Time to Dry 2-, 3-, and 4-Inch S4S Southern Pine at 240°F, as Related to Board Width

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Abstract

With 80°F wet-bulb depression and air cross-circulated at 1,000 fpm, southern pine in 2-, 3-, and 4-inch thicknesses attained 10 percent moisture content in 22.4, 35.6, and 45.3 hours. In 3- and 4-inch thicknesses, 4-inch-wide lumber required less time to dry than that 8 or 12 inches wide. Surface checks were absent or moderate in all thicknesses and widths. End-checking, absent or minor in 2-inch lumber, was moderate to severe in 3- and 4-inch lumber. At 10 percent moisture content, end checks in the thicker lumber were several inches long. Shrinkage and warp were within acceptable limits, and casehardening was relieved by 3 or 4 hours of conditioning.

Prior work (1,2,3) has shown that southern pine lumber up to 2 inches in thickness can be dried to 10 percent moisture content in 21 hours or less at a dry-bulb temperature of 240°F and wet-bulb depression of 80°F. With this schedule, lumber in 4-inch widths did not develop surface checks or excessive end checks. Drying time to 10 percent moisture content was linearly correlated with thickness, so that 1.0-, 1.5-, and 1.9-inch-thick lumber in 4-inch widths needed 10.4, 15.8, and 20.7 hours.

The present experiment was designed to see if drying time to 10 percent moisture content is linearly correlated with thickness in the range of 2-, 3-, and 4-inch thicknesses. Also, lumber in widths of 4, 8, and 12 inches was compared in an assessment of drying time, shrinkage, damage from warp, and end and surface checks.

Sawmillers are under considerable pressure to saw accurately to the minimum dimensions that will clean up in planing. The data here provided on shrinkage, warp, and severity of checking should help them to attain these minimum sizes.

Methods

Over a 5-week period, 10 kiln loads of green southern pine lumber (species unidentified but probably loblolly) were dried in a kiln held at 240°F with wet-bulb depression of 80°F and air-circulation velocity of 1,000 feet per minute. Direction of air circulation was reversed every 75 minutes.

Each of the 10 kiln loads was comprised of eighteen 100-inch-long S4S planks in a replicated factorial combination of three thicknesses (2, 3, and 4 inches) and three widths (4, 8, and 12 inches). In each load, the nine pieces making up one replicate were located on the top half of the charge; the other replicate was placed on the bottom. Within each replicate, vertical placement of the three thicknesses was random; and in each layer the placement by lumber width was random (Fig. 1).

The 10 kiln loads were dried in two blocks (in time) of five each. The five loads from each block were kilned for 6, 12, 24, 36, or 48 hours. The sequence of these runs was randomized within each block.

Each piece was weighed and measured immediately before charging and immediately after discharge from the kiln. Green measurements of length, width, and thickness were taken at three locations—the quarter points. On discharge, the length, width, and thickness were remeasured at the same locations; crook, bow, and twist were also measured. Cup was not evaluated, as its occurrence was negligible.

Records were made of the number and length of all checks visible on the top and bottom surfaces at each quarter point and on the end that appeared to be the most severely checked. In addition, depths of all surface checks were measured at the quarter points.

Finally, 1-inch cross-sectional slices were removed from the quarter points. One set of these slices was weighed immediately and again after ovendrying; from these data the moisture content of each piece (before and after drying) could be established, as well as the specific gravity. From the second set of slices for all thicknesses, the outer 2/3-inch layer (the shell) was removed from top and bottom surfaces and a central 2/3-inch layer (the core) excised; these components were weighed immediately, then ovendried and weighed again to yield moisture contents of shell and core.

Specific gravity of the 4- and 8-inch-wide boards averaged 0.48 (basis of green volume and ovendry weight); the 12-inch-wide boards had slightly higher specific gravity (0.51). Green moisture content averaged 119 percent, with 4- and 6-inch widths having slightly higher moisture (123 percent) than the 12-inch widths (110 percent); green moisture content did not vary significantly with board thickness.

