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Process for Straightening And Drying Southern Pine 2 by 4's in 24 Hours

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Abstract

In 21 hours under mechanical restraint and in a kiln providing a cross-circulation velocity of 1,000 f.p.m. at dry- and wet-bulb temperatures of 240 and 160°F., followed by 3 hours at 195 and 185°F., southern pine 2 by 4 studs cut from steamed veneer cores or small logs were dried to 9-percent moisture content (standard deviation was 3 percent). Compared to studs dried at temperatures not in excess of 180°F., the high-temperature studs were substantially straighter (crook, bow, and twist averaged 0.12, 0.21, and 0.09 inch), of higher grade (91 percent in SPIB grades 1, 2, and Stud), and not significantly weaker. Neither schedule caused casehardening. The high-temperature schedule took less than one-fourth the time and about one-half the total energy required by the low-temperature schedule. When lumber dried on both schedules was exposed to extremely humid or dry atmospheres, warp in the steam-straightened 2 by 4's remained less than that measured on conventionally dried studs.

Developments in the decade 1960-1970 interacted to sharply increase interest in methods of manufacturing dimension lumber from veneer cores and small logs cut from southern pine. Currently in the South, logs 12 inches in diameter and larger bring their best prices at plywood plants; bolts smaller than 6 inches in diameter are most effectively utilized by pulpmills. Logs intermediate to these size classes, plus veneer cores 5-1/4 to 6 inches in diameter, have greater value for lumber than as pulp chips. Conversion of this material into lumber has been greatly facilitated by the chipping headrigs (Koch 1964, 1967) that have been installed in large numbers throughout the South. But such utilization of juvenile wood, while increasing the value returned, is not without penalty: the lumber is prone to warp when dried.

Previous research at the Pineville laboratory of the Southern Forest Experiment Station led to the development of one system of manufacturing straight studs from southern pine veneer cores (Koch 1966, 1968, 1969). The procedure, while effective, has seen only limited application because it calls for cutting studs oversize when green.

In the study reported here, the objective was development of a more broadly applicable process. The experiment focused on drying southern pine studs to 10-percent moisture content—quickly and without warp. The green studs were cut with very little allowance for planing, and all contained warp-prone juvenile wood.

The approach was guided by several observations made during prior research at this laboratory and elsewhere:

1) Southern pine can be bent—and will retain its bend—if it is first steamed for a short time (Lemoine and Koch

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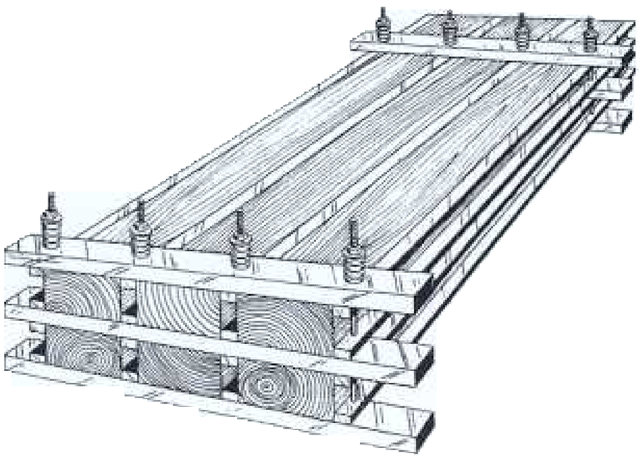
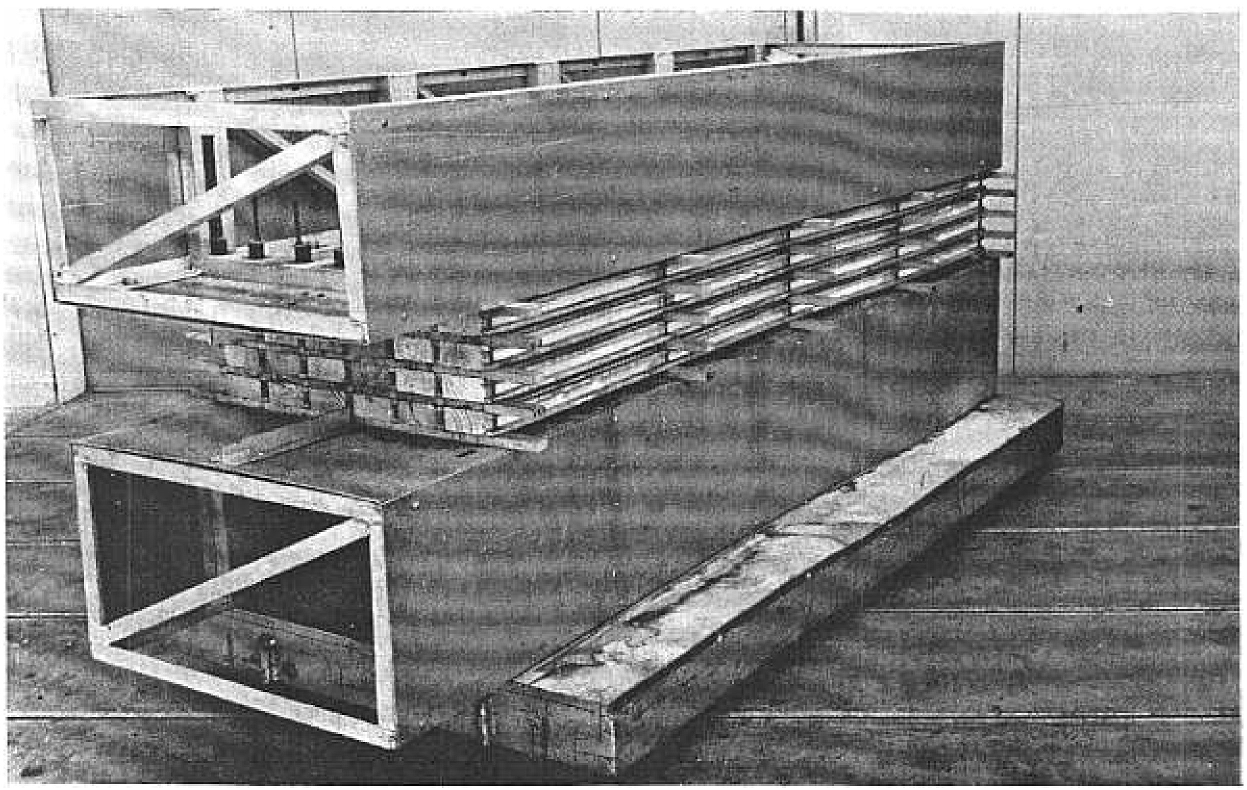


