Trials of Prototype Roll-Feed, High-Temperature Dryer for 8/4 Southern Pine

Peter Koch

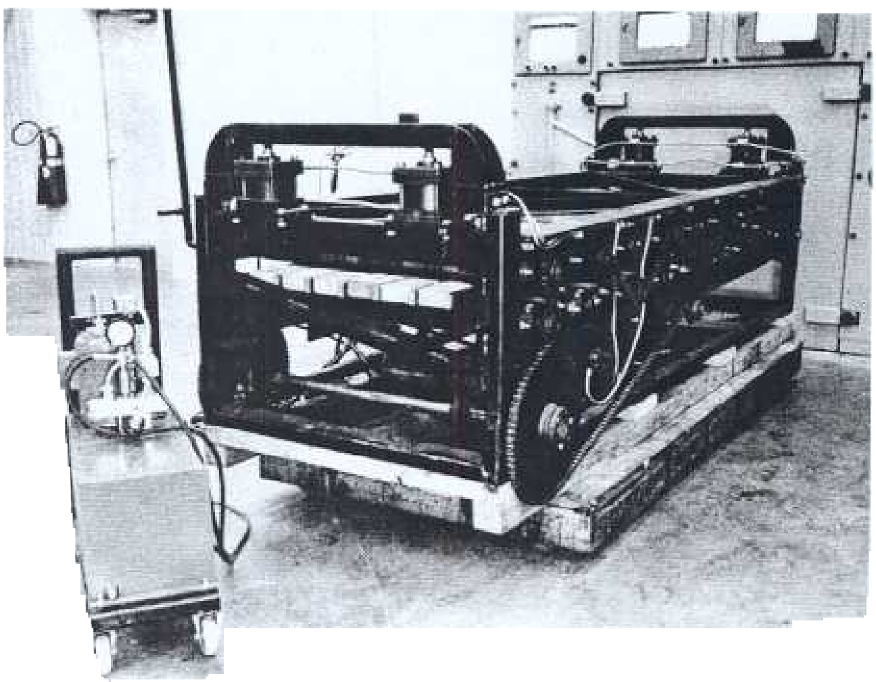

Figure 1. — Prototype roll-feed kiln. Fixed steel guidebars are observable on either side of each stud. The hydraulic power package (left foreground) by which rotation direction of the rolls was periodically reversed was mounted on wheels outside the kiln. Hydraulic and air lines were piped through the door of the compartment kiln (background) into which the roll-feed apparatus was inserted during the drying cycle.

Abstract

Eight-foot studs measuring 1.75 by 3.84 inches in cross section were cut from veneer cores and dried in a prototype continuous kiln that provided complete mechanical restraint against warp. Twenty-four hours on a high-temperature schedule brought the pieces from 87.9 to 8.3 percent moisture content without casehardening. Crook, bow, and twist were half that found in conventionally stickered studs dried on the same schedule. It was concluded that the reduction in warp (with resultant increase in lumber value), together with the system's inherent labor efficiency, justifies continuing work on mechanical design of roll-feed continuous kilns.

PREVIOUS RESEARCH (Koch 1971b, 1972ab) showed that 8-foot southern pine studs measuring 4 inches wide and 1.9 inches thick can be dried to 9 percent moisture content in 21 hours in a kiln providing a cross-circulation velocity of 1,000 fpm at dry- and wet-bulb temperatures of 240°F and 160°F. Casehardening can be relieved during an additional 3 hours at 195°F dry-bulb and 185°F wet-bulb temperatures. Moreover, the research showed that very straight studs can be obtained if mechanical restraint is applied during the drying process.

The speed of drying possible at high temperature and the possibilities for economical mechanical restraint in a roll-feed dryer prompted construction and testing of

The author is Chief Wood Scientist, USDA Forest Service, So. Forest Expt. Sta., Alexandria, La. This paper was presented at Session 18 — Drying & Storage — of the 27th Annual Meeting of the Forest Products Research Society, June 27, 1973, in Anaheim, Calif. It was received for publication in November 1973.

a prototype continuous kiln for 8/4 lumber. For reasons of economy and laboratory control, a reciprocating roll-feed mechanism was designed for insertion into an existing high-temperature compartment kiln.