For each board size, values of warp, data on surface and end checks, and measurements of shrinkage were all plotted against moisture content. From these plots (one for each block), values of the property at 10 percent

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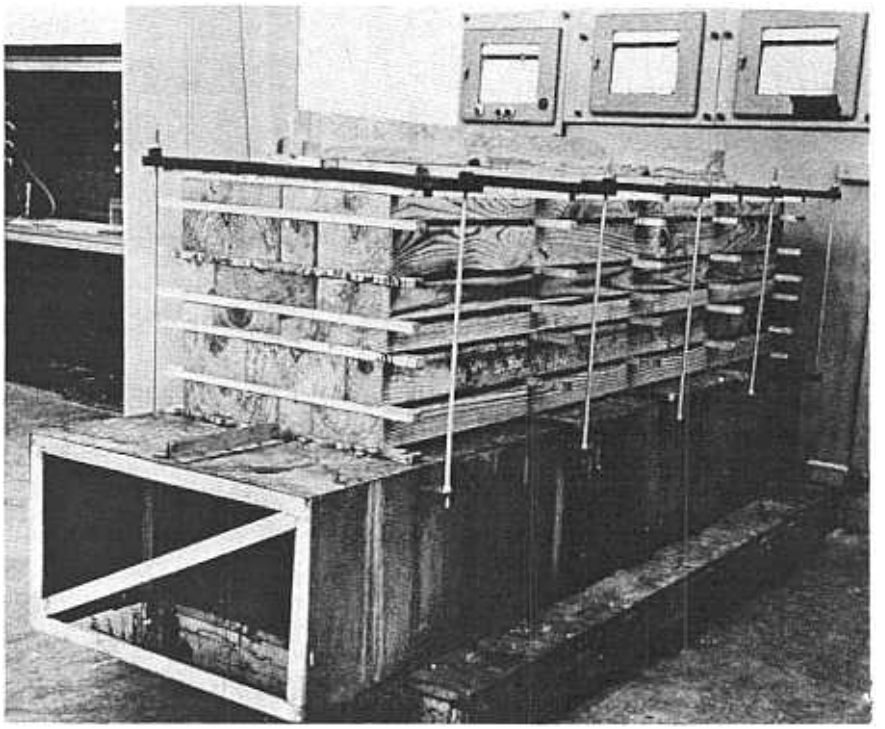

Figure 1. — Green lumber ready for charging into kiln. Lumber was given a top-load by means of spring-loaded tension rods. Stickers were conventionally placed; they were 1-1/2 inches wide and 3/4-inch thick.

