunks to be the same thickness. Bow could just as well increase if the lumber was held in a bowed position during drying.

Crook

There was no preferred direction for either green or dry crook; therefore, only the positive values for crook are presented in Table 5. The results show no differences in crook due to log size, dry-bulb temperature, or drying rate. This is a surprising result and might be explained by two things. First, in a large log there is a greater likelihood of getting a quarter sawn board. In such a board, the edge nearest the pith would probably shrink more than the other edge and cause crook. Secondly, there was more sawing variation in the lumber from large logs. This could reduce the effectiveness of the stickers in holding the lumber in place during drying.

Table 5. Average crook before and after drying. In each case the crook is expressed as a positive number.

Average crook in green boards, inches

Dry-bulb	SMALL LOG		LARGE LOG	
Temperature,F	SLOW	FAST	SLOW	FAST
160	0.117	0.105	0.140	0.150
190	0.083	0.107	0.134	0.131

Average crook in dry boards, inches

Dry-bulb	SMALL LOG		LARGE LOG	
Temperature,F	SLOW	FAST	SLOW	FAST
160	0.158	0.119	0.163	0.203
190	0.138	0.157	0.151	0.136

Table 6 shows the number of boards which would not meet the very light and light crook categories according to the WWPA rules. For L1, the light crook section would apply. Only 7 boards out of the 1280 in the study were crooked enough to not make L1. This is not enough upon which to base any conclusions regarding the effect of log size, dry-bulb temperature, or schedule.

Table 6. Number of boards losing grade due to crook according to WWPA grading rules.

Very light crook

Dry-bulb	SMALL LOG		LARGE LOG	
Temperature,F	SLOW	FAST	SLOW	FAST
160	6	1	7	15
190	3	6	6	05

Light crook

Dry-bulb	SMALL LOG		LARGE LOG	
Temperature,F	SLOW	FAST	SLOW	FAST
160	2	0	0	5
190	0	0	0	1

Wood Properties

The remainder of the results will show how the board properties affected the amount of warp. Only plots from the small logs will be shown. Plots for the lumber from large logs would very look similar and are not shown to save space.

One of the main wood factors suspected of causing warp is juvenile wood. In Figure 3 the bow, crook, or twist in a piece are plotted against the amount of juvenile wood in that piece for lumber from the small logs. When juvenile wood was a covariate (other independent variables were log source, dry-bulb temperature, and drying rate) in an analysis of variance with the amount of bow, crook, or twist as the dependent variable, the warp was significantly affected by the percentage of juvenile wood in the piece. This is not apparent in the plots, however. The 1271 degrees of freedom available to test juvenile wood makes it an over-sensitive test. Thus, in a practical sense, the effect of the percent juvenile wood in the piece on warp is minimal.

Based on Figure 4, it appears that boards with a lower ring count might tend to have increased warp; however, this trend, if present, is not pronounced and certainly not of statistical significance.

There were no relationships evident for bow, crook, or twist as functions of the out-of-kiln moisture content, wood density, or the board thickness.

CONCLUSIONS

Based on experience, many kiln operators would conclude that lumber from small logs warps a lot more than lumber from large logs. This study did not confirm or refute that because of the small amount of warp observed regardless of the log size, dry-bulb temperature, or rate of drying. This may have occurred for several reasons. The species was Douglas-fir which is less prone to warp that some of the other Western species. The logs were selected to be likely to yield lamstock. Thus, the lumber may have been from better-than-average logs. Much of the warp observed in commercial kilns occurs at the top of the stack. In this study, we eliminated the effect of the top of the stack by using mild restraint. Also, the boards were very carefully stacked on a solid foundation with laminated stickers which were very uniform in thickness. Proper technique may be the best defense to prevent warp in lumber, regardless of the source of the wood.