The mechanism has nine pairs of 4-inch-diameter, 34-inch-long, power-driven, smooth rolls spaced 12 inches apart (Fig. 1). Four air cylinders located at the corners of the top roll case apply force between roll pairs; for the study reported here, air pressure of about 80 psi was applied to the 5-inch-diameter cylinders. Actual force per roll pair was difficult to estimate because the chain drive applied vectors additive to the squeezing force delivered by the cylinders.

The studs—separated by fixed steel bars as shown in Figure 2—were reciprocated linearly through an 18-inch stroke by a hydraulic device for reversing roll feed direction. A complete cycle (18 inches of forward and 18 inches of reverse motion) required about 1 minute.

It was reasoned that success in maintaining reciprocating motion of the studs would prove the practicality of a contemplated commercial design in which studs would travel in one direction at about 10 feet per hour for a 24-hour period. The commercial kiln would therefore be 240 feet in length; green studs would enter at one end and dry studs would emerge at the other.

Procedure

Eight kilnloads were dried. Each load contained six 8-foot 2 by 4's held by the roll-feed mechanism, and another six dried in a single layer conventionally stacked with a top load of 15 pounds per square foot. Factors were as follows:

Treatment

1) Roll-dried.
2) Conventionally stickered.

Replications within load: 6 studs per treatment

Load replications: 8

The 96 studs required were purchased in central Louisiana in two lots of 48 (widely separated in time).

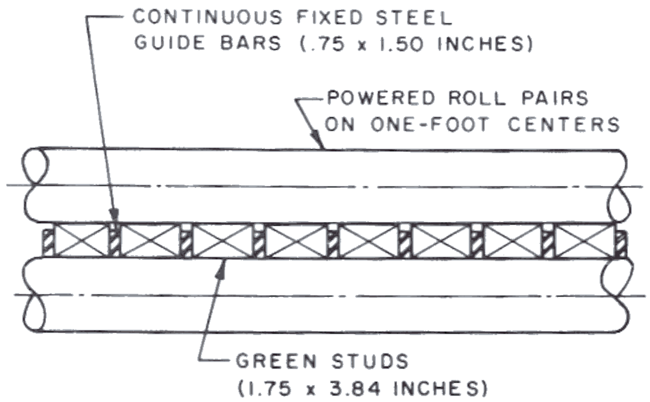

Figure 2. — Arrangement of the fixed guidebars that provided restraint against crook in the roll-feed dryer.

Studs rough sawed from veneer cores were chosen, since they have a propensity to warp.

All pieces were trimmed to 96.0-inch length, surfaced to 1.75-inch thickness and 3.84-inch width, randomly assigned to treatment and replication, and then stored under water pending use.

Table 1. — PROPERTIES OF STUDS WHEN GREEN AND AFTER BEING DRIED AT 240°F. UPPER VALUES OF EACH PAIR ARE FOR STUDS DRIED UNDER RESTRAINT IN ROLL-FEED KILN; LOWER VALUES IN EACH PAIR ARE FOR THOSE DRIED WITH CONVENTIONAL STICKERING.

Property	Mean	Standard deviation	Maximum	Minimum
Green studs				
Moisture content (%)	88.96	35.58	161.36	38.02
	86.83	34.98	169.92	36.48
Weight (lb.)	20.21	2.64	25.60	14.02
	19.93	2.87	25.38	14.42
Length (in.)	95.95	.06	96.00	95.82
	95.95	.07	96.00	95.82
Width (in.)	3.83	.01	3.85	3.78
	3.84	.01	3.86	3.82
Thickness (in.)	1.75	.02	1.78	1.71
	1.75	.02	1.78	1.71
Crook (in.)	.06	.01	.10	.04
	.07	.03	.20	.02
Bow (in.)	.09	.04	.20	.04
	.10	.06	.28	.04
Twist (in.)	.06	.02	.10	.03
	.07	.02	.11	.04
Dry studs				
Moisture content (%)	7.92	2.57	16.36	4.87
	8.68	2.38	15.06	5.25
Weight (lb.)	11.74	1.65	17.26	8.96
	11.77	1.66	17.77	9.87
Length (in.)	95.82	.12	95.96	95.27
	95.83	.11	95.97	95.42
Width (in.)	3.70	.03	3.77	3.62
	3.71	.03	3.76	3.63
Thickness (in.)	1.67	.03	1.73	1.62
	1.68	.03	1.72	1.63
Crook (in.)	.17	.10	.54	.05
	.30	.18	.74	.05
Bow (in.)	.16	.12	.70	.05
	.34	.17	.70	.10
Twist (in.)	.14	.10	.50	.05
	.32	.29	1.37	.04
Specific gravity[1]	.47	.06	.64	.35
	.47	.06	.67	.38
Length shrinkage (in.)	.14	.12	.70	.01
	.12	.09	.55	.02
Width shrinkage (in.)	.13	.03	.19	.07
	.13	.03	.19	.08
Thickness shrinkage (in.)	.08	.02	.12	.05
	.07	.02	.12	.04