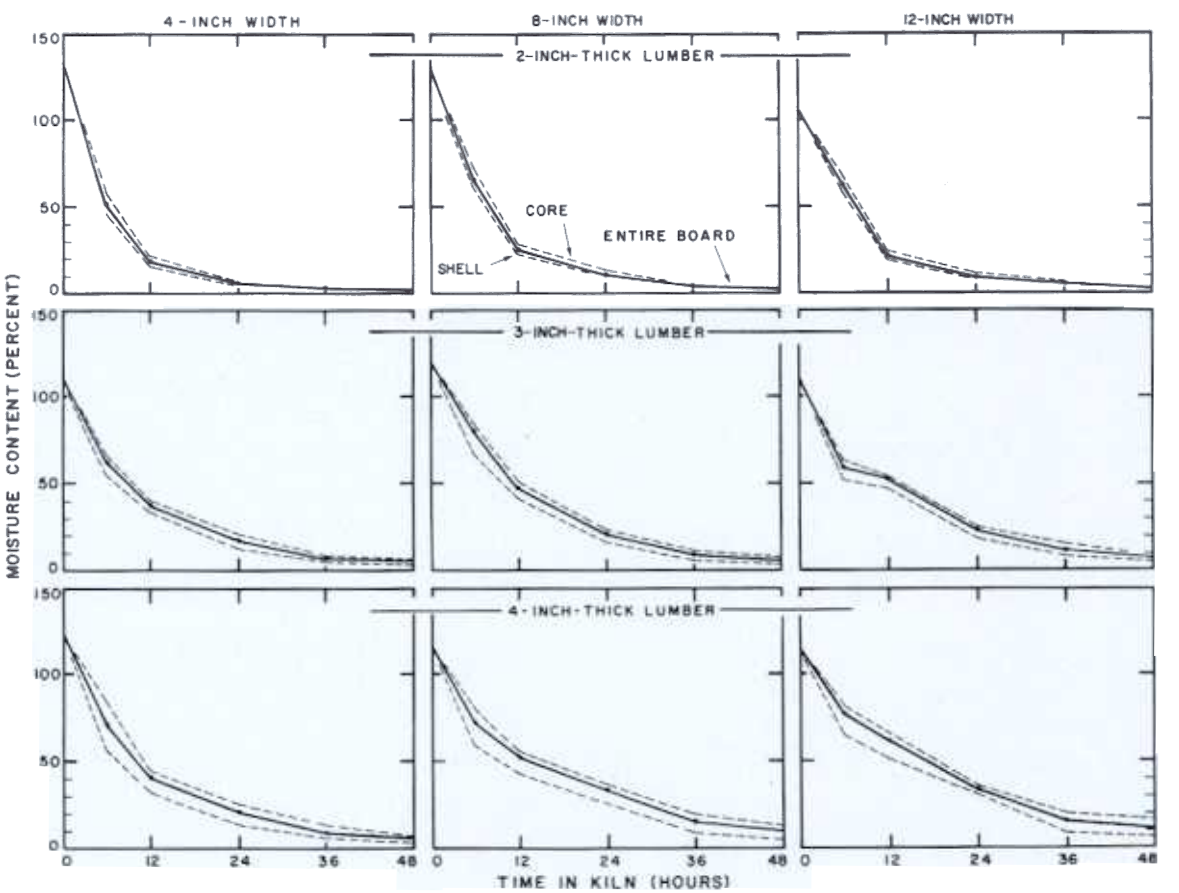

Figure 2. — Moisture content change in three widths of southern pine of 2-, 3-, and 4-inch thickness dried at 240°F with 80°F wet-bulb depression and air circulation velocity of 1,000 fpm. Each data point is the average of values from four boards.

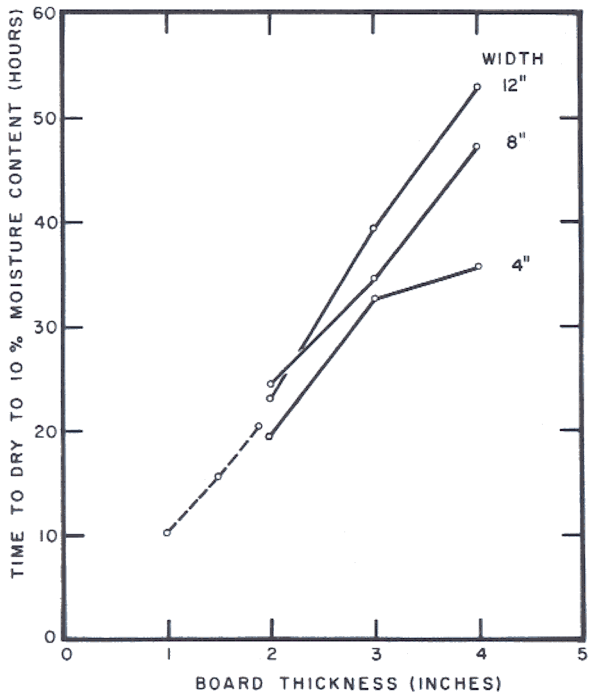

Figure 3. — Time to dry (at 240°F with 80°F wet-bulb depression) various thicknesses and widths of southern pine lumber from green to 10 percent moisture content. Dotted line shows data from previous experiment (2) with 4-inch-wide lumber.

moisture content were predicted from regression or from a smooth curve drawn by eye.

