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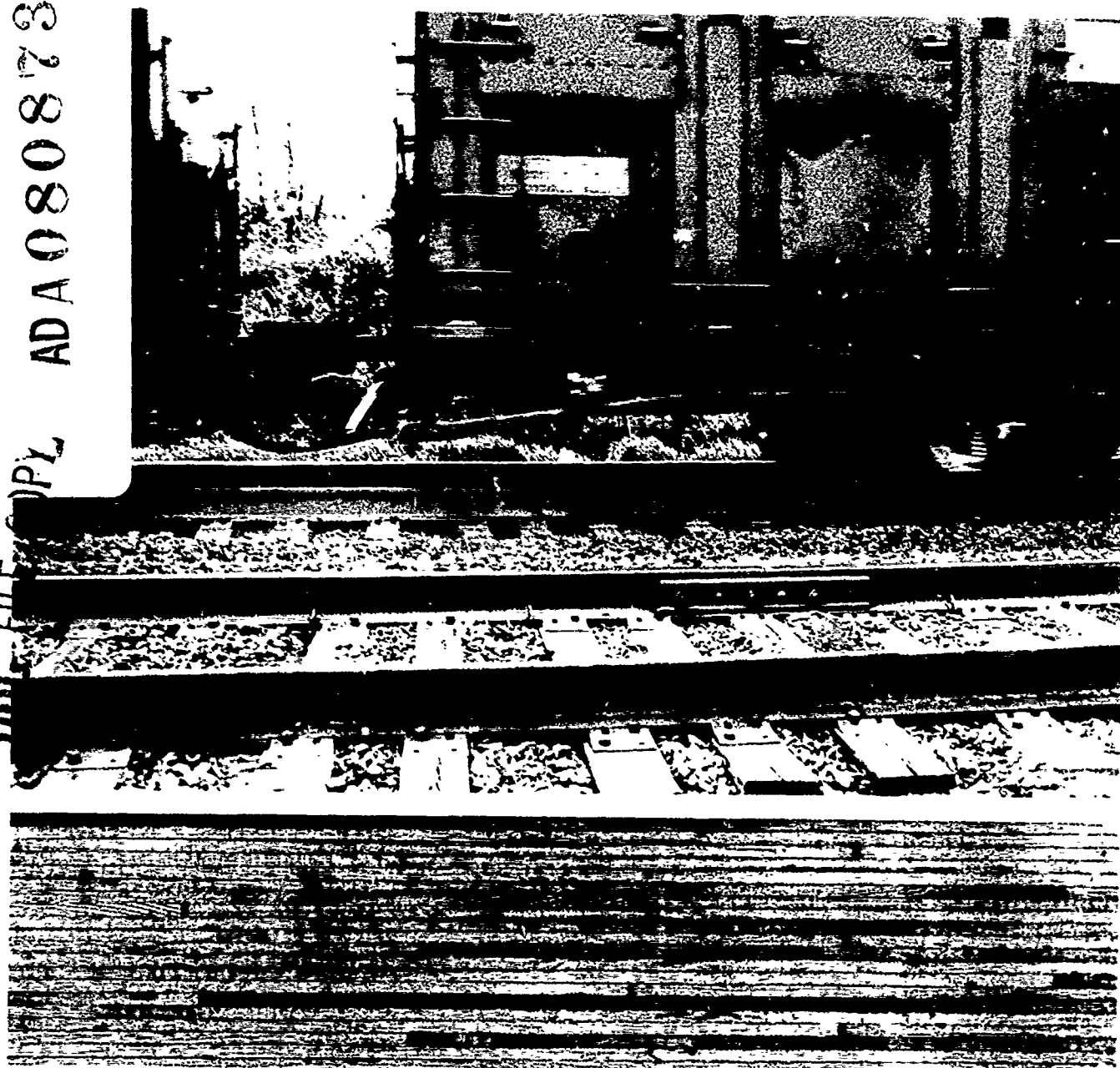
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Hardwood Press-Lam Crossties: Processing and Performance

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ABSTRACT

Crossties were made by the Press-Lam process, in which logs are peeled into veneers, dried, and glued into billets in a continuous procedure. Billets were made from 8.5-foot-long veneers and from 4-foot-long veneers, cut into final product dimensions, and treated with preservative.

In laboratory tests, bending strength and stiffness of the Press-Lam ties were found to exceed those of solid-sawn red oak crossties; shear strength was only adequate.

Tie wear tests showed low surface wear for laminated ties, comparable to the performance of solid specimens. Results of spike driving tests, however, indicated problems in some species. All Press-Lam ties met the performance criteria in the cyclic delamination tests, and, in lateral resistance tests, Press-Lam ties were not significantly different from solid-sawn ties.

Volume yields are discussed and cost estimates are provided for use in calculating total tie costs for specific cases.

ACKNOWLEDGMENT

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INTRODUCTION

In 1973 crosstie demand increased considerably over previous requirements. Hardwood normally used for ties was being diverted for other uses such as pallets and furniture. Annual tie production had previously averaged 20 to 22 million, but needs in 1973 and projected beyond were for 26 million or more. Crossties were in short supply and prices were approaching \$20 per treated crosstie in comparison with \$8 to \$9 common before.

By 1979, production of treated crossties was meeting the demand, but prices had risen to a delivered cost of \$16 to \$22 per tie. Of this, \$5.50 was the cost of treating (9). Adequate hardwood supplies now appear to be available long into the future (22). The sawn crosstie industry can meet demand when "track maintenance is planned well in advance of actual need" (7). At issue now is the ability to produce crossties rapidly at reasonable cost. This cannot be accomplished by processing sawn treated crossties because of the extensive drying time required for large solid-sawn sections.

The high potential of producing railroad ties by a modified Press-Lam

system has been recognized by both the Forest Products Laboratory (FPL) and Koppers Company, Inc. (Pittsburgh Pa.) for several years. The most attractive features of this processing scheme are treatability and the high yield of and rapid conversion to dry structural products. A tremendous inventory problem could be virtually eliminated because dry ties can be produced in days, whereas they now require up to a year of air drying when sawn.

Two studies were completed in cooperation with Koppers to evaluate the Press-Lam processing and performance of crossties. The first study, begun in April 1973, produced ties of 8-foot-long veneer. Sixteen ties were full-sized "Standard Heavy-Duty" ties, and ten were the same length but narrow. Six of the full-sized ties were placed in track for the Penn Central Transportation Company at Orrville, Ohio, in May 1974 (fig. 1), three were kept for spike tests and general observations, and seven were placed in the Koppers yard track. The ten narrow ties were tested at FPL to evaluate bending stiffness (in which one tie broke), then were cut in two, with the short length kept at FPL for preservative-treatment tests and the

longer section sent to Koppers for tie-wear tests.

The second study, begun in August 1975, produced 25 full-sized ties from 4-foot-long veneers. All 25 were tested to evaluate bending stiffness. Nine were retained at FPL for bending strength and shear strength determinations, and 16 were sent to Koppers for preservative treatment. From Koppers, eight ties were put into the Burlington Northern track near Moine, in May 1976, four into the Koppers yard track, and four into the Federal Railroad Administration's FAST Track in Pueblo, Colo., in June 1976.

This report discusses the research undertaken, the results obtained, preliminary plant economics, and in-track performance to date.

Background

The potential for hardwood Press-Lam crossties was recognized following work on Press-Lam-type processing of pallet deckboards from low-grade hardwood logs (13). Preliminary estimates of the cost to process crossties using Press-Lam techniques

Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

Underlined numbers in parentheses refer to literature cited at end of report.

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were encouraging enough to investigate the technical aspects further. Of particular interest was the enhanced treatability of large Press-Lam sections of a difficult-to-treat species (heartwood Coast Douglas-fir) (21). This was felt to be a distinct advantage to provide biological durability in service.

Critical to evaluating the suitability of experimental cross-ties are the requirements for and actual performance of cross-ties. In general the in-service loads on cross-ties have been weakly documented in the literature. It was suspected that the primary failure in service was due to mechanical wear and decay at the tie plates, followed by bending-induced failures in about 20 percent of replacements (24). Earlier reports by the American Railway Engineering Association (AREA) indicated more failures due to splitting and decay (62 pct) than to mechanical wear (33 pct) (8). However, decay at the tie plates may have been classed as general decay and not a combination of mechanical wear and decay. It is likely that the increasing use of heavier freight cars will change the statistics to emphasize a higher percentage of structural failures (18).

An AREA specification (3) on concrete ties represents the first performance specification for any type of tie. The AREA specification for timber cross-ties addresses only species, limitations on defects, and dimensional requirements (2). A tie size of 7 inches deep by 9 inches wide by 9 feet long is recommended as the minimum standard for all North American railroads with heavy traffic.

Allowing the maximum defects for red oak ties (2), ASTM Standards D 245-74 and D 2555-73 (5,6) were used to estimate allowable design properties for visually graded red oak cross-ties (11):

Bending strength (MOR) : 1,475 psi
Bending stiffness (MOE) : 1,100,000 psi
Shear strength : 105 psi

Limited data are available on spike withdrawal and tie-plate wear as obtained in the AAR tie wear test (14). Tie wear appears to depend upon species density, with higher-density red and white oak exhibiting less wear than pine. Spike withdrawal load levels are similarly affected.

