Techniques for Drying Thick Southern Pine Veneer

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THICK VENEERS CUT from southern pine are relatively easy to dry, but they are not easy to dry free of distortion. The research reported here was undertaken to compare five drying systems. Factors evaluated included rate of water loss, degree of distortion, and the effect on strength. Effects on gluability were also briefly studied.

Preparation of Veneers

Sliced veneer was simulated by cutting heart-center cants measuring 4, 6, 8, 10, and 12 inches square and then sawing the cants through-and-through to obtain 120 veneers of each cant width—600 veneers in all, plus some practice veneers. The veneers of each width were sequentially dealt into five sorts as they came from the headrig—as though one were dealing five hands of cards with each hand holding 24 cards.

This procedure produced five matched groups of veneers (A through E) for five drying treatments, with each group containing a total of 120 veneers, 24 in each of five widths. The rough green veneers were planed to 7/16-inch thickness, double-end trimmed to 100 inches in length (± ⅛ inch), and edge-planed to exact widths of 4, 6, 8, 10, and 12 inches. The cants were principally of loblolly pine, with a scattering of shortleaf and longleaf pine. The logs were picked at random out of a large deck of freshly cut pine. Before drying was begun, the veneers were kept submerged in water, except that those to be air-dried were placed directly on sticks.

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Drying Procedures

The five groups of veneers were randomly assigned to drying by: A.) air-drying (Figure 1); B.) cross-circulating lumber kiln at dry-bulb temperatures not exceeding 186° F.; C. commercial jet veneer dryer at 300° F. (Figure 2); D.) small conventional roller veneer dryer at 300° F.; and E.) hot-plate press, between screens and ventilated cauls (Figure 3) at 300° F. and a specific pressure of 82.6 pounds per square inch.[1]

The green weight, thickness, width, and length of each S4S veneer were recorded. After drying, the veneers were equalized for 2 weeks under controlled atmospheric conditions of 114-½° F. dry bulb temperature and 99½° F. wet bulb. The individual veneers were then immediately weighed and measured to determine length, width, thickness, cup, twist, bow, crook, and widest salvageable piece with parallel sides.

A minimum of 12 practice veneers were subjected to each drying treatment (with the exception of group B, for which no practice veneers were available), then weighed, oven-dried, reweighed, and finally equalized for 2 weeks under conditions identical to those used for the test veneers, and weighed again. By this procedure equilibrium moisture content (EMC) was estimated for the test veneers in each drying treatment. Oven-dry weights of the air-dried practice veneers were not established until after the EMC weights had been determined.

With the EMC for each group, it was possible to calculate oven-dry weight and specific gravity of individual veneers. Subsequently the veneers were stored in an atmosphere controlled at 50 percent relative humidity ± 10 percent.

Rate of Drying

The rate of drying was, of course, controlled by the drying treatment. After 3 months of air-drying in central

[1] Heebink, Bruce G. 1952. Veneer flooring. For. Prod. Jour. 2(3): 138–139.

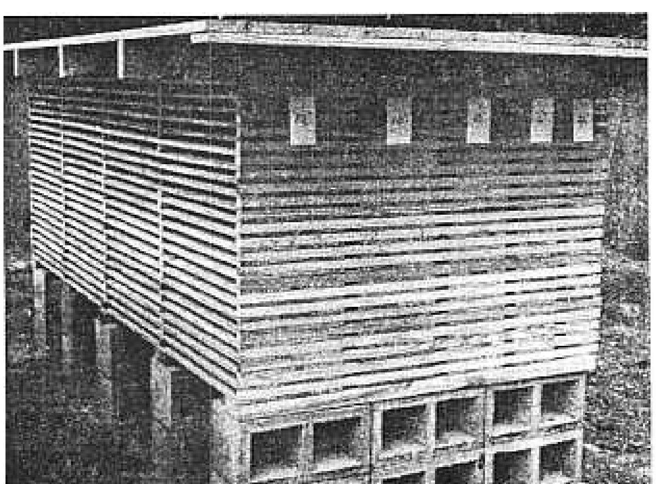

Figure 1.—Veneers stacked for air-drying. Symmetry of veneers about pith is due to method of production. Number of rings per inch varies greatly, both between and within individual veneers.