Results

Drying Rates

Time to dry was positively correlated with both board width and thickness (Figs. 2, 3, and 4). When data for all widths were pooled, time to dry to 10 percent moisture content had a near-linear correlation (Table 1 and Fig. 3). Average times (width data pooled) to reach 10 percent moisture content were as follows:

Lumber thickness (in.)	Time in kiln (hr.)
2.0	22.4
3.0	35.6
4.0	45.3

These data further confirm results obtained in earlier experiments (2) which yielded the following near-linear relationship between board thickness and time to dry 4-inch-wide southern pine under nearly identical conditions (Fig. 3):

Lumber thickness (in.)	Time in kiln (hr.)
1.0	10.4
1.5	15.8
1.9	20.7

Analysis of variance and visual inspection of Figure 3 show that the 4-inch widths differed significantly from the 8- and 12-inch widths in relationship between thickness and time to dry to 10 percent moisture content. In brief, 4-inch-thick narrow lumber appears to dry more quickly than a linear relationship would suggest. This interaction between width and thickness was also evident at target moisture contents of 15 and 30 percent (Fig. 4). With width data pooled, times to dry to various moisture contents were as follows:

Lumber thickness	Drying time To 10%	To 15%	To 30%
		(hr.)	
	22.4	17.9	10.7
	35.6	29.7	18.5
	45.3	34.8	23.7

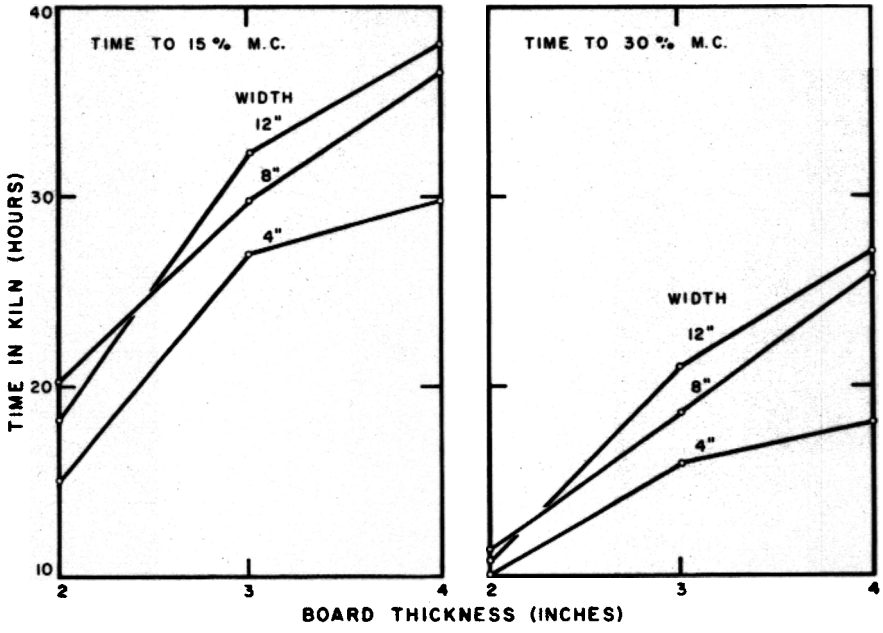

Figure 4. — Time to dry (at 240°F with 80°F wet-bulb depression) various thicknesses and widths of southern pine lumber from green to 15 and 30 percent moisture contents.

Table 1. — TIME TO DRY (AT 240°F WITH 80°F WET-BULB DEPRESSION) SOUTHERN PINE FROM GREEN TO 10 PERCENT MOISTURE CONTENT.