An analysis and proposed performance level for wood cross-ties has been advanced recently (1977) (18). It concludes the following.

1. Optimum length of a tie to prevent



Figure 1.—Press-Lam cross-tie being placed in track.

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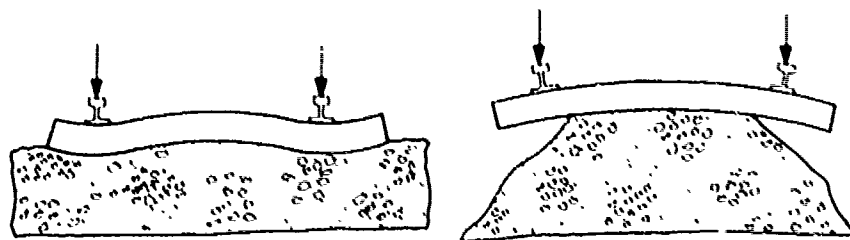


Figure 2.—Loading modes to which a cross tie is subjected

Left. Ballast remains essentially in place. Shear and flexure properties are equally important.

Right. Centerbind is caused by erosion of ballast from beneath railseats. Flexure is the critical loading mode.

(M 145 021)

centerbinding, assuming consistent ballast competence, is 8.5 feet plus one-half tie plate length (approximately 9 ft).

2. Assuming a maximum ballast bearing pressure of 65 psi can occur, then:

a. A 9-foot tie subject to centerbinding (fig. 2) should be 7.6 inches thick to meet flexural requirements when allowable bending stress is 1,100 psi.

b. A hardwood tie would be required to tolerate the crushing stresses below the tie plate.

c. The maximum anticipated shear stress is 250 psi in a 9-foot-long, 7-inch-

deep tie. This shear stress is somewhat higher than the design stress for a typical hardwood and if such information is adopted as a standard, larger wood cross-tie cross sections will be required. Press-Lam test data in later sections of this report will be compared with proposed performance levels (18).

Research Objectives

The aim of this work was to evaluate (a) the effectiveness of Press-Lam-type processing of thick rotary-cut hardwood veneer into parallel-laminated wood cross-ties and (b) the performance

properties of such cross ties as compared to those of currently solid-sawn cross ties.

METHODS

Processing

Synopsis

The Press-Lam process embodies stored-heat laminating (curing) of thick-sliced veneer (0.25 in. or more thick) using the residual heat of the wood as removed from a veneer dryer (10, 12). The ideal process is envisioned as a continuous conversion of green veneer into structural lumber. The variation of this process used in the laboratory necessarily deviates from the ideal process due to the lack of continuous production line facilities.

With 8.5-foot-long veneer, it was impossible to press dry and assemble immediately because only one 8-foot 8-inch press was available at the Forest Products Laboratory. Therefore a modified processing scheme was used to simulate a Press-Lam operation. The thick veneer was press dried in advance, cooled, and wrapped in plastic. These veneers were then reheated in a Coe roller veneer dryer and laminated in the 8-foot 8-inch press.

Materials

Six species of 14- to 18-inch-diameter logs (Grade 2 and 3) were selected for evaluation in Press-Lam production and performance: red oak, white (including water) oak, sweetgum, blackgum, beech, and hickory. For the first study groups of 10 logs per species selected in Alabama were bucked to 8-foot 10-inch lengths for subsequent rotary cutting.

For the second study 28 peelable red oak cross tie logs (8 ft. 9 in. long), Forest Service Grade 3 or lower, were purchased from a sawmill in southern Wisconsin that was cutting cross ties. These were bucked to 4-foot 3-inch lengths for subsequent rotary cutting. Small-end diameter averaged 16 inches and ranged from 11 to 24 inches.

Rotary Cutting

The intent was to rotary cut two thicknesses (0.25 and 0.40 in.) of veneer from each species of 8-foot 6-inch-long logs and 0.40-inch-thick veneer from the 4-foot 3-inch red oak bolts.

The 8-foot 6-inch bolts were steam heated and rotary cut commercially in a mill (in Alabama) normally set up to

rotary cut and clip for southern pine plywood fabrication. Due to production pressures and the unfamiliarity of the operator to hardwood rotary-cutting techniques, the quantity and thickness quality of the veneer was substandard. The lathe nosebar was backed off completely and the knife angle was improper. Stopping prior to retracting outer chucks and restarting with smaller chucks led to excessive spinout of bolts. The clipper could only be manually operated to cut a 10-inch width, resulting in inconsistent veneer widths. Although the actual thickness of the nominal 0.25-inch veneer was acceptable, ranging from 0.239 to 0.252, the nominal 0.40-inch veneer was substantially undersized, ranging from 0.333 to 0.366 inch. This did not allow

The average of spot checks of one lamina from each bolt (at three positions) was 0.400 inch. There was no systematic variation of thickness across the cut length (along the grain), and the resulting veneer was of good quality. Spinout and splitout were minimal. The veneer was clipped to 10 inches. The green veneer thickness averaged 0.400 inch with a coefficient of variation of 2 percent.

The veneer was graded for knot content (fig. 3) (table 1). Class 1 knots occupied 1/3 to 1/2 the cross section with associated grain deviation occupying 1/2 or more of the cross section. Class 2 knots occupied 1/4 to 1/3 the cross section with associated grain deviation occupying 1/3 to 1/2 the cross section. Class 3 knots

Table 1.—Knot defect measurement in 1,300 veneers*

Class	Knot class frequency		Classification of veneers	
	Number of knots	Percent	Number of veneers	Percent
Clear			540	41.5
No. 4	120	28	331	25.5
No. 3	324	26	237	18.2
No. 2	144	11.8	137	10.5
No. 1	25	4.4	33	4.3
Total	1,245	100.0	1,300	100.0
Water oak (class 4)			26	2.0

*Data by L. J. J. J. J.

Veneers are classified by the largest knot present. Knots smaller than the number of knots in the veneer are not counted.

differentiation in the processing between 0.25 inch and 0.40 inch veneer.

The green southern Wisconsin red oak bolts, 4 feet long, were debarked and heated by submersion in water.

Temperature (°F)	Average time (hr)
70°-120°	1.5
At 120°	20
120°-160°	4
At 161°	34.5
	66 (2-75 days)

The lathe was set at a feed of 0.386 inch.

Two bolts were cut at 0.3862 feed with a 0.347- to 0.348-inch gap (10 pct compression or 90 pct of feed). remaining bolts were cut at 0.3865 feed with a 0.348- to 0.352-inch gap (Note: 90 pct of 0.3865 = 0.3478 in.).
Lead = 0.060 inch for all cuttings.

occupied 1/8 to 1/4 the cross section with associated grain deviation occupying 1/4 to 1/3 the cross section. Class 4 knots occupied less than 1/8 the cross section with associated grain deviation occupying less than 1/4 the cross section.

Much of the veneer (41.5 pct) was essentially clear even though the logs from which it was cut were relatively low quality.

Press Drying

Problems in obtaining the veneer from the six Alabama species and the predicted condition (during shipment) of those veneers (Appendix A) prevented accurate determination of their press drying properties. To estimate drying times to 20 percent moisture content as a function of species and thickness, a pair of 8-foot veneers were cut into two parts each (total of four 48-in. boards) and dried, on the basis of past experience, to a moisture content