Figure 1. — The experimental setup provided restraint against warp during high-temperature drying. (Left) Longitudinal strips between 2 by 4's prevented excessive crook. Spring-loaded bolts running through the strips, from top to bottom of the pile, prevented excessive twist and bow. The studs were 4 inches wide and 1-7/8 inches thick. Aluminum cross stickers measured 3/4-inch thick and 1-1/2 inches wide. Longitudinal strips (fixed to cross stickers) are visible between studs. (Below) Load ready to be charged into kiln. Aluminum baffles above and below the lumber permitted close control of air velocity between courses.



1971). Conversely, a bent piece can be steam-straightened.

2) Water leaves southern pine readily at temperatures above the boiling point.
3) High temperatures and large wet-bulb depressions accelerate drying. If exposure time is short, strength loss in the wood may be minor at temperatures up to 240°F.
4) During the early stages of drying, water leaves wood at a rate positively correlated with the velocity of the circulating air.
5) In kiln-drying, energy costs are proportional to total drying time.
6) Casehardening and internal stresses in kiln-dried coniferous wood can be eliminated by several hours of steaming.

Factors in the experiment were: 1) source of 8-foot 2 by 4's: logs 6 to 8 inches in diameter, and cores residual from steamed veneer logs, 2) kiln schedule: low-temperature long schedule with studs conventionally stacked, and high-temperature 24-hour schedule with studs restrained against warp, 3) replication of kiln charges:

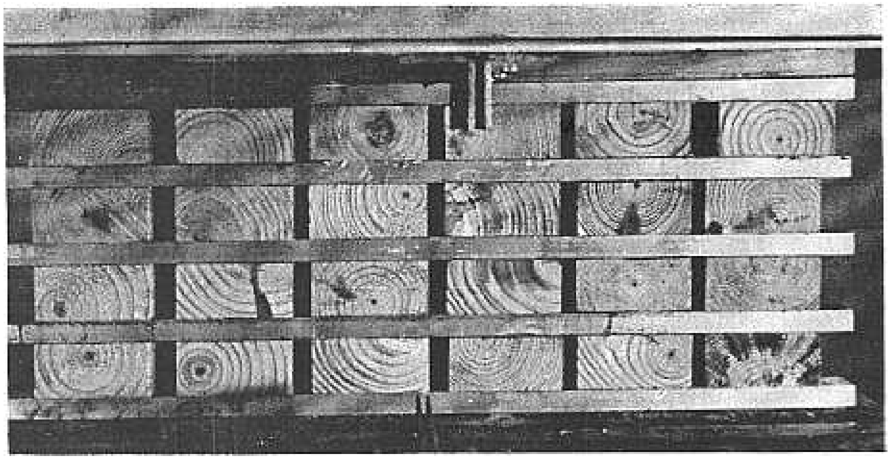


Figure 2. — End view of studs stacked without restraint for low-temperature drying. Visible pith was typical. Although top and bottom baffling of the lumber was identical to that shown in Figure 1 (bottom), neither longitudinal strips nor tie-bolts were used in the loads dried at low temperature.

three, and 4) replication of studs in each kiln charge: 24. The total number of studs evaluated was therefore 288, *i.e.* (2 sources) (2 schedules) (3 replications of kiln charges) (24 replications of studs).