Lumber thickness and width (in.)	Kiln time		
	Block 1[1]		Average
	(hr.)		
2-inch thickness			
4	20.0	19.0	19.5
8	23.4	25.5	24.5
12	24.4	21.9	23.2
		$\bar{x}$ =	22.4
3-inch thickness			
4	33.4	31.7	32.6
8	35.0	34.3	34.7
12	39.8	39.4	39.6
		$\bar{x}$ =	35.6
4-inch thickness			
4	33.8	37.7	35.8
8	48.9[2]	45.7	47.3
12	54.3[2]	51.7[2]	53.0
		$\bar{x}$ =	45.3

[1]Each value is for one block of five boards and was read directly from graphs of moisture content vs. time in kiln; ten data points determined each graph.

[2]Extrapolated values.

During early hours of drying, core moisture contents were greater than those for shells. As board averages approached 10 percent, the core and shell values converged (Fig. 2) except in wide boards of 4-inch thickness. In 3- and 4-inch pieces both core and shell dried more slowly as width increased (Table 2). In all thicknesses, times to dry both core and shell were positively correlated with thickness:

Portion and lumber thickness (in.)	Kiln time		
	To 10%	To 15%	To 30%
Core			
2	24.8	20.3	11.2
3	40.4	33.4	20.0
4	57.1[1]	45.2	25.9
Shell			
2	21.5	16.3	10.1
3	31.4	26.0	16.9
4	33.1	29.5	20.1

[1]Extrapolated value.

Shrinkage When Dried From Green To 10 Percent

Width shrinkage from green to 10 percent moisture content differed significantly (0.05 level) with width, but not with thickness:

Board width, green (in.)	Width shrinkage (in.)
4	0.13
8	.23
12	.37

Thickness shrinkage varied with both board width and thickness in a significant interaction. Four-inch-wide boards had less thickness shrinkage than 12-inch boards:

Board thickness and width (in.)	Thickness shrinkage (in.)
2-inch thickness	
4	0.07
8	.10
12	.10
3-inch thickness	
4	.14
8	.13
12	.17
4-inch thickness	
4	.13
8	.18
12	.19

All boards were 100 inches long when green. Average length shrinkage in drying to 10 percent was 0.08 inch, with no significant differences attributable to width or thickness.

Warp in Wood at 10 Percent Moisture Content

Crook averaged 0.20 inch and varied significantly with board width but not with thickness. Crook was greater (0.25 inch) in 4-inch widths than in 8- and 12-inch pieces (0.18 and 0.17 inch).

Bow in dry boards also averaged 0.20 inch, but was not significantly correlated with board thickness or width.

Twist averaged 0.23; it was not significantly related to thickness or width. As noted in the procedure section, cup was slight or absent.

Surface Checks in Wood at 10 Percent Moisture Content

The surface of wood dried to 10 percent moisture content showed few checks; on average, only one check was observed for each 28 inches of sample line drawn perpendicular to the grain on the face or back. Frequency of checks was not significantly related to board thickness or width.

Surface checks averaged 1.4 inches in length and 0.09 inch in depth. Checks were longest and deepest in thick, wide stock:

Board thickness and width (in.)	Surface check	
	Length	Depth
	(in.)	
2-inch thickness		
4	0.3	0.01
8	.0	.00
12	1.3	.08
3-inch thickness		
4	.2	.01
8	1.7	.11
12	2.1	.13
4-inch thickness		
4	.3	.01
8	2.2	.23
12	4.2	.27

Table 2. — KILN TIMES TO DRY CORES AND SHELLS (AT 240°F WITH 80°F WET-BULB DEPRESSION) OF SOUTHERN PINE FROM GREEN TO 10, 15, AND 30 PERCENT MOISTURE CONTENT.

Lumber thickness and width (in.)	To 10%		To 15%		To 30%	
	Core	Shell	Core	Shell	Core	Shell
			(hr.)			
2-inch thickness						
4	19.6	20.0	17.2	13.2	10.6	9.1
8	28.6	22.9	22.9	19.1	11.8	10.9
12	26.3	21.7	20.7	16.7	11.2	10.3
3-inch thickness						
4	35.2	28.2	30.4	23.1	18.2	14.4
8	40.7	31.9	32.8	26.3	19.9	16.9
12	45.4	34.1	37.1	28.5	22.1	19.3
4-inch thickness						
4	42.2	29.0	34.6	23.7	20.4	13.7
8	57.8[1]	35.1	46.5	31.8	28.4	21.3
12	71.3[1]	35.2	54.5[1]	33.1	28.8	23.3

[1]Extrapolated values.