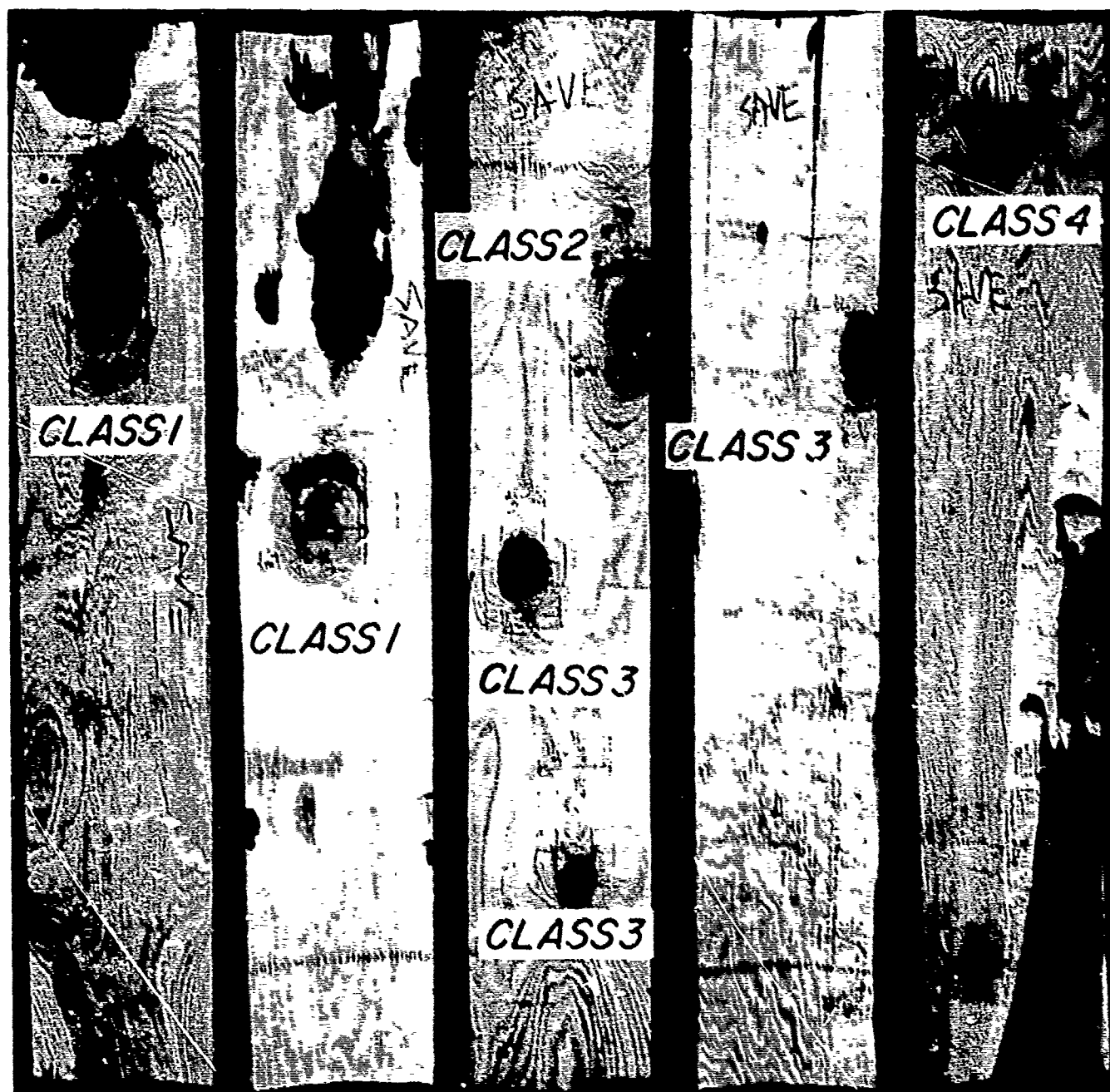


Figure 3 — Classification of knots in typical 10-inch-wide by 4-foot-long red oak veneer. Knot diameter and grain deviation expressed as a fraction of veneer width. The veneer shown was not used in tests because of wane.

(M 143 871)

approaching 20 percent. This was a compromise inasmuch as there was considerable variation of the moisture content within a species as well as the usual heartwood and sapwood presence. Based on this limited data and past experience, drying curves were developed (fig. 4 and 5). For each given species and thickness, all veneer

was dried for a single time period. In the process of reheating, moisture loss was anticipated to be about 5 percent to arrive at a desired moisture content of approximately 15 percent. Samples taken during processing indicated that the moisture content was closer to 10 percent for the thinner 0.25-inch veneer, and for the assembled test tie

series.

All of the 0.40-inch-thick veneer from 4-foot 3-inch bolts was squared to 49 inches in length after cutting, graded for knot size classes (fig. 3), and press dried in sets of four in a 50- by 50-inch press with vented cauls at 375° F, 50 psi.

One sample, clipped board was

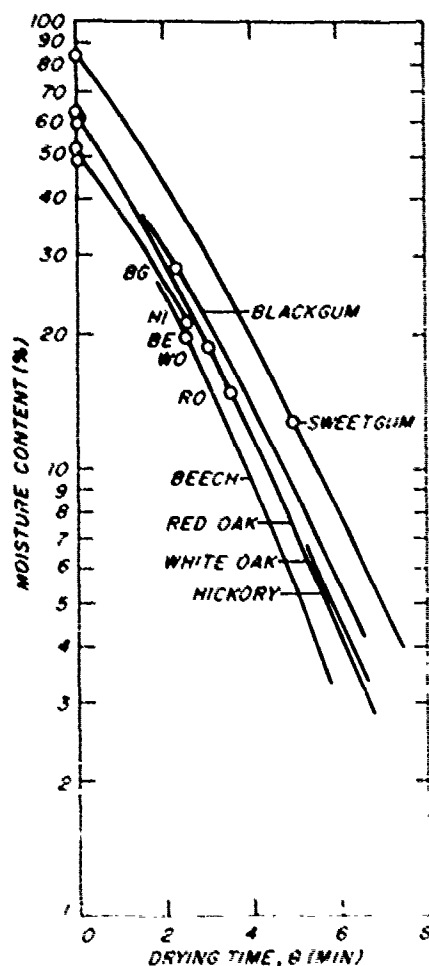


Figure 4.—Moisture content changes in 8.5-foot veneers during press drying at 375°F, 50 psi ($l = 0.25$ in.).

(M 148 257)

removed from each bolt to be used for the preliminary drying rate observations. The average moisture content of these veneers was 82 percent (range 69 to 93 pct), varying between trees. The effects of drying time (fig. 6) and pressure (fig. 7) on moisture content and thickness loss indicates that 50 psi is a good compromise for rate of drying and thickness loss. With the cauls used here (1/8-in. holes, 1-in. on center, square), this veneer blew up at 200 psi because of insufficient venting (fig. 8).

Using these preliminary observations as a guide, all veneer was predried to an estimated 12 percent moisture content in 13 minutes. Because sapwood and heartwood of red oak are at about the same moisture content and dry at essentially the same rate, no segregation was necessary.

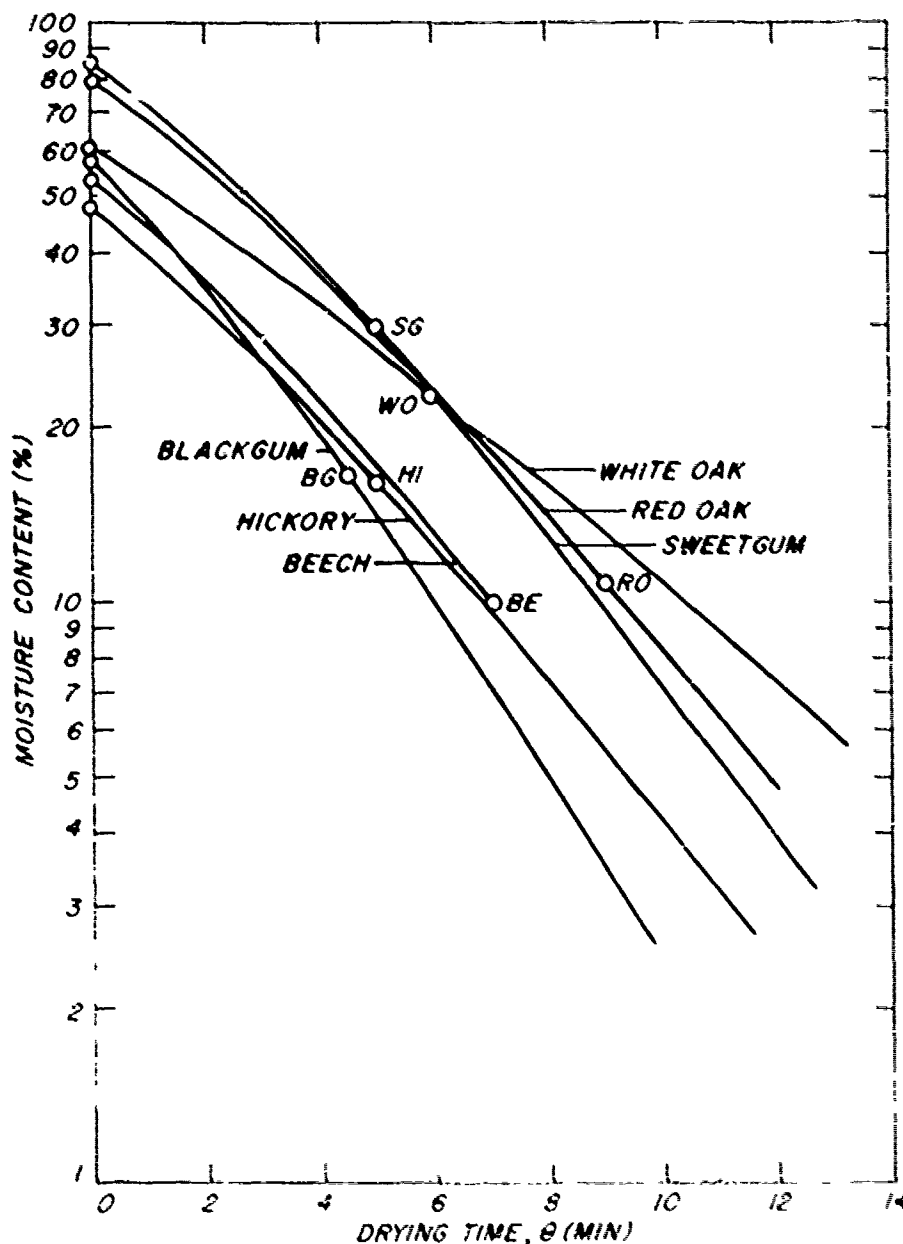


Figure 5.—Moisture content changes in 8.5-foot veneers during press drying at 375°F, 50 psi ($l = 0.40$ in.).