[1]Basis of green volume and ovendry weight.

The guidebars on the continuous dryer were 3.85 to 3.93 inches apart, so that a stud width of 3.84 gave minimum clearance.

Studs were measured green for weight, length, width, thickness, twist, bow, and crook.

For each load replication, the studs were charged into a cold kiln, the roll-dryer made operational, and the kiln heated to 240°F/160°F and held for 21 hours after startup; about 2 hours of the 21 were required to reach set point. Finally, each load was steamed for 3 hours at 195°F/185°F. At discharge after 24 hours each stud was measured for weight, dimensions, and warp. One-inch cross-sectional slices were taken at quarter points of each stud to permit computation of ending moisture content and specific gravity.

Specimens for evaluation of casehardening were cut from quarter points of three studs from each load of each treatment.

Table 2. — AMOUNT OF CROOK, BOW, AND TWIST IN THOSE ROUGH DRY STUDS IN WHICH WARP EXCEEDED THE DEGREE PERMITTED IN STUD GRADE.

Warp	In 48 roll-dried studs	In 48 conventionally stickered studs
	———— Inch ————	
Crook	.54, .43, .42, .35, .31, .26	.74, .71, .70, .61, .60, .50, .47, .46, .45, .45, .44, .42, .40, .38, .36, .35, .33, .32, .32, .31, .31, .30, .30, .30, .28
Bow	.70*	.70, .57, .77, .53, .51, .67*, .64*, .59*, .55*
Twist	.50	.43, .39, 1.37*, .76*, .65*, .58*, .50*, .40*

*These studs also had crook in excess of that allowed in Stud grade.

Results

The green studs averaged 87.9 percent in moisture content and 20.1 pounds in weight (Table 1). Crook, bow, and twist averaged 0.064, 0.094, and 0.065 inch, respectively. Specific gravity was 0.47 (green volume and ovendry weight).

Dry studs averaged 8.3 percent in moisture content. Length shrinkage was 0.126 inch or 0.13 percent, and width shrinkage was 0.128 inch or 3.33 percent. Moisture content range was from 4.9 to 16.4 percent with standard deviation of 2.5 percent. Average stud weight on discharge was 11.8 pounds. These statistics were the same for studs dried by both methods.

Thickness shrinkage was significantly greater (0.01 level) in studs roll-dried (0.079 inch, 4.5 percent) than