Figure 2.—Infeed end of jet dryer used to dry group C veneers. Only the center and bottom decks were used. This dryer has four heated sections and one cooling section. Each section is 6 feet long. The veneers shown were not used in this study but the photo illustrates the infeed mechanism. (Photo by Moore Dry Kiln Company.)

Louisiana (September 13 to December 11, 1963), group A was taken off sticks during very humid weather. The veneers were then at 20.0 percent average moisture content and ranged from 16.0 to 28.1 percent. After 2 weeks under equilibrium conditions they reached an approximate EMC of 11.19 percent. When green, they had ranged from 34 to 171 percent moisture content and averaged 102.9.

Group B veneers were dried 24 hours at approximately 165° F. dry bulb and 150° F. wet bulb, plus 42 hours at approximately 180° F. dry bulb and 156° F. wet bulb, and a final 6 hours at 186° F. dry bulb and 156° F. wet bulb. They reached an average moisture content of 4.7 percent with a range from 2.3 to 7.2 percent. The green test veneers had averaged 121 percent and ranged from 51 to 181 percent. After 2 weeks under equilibrium conditions, group B was assumed to have reached an EMC of 9.6 percent (see table 38 of *Wood Handbook*[2]).

Group C veneers were dried in two successive 28-minute passes through the 24-foot-long heating zone of a jet dryer (Figure 2). In this dryer design, the 14-foot-long top and bottom feed rolls are 3¾ inches in diameter and the roll-pairs are spaced 1 foot apart along the length of the dryer. Between each roll-pair, curtains of hot air impinge vertically on both the top and bottom surfaces of the veneer as it moves through the dryer. The air travels at a stated velocity of 3,500 feet per minute. Temperature is variable. Green test veneers dried at 300° F. had an average moisture content of 117 percent but ranged from 45 to 177 percent. At the end of the first 28-minute pass they averaged 39.8 percent and ranged from 10.4 to 71.5. After the second and final 28-minute pass they averaged 5.1 percent and ranged from 0.2 to 14.3. These two passes were considered equivalent to a single 60-minute pass, for residual heat caused drying between passes. After 2 weeks under equilibrium conditions, group C veneers reached an approximate EMC of 9.04 percent. Drying curves (Figure 4) were determined by running practice veneers through a series of 12-minute passes until they were virtually oven-dry.

Group D veneers were dried in two 44-minute passes through the 30-foot-long heating zone of a conventional roller veneer dryer. Temperature in the heating zone was 300° F. On this particular dryer, the 6-foot-long top and bottom feed rolls are 3 inches in diameter and the roll-pairs are spaced 4 inches on centers. The veneer is fed longitudinally as in the jet dryer, but the hot air is circulated in a counter flowing horizontal direction instead of impinging vertically. Nominal air velocity is 600 feet per minute, but turbulence around the rolls causes velocity adjacent to the veneer to vary widely. The green test veneers averaged 112 percent in moisture content, varying from 45 to 180. At the end of a first 44-minute pass they averaged 36.5 percent and varied from 10.7 to 72.1. After a second and final 44-minute pass, the average was 4.4 percent and the range was from 0 to 17.6. These two 44-minute passes were considered equivalent to a single 90-minute pass because residual heat caused drying between passes. After 2 weeks under equilibrium conditions, the veneers reached an approximate EMC of

Abstract

This paper is the second of four describing a system for maufacturing laminated beams of uniformly high strength from southern pine boltwood.

Heart-center cants in sizes from 4 by 4 inches through 12 by 12 inches were sawn through-and-through to produce veneers thick enough to be surfaced green to 7/16-inch. These S4S veneers were then dried: 1) in air, 2) in a lumber kiln, 3) in a jet dryer, 4) in a conventional roller veneer dryer, 5) in a hot-plate press with ventilated cauls. Temperatures in the last three treatments were as high as 300° F. Press drying was the fastest (23 minutes) and caused least distortion. Veneers from the jet dryer, conventional dryer, and hot press showed heavy resin exudation that would cause gluing difficulties unless removed by surfacing. None of the treatments significantly affected stiffness of individual veneers. Beams from veneer dried on mild schedules were not significantly stronger than those from veneer dried on accelerated schedules.