REFERENCES

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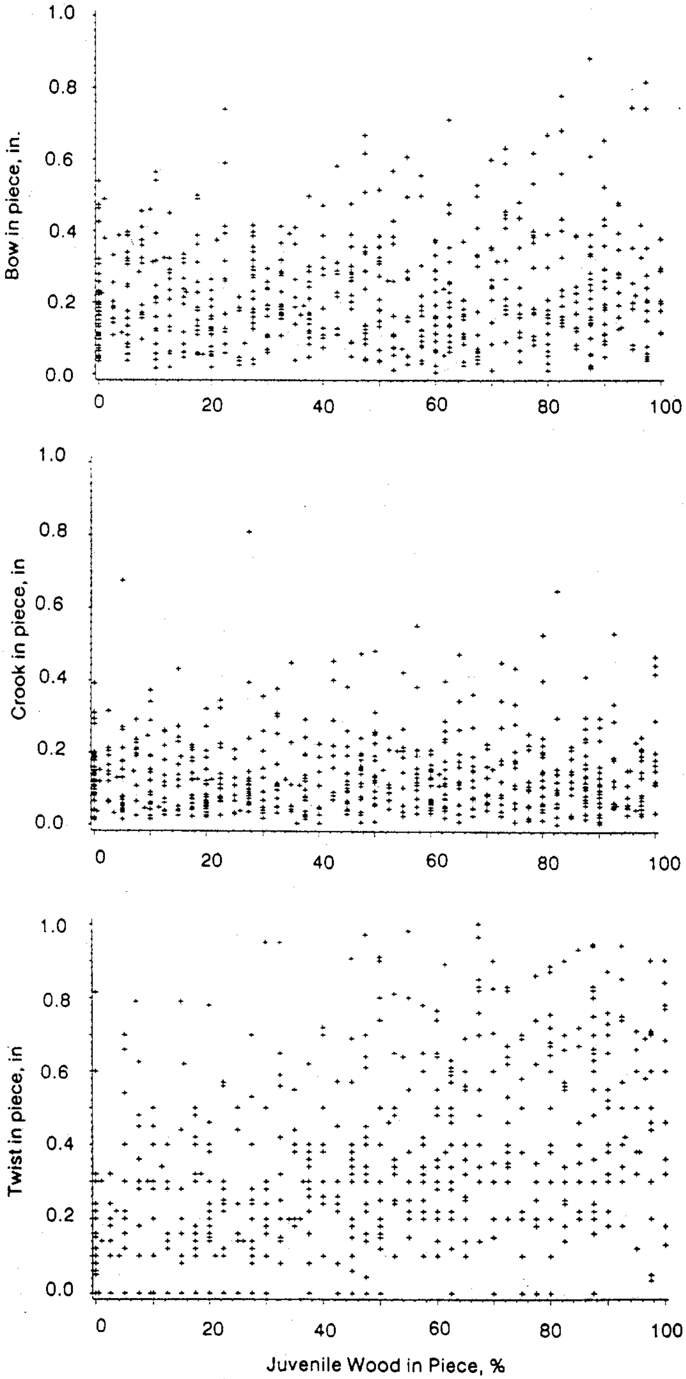

Figure 3. Bow, crook and twist in a board as a function of the amount of juvenile wood in the board for lumber from small logs.

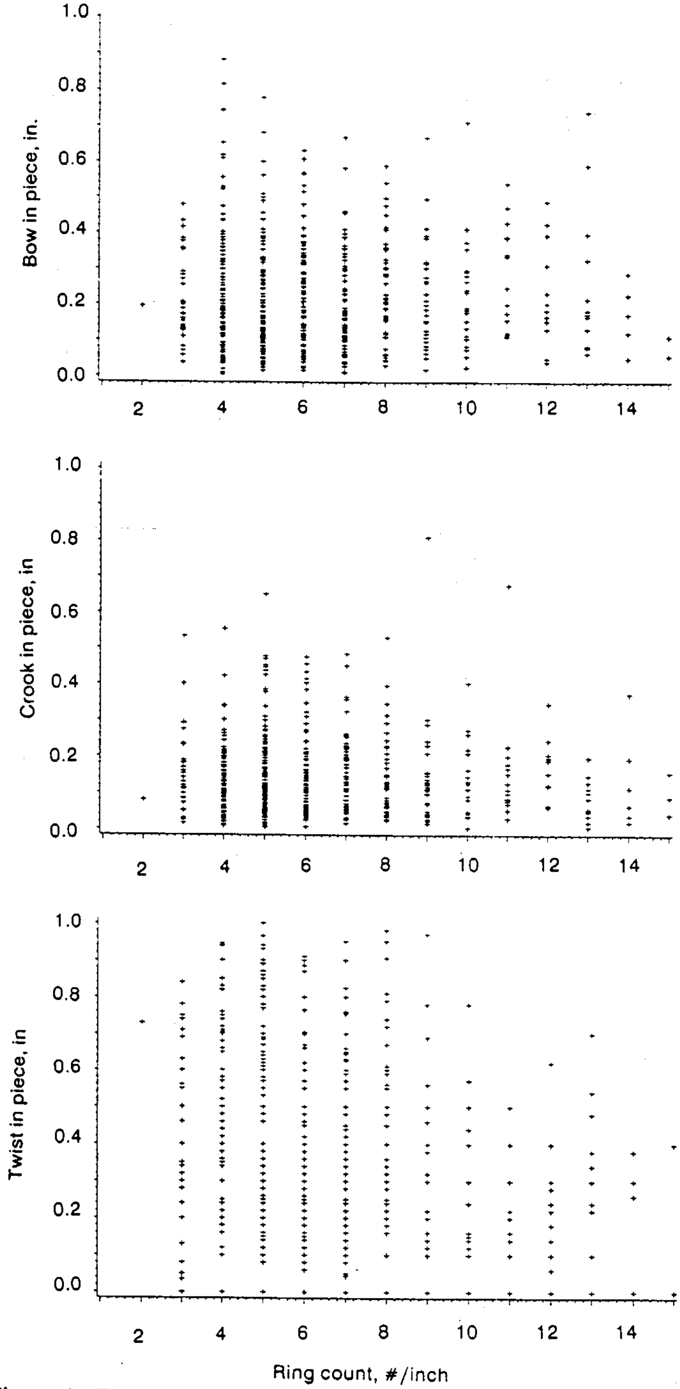

Figure 4. Bow, crook and twist in a board as a function of the ring count for lumber from small logs.