(M 148 258)

Lamination 8.5-Foot Veneer

The veneer previously dried in a press to 15 percent average moisture content was reheated in a roller veneer dryer operating at 300°F for periods adequate to develop glue line temperatures approaching 200°F (5 to 7 min for each veneer). Because of limited open time and thickness of the veneer (and associated cooling effect), only three

lamina could be assembled at one time. Thus a 7-inch-thick tie of 0.25-inch veneer would require about 10 subsets.

The experimental resole-type adhesive (modified phenol-resorcinol) used was supplied by Koppers Company (16). Spread rate for the adhesive was 60 to 65 pounds per thousand square feet (lb/Msf) of glue line. For purposes of quality control, glue line temperatures

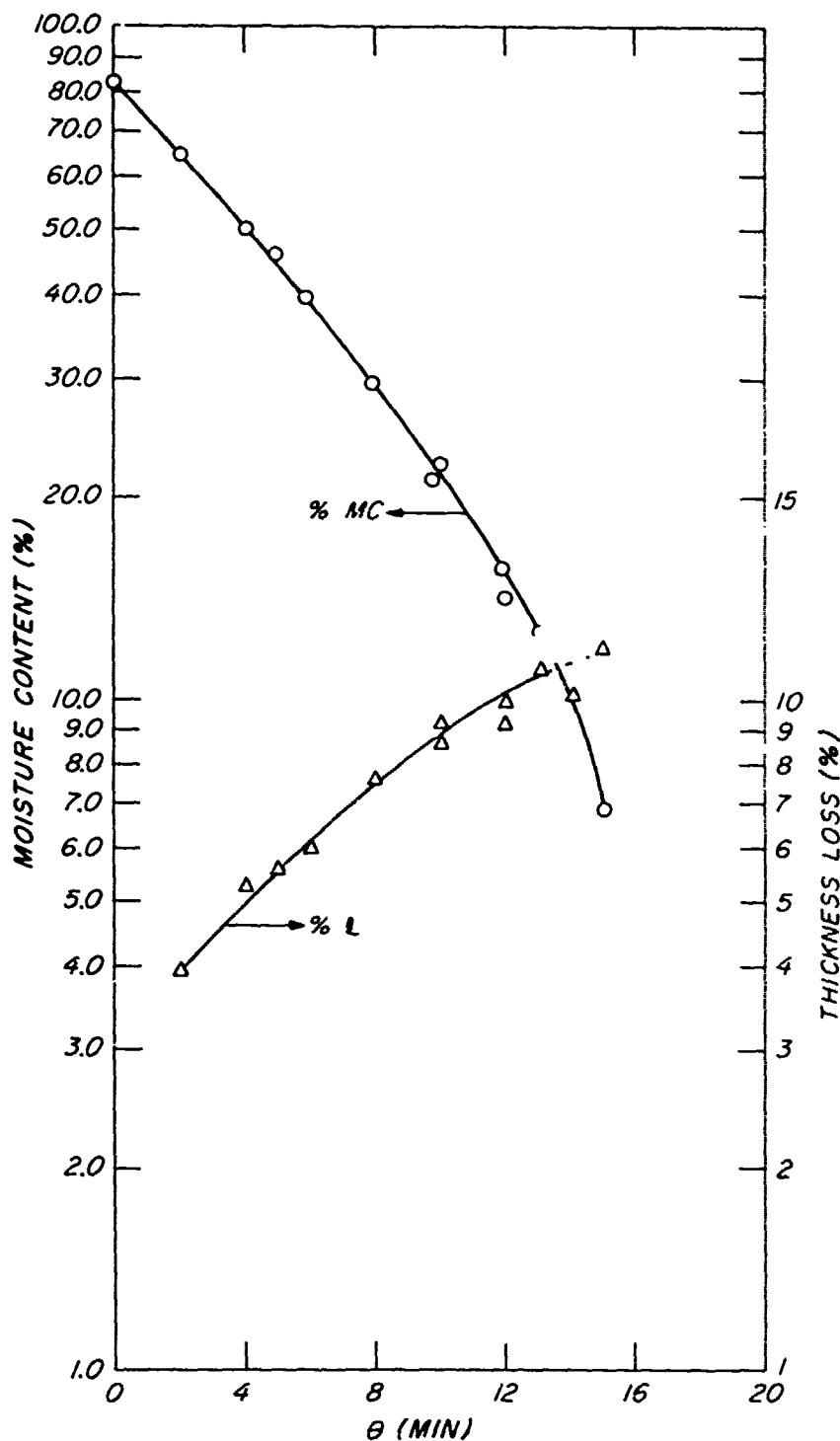


Figure 6.—Press drying and thickness loss curves for red oak veneer as functions of drying time
(10 in. x 48 in. x 1)
 $M_o = 81.5$ percent
 $t_o = 0.400$ inch
Press: 50 inches by 50 inches (vented cauls), 375° F, 50 psi.
Each data point average of four boards.

(M 145 349)

approaching 200°F were monitored using thermocouples.

All laminating was done in a 2- by 8-foot press at 150 psi (fig. 9). The time-temperature pattern of the glue bond is shown in table 2. Another variation from

Table 2.—Typical glue-line temperature as measured by copper-constantan thermocouples in 8.5-foot veneer ties

Time	Thermocouple location		
	3-1	1-2	2-3
Min	°F	°F	°F
0.0	160	130	130
0.5	180	170	175
1.0	188	178	185
2.0	192	192	195
3.0	195	198	200

the original Press-Lam concept (19) is the need for maintaining the high temperature at interst boundaries for 7 minutes between add-on veneers. Therefore the top platen of the assembly press was maintained at 200°F.

Veneer more than 9.5 inches wide was made into 16 ties (dressed to 7 by 9 in.) for intrack tests. Veneer less than 9.5 inches was made into 10 narrow ties for wear tests (dressed to 6 by 8 in.).

No moisture content estimate could be made of the intrack series; moisture content sections obtained from the narrow series (table 3) were supposed

Table 3.—Final average moisture content (oven-dry basis) of finished crossties of 8.5-foot-veneer

Tie species	Tie moisture content
	Pct
Red oak	9.4
Hickory	7.0
Beech	10.1
White oak	11.0
Blackgum	11.4
Sweetgum	6.2

to have been 15 percent, but excessive drying and reheating lowered this to closer to 10 percent. The overall thickness loss from green veneer to finished tie averaged 9.3 percent with a coefficient of variation of 14 percent. This value includes a loss of thickness in press drying plus a small loss in reheating and lamination.

4-Foot Veneer

The tie assembly scheme for 4-foot

veneer differed from that of 8.5-foot veneer. In this series, no veneer reheating was necessary. Sets of four veneers were press dried and immediately step laminated to produce subassembly Press-Lam dimension boards, 8.5 feet long, about 1.5 inches thick, with staggered butt joints (fig. 10). To stagger butts in an orderly fashion, the veneer was cut to 49 inches and the ties were cut to 104 inches. This combination enabled butts to shift six inches from board to board in final tie assembly (fig. 11). These dimension boards were in turn reheated in a roller veneer dryer (325° F) and laminated, one at a time, for a total of five boards per tie (a total of 20 lamina deep). No surfacing was performed prior to either of the two laminating steps.

The adhesive was applied using an extruder or ribbon-type spreader. The spread rate was maintained at 60 to 65 lb/Msf. Because the veneer drying time was long, the laminating cycle was slow (14 min), more than ample time for resin cure. Figure 12 shows the sequence of green veneer grading, press drying, step lamination, dimension board recovery, and reheat laminating.

Glueline temperatures in excess of 195° F were found desirable during laminating for this experimental resin. Thermocouple measurements indicated glueline temperatures ranging from 190° to 200° F. Every sixth board was removed from the continuous production flow to be used for other strength tests. A total of 149 boards was fabricated. Glue bond shear tests were made on test specimens recovered from other mechanical tests.

Five dimension boards were reheated in a tunnel roller veneer dryer (325° F, 14 min) forming four glue bonds, one at a time. The upper platen in the press (2 by 8 ft) was maintained at 200° F to provide a 200° F bonding surface temperature. A wooden caul was used on the bottom of the tie assembly.

The boards were assembled with sequential veneers; the ties were assembled from boards in the order produced. The method of assembly was chosen to be consistent with manufacturing processes, so data derived from the study should be translatable to a manufacturing scheme without much difficulty.

