

High-Temperature Drying Of Southern Pine Timbers, Lumber, And Thick Veneer

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Southern pine sawmillers are becoming increasingly aware of economies in manufacture achievable through kilning in a steam-air mixture at temperatures above the boiling point of water.

The purpose of this paper is to summarize recent research specific to Southern pine timbers, lumber, and thick veneers. Readers wishing a more complete discussion are referred to the 1973 *Proceedings of the American Wood Preservers' Association* (Koch 1973a), which also includes information on high-temperature drying of Southern pine poles.

THICK VENEERS

Techniques are being developed for laminating dimension lumber from thick Southern pine veneers (Koch 1973b; Schaffer et al. 1972). Methods for drying such pieces are therefore receiving considerable attention.

About 10 years ago I studied the drying of sawn Southern pine veneers planed to 7/16-inch thickness (Koch 1964). The veneers ranged in moisture content from 45 to 180 per cent. Three high-temperature treatments were tried: a conventional roller-veneer dryer at 300° F., an impingement-jet dryer at 300° F., and the same jet dryer at 350° F.

A 90-minute pass through a conventional roller dryer at 300° F. brought the moisture content to an average of 4.4 per cent with a range from 0 to 17.6 per cent (fig. 1). The veneer was continuously fed longitudinally, as in a jet dryer, but the air was circulated in a counter-flowing horizontal direction instead of impinging vertically. Nominal air velocity was 600 f.p.m. Resin exudation was light but solid over a considerable portion of the veneers.

A 60-minute pass through an impingement-jet dryer at 300° F. with air velocity of about 3,500 f.p.m. brought the 7/16-inch veneers to an average moisture content of 5.1 per cent, with range from 0.2 to 14.3 per cent (fig. 1).

When the impingement-jet dryer was raised to 350° F., all of the veneers were dried to less than 10 per cent moisture content in 40 minutes (fig. 1). In both the jet dryer trials, resin exudation was heavy and solid over portions of many veneer surfaces.

Kimball (1963) evaluated drying times for sawn and sliced loblolly pine veneers from 3/16- to 9/16-inch in thickness. Figure 2 shows that the sliced veneer dried somewhat faster than the sawn veneer in a jet dryer with air at 300° F. impinging at a velocity of 4,000 f.p.m. The 3/16-inch veneer dried to 10 per cent average moisture content in about 20 minutes, the 3/8-inch in about 40 minutes, and

the 9/16-inch in approximately 70 minutes. These times were averages; to achieve a uniform final moisture content, Kimball concluded, either the original (green) moisture content must be uniform or the dried veneer must be equalized.

In summary, thick Southern pine veneers can be readily dried in impingement-type roller veneer dryers at temperatures ranging from 300° to perhaps 400° F. Resin exudation may or may not be troublesome. Koch (1964) observed severe exudation, while Kimball (1968) did not. In thicknesses less than 5/8-inch, time in the dryer is of such short duration (approximately an hour) that diminution of strength should not be a problem.

In the data of Koch and Kimball, a linear relationship was apparent between thickness and drying time to 10 per cent moisture content. Extension of these data indicates that an impingement dryer operating at 300° F. would reduce one-inch lumber to this average moisture content in about 120 minutes.

Readers needing information on high-temperature drying of thin Southern pine veneers should consult the review found on pages 1004-1009 of *USDA Agriculture Handbook 420, Utilization of the Southern Pines*.

STUDS AND BOARDS

Enormous footages of Southern pine studs are being manufactured from small logs and veneer cores. Many of

the studs contain pith-associated wood, which is prone to warpage.

If they are to be grade-marked as kiln-dried, Southern pine studs must not have moisture contents above 15 per cent. Industry practice is to grade and ship kiln-dried studs at moisture contents of 12 or 13 per cent. Most of the studs find use in air-conditioned or heated buildings, however, and in service their moisture content declines to 9 or 10 per cent. Both experience and research have shown conclusively that the additional drying causes studs to deform considerably.

In the author's opinion, manufacturers would best serve the consumer by grading and shipping Southern pine studs at 10 per cent moisture content. Such practice would require major changes in manufacturing procedures, but in the long run the industry would profit. Moreover, research has developed information that makes the necessary new drying technology possible.

This technology will be new in two important ways. First, the pieces will go through the kiln under some form of mechanical restraint that will in effect steam-straighten them and thus greatly increase the proportion that meet Stud grade. Second, drying times will be drastically shortened. Research on this phase has been described in the May 1971 issue of *Forest Products Journal*, p. 17-24 (Koch 1971), and in the October 1, 1969, issue of *Southern Lumberman*, p. 26, 28, 29 (Koch 1969).