The experiment was not designed to compare warp in restrained and unrestrained studs dried at high temperature; nor was it designed to compare warp in restrained and unrestrained studs dried at low temperature. Both comparisons would be of interest and perhaps should be elucidated in future studies.

Source of Studs

To fill the requirements for three replications of each kiln run, three 48-stud samples were randomly drawn during 3 different weeks from a plywood operation[3] that converts veneer cores into 2 by 4's; another three samples, also comprised of 48 studs each, were similarly drawn from an east Texas mill where logs 6 to 8 inches in diameter were being sawn. To increase the number of trees sampled, only one rough green stud was taken from each veneer core or log. Studs were mill-run, and pith was visible in most (Figs. 1 and 2). The logs at the east Texas mill were sawn as they came from the woods. The logs yielding veneer cores, however, had been steamed for about 18 hours prior to peeling. Each stud came direct from the saw and was promptly wrapped in polyethylene for immediate transport to the laboratory.

At the laboratory, each 48-stud sample was randomly divided into two groups of 24—one to be dried at high temperature and the other at low temperature.

Immediately prior to kiln-drying, the 24 rough green 2 by 4's in each charge were surfaced to a net dimension of 1-7/8 by 4 inches and double-end trimmed to length (100 inches in the case of the studs from cores and 96-1/2 inches for the 2 by 4's cut from small logs). The green moisture content of each 2 by 4 was then estimated from four increment cores drawn 10 and 20 inches from each end, and the green weight of the entire stud was recorded.

A comparison of basic characteristics of 2 by 4's cut from steamed veneer cores and those from small logs is of interest. Studs from cores were significantly (0.05 level) lower in moisture content and higher in heartwood content (determined by chemical indicator) than those from small logs; they also had more rings per inch. Specific gravity did not differ significantly.

	From cores	From small logs
Green moisture content, percent		
Average	75.1	92.9
Standard deviation	33.0	37.1
Range	28.0-184.7	27.6-172.2
Specific gravity (basis of ovendry volume and weight)		
Average	0.51	0.51
Standard deviation	0.070	0.085
Range	0.37-0.70	0.35-0.81
Heartwood content (average of both ends), percent		
Average	50.4	34.2
Standard deviation	31.1	29.4
Range	0-100	0-100
Growth rate (average of both ends), rings per inch		
Average	7.6	6.4
Standard deviation	5.0	4.4
Range	2.0-26.5	1.5-23.5

Procedure

Kiln schedules.—The 24-hour high-temperature schedule was simple. The green lumber was clamped rigidly in aluminum frames, in almost total mechanical restraint against crook, bow, and twist (Fig. 1). Still in frames, the studs were wheeled into the preheated kiln and dried for 21 hours at a dry-bulb temperature of 240°F. and a wet bulb temperature of 160°. Then, for the last 3 hours, they were steamed at a dry-bulb temperature of 195°F. and a wet-bulb temperature of 185°F. Throughout the 24 hours, air was cross-circulated at 1,000 f.p.m.; direction of air flow was reversed every 75 minutes. Weight of charge together with energy consumption for heat, humidity control (steam spray), and fan was continuously charted against time. With the schedule completed, the studs were wheeled from the kiln and cooled 48 hours in an atmosphere that ranged from 70 to 80°F. and 40- to 60-percent relative humidity.

[3]The studs cut from cores were contributed by Tremont Lumber Company, Joyce, La.

Studs dried at low temperature were not restrained in clamps but were piled on sticks in the conventional manner (Fig. 2). The low-temperature schedule was intended to follow schedule T12-C5 from Rasmussen (1961), in which initial dry-bulb temperature is 160°F. and initial wet-bulb depression is 10°F. In this schedule dry-bulb temperature never exceeds 180°F. After the kiln runs were completed, it was found the data from the increment cores had underestimated green moisture content; heat generated by the core cutter had caused some drying, even though the cores were weighed immediately. Figure 3 depicts the actual regime; had step 1 been extended about 10 hours, results would have conformed more closely to the intended schedule.

Air velocity was 500 f.p.m., with fan reversal every 75 minutes. As with the high-temperature schedule, weight and energy consumption were recorded, and the lumber was cooled 48 hours on sticks.