With an overall average thickness loss of 12 percent, the final tie depth was a little over 7 inches. One consequence of the assembly from five boards was the location of a bond between loose faces (surface containing lathe checks) of two

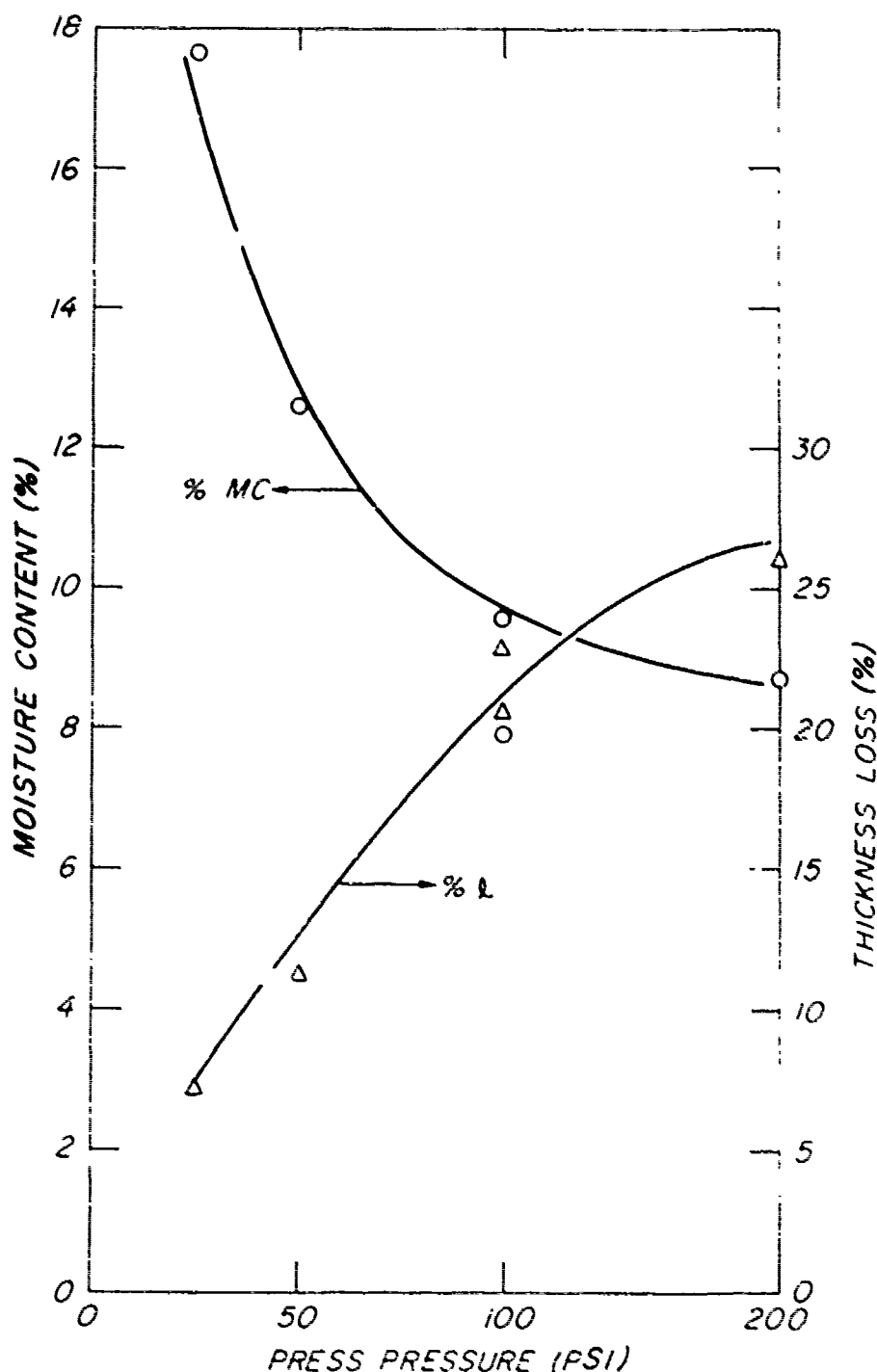


Figure 7 — Percent moisture and thickness loss as a function of press dryer pressure at constant temperature and drying rate for red oak veneer (10 in. by 48 in. by 1)

$M_s = 82.3$ percent

$t_s = 0.400$ inch

Press: 50 inches by 50 inches (vented cauls), 375° F, 13 minutes

Each data point average of four boards.



Figure 8—Appearance of red oak veneer (0.40 in.) as press dried at 200 psi, 375°F for 13 minutes showing blow-up due to insufficient venting (cauls 1/8-in. holes 1-in. o.c. square)

(M 145 102)

adjacent veneers (L-L) symmetrically in the center of the tie. In addition, the tie has four other L-L bonds. In contrast, the tie without butt joints (8.5-ft veneer) has only one loose-to-loose bond again in the center of the tie, with all the other bonds loose-to-tight.

A total of 25 red oak crossties composed of 4-foot veneer was prepared. The ties were dressed to final width and crosscut to 8 feet 6 inches in length. The average moisture content of the finished ties was 11.4 percent, unnecessarily low for railroad ties, but close to normal for use in standard bending strength tests.

Preservative Treating

8.5-Foot-Veneer Ties

Treatability of seven sections from the narrow series was evaluated in the

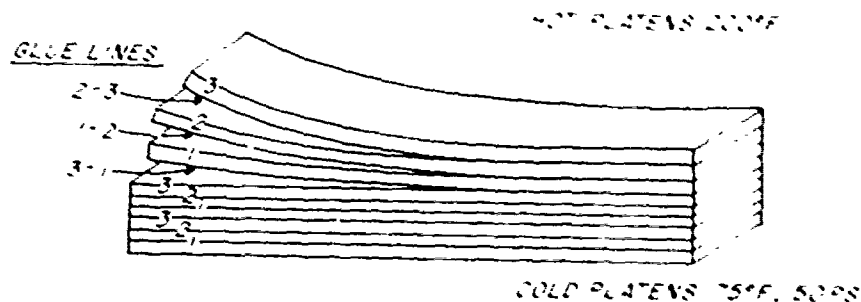


Figure 9—Schematic of subset laminae showing the positions of the glue line temperature measurements (table 2)

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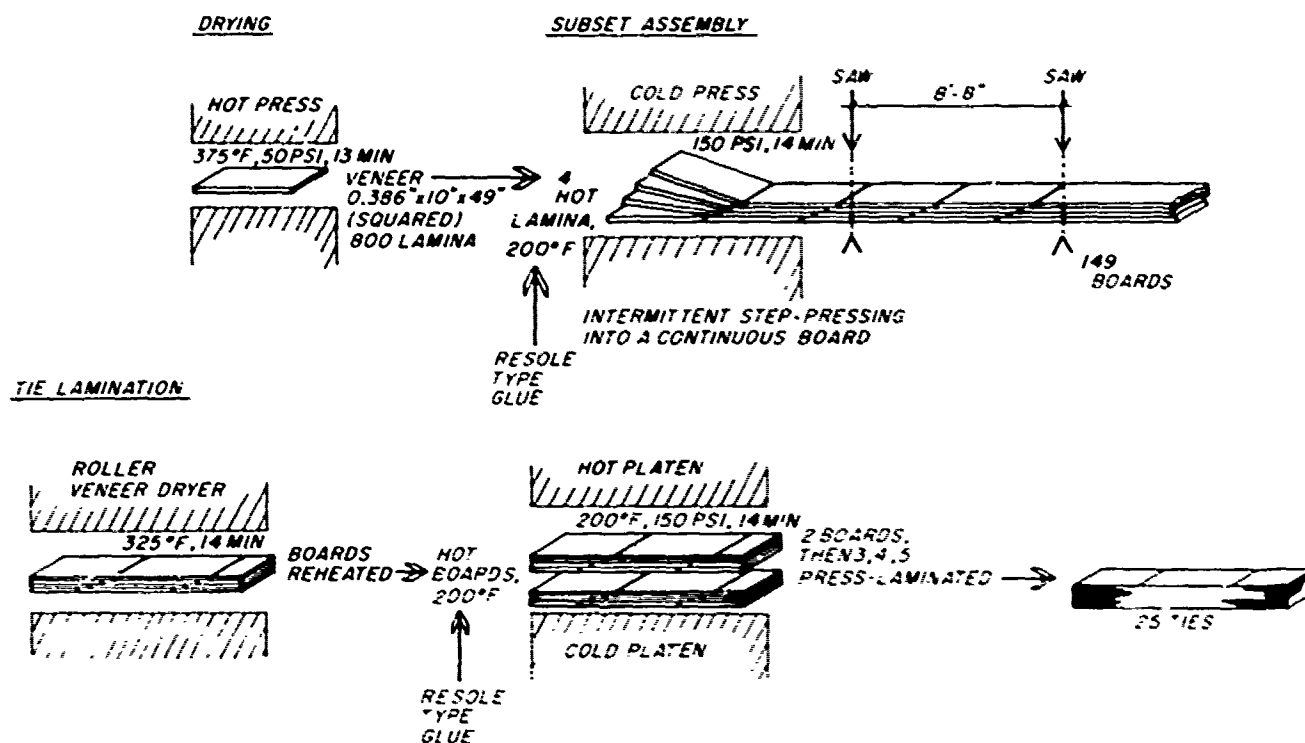


Figure 10 —Process strategy in Press-Lam tie production. Drying and subset assembly of hot, 49-inch-long veneers yields boards 1.5 inches thick by 10 inches wide (note staggered butt joints between layers), and Tie laminating five hot boards in four sequential steps (four glue-lines per tie) yields one finished tie

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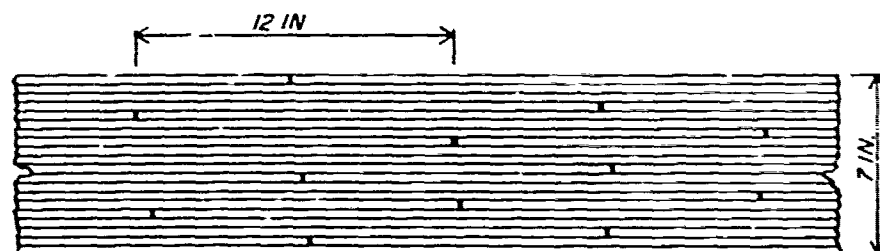


Figure 11.—Diagrammatic representation of typical butt joint locations in cross-ties produced from 4-foot-long veneer.