In brief, mechanically restrained studs dried in 24 hours at 240° F. developed only about half the average crook and twist observed in conventionally stickered studs dried in twice the time at temperatures not exceeding 180° F.:

	24-hour schedule	Conventional drying
	Inch	
Crook	0.14	0.25
Twist	.11	.28
Bow	.22	.24

Moreover, the energy requirement to dry studs to 10 per cent moisture content at 240° F. was substantially less than that needed at 180° F. The short schedule caused minor checking on the ends and considerable resin exudation on the surface but not enough to degrade the planed studs.

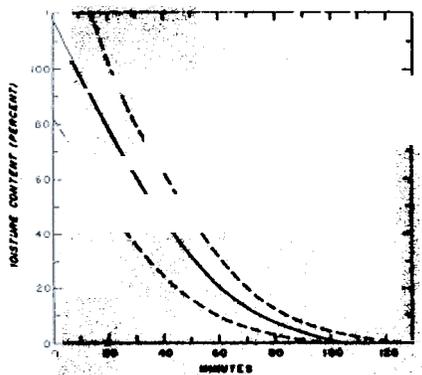
The articles just referred to outline a high-temperature schedule found to be successful. Following is a summarization of additional research (Koch 1972) that confirmed the schedule and yielded information about the effects of air velocity, lumber thickness, and wet-bulb depression.

In this confirmatory research, 108 kiln-loads (24 boards per load) of

and averaged about 117 percent.

Portion and lumber thickness	Kiln time to moisture content of--		
	10%	15%	30%
Inches	-----Hours-----		
Core			
2	24.8	20.3	11.2
3	40.4	33.4	20.0
4	57.1	45.2	25.9
Shell			
2	21.5	16.3	10.1
	31.4	26.0	16.9
4	33.1	29.5	20.1

Table 1—Drying time for Southern pine lumber and timbers kilned at 240 F. with 80 F. wet-bulb depression. (Air cross-circulated at 1,000 feet per minute and reversed every 75 minutes.)

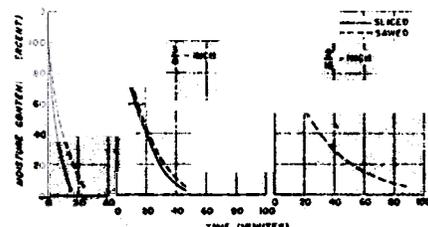


1. Drying curves for S4S, 7/16-inch-thick Southern pine veneers. Solid lines show average; dotted lines define envelope containing all veneers. Top: Conventional roller veneer dryer at 300° F. Bottom: Impingement-jet dryer at 300° and 350° F. (Drawings after Koch 1964.)

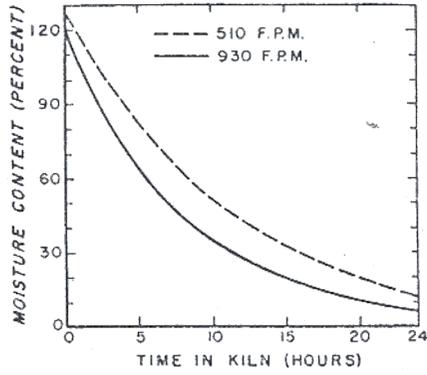
Southern pine lumber were dried at 240° F. in an air-steam mixture. Boards were eight feet long, four inches wide, and planed green to exact thicknesses of 1.9, 1.5, and 1.0 inches. Prior to drying, the lumber was stored in water, and therefore green moisture content was somewhat above normal, averaging about 120 per cent.

Air velocities.—Air velocities tested were 510 and 930 f.p.m. In the early stages of drying, moisture content was reduced more rapidly at the high velocity. For example, the 1.9-inch lumber (about equal in thickness to unplanned studs) was brought to about 60 per cent moisture content after five hours in high-velocity air at 80° F. wet-bulb depression. In low-velocity air, similar boards were near 80 per cent after five hours (fig. 3). This early advantage was reflected in the number of hours required to reach 10 per cent moisture content—that is, 21 hours at the high velocity and nearly 25 hours at the low.

Wet-bulb depression.—Three wet-bulb depressions were tested. A depres-



2. Drying curves for S4S (sawed and planed) and sliced loblolly pine veneer in an impingement jet dryer at 300° F. (Drawing after Kimball 1963.)