[2] U.S. Forest Products Laboratory. 1955. Wood Handbook. U.S. Dept. Agr. Agr. Handb. 72.

This paper was presented at the 18th annual meeting of the Forest Products Research Society, June 22, 1964, in Chicago, Ill.

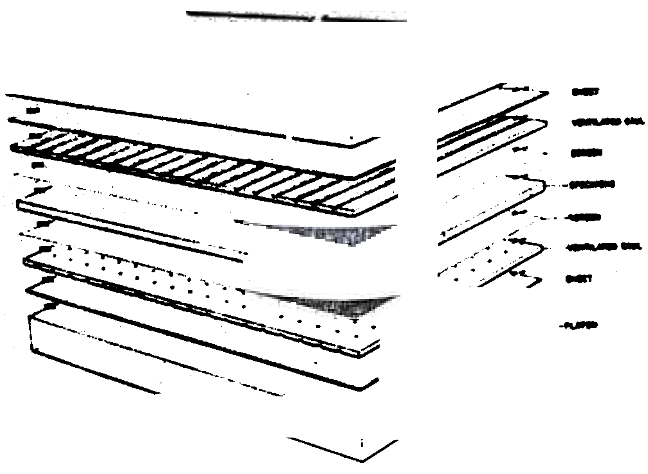

Figure 3.—System of ventilated cauls for drying group E veneers in a hot-plate press. The aluminum protector sheets are 0.064-inch thick. Top and bottom cauls are of aluminum and measure ¼ by 26 by 104 inches. Rectangular grooves 1/16-inch deep by 3/16-inch wide were milled on 1-inch centers on the back of each caul. One-eighth inch holes were drilled at 1-inch intervals along each groove. A 75-mesh Fourdrinier wire screen was interposed between the veneer and each ventilated caul.

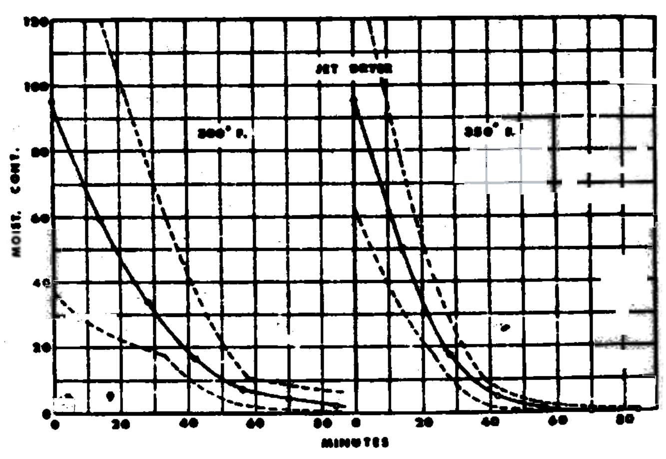

Figure 4.—Drying curves for 7/16-inch southern pine S4S veneers in jet dryer at 300 and 350° F. Solid lines are [illegible], dotted lines define envelope containing all veneers.

Table 1. — EFFECTS OF DRYING TREATMENTS ON PROPERTIES OF 7/16-INCH THICK, S4S VENEERS SAWN FROM HEART-CENTER SOUTHERN PINE CANTS[1]

Levels of perform-ance[2]	Moisture loss[3]: Drying time	Moisture loss[3]	Resin exudation	Recover-able width with paral-lel sides (Pct. of original width)	Width shrinkage (Pct.)	Length shrinkage (Pct.)	Thickness shrinkage (Pct.)	Crook (In.)	Cup (In.)	Twist (In.)	Bow (In.)
				Dimensional change from green to EMC							
Level 1	E 23 min.	E 3.41	A none	E 95.5	E 0.82	E 0.051	B 3.31	E 0.111	E 0.039	E 0.071 D 0.082 C 0.083 A 0.089 B 0.095	E 0.209 D 0.242
Level 2	C 60 min.	B 3.49	B slight	B 92.0 C 91.7 A 91.4 D 91.1	B 2.98	B 0.095	A 3.59	A 0.201 B 0.205 C 0.240 D 0.250	D 0.048		C 0.292 A 0.304
Level 3	D 90 min.	D 4.41	E severe D severe C severe		C 3.27 D 3.34 A 3.39	C 0.120 A 0.139	C 4.23		{B 0.054 {C 0.057		B 0.374
Level 4	B 72 hrs.	C 4.73				D 0.166	D 4.63		A 0.069		
Level 5	A 3 mos.	A 19.98					E 8.07				