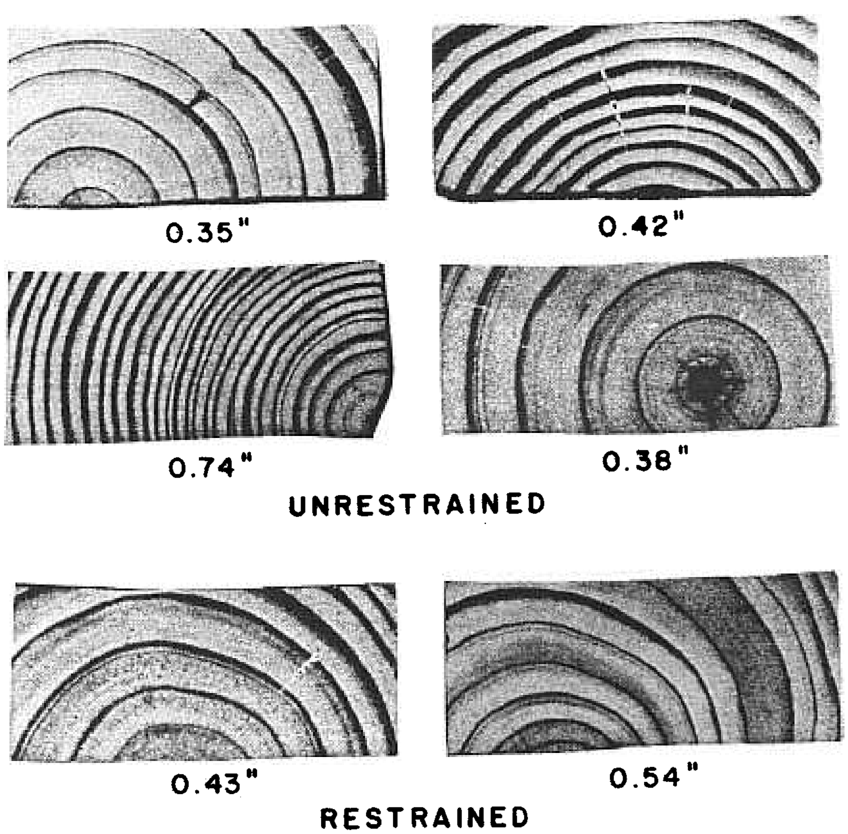

Figure 3. — Cross-sectional views of representative studs that warped excessively during drying. Values shown are those for crook. The four top studs were conventionally stickered, and the two bottom ones were roll-dried under restraint. Compression wood is visible in most of these studs.

in those conventionally stickered (0.070 inch, 4.0 percent).

Warp was significantly less in roll-dried studs:

Warp	Roll-dried	Conventionally stickered
	Inch	
Crook	0.17	0.30
Bow	.16	.34
Twist	.14	.32

By the Southern Pine Inspection Bureau's 1970 rule book, planed 8-foot 2 by 4's in Stud grade cannot exceed 1/4-inch in crook, 1/2-inch in bow, or 3/8-inch in twist. Only seven (15 percent) of the roll-dried rough studs exceeded these limitations, as compared to 32 (67 percent) of the conventionally stickered pieces (Table 2).

Of the seven excessively warped roll-dried studs, all but one could have been brought to Stud grade in a crook-reducing planer. With conventionally stickered studs, at least 11 would have fallen below Stud grade after planing. Studs that developed excessive crook typically contained compression wood or pith (Fig. 3).

Roll-dried studs ended somewhat darker and had resin spread more widely (Fig. 4) than conventionally stickered studs. Both the exudation and the discoloration were surface effects readily removed by planing. Some resin transferred to the roll surfaces, thus increasing the coefficient of friction (and driving efficiency) between roll and studs (Fig. 5).

The 3 hours of steaming relieved most casehardening, supporting findings documented in earlier research (Koch 1971b).