End Checks Visible on Exterior

As noted in the procedure section, the most severely checked end of each board was evaluated to obtain data on frequency of occurrence and length along the grain (average and maximum length observed). These data were recorded from checks visible on the outer surface.

One end check was observed for each 9.4 inches measured across the grain on the top or bottom surface of board ends; this frequency was not significantly related to board thickness or width. The checks averaged 1.6 inches in length; the longest check in each board averaged 2.4 inches. Visible end checks were longest in wide thick lumber:

Board thickness and width (in.)	Length of end check on board surface	
	Average	Maximum
	(in.)	
2-inch thickness		
4	0.4	0.5
8	.4	.5
12	1.4	1.7
3-inch thickness		
4	.2	.2
8	1.4	1.9
12	3.2	5.7
4-inch thickness		
4	.4	.5
8	2.0	2.9
12	5.5	7.8

End Checks Observed by Dissection

In addition to checks visible on board ends, substantial checking was found in interiors adjacent to the ends. In general, the 2-inch lumber had minor end-checks, although some boards had checks extending in 3 to 4 inches. Three-inch lumber, when dried to 10 percent, had more severe checks, which in some cases extended 5 or 6 inches. In lumber 4 inches thick, some checks extended 7 to 9 inches in from board ends.

After the main experiment was concluded, three 4 by 8's were dried for 48 hours at 240°F with 80° wet bulb depression, and then conditioned for 4 hours at 195°F with 10° wet bulb depression to yield an average moisture content of 10 percent (shell about 8 and core about 11 percent). When the timbers were dissected after cooling and equilibrating in the laboratory for a week, checks were observed to extend about 9 inches into each end of each timber. Casehardening was minimal.

In the entire experiment, only two internal checks were observed at a distance from board ends; both were found in 4 by 4's dried to less than 10 percent moisture content in 48 hours.

Discussion

Southern pine dried at a dry-bulb temperature of 240°F and a wet-bulb temperature of 160°F with air cross-circulated at 1,000 fpm attained 10 percent moisture content when kilned 11 or 12 hours per inch of thickness. This generalization is true for medium-width lumber (e.g., 8 inches) in thicknesses from 1 through 4 inches.

In 3- and 4-inch thicknesses, 4-inch-wide lumber required less time to dry than that 8 or 12 inches wide.

Surface checks were moderate or absent in lumber of all thicknesses so dried. End checks were minimal in lumber 2 inches thick or less but penetrated several inches into 3- and 4-inch lumber. An end coating resistant to high temperature would probably reduce severity of such checks.

Internal checks were rare; they were observed only in 4 by 4's dried to 10 percent moisture content or less. They were not observed in 2- and 3-inch lumber.

Casehardening in 4 by 8's was relieved by 4 hours of steaming at 195°F dry-bulb temperature and 185°F wet-bulb. Prior experience (1,2,3) indicates that 3 hours of conditioning is sufficient to relieve casehardening in 2-inch lumber.

Crook and bow in this experiment averaged 0.20 inch, while twist averaged 0.23 inch. Width shrinkage to 10 percent moisture content averaged about 0.03 inch per inch of green width. Thickness shrinkage was somewhat less in 4-inch-wide boards than in wider boards; with width data pooled, thickness shrinkage averaged 0.09, 0.15, and 0.17 inch for 2-, 3-, and 4-inch-thick lumber dried to 10 percent moisture content.

Considerable resin exuded to the surface of a few pieces, but most remained clear. Where such exudations would be objectionable, they could be removed by a light planing.

Literature Cited

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