[1]Dimensional values represent averages for 120 veneers in each treatment. Drying treatments were: A, air-dried; B, lumber dry kiln; C, jet dryer; D, conventional roller veneer dryer; E, hot-plate press with ventilated cauls. Dried veneers attained following approximate EMC's after 2 weeks of conditioning at 114½° F. dry bulb and 99½° F. wet bulb: A, 11.19 percent; B, 9.60 (assumed); C, 9.04; D, 8.31; E, 7.08.

[2]Best performance is placed in level 1, worst in level 5. Levels of performance differ significantly (0.05) by Duncan's multiple range test. Bracketed values are not significantly different from each other, even though listed on different levels.

[3]Not statistically analyzed.

8.31 percent. The drying curve (Figure 5) was determined by running practice veneers through a series of 12-minute passes util they were oven-dry.

Group E veneers were dried in a 2- by 8½-foot, single-opening, hot plate press. Platen temperature was 300° F. and specific platen pressure was 82.6 pounds per square inch. Drying was accomplished in a single closed-press cycle of 23 minutes. Thermocouples placed in test boards indicated that the surface of the veneers reached 250° F. within ½ minute after press closure, and moved slowly up to a maximum of 280° F. during the remainder of the cycle. The center of these 7/16-inch-thick S4S veneers reached 235° F. within 5 minutes after press closure and increased slowly to a maximum of 250° F. by the end of the cycle. Within 7 minutes from the time the press opened and the veneers were removed, surface temperature dropped to 175° F. and the center temperature to 145° F. The green test veneers had an average initial moisture content of 105 percent and ranged from 36 to 164 percent. The 23-minute drying procedure reduced the average to 3.4 percent, with a range of 0 to 15.1 percent. After 2 weeks under equilibrium

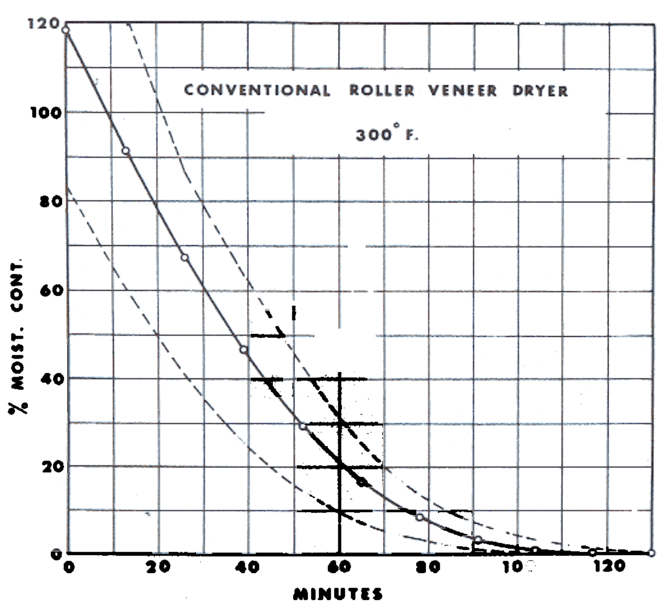

Figure 5.—Curves for conventional roller veneer dryer. Solid line is an average, dotted lines define envelope containing all veneers. Dryer temperature, 300° F. for S4S southern pine veneers, 7/16-inch.