(M 148 261)

laboratory. Until then, no creosote treatments of Press-Lam hardwood beams had been made. Preliminary commercial treating in the spring of 1974 on tie sections indicated a very high pickup by conventional treating schedules (21). Because each tie in this test group was unique, no variation of treating conditions could be explored. All were treated with the same schedule at the same time. Because of the short specimen length, one end of each specimen was coated with epoxy. Variation in preservative pickup (table 5) was not unlike that for solid members

of these species and was similar to retention levels achieved commercially (table 4).

To reveal creosote distribution patterns, photographs of various cross sections in the beam were taken about 16 hours after treatment (fig. 13). All specimens, photographed within seconds after each section was sawn, showed the same pattern: Good distribution 8 inches from the open end and far less creosote at the center of the cross section within 1 inch of the end coating.

The sixteen full-size specimens and

seven short-section specimens made from the narrow series were commercially creosote treated (table 4) using a Rueping-type treatment schedule similar to that used in the laboratory

4-Foot-Veneer Ties

Sixteen ties from 4-foot veneer were also given a Rueping-type treatment at the Koppers plant. The treatment was developed at FPL for Press-Lam (21). This was used to creosote the ties for an average retention of 6.2 pounds per cubic foot (pcf). The schedule used for the treating was:

Initial air at 40 psi for approximately 5 minutes

Cylinder filled at 60 psi with preservative at 200° F for about 5 minutes.

Pressure was raised to 85 psi with preservative at 200° F over a period of 5 minutes.

Cylinder pressure and preservative temperature were held to 85 psi and 200° F for 2 hours.

Pressure was bled off to 20 psi over a 5-minute period and the preservative was blown back to the work tank.

Final vacuum was held for 1 hour

during which the mercury gauge averaged 25 inches of vacuum. The cylinder was neutralized and the tie remover.

This treating cycle with 60/40 creosote-coal tar solution achieved complete penetration and 7-pcf retention levels. However, uniform penetration across the annual rings was not achieved. Borings showed nearly complete penetration in the treated crossties produced from 4-foot red oak veneer, whereas solid ties in the same charge retained the preservative mostly in the outside shell area (for equal retentions). This result is consistent with that reported previously (21).

Physical/Structural Properties

Bending Strength

Selected specimens were tested to failure in bending. The ties were third-point loaded on a 90-inch span as horizontally laminated beams (ASTM D 198 (4)).

Loads and deflections were monitored to failure.

Bending Stiffness

Some of the ties were tested in bending to determine stiffness.

A dynamic MOE of all specimens was obtained by "stress wave" equipment which determines the transit time of a pulse over a specified gauge length. One of two procedures was followed:

The first procedure (on ties of 8-foot-long veneer) used an accelerometer placed on the wide face about 1 foot from the end and the other 6 feet away. One end of each tie was struck with a hammer and the pulse transit time was measured (fig. 14).

The second procedure (on crossties of 4-ft veneer) measured the speed of transmission of an ultrasonic pulse from one end of the tie to the other. Both the transmitter and receiver were placed on the end grain with a grease couplant. As will be noted, either this procedure or the butt joints between veneer produced inconsistent readings, and the results are not reported.

Shear Bond

To evaluate the adhesive bond quality of the ties, a section 12 inches long was removed from each of the ties tested to failure in bending. This section was removed near one end where there was no damage. From each of these sections, three 1-inch-diameter cores were removed, the long axis being

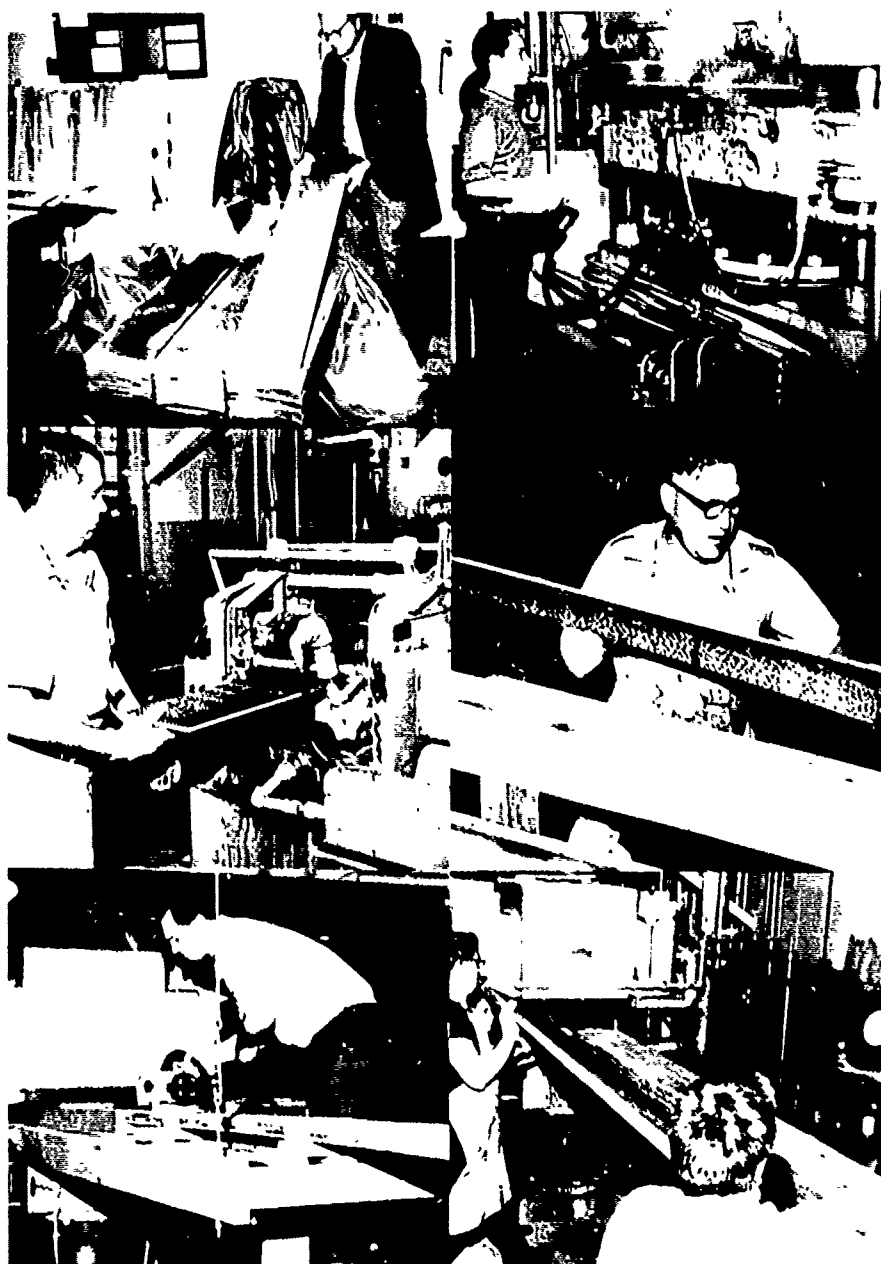


Figure 12 —Processing of 4-foot red oak veneer to crossties

- | | |
|---------------|--|
| Upper left: | Grading green veneer |
| Upper right: | Press drying veneer |
| Center left: | Applying resin |
| Center right: | Step laminating |
| Lower left: | Cutoff continuous boards assembly |
| Lower right: | Laminating tie from Press Lam dimension boards |

(M 145 757)

perpendicular to the gluelines. The cores were marked so that glueline 1 was the one nearest the top of the tie during manufacture and testing. The gluelines in these cores were then

subjected to shear tests using a method similar to one described by Selbo (20). The load at failure and the estimate of the percentage wood failure were recorded for each glueline tested.

U.S. Forest Products Laboratory.

Hardwood Press-Lam Crossties: Processing and Performance, by J. L. Tschernitz, E. L. Schaffer, R. C. Moody, R. W. Jakerst, D. S. Gromala, C. C. Peters, and W. T. Henry, Madison, Wis., FPL., 1979

24 p. (USDA For. Serv. Res. Pap. FPL 313).

The crosstie demand in 1973 increased considerably over previous requirements. The hardwood normally used for crossties was diverted to other uses.

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This report discusses the research undertaken and results obtained to date.