3. Increasing kiln air-speed from 510 to 930 f.p.m. considerably reduced the time required for drying Southern pine lumber. This chart is for boards 1.9 inch thick, dried at 240° F. and a wet-bulb depression of 80° F.

sion of 80° caused substantially faster water loss than a depression of 40° at both air velocities. A depression of 115° appeared slightly preferable to 80° in slow air, but in fast air it was no better and may have been inferior (fig. 4).

Board thickness.—For drying at 240°, then, 80° wet-bulb depression and 930-f.p.m. velocity proved faster than all other combinations tested. With this combination, times required to dry lumber to 10 per cent moisture content were closely proportional to board thickness:

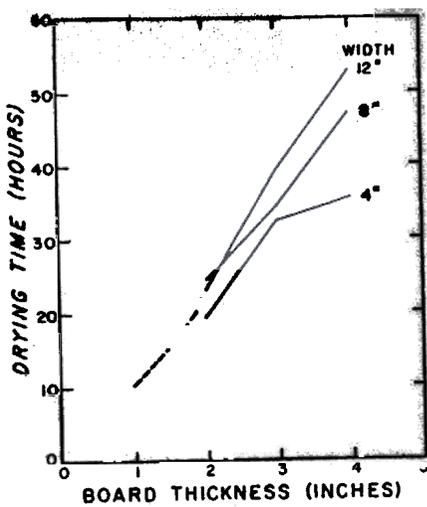
Lumber thickness Inches	Time in kiln Hours
1.0	10
1.5	16
1.9	21

Thus, wood of stud thickness was dry in 21 hours (fig. 5). Prior work had shown that case-hardening in studs dried at 240° F. can be relieved by steaming for an additional three hours at dry- and wet-bulb temperatures of 195° and 185° F.

Kilns for fast drying under restraint.—Partly because of limitations on the temperature to which the experimental kiln could be raised, and because of doubts as to the effects of heat on strength properties, tests on studs were limited to 240° F. But the 1963 work with thick veneers showed that dwell time—and hence length of a continuous kiln—could be substantially reduced through use of higher air temperatures and velocities.

Tests of an initial prototype kiln have proved that continuous roll-drying under restraint is a sound concept. Data from this prototype are being used to design a pilot model that should yield data sufficient for construction of a full-scale commercial kiln. Maximum practical operating temperatures and air velocities remain to be determined.

PLANKS AND TIMBERS
Published information on high-temperature kiln-drying of Southern pine planks and timbers is limited to



4. In 240° air moving at 930 f.p.m., a wet-bulb depression of 80° was at least as effective as a depression of 115°.

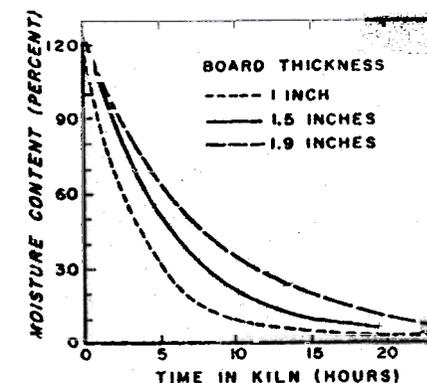
that from a single study (Koch 1973a, p. 133-137).

In this study, 10 kiln-loads of green Southern pine (species unidentified but probably loblolly, *Pinus taeda* L.) were dried in a kiln held at 240° F. with wet-bulb depression of 80° F. and air-circulation velocity of 1,000 f.p.m. Direction of air circulation was reversed every 75 minutes. Kiln charges were given a top load but were not otherwise restrained against warp. Stickering was conventional.

Each of the 10 kiln-loads was comprised of eighteen 100-inch-long S4S planks in a replicated factorial combination of three thicknesses (two, three, and four inches) and three widths (four, eight, and twelve inches).

Specific gravity (basis of green volume and oven-dry weight) averaged 0.49, and green moisture content averaged 119 per cent.

Drying rate.—Time to dry was positively correlated with both board width and thickness (fig. 6). When data for all widths were pooled, the correlation with thickness was almost linear. Average times (width data pooled) to reach 10 per cent moisture content were 22.4,



5. Time in kiln as related to moisture content of Southern pine lumber of various thicknesses. Air temperature was 240° F., airspeed 930 f.p.m. wet-bulb depression 80°.

35.6, and 45.3 hours for lumber two, three, and four inches thick. These data confirmed earlier experiments which yielded the following near-linear relationship between board thickness and time to dry four-inch-wide Southern pine under almost identical conditions (fig. 6).