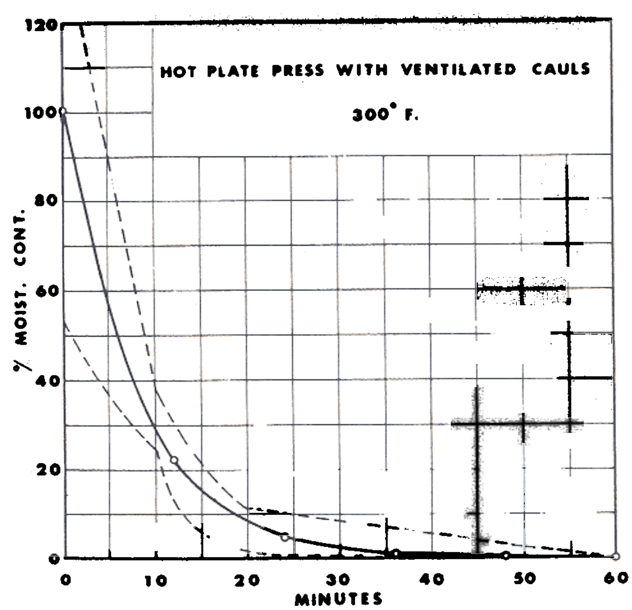

Figure 6.—Curves for hot-plate press. Solid line is average, dotted lines define envelope containing all veneers. Temperature of platens, 300° F. Specific pressure, 82.6 psi. S4S southern pine veneers 7/16-inch.

Table 1A. — EFFECTS OF DRYING TREATMENTS ON SPECIFIC GRAVITY, STIFFNESS, AND STRENGTH [1] OF S4S VENEERS [2]

Levels of performance	SG of veneers, oven-dry wt. and EMC vol.	MOE of veneers in bending at EMC (Psi) (10^{-3})	Proportional limit (bending) of beams made from veneers (Psi)	MOR (bending) of beams made from veneers (Psi)	MOE of beams in bending, as observed (Psi) (10^{-3})	MOE of beams in bending, corrected for shear (Psi) (10^{-3})	SG of beams incl. adhesive, at oven-dry wt.
Level	E 0.60	E 1,780 A 1,720 D 1,690 C 1,660 B 1,660	D 5,900 E 5,890 A 5,670 B 5,400	E 10,630	E 1,740	E 1,910	E 0.54 D 0.53 B 0.53 A 0.53 C 0.52
Level 2	D 0.54 B 0.52 C 0.52 A 0.52		C 5,280	D 10,470 A 9,620 B 9,570 C 9,210	D 1,680 A 1,670 B 1,600 C 1,600	D 1,850 A 1,840 B 1,760 C 1,760	

[1] Average moisture content of the beams when tested for strength was 11.8 percent.
[2] This is a continuation of Table 1; all data, notes, and descriptions in Table 1 are applicable here.

conditions, group E veneers reached an approximate EMC of 7.08 percent. Drying curves (Figure 6) were determined by running practice veneers through a series of 12-minute closed press cycles until they were virtually oven-dry.

It is felt that Figures 4, 5, and 6 give fairly accurate indications of the range in moisture content through the drying cycles, inasmuch as each veneer contributing to the curves was oven-dried in its entirety to permit establishing its moisture content at intermediate points. For practical purposes, it is noteworthy that all veneers (except in Treatment A) were at or below 10 percent moisture content by the time the average reached 5 percent.

Effects of the five drying treatments on dimensions of the veneers were analyzed statistically (Table 1). Length shrinkage, width shrinkage, crook, cup, and bow were all significantly minimized by press-drying. Thickness shrinkage was significantly greater in press drying than in other treatments, and was accompanied by significant densification. Twist was not significantly affected by treatment. Air drying produced the most severe cupping.

Recovery of raw material was greatly affected by width shrinkage in combination with crook. Press drying was superior in this respect, but from all treatments, 21 veneers out of 24 in each width were salvageable for lamination if they were straight-line ripped 1 inch narrower than their nominal green widths. Maximum length shrinkage encountered in any veneer in any drying treatment was 0.78-inch reduction from an original 100-inch length; the average was 0.11 inch.

With all treatments other than press drying, it would have been possible to plane the dry veneers S2S 3/8-inch thick (from an original green thickness of 7/16-inch). Because of the extreme thickness shrinkage caused by press drying, all dry veneers were planed S2S 1/3-inch thick in order to avoid skipped spots on group E veneers.

In supplementary exploration of thicknessing losses, some southern pine was sliced 7/16-inch thick on a conventional slicer. This rather rough veneer was then dried in the hot-plate press on the same schedule as group E veneers. The press flattened the veneers, reduced the roughness, and densified them slightly. Some of the dry veneers were sanded S2S and some were planed S2S. In general, planing gave the best results. While resin exudation rapidly loaded both drums on the two-drum sander, it caused no difficulty in planing. Approximately 1/10-inch may be considered a minimum reduction in thickness from green to dry veneer surfaced sufficiently for gluing and laminating.