Warp and grade evaluation.—Promptly on removal from the cooled load, each stud was weighed and its moisture content computed by evaluating two 5/8-inch borings, one taken 10 inches from one end and a second taken 20 inches from the other end; from these data were calculated the ovendry weight of each 2 by 4 and a corrected initial green moisture content (based on initial green weight of each stud). Crook, bow, and twist were measured, and the lumber was piled on sticks in a room held at about 50-percent relative humidity and 72°F.

After several weeks the lumber was weighed, double-end trimmed to 96-inch length, remeasured for warp, and surfaced on all four sides by a machine equipped with a crook reducer between feed table and planer; the crook-reducing cutterhead was set to remove 3/16-inch from the concave edge of each stud. Final planed dimensions were 1-1/2 by 3-9/16 inches. After planing, each stud was promptly reweighed, remeasured for crook, bow, and twist, and graded by an inspector from the Southern Pine Inspection Bureau.

The 2 by 4's were then transferred to a room held at 81°F. dry-bulb and 78° wet-bulb temperature (87-percent relative humidity), where they were individually and freely suspended from hooks placed in one end. After 20 days, they were removed, weighed, and evaluated for warp.

Next, they were placed singly on shelves in a kiln held at 130°F. (wet bulb uncontrolled but near 80°F.). After 20 days of drying, they were again weighed and measured for warp.

Strength evaluation.—All 288 studs were then stacked on sticks in the laboratory for at least 2 weeks at about 72°F. dry-bulb and 60°F. wet-bulb temperature (50-percent relative humidity). Following this equilibration period they were weighed and 15 inches were trimmed from each end. The resulting 66-inch length was evaluated for modulus of elasticity (*MOE*), proportional limit (*PL*), and modulus of rupture (*MOR*) in edgewise bending over a 60-inch span with two-point loading; load points were 14 inches apart at midspan. The apparatus and speed of loading followed ASTM D 192-27, Static Tests of Lumber.

Specific gravity and moisture content at test were determined from a 1-inch cross-sectional slice from the freshly cut end of one of the trim pieces from each stud. From a calculated ovendry weight for each 96-inch stud, it was then also possible to calculate the moisture content when the studs were planed and graded, and when removed from the high-humidity and low-humidity cycles.

Stress at proportional limit and modulus of rupture (*MOR*) were calculated from the standard flexure formula:

$$f = \frac{Mc}{\quad}$$

where f is the calculated stress, M is the applied moment, c is the distance from the neutral axis to the outer face of the beam, and I is the moment of inertia of the cross section. *MOE*'s were calculated from the deflection formula:

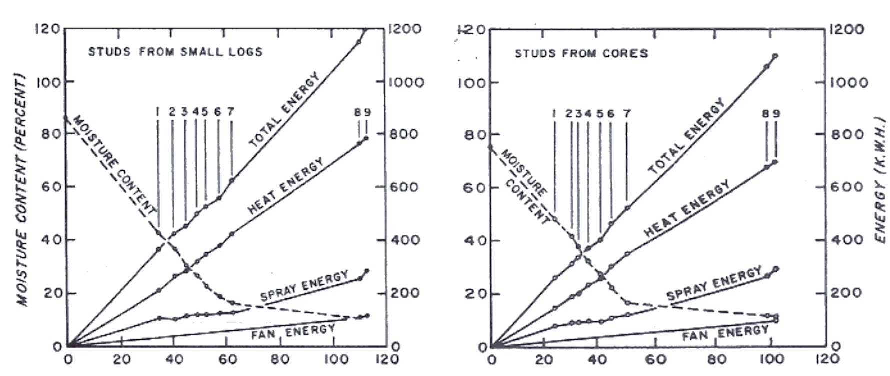
$$\Delta = \frac{Pa}{48EI}(3L^2 - 4a^2) + \frac{3Pa}{5GA}$$

where Δ is midspan deflection, inches
P = total load on beam, pounds
a = distance from support to load point, inches
E = *MOE*, pounds per square inch
I = moment of inertia of cross section, inches^4
L = span length, inches
A = cross-sectional area, square inches
G = shear modulus, pounds per square inch

Figure 3. — Moisture content change and kilowatt-hour demand by 24-stud charges dried on the low-temperature schedule:

Step	Dry-bulb	Wet-bulb depression
	- - - - - °F. - - - - -	
1	160	10
2	160	14
3	160	20
4	170	25
5	170	30
6	180	35
7	180	50
8	180	18
9	180	7

Numbered points locate time each step ended. Air was cross-circulated at 500 f.p.m. Data from three charges were averaged to derive each curve. Moisture contents were calculated from the green and ovendry weights of each entire charge.



This formula accounts for deflections caused by both bending and shear stresses; the shear modulus (G) was assumed to equal one-sixteenth the *MOE*.