Lumber thickness Inches	Time in kiln Hours
1.0	10.4
1.5	15.8
1.9	20.7

Inspection of Figure 6 shows that the four-inch widths differed significantly from the 8- and 12-inch widths in the relationship between thickness and time to dry to 10 per cent moisture content. In brief, four-inch-thick narrow lumber appears to dry more quickly than a linear relationship would suggest.

During the early hours of drying, moisture contents in the core (innermost 0.66 inch of thickness) were greater than those in the shells (outermost 0.66 inch of thickness at top and bottom surfaces), but as board averages approached 10 per cent the core and shell values converged. In three- and four-inch pieces, both core and shell dried more slowly as width increased. In all thicknesses, times to dry both core and shell were positively correlated with thickness, as shown in Table 1.

Shrinkage.—Width shrinkage from green to 10 per cent moisture content differed with width, but not with thickness:

Board width, green Inches	Width shrinkage Inch
4	0.13
8	.23
12	.37

Thickness shrinkage varied with both board width and thickness. Four-inch-wide boards shrank less than 12-inch boards.

Board thickness and width (inches)	Thickness shrinkage Inch
Two-inch thickness	
4	0.07
8	.10
12	.10
Three-inch thickness	
4	.14
8	.13
12	.17
Four-inch thickness	
4	.13
8	.18
12	.19

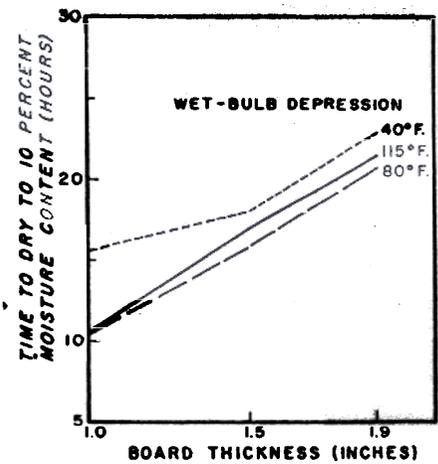
All boards were 100 inches long when green. Average length shrinkage in drying to 10 per cent was 0.08 inch, with no significant differences attributable to width or thickness.

Warp in wood at 10 per cent moisture content.—Crook averaged 0.20 inch and was greater (0.25 inch) in 4-inch widths than in 8- and 12-inch pieces (0.18 and 0.17 inch). Crook did not vary with board thickness.

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

Twist averaged 0.23; it was not related to thickness or width. Cup was slight or absent.

Checking at 10 per cent moisture content.—The surface of wood dried to 10 per cent 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



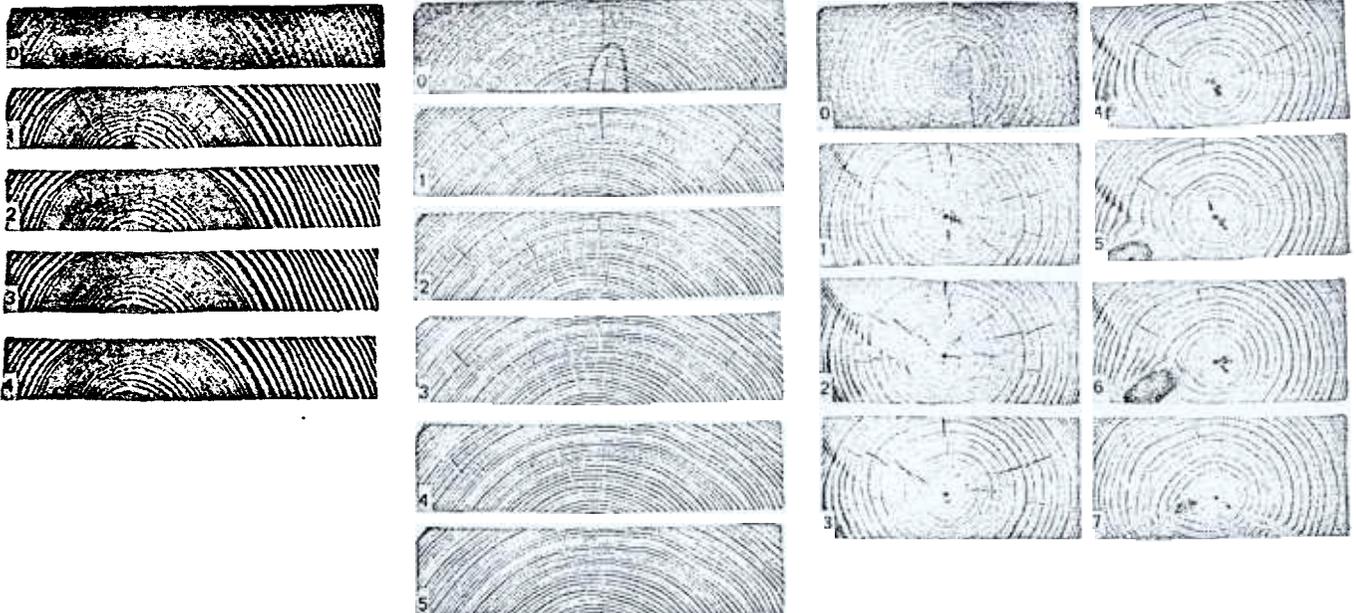
6. Time to dry (at 240° F. with 80° wet-bulb depression) various thicknesses and widths of Southern pine lumber from green to 10 per cent moisture content (Koch 1973b). Dotted line shows data from previous experiment (Koch 1972) with four-inch-wide lumber. Air-speed was about 1,000 f.p.m.