Table 4.—Treating data for 8.5-foot-veneer ties

Tie species	Nominal veneer thickness	Cycle		Creosote retention
		Initial air	Pressure time	
Red oak	In 0.25	10	85 2	11.4
		40	85 2	16.2
		10	85 2	10.3
	40	40	100 2	8.7
		40	100 2	6.8
		50	85 2	4.8
Blackgum	25	40	100 2	10.8
		40	85 2	8.5
		40	85 2	8.8
		40	85 2	9.7
White oak	25	10	85 2	9.8
		40	100 2	7.8
		40	85 2	5.4
	40	40	85 2	4.4
Hickory	25	40	100 2	9.5
		40	85 2	11.0
Sweetgum	25	40	100 2	8.9
		40	85 2	7.7
	40	40	85 2	7.7
Beech	25	40	85 2	8.2
		40	100 2	7.0
		40	85 2	5.8
Mixed hardwoods	25	40	85 2	6.6
	40			

*Final vacuum was 1 h long

*Field test, Koppers Company, Inc.

*Field test, Penn Central railroad

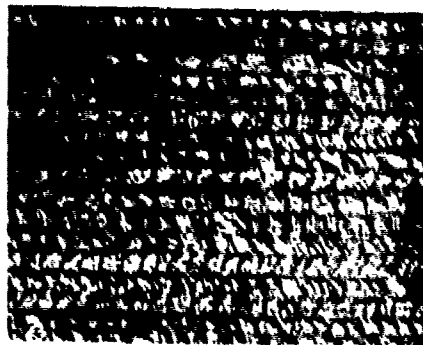


Figure 13—Treated red oak tie of 8.5-foot veneers, cross-cut 8 inches from open end. Dark areas are creosote-treated wood

(M 142 091 10)

Table 5.—Creosote retention test sections for one treating schedule for 8.5-foot-veneer ties

Tie species	Number of ties	Retention
Red oak	19	6.6
Red oak	19	5.8
Blackgum	28	9.8
White oak	28	5.2
Hickory	28	7.6
Sweetgum	28	7.7
Beech	31	7.3

Treating schedule: Air 40 psi 15 min; creosote 90 psi 27.200; 1 60 min vacuum

Tie Wear

Crosstie sections from narrow ties of 8.5-foot veneer were subjected to test in an Association of American Railroads (AAR) tie wear machine (fig. 15). To conduct the test, a 14-inch steel tie plate and short length of rail are fastened to the tie section using conventional 5/8-inch spikes driven into 5/8-inch holes.

In the test, both vertical and lateral loads are applied. The lateral forces simulate the pattern of the outward and inward forces on the outer rail of a curve. A typical test with a 14-inch tie plate on a creosoted oak tie would yield average force components of 20,000

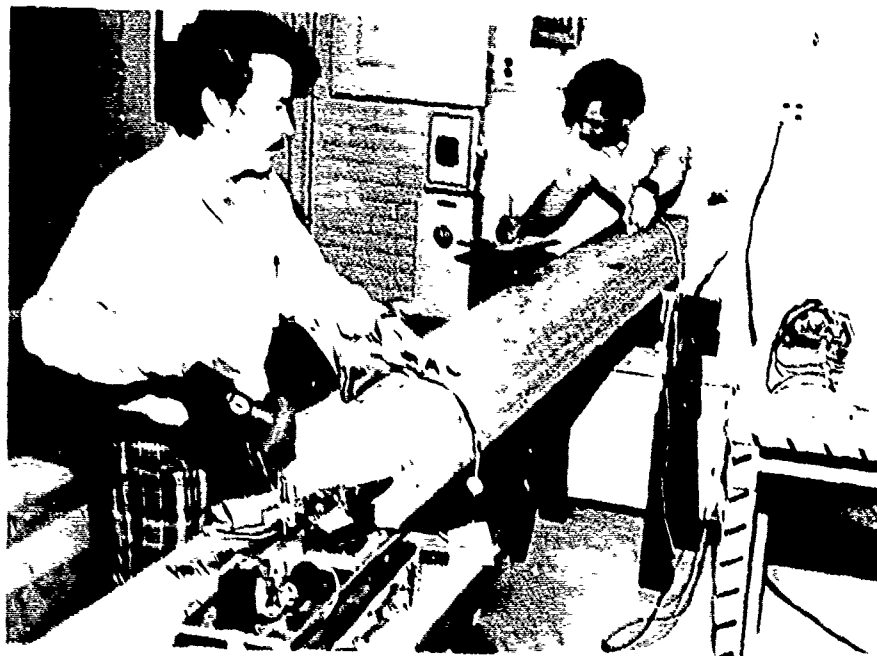


Figure 14—Stress-wave measurement on an 8-foot-veneer tie

(M 142 014 3)

pounds vertical, 4,000 pounds inward, and 8,000 pounds outward of the track. The optimum speed of the tie wear machine is about 120 revolutions per minute. Two and one-half million cycles of alternating vertical and lateral loads constitute a full test. A constant drip of water is applied on each side of the rail and sand is added to the vacant spike holes in the plates to accelerate tie wear. No sand and water are used in the first 20-minute seating period.

Cyclic Delamination

Cyclic bond delamination tests, conducted according to AITC 201-73 (1), were performed on test blocks taken from five cross-ties previously tested in bending.

Lateral Resistance

The rail-holding ability of a tie is a crucial consideration in its performance, especially around curves where maximum lateral thrust would be encountered.

In the lateral resistance test (17), a short section of 136-pound rail was spiked to a 25-inch length of 7- by 9-inch Press-Lam cross-tie made of 4-foot veneer. Two new rail spikes cut 5/8 inch by 6 inches were driven flush with the tie plate into a 1 1/2-inch predrilled and creosoted hole and then withdrawn approximately 1 1/2 inch (emulating in-track conditions). Both spikes were of the rail holding type. The rail was loaded with 2 1/2 (vertical/horizontal) components so that the load vector would traject just inside the edge of the rail base (causing rail lateral movement and not rail overturning). Lateral displacement of the rail head and rail base were recorded.

In-track Installation

8.5-Foot-Veneer Ties

Six Press-Lam cross-ties were placed in the Penn Central Class 3 tracks at Orrville, Ohio, (May 1974). Four of the ties were placed in a relatively dry location and two in a low, wet spot in the line. Spike holes were predrilled (5/8-in. diameter). No problems were encountered during installation.

Seven cross-ties were inserted in-track in the Koppers Company yard at the same time. The track sees very limited engine and car use, but submits the ties to other weathering and in-ground conditions.

Tie performance was monitored weekly for a month, then monthly for a year, and periodically thereafter.

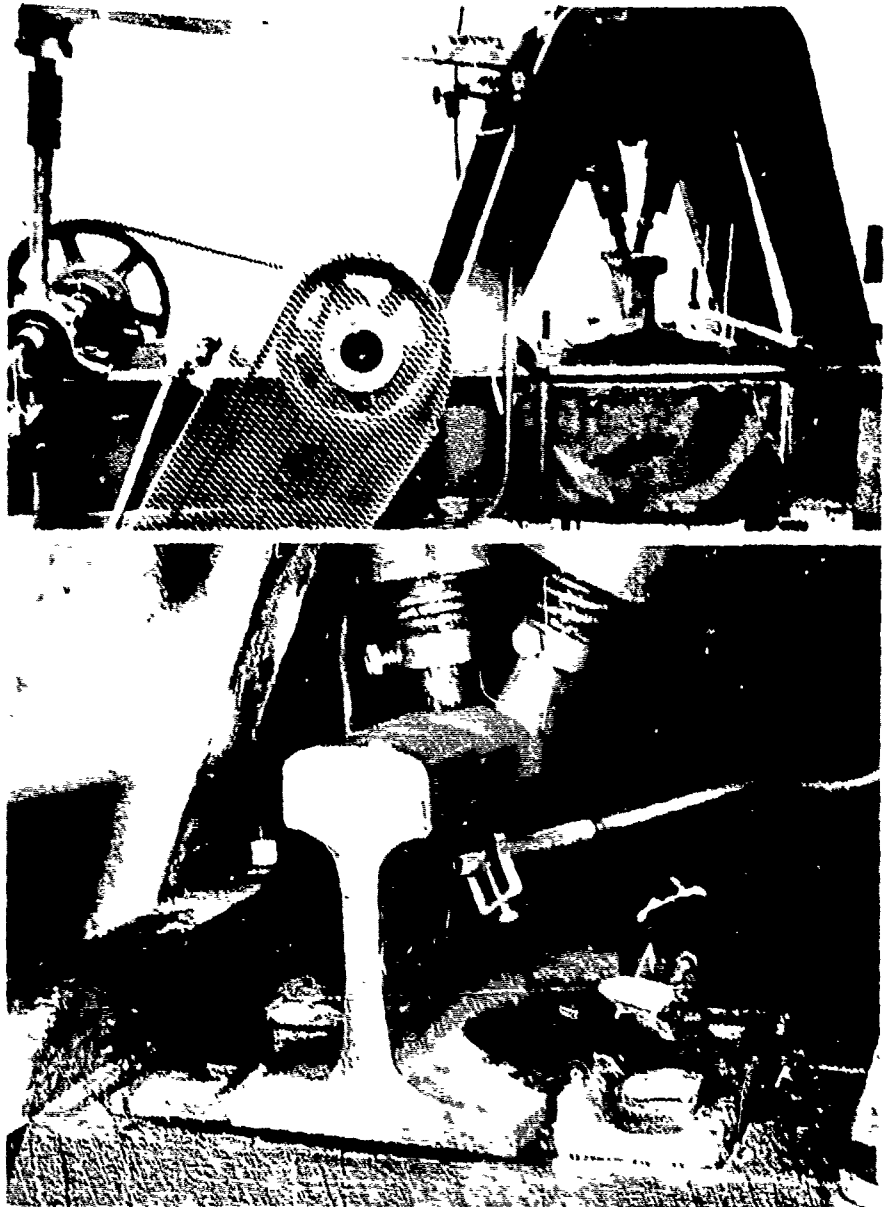


Figure 15 — Tie wear machine (upper) and close up (lower) showing grit and water dripping onto rail and tie section.