Finally, a pair of 2- by 2- by 28-cm. clear specimens were cut from the two trim ends of each stud and evaluated for toughness according to the procedure specified in ASTM Standard D143-52, par. 74. Moisture content and specific gravity of each specimen were determined from a 1-inch slice removed immediately after each test.

Results

Moisture content and kiln times.—Ending moisture contents averaged 11.8 percent for the six low-temperature charges and 9.1 percent for the six high-temperature charges:

	Moisture content 48 hours after discharge from kiln	
	High-temperature schedule	Low-temperature schedule
	(percent)	
Studs from veneer cores		
Average	9.3	11.8
Standard deviation	3.3	2.4
Range	5.4-21.2	2.1-21.7
Studs from small logs		
Average	8.9	11.7
Standard deviation	3.2	2.7
Range	5.2-21.2	5.3-21.3

Prong tests showed that neither schedule caused casehardening.

Figures 3 and 4 show moisture contents over time in kiln for the two schedules. On the high-temperature schedule, only 7-1/2 hours were required to drive off three-fourths of the total water removed. Drying times on the low-temperature schedules averaged 102 hours for studs from cores and 113 hours for those from small logs. The 24-hour high-temperature schedule required less than one-fourth of this time—and the studs were drier.

Energy requirements.—The experimental kiln was heated by electricity, and steam for humidification was provided by immersion heaters in a water bath. Energy requirements per MBF cannot be scaled directly to commercial kilns, which may have different radiation losses and normally are both heated and humidified with steam. However, energy comparisons between the fast and slow schedules are probably valid for commercial practice.

Largely because it was faster, the high-temperature schedule took half as much energy as the other. The longer, low-temperature schedule, with its high initial humidities, required five times as much energy for humidity control, and more than 1-1/2 times as much for heat. Power for fan motors was halved by the high-temperature schedule, despite the 1,000-f.p.m. circulation rate.

Average energy requirements for drying a charge of 24 studs were:

	High temperature		Low temperature	
Requirement	From cores	From small logs	From cores	From small logs
	(kilowatt hours)			
Heat	442	500	700	790
Humidity control	54	61	295	290
Fan	55	57	107	119
Total	551	618	1,102	1,199

Warp.—Studs dried under restraint at high temperature warped significantly less than those conventionally stickered and dried at low temperature. The differences charted in Figure 5 were significant at all stages of manufacture.

Warp measured immediately after planing largely determines the mill grade and selling price of studs. Average values at this stage were:

Warp	High temperature, restrained	Low temperature, unrestrained
	(inch)	
Crook	0.12	0.23
Bow	.21	.29
Twist	.09	.24

When studs are incorporated in buildings, they are frequently exposed to high humidities until the roof is in place and the heating or air conditioning system activated.

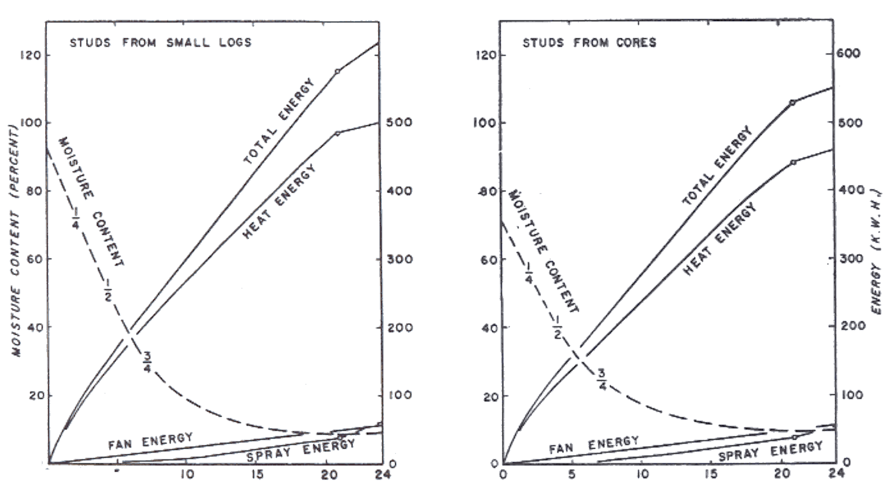


Figure 4. — Moisture content change and kilowatt-hour demand by 24-stud charges first dried 21 hours with dry- and wet-bulb temperatures of 240 and 160°F., and then steamed 3 hours with dry- and wet-bulb temperatures of 195°F. and 185°F. Air was cross-circulated at 1,000 f.p.m. Moisture contents were calculated from the green and ovendry weights of each entire charge. Data from three charges were averaged to derive each curve. Numbers inset in moisture content curve indicate time to 1/4, 1/2, and 3/4 of total moisture loss during the schedule.