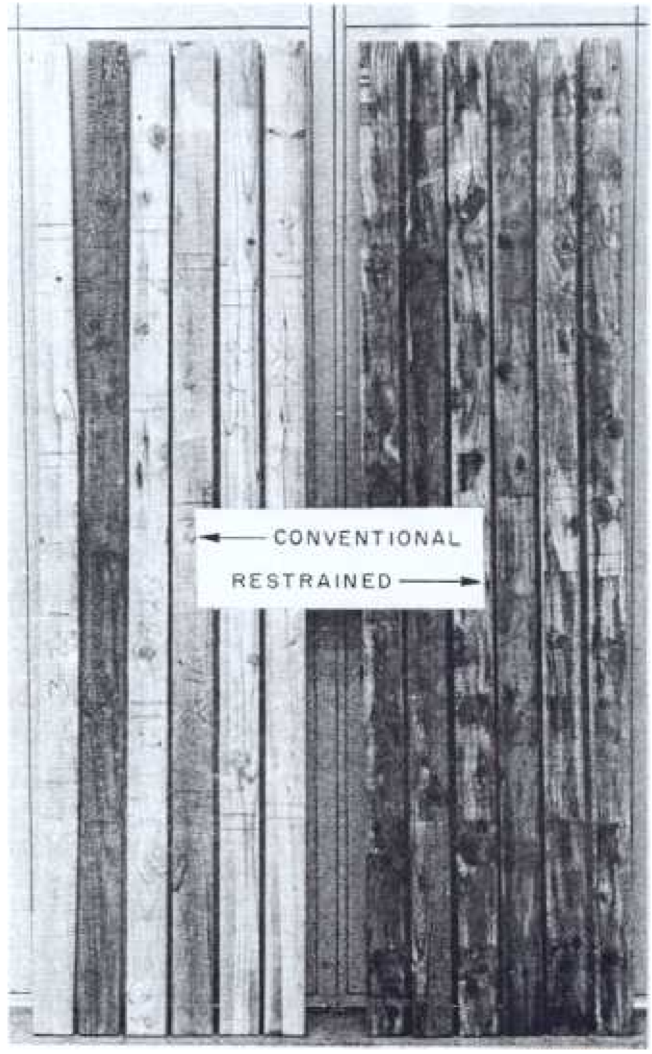

Figure 4. — Rough dry studs conventionally stickered (left) and roll-dried (right). Some of the dark marks on the roll-dried studs are attributable to the repeated reversals and would not develop in a through-feed kiln.

Discussion

Although the opinion is hotly contested by industry, I still maintain that southern pine studs should be shipped from mills at 10 percent moisture content rather than at the 13 percent (or higher) common in industrial practice. Most studs equilibrate in use to 10 percent. If warp-free when shipped at that moisture content, they will likely remain straight. If shipped at 13 percent moisture content or higher, they may develop substantial warp—particularly crook—after being put in place; such warp, when not remedied by carpenters on the job, damages finished walls.

Industry resists drying to 10 percent because of excessive degrade from warp. Development of a commercial roll-feed dryer should overcome this resistance by virtually eliminating such degrade. It is recognized that studs dried to 10 percent moisture content will likely be somewhat more difficult to nail than those at 13 percent.

Commercial Design

On the basis of 1963 research on thin-sawed lumber, and after further work during 1963-1968, it was proposed that a multiple-deck, roll-feed dryer for southern pine lumber should be feasible (Koch 1964, 1969, 1971a, 1972b). The present study reinforces this conviction.

It is now proposed that a 240-foot-long dryer could be built that would contain 300 channels in which studs would run longitudinally between roll pairs under mechanical restraint. Green studs would have to be blanked on one side and edge to correct tapered and oversize pieces; longitudinal feed speed would be 10 feet per hour; 21 hours would be required to traverse a 210-foot-long drying zone, and 3 hours would be needed in a 30-foot conditioning zone. Total time in kiln would therefore be 24 hours.

With 300 openings, and studs traveling at 10 feet per hour, hourly production would be 2,000 board feet. A continuous kiln of this nature would probably be operated on a 24-hour basis, 7 days a week. Weekly output would thus be 336,000 board feet.

The system has some disadvantages. Resin buildup will cause some maintenance expense, as will the