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.

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 related to board thickness or width. The checks aver-



7. With boards near 10 per cent moisture content, some checks penetrated several inches into the ends. The numerals on each section indicate distance in inches from board end. Left: 2 by 12 after 24 hours in kiln. Center: 3 by 12 after 36 hours. Right: 4 by 8 after 48 hours. The specimens illustrated had the worst checks observed. (Photos from Koch 1973a.)

aged 1.6 inches in length; the longest in each board averaged 2.4 inches. Visible end-checks were longest in wide, thick lumber.

In addition to checks visible on board ends, substantial checking was found in interiors adjacent to the ends. In general, the two-inch-thick lumber had minor end-checks, although one board had checks extending in three to four inches. Three-inch lumber, when dried to 10 per cent, had more severe checks, which in some cases extended five or six inches. Lumber four inches thick in some cases had checks that extended seven to nine inches in from board ends (fig. 7).

To ascertain effects of conditioning and equilibration on check development, three four-by-eight's were dried for 48 hours at 240° F. with 80° wet-bulb depression and then conditioned for four hours at 195° with 10° wet-bulb depression to yield an average moisture content of 10 per cent (shell about 8 per cent and core about 11 per cent when the timbers were dissected). After the pieces had cooled and equilibrated in the laboratory for about a week, checks were observed to extend about nine inches into each end of each timber. Case-hardening was minimal.

In the entire experiment, only two internal checks were observed at a distance from board ends; both were

found in four-by-four's dried to less than 10 per cent moisture content in 48 hours.

Literature Cited

- KIMBALL, K. E. 1963. Accelerated methods of drying thick-sliced and thin-sawed loblolly pine. *For. Prod. J.* 13(1) : 31-33.
- KOCH, P. 1964. Techniques for drying Thick Southern pine veneer. *For. Prod. J.* 14(9) : 382-386.
- KOCH, P. 1969. At 240° F. Southern pine studs can be dried and steam-straightened in 24 hours. *South. Lumberman* 219(2723) : 26, 28-29.
- KOCH, P. 1971. Process for straightening and drying Southern pine 2 by 4's in 24 hours. *For. Prod. J.* 21(5) : 17-24.
- KOCH, P. 1972. Drying Southern pine at 240° F.—effects of air velocity and humidity, board thickness and density. *For. Prod. J.* 22(9) : 62-67.
- KOCH, P. 1973a. High-temperature kilning of Southern pine poles, timbers, lumber, and thick veneer. *Proc. Am. Wood-Preserv. Assoc.* 69 : 123-140.
- KOCH, P. 1973b. Structural lumber laminated from 1/4-inch rotary-peeled Southern pine veneer. *For. Prod. J.* 23(7) : 17-25.
- SCHAPFER, E. L., JOKERST, R. W., MOODY, R. C., PETERS, C. C., TSCHERNITZ, J. L., and ZAHN, J. J. 1973. Feasibility of producing a high-yield laminated structural product: general summary. USDA For. Serv. Res. Pap. FPL-175, 18 p. For. Prod. Lab., Madison, Wis.

Program Announced

EUGENE, Ore., Jan. 24.—Dr. Stuart U. Rich, director of the Forest Industries Management Center of the University of Oregon, announces preliminary program of the Forest Industries Conference to be held at the Ramada Inn, Portland, March 19. A final program will be announced next month.