Exposing planed studs to high humidity for 20 days simulated this situation; average warp after exposure was least in wood dried at high temperature:

Warp	High temperature, restrained	Low temperature, unrestrained
	- - - - - - (inch) - - - - - -	
Crook	0.10	0.17
Bow	.15	.18
Twist	.08	.14

Studs built into attic spaces may first go through a period of high humidity as described above, and then be subjected to extremely dry atmospheres when heat is turned on in winter. At the end of the 20-day dry cycle following the humid cycle, average warp was severe in all studs, but less extreme in the wood dried under restraint at high temperature:

Warp	High temperature, restrained	Low temperature, unrestrained
	- - - - - - (inch) - - - - - -	
Crook	0.23	0.35
Bow	.42	.52
Twist	.23	.44

On average, studs cut from cores twisted significantly less than those cut from small logs when measured just after planing and after the dry cycle. When data from both schedules were pooled, average values were as follows:

Time of measurement	Twist in studs from veneer cores	Twist in studs from small logs
	- - - - - (inch) - - - - -	
Just after planing	0.14	0.19
After dry cycle	.28	.39

With these exceptions warp in studs from cores did not differ (0.05 level) from that in studs from small logs.

Grade.—By SPIB rules (Southern Pine Inspection Bureau 1968), each of the three top grades and the Stud grade are limited to certain maximum warp. For 8-foot 2 by 4's, these allowable distortions are:

Grade	Crook	Bow	Twist
	- - - - - - -	(inches)	- - - - - -
No. 1	0.28	0.84	0.38
No. 2	.38	1.13	.50
Stud grade	.19	.56	.25
No. 3	.56	1.69	.75

The two upper grades require a minimum of four rings per inch; a piece with less than this number of rings can qualify for Stud grade if it meets straightness standards somewhat more stringent than those for higher grades.

The 288 studs averaged 7.7 rings per inch as observed on the end exhibiting the most rings per inch. Cores averaged 8.3 and small logs 7.2. Approximately 15 percent of studs from cores and 20 percent of studs from small logs had less than four rings per inch; these open-grain pieces could at best qualify for Stud grade, and then only if crook graded less than 3/16-inch (Southern Pine Inspection Bureau 1968, pp. 12, 64, 121).

Several of the studs from both cores and small logs contained readily identifiable compression wood, and these pieces could not be admitted to Stud grade regardless of how well warp was controlled.

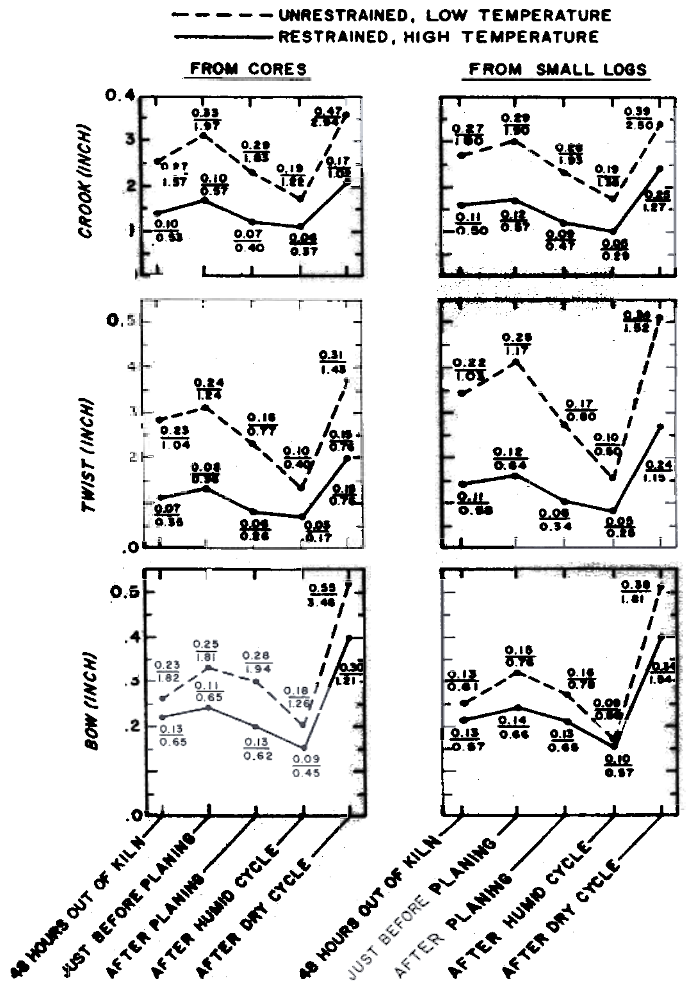


Figure 5. — Warp in 8-foot southern pine 2 by 4's cut from small logs (right) and steamed veneer cores (left), when kiln-dried at high temperature under restraint and at low temperature stacked conventionally. Each plotted point is the average for 72 studs; adjacent to each point, the standard deviation is printed just above the maximum value of warp observed at that point.