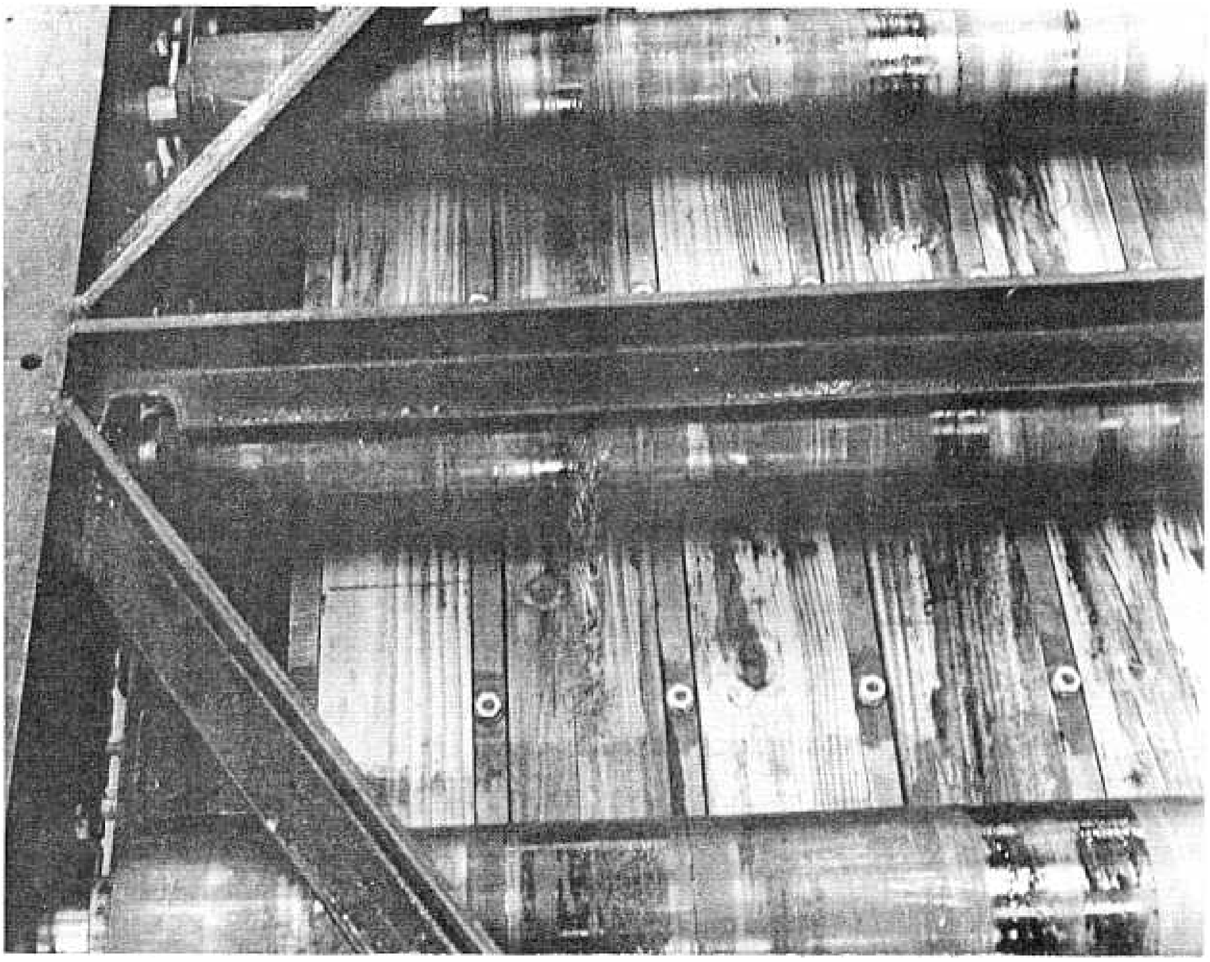

Figure 5. — Hot, viscous resin moved to the surface of roll-dried studs. It tended to transfer to roll surfaces, thereby increasing friction coefficient between stud and roll. Resin buildup may pose a problem for commercial kilns.

extreme temperatures—but perhaps these problems would be no more severe than in jet veneer dryers operating at temperatures up to 400°F. Also, the necessity of blanking studs to size prior to admitting them to the kiln will add to drying costs.

Offsetting these disadvantages are several major advantages. One is elimination of the cost of placing and removing sticks, and of the sticks themselves.

More importantly, studs would be dried to 9 or 10 percent moisture content without excessive warp. When studs cut from veneer cores are brought to these moisture levels in a conventional kiln, 25 percent degrade from Stud to No. 3 Common is usual. By the roll-feed method described, such degrade should be reduced to 5 percent. On the basis of 48 Mbf per 24-hour period, the difference amounts to an increase in lumber value of perhaps $400. Such a gain in product value, when added to savings of costs associated with conventional stacking procedures, would perhaps justify the likely high initial price of the kiln. It is possible that even higher temperatures and air velocities would further reduce dwell time (without reducing lumber strength significantly), thereby reducing kiln length and cost.

Work on the mechanical design of a commercial roll-feed dryer is continuing.

Literature Cited

KOCH, P. 1964. Techniques for drying thick southern pine veneer. Forest Prod. J. 14:382-386.

———. 1969. Southern pine studs can be dried and steam-straightened in 24 hours. South. Lumberman 219(2723):26, 28, 29.

———. 1971a. One-day kilning dries pine studs to 10 percent moisture. Forest Ind. 98(12):70-71.

———. 1971b. Process for straightening and drying southern pine 2 by 4's in 24 hours. Forest Prod. J. 21(5): 17-24.

———. 1972a. Drying southern pine at 240°F.—Effects of air velocity and humidity, board thickness, and density. Forest Prod. J. 22(9):62-67.

———. 1972b. Process for steam straightening and kiln drying lumber (U.S. Pat. No. 3,680,219) U.S. Pat. Off., Washington, D.C.