Gluability of Unsurfaced Veneers

The five drying treatments brought varying concentrations of resin to the surface. To determine the effect of resin exudation on gluability, an auxiliary test was undertaken with representative portions of the 7/16-inch by 6-inch by 100-inch practice veneers. The practice veneers were subjected to six drying schedules that resembled those applied to the test veneers, except that cycles for all but air-drying were extended until the wood became oven-dry. The veneers are illustrated in Figure 7.

Fifty block shear specimens were prepared for each of the six drying treatments, i.e., 300 specimens in all.[8] Samples 5 5/8 inches wide and 11 inches long were cut so that the majority of defects were eliminated. The

[8] Timber Engineering Company, Corvallis, Ore., prepared, tested, and evaluated the shear specimens in March, 1964, under contract.

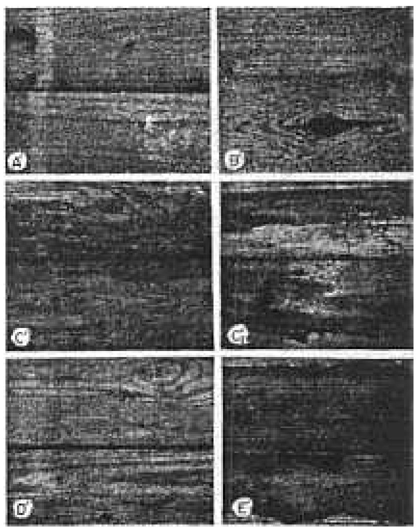

Figure 7.—Resin exudation on veneers in auxiliary test. White dust on veneers in treatment A' is sodium pentachlorophenate, which was applied prior to all treatments as a stain preventative.

Table 2. — LAMINATION PROCEDURES FOR BLOCK SHEAR SPECIMENS

Adhesive	Spread per M. sq. ft. of glueline	Assembly time	Pressures	Press temp.	Press time
	(Lbs.)	(Min.)	(Psi)		
Casein	95	3 closed	175		
Urea-formaldehyde	40	0	200		
Phenol-resorcinol (hot)	70	15 open & closed	200		
Urea-melamine	100	5 open & closed	200		
Phenol-resorcinol (cold)	90	5 closed	200		

Table 3. RESULTS OF BLOCK SHEAR TESTS, BY DRYING TREATMENT AND TYPE OF ADHESIVE [1]

Drying treatment [2]	Resin exudation	Rings per inch	Casein Shear	Casein Wood failure	Urea-formaldehyde Shear	Urea-formaldehyde Wood failure	Hot phenol-resorcinol Shear	Hot phenol-resorcinol Wood failure	Urea-melamine Shear	Urea-melamine Wood failure	Cold phenol-resorcinol Shear	Cold phenol-resorcinol Wood failure	Average Shear	Average Wood failure
			(Psi)	(Pct.)	(Psi)	(Pct.)	(Psi)	(Pct.)	(Psi)	(Pct.)	(Psi)	(Pct.)	(Psi)	(Pct.)
A′	None	4	1,418	76	846	5	1,513	90	985	29	1,210	50	1,194	50
B′	Light, spotty, over 25% of each surface	9	1,618	83	1,274	65	1,659	83	792	59	1,526	76	1,374	73
C′	Heavy-solid over 81%	17	834	12	46	0	1,290	71	162	0	846	48	636	26
C′-1	Heavy-solid over 68%	11	926	31	594	3	1,244	92	574	3	935	54	855	37
D′	Light-solid over 92%	7	1,437	45	649	4	1,576	95	811	6	1,530	69	1,201	44
E′	Heavy-solid over 79%	5	860	41	170	0	1,410	72	226	2	858	35	705	30
Average			1,182	48	597	13	1,449	84	592	17	1,151	55	994	43