Knots occupying more than four-ninths the cross section at an edge of the wide face or more than two-thirds the cross section along the centerline of the wide face eliminated a few more of the pieces from Stud grade.

In general, studs dried under restraint at high temperature graded substantially higher after planing than those dried at low temperature (Table 1). Because 8-foot 2 by 4's of Stud grade or better have approximately twice the value of studs in grades 3 and 4, a tabulation is of interest:

Grade	High temperature	Low temperature
	- - (percent) - - - - - -	
No. 1, No. 2, and Stud	91	59
No. 3 and No. 4	9	41
Total	100	100

With data from both schedules pooled, cores yielded more No. 1 Common and less No. 3 and 4 Common than small logs:

Grade	Studs from cores	Studs from small logs
	- - - - - - (percent) - - - - - -	
No. 1	37	19
No. 1, No. 2, and Stud	80	70
No. 3 and No. 4	20	30

The higher grade yield in studs cut from cores was particularly evident with the high-temperature schedule:

	High temperature, restrained		Low temperature, unrestrained	
Grade	From cores	From small logs	From cores	From small logs
	- - - - -	(percent)	- - - - -	
No. 1, No. 2, and Stud	96	86	64	54
No. 3 and No. 4	4	14	36	46
Total	100	100	100	100

The 24-hour schedule brought considerable resin to the surface of the rough, dry 2 by 4's, but planing removed all traces of resin and discoloration.

All of the studs dried on the 24-hour schedule developed end checks that ranged from 1.5 to 2.1 inches in depth. In no case, however, were the checks a cause for degrade.

Strength properties.—Since studs cut from very small logs and veneer cores contain juvenile wood of low specific gravity, as well as defects such as knots and cross grain, they vary greatly in strength.

By analysis of variance, the edgewise bending properties of modulus of elasticity, proportional limit, and modulus of rupture did not differ significantly between the two drying treatments. In all three strength properties, however, the studs cut from veneer cores were significantly stronger than those from small logs (Table 2).

Table 1. — GRADE DISTRIBUTION OF STUDS IMMEDIATELY FOLLOWING PLANING.

	High temperature		Low temperature	
Grade[1]	From cores	From small logs	From cores	From small logs
No. 1 Common	31	17	22	11
No. 2 Common	21	17	18	19
Stud grade	17	28	6	9
No. 3 Common	1[2]	6[4]	20	23
No. 4 Common	2[3]	4[4]	6	10
Total	72	72	72	72

[1]Southern Pine Inspection Bureau (1968).

[2]Had crook of 0.38 inch.

[3]Warp was within Stud grade limitations on both of these pieces, but both were downgraded to No. 4 because of readily identifiable compression wood.

[4]Three of the 10 studs in grades 3 and 4 were within Stud grade limitations on warp.

Studs from small logs had the same specific gravity as those from cores (0.51, basis of ovendry volume and weight). It is likely, however, that knots in the wood from cores were smaller than those in wood cut from small logs. In the southern pines, the butt log (source of most veneer cores) tends to shed its limbs at an early age, whereas tops of mature southern pines (probably the source of most of the small logs) may have fairly large, live branches; large knots reduce the strength of studs containing them.

Toughness and specific gravity of clear wood cut from the studs did not differ significantly (0.05 level) between the two drying treatments. Each value in the following

Table 2. — COMPARISON OF EDGEWISE-BENDING PROPERTIES OF SOUTHERN PINE STUDS CUT FROM SMALL LOGS OR VENEER CORES WHEN KILN-DRIED FOR 24 HOURS AT TEMPERATURES NOT EXCEEDING 240°F. OR FOR ABOUT 100 HOURS AT TEMPERATURES NOT EXCEEDING 180°F.[1,2]

Property[3]	High temperature: From cores	High temperature: From small logs	Low temperature: From cores	Low temperature: From small logs
	— — — — —	— — — — — Psi	— — — — —	— — — — —
Modulus of elasticity				
Average	1,624,000	1,457,000	1,630,000	1,510,000
Standard deviation	393,000	433,000	498,000	496,000
Range	812,000-2,585,000	594,000-2,828,000	550,000-2,692,000	584,000-2,858,000
Proportional limit				
Average	5,050	4,650	5,390	4,740
Standard deviation	1,850	1,770	2,190	1,950
Range	1,490-9,130	1,090-9,600	1,180-10,000	1,100-10,220
Modulus of rupture				
Average	6,980	6,520	7,540	6,560
Standard deviation	3,330	3,020	3,620	3,290
Range	1,600-17,100	1,960-13,820	1,450-16,725	1,630-18,210

[1]Each average value shown represents data form 72 studs. Average moisture content at test was 7.6 percent with range from 6.1 to 9.6 percent.

[2]Studs were cut from cores or small logs, dried at either high or low temperature; all averaged 0.51 specific gravity (basis of ovendry volume and weight).

[3]For all three properties, values for studs from cores were significantly higher than values for studs from small logs; the kiln schedules, however, did not significantly (0.05 level) affect values. Interactions were not significant.

tabulation represents data from 72 studs (two replications per stud); average moisture content at test was 8.6 percent with standard deviation of 0.5 and range from 7.1 to 11.4 percent.

Property	High temperature: From cores	High temperature: From small logs	Low temperature: From cores	Low temperature: From small logs
Toughness, inch-pounds				
Average	202	191	200	183
Standard deviation	71	75	77	63
Range	56-402	59-355	79-368	61-338
Specific gravity (basis of volume at test and ovendry weight)				
Average	0.52	0.52	0.53	0.52
Standard deviation	.06	.08	.08	.10
Range	.41-.70	.38-.72	.40-.85	.37-.89

Clear wood in studs from veneer cores was significantly tougher (201 inch-pounds) than clear wood in studs from small logs (187 inch-pounds). Since the specific gravities did not differ significantly, an explanation of this result is not readily seen.

Discussion

The small size of this test—288 studs in all—perhaps limits the generality of conclusions that may be drawn. The statistical design was sound, however, and so some observations seem warranted.

Reductions in modulus of elasticity, proportional limit, modulus of rupture, and toughness caused by the high-temperature schedule did not prove statistically significant (0.05 level) in this small-scale test; it is probable, though, that large-scale tests would indicate that the 24-hour, high-temperature schedule slightly reduces (1 to 4 percent) major strength properties of log-run 2 by 4's in comparison with schedules that do not exceed 180°F.

Stress relief following the 21-hour, 240°F., high-temperature schedule probably could have been achieved in less than 3 hours if dry- and wet-bulb temperatures of 205 and 200°F. (instead of 195 and 185°F.) could have been maintained during the conditioning period (Kubler 1956). Achievement of these higher temperatures would require reduction of condensation on interior surfaces of the kiln walls, possibly by internally heating them to about 205°F.

While admitting to some bias, the author concludes that this new process of steam-straightening and drying southern pine lumber at high temperature will be applied by industry. The new kilns may use adaptations of the restraining rack illustrated in Figure 1. More likely, they will combine top loads of about 150 pounds per square foot with some type of crook-restraining force exerted across the width of the charge.

Within the realm of practicality are continuous, multi-deck, roll-feed kilns patterned after jet veneer dryers. At a continuous speed of 0.5 f.p.m., a single deck 10 feet wide (120 inches ÷ 4 = 30 studs across) and 720 feet long could discharge about 2,700 studs or 14,400 board feet every 24 hours. Multideck machines would conserve floor space and probably effect economies in heat utilization.

Each deck of longitudinally traveling lumber would be forcibly held between fixed rollers on a lower bed and a multitude of movable top-pressure rolls; the rolls would restrain the lumber from bowing and twisting. Each deck would probably have a power-driven edge guide comprised of an endless bed or a series of 2-inch-high, closely spaced vertical rolls. On the opposite side of the deck, vertical endless beds or vertical rolls (visualize the feedworks of a line-bar resaw) would exert force across the entire moving stream of lumber to prevent any board from crooking. For the restraint mechanism to function well, the lumber would have to be accurately cut.

Preliminary trials indicate that 1-inch boards can be dried to 10-percent moisture content in 12 hours rather than in the 24 hours required for studs. If more than one thickness of lumber is to be dried, each thickness would have to be assigned a deck moving at the appropriate speed.

Such continuous drying would have the obvious advantage of eliminating the cost of placing and removing kiln sticks, as well as the cost of the sticks themselves.

Not yet resolved is a method for cooling the lumber while it is still under restraint. Perhaps a short refrigerated section, equipped with chilled rolls, could accomplish the necessary cooling as the lumber leaves the dryer.

Still another approach is application of traveling clamps patterned after the clamp carrier that used to be popular in plants manufacturing glued panels. To continuously dry studs direct from the saw, the clamp carrier would be positioned at an accumulation station at the end of the green chain. The single operator (three-shift basis) would secure 4-foot-wide layers of studs in clamps equipped with restraint against crook, twist, and bow; as each clamp was filled, it would be indexed on a chain to permit the next clamp to be filled. If each clamp was spaced 8 inches from the next, kiln length of 520 feet would be required to dry 50,000 board feet of studs each 24 hours. Under these conditions, the operator would have about 1-1/2 minutes to fill a clamp. Lumber retained in the clamps would travel 24 hours through the kiln and then cool for 24 hours as it returned to the operator for discharge.

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