[1] Values for individual treatments are averages of 10 specimens.
[2] Treatments were as follows: A′, air-dried at not more than 100° F., to approximately 9 percent MC; B′, dried to 16 percent MC at not more than 100°, then oven-dried in kiln at 215°; C′, oven-dried in jet dryer at 300°; C′-1, oven-dried in jet dryer at 350°; D′, oven-dried in conventional roller veneer dryer at 300°; E′, oven-dried in hot-plate press at 300°.

few small knots that could not be eliminated were allowed for when wood failure was determined. Ten samples from each drying treatment were fabricated with each of five adhesives applied according to the recommendations of the manufacturers (Table 2). Prior to assembly the specimens to be hot-pressed were brought to approximately 5.4 percent EMC, and the specimens for cold-pressing to approximately 6.8. After the glued samples had aged 7 days, the shear tests were conducted according to ASTM Designation D905–49.

Drying treatment B′ produced the best results, with A′ and D′ next (Table 3). This trend was evident in shear strength as well as in wood failure. Group C′ showed the poorest results, probably because of surface resin and possibly because the number of growth rings per inch was high. Group A′ might have performed better if the urea-formaldehyde adhesive had not penetrated excessively.

Of the adhesives, hot-pressed phenol-resorcinol gave the best and most consistent results. It performed very well in groups with much surface resin. Casein and cold-pressed phenol-resorcinol were next in line. Urea-formaldehyde and urea-melamine performed poorly.

For southern pine, Commercial Standard CS–253–63 (Structural Glued Laminated Timber) calls for at least 1,360 pounds per square inch shear strength and 80 percent wood failure By this standard, only hot-pressed phenol-resorcinol in combination with drying treatments A′, B′, and D′, and casein in combination with B′, met the requirements. The scope of this auxiliary test was very limited. Further experimentation would, no doubt, permit improvement in the performance of the various adhesives.

Stiffness and Strength of Veneers

To learn if drying affected stiffness, modulus of elasticity was determined for the 120 veneers in each treatment (procedures will be described in a subsequent article). As Table 1 indicates, differences among treatments were not significant.

To evaluate strength, the veneers were straight-line ripped 1 inch narrower than their nominal green width, planed on two sides to ⅓-inch thickness, and then assembled by width and drying treatment into laminated beams. Each beam had 21 laminae—the other 3 veneers in each set of 24 were discarded because of breakage or extreme distortion, or simply because they were the most limber. This procedure resulted in 25 beams, or 5 in each width class (3, 5, 7, 9, and 11 inches net) from each drying treatment. By procedures to be described in the next article, each beam was bent to the point of failure.

As Table 1A shows, beams from veneer dried on the two mild schedules did not prove to have significantly higher modulus of elasticity, proportional limit, or modulus of rupture than beams from veneer dried on the three accelerated schedules.

Conclusion

If all conditions and properties listed in Table 1 and 1A and Figures 4, 5, and 6 are given equal weight, the hot-press treatment (E) appears in the most favorable light, followed by lumber dry-kiln treatment (B). Air-drying (A), jet-drying (C), and conventional veneer drying (D) are tied for third place. Air-drying must be eliminated from consideration because it does not dry the veneers sufficiently for lamination.

It was not clearly established that any drying treatment adversely affected proportional limit, modulus of rupture, or modulus of elasticity.

Treatment B is practical and causes only slight resin exudation. It does, however, occasion stacking and unstacking labor. Treatments C and D both seem practical and both eliminate stacking with stickers. Both cause relatively severe resin exudation.

Treatment E caused significant densification, accompanied by significantly increased thickness shrinkage, but it significantly reduced width and length shrinkage as well as most other deformations due to drying stresses. In production, accumulation of resin on the plates and cauls might be troublesome. A combination of acetone and toluene readily dissolved resin that accumulated on the experimental press.

In summation, press-drying treatment E is best from a technical point of view. However, selection of a treatment for commercial application will be strongly influenced by the initial outlay and by unit operating costs. These economic considerations seem to favor kiln-drying or jet-drying.

In next month's issue of the *Journal*, Dr. Koch will report on the "Strength of Beams with Laminae Located According to Stiffness." His final article, which will appear in the November issue of the magazine, will examine the production and economic aspects of his proposed system. For a discussion of the sawing problems involved in producing square cants from round bolts, see the August *Journal*, pages 332–336.