Table 6.—Results of bending tests on laminated cross-ties of 8.5-foot veneers

Tie species	Modulus of rupture	Shear stress at failure	Type of failure
	Psi	Psi	
Red oak	7,760	430	Bending and horizontal shear
Red oak	-	153	Horizontal shear
White oak	4,929	278	Horizontal shear

Veneers were 0.25 in. thick.

Table 7.—Results of ultimate bending strength tests of cross ties from 4-foot red oak veneer

Tie moisture content	Dry specific gravity ^a	Modulus of rupture	Shear stress at failure
Pct		Psi	Psi
11.0	0.61	5,680	330
12.4	56	5,030	301
11.6	59	6,240	362
10.5	60	5,100	288
11.6	59	2,900	171
10.5	59	5,260	304

^aBased on oven-dry weight and volume of sample cut from specimen

^bFailure occurred at a glue line which appeared to have pre-cured

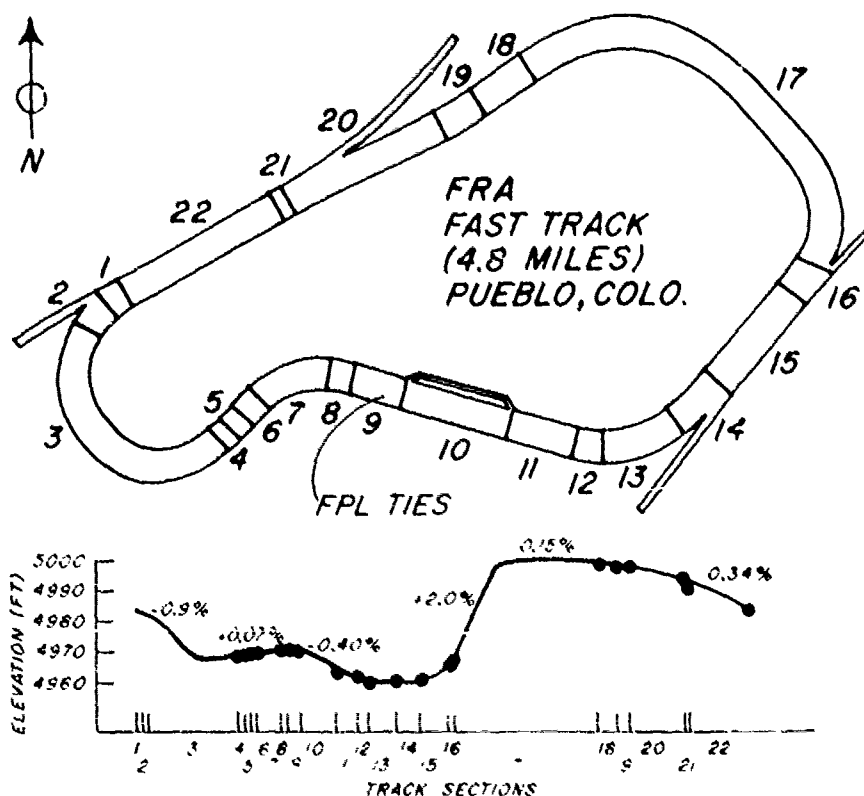


Figure 16—Federal Railroad Administration's FAST Track layout at Pueblo, Colo., and grade for each track section. Numbers above curve indicate grade

(M 148 264)

4-Foot-Veneer Ties

Of 16 creosote-treated Press-Lam cross ties made from 4-foot veneers, eight were installed in the Burlington Northern track near Moline, Ill. (May 1976), four were installed in a Federal Railway Administration accelerated test track ("FAST Track") in Pueblo, Colo. (June 1976), and four were retained for future installation in track in the Koppers yard.

The Federal Railway Administration

FAST Track installation was activated in October 1976. This accelerated evaluation test facility subjects track components to accumulated service loads ten times faster than can be achieved in commercial service. In addition, FAST Track has a higher percentage of curved track than is common in the U.S. (fig. 16), thereby increasing the potential for a higher rate of wheel and track wear. A train is continuously run over the track for 16

hours a day, and inspection of the track is done during the remaining 8-hour period. Tie plate cutting measurements were initially conducted on a 20-day cycle and changed to a 40-day cycle after 11 months.

RESULTS AND ANALYSES

Physical/Structural Properties

Bending Strength

One red oak and one white oak cross tie laminated from 8 5-foot-long veneer were tested to destruction in bending (table 6). Another red oak tie failed in shear at mid-depth during stiffness testing.

Similar results for six of 25 cross ties from 4-foot red oak veneer are also shown (table 7). One failed during stiffness testing at a glue line in the bottom subassembly. All other failures were in flexure and were believed to initiate at the bottom butt joint located near midspan.

Examination of AREA requirements for timber cross ties indicated an expected average MOR for minimum quality solid-sawn ties to be about 4,400 psi with a near-minimum value of the population of 3,100 psi. Although no data of typical solid-sawn ties are available, this provides a value for comparison.

The ties of 4-foot-long butt-jointed red oak veneer are not as strong as those manufactured from full-length veneer without butt joints. However, their bending strength properties compared favorably with those predicted for solid-sawn ties. The expected performance of the Press-Lam ties in bending is likely comparable to solid-sawn oak ties. Considering the five ties produced from 4-foot veneer and loaded to failure (and eliminating the defective tie), the average MOR was 5,460 psi, a 24 percent increase over the expected average MOR of minimum-quality solid-sawn timber cross ties. The defective tie had a strength close to the near-minimum expected of solid-sawn ties.

From the Wood Handbook (23), average MOR for small, clear, red oak specimens is 14,300 psi. It has been shown that conversion of logs into Press-Lam results in a material with approximately 82 percent of the bending strength properties found in comparable solid-sawn material (15). Application of this "Press-Lam" factor and correcting for member size and loading configuration would result in an

Table 8.—Modulus of elasticity values calculated from stress-wave results for ties from 8.5-foot veneer

Tie species	Nominal veneer thickness	Cross-section dimensions (height & width)	Specific gravity	Modulus of elasticity	
				— Million psi —	
Red oak	In	In	0.66	1.6	
			72	1.5	
	40	7 x 9½	66	1.9	
		7 x 9¼	68	2.0	
Blackgum	40	7 x 9	52	1.4	
White oak	25	7 x 9¼	72	2.3	
		7¼ x 9	74	2.2	
	40	7 x 9¼	72	2.0	
Hickory	25	7 x 9	81	2.5	
Sweetgum	25	7 x 8¼	65	1.8	
	40	7 x 8¼	56	1.6	
Mixed gum	25	7 x 8¼	55	1.7	
	—	7 x 8¼	54	1.5	
Beech	25	7½ x 8¼	66	1.5	
		7½ x 8¼	69	1.8	
Mixed hardwoods	Mixed	6¼ x 8½	75	2.0	

^aBased on volume at 10 pct moisture content and oven dry weight

Table 9.—Stress-wave and bending modulus of elasticity values for narrow crossties from 8.5-foot veneer

Tie species	Nominal veneer thickness	Cross-section dimensions (height and width)	Specific gravity	Modulus of elasticity	
				Stress wave	Long span bending
Red oak	In	In		— Million psi —	
	0.25	6¼ x 8	0.64	1.8	1.6
		6¼ x 7¼	66	1.7	1.7
	40	6 x 8	63	1.7	1.8
Blackgum	25	6 x 8	54	1.7	1.9
		6¼ x 8	53	1.5	1.5
White oak	25	6 x 8	71	2.2	2.1
		6¼ x 7½	69	2.0	1.9
Mixed oak	25	7¼ x 8	67	1.9	1.8
Hickory	25	6½ x 8	75	2.2	2.3
Sweetgum	25	6¼ x 8	57	1.8	1.6
Beech	25	7¼ x 8	64	1.7	1.5

^aBased on volume at 10 pct moisture content and oven dry weight

average MOR of 9,200 psi. This becomes the estimated strength of clear straight-grained Press-Lam ties.

Estimating a strength ratio of 85 percent, the average expected MOR of specimens with knots becomes 7,820 psi. This value compares favorably with the properties of Press-Lam crossties made from 8-foot-veneer lengths (MOR = 7,760 psi). In ties made from 4-foot-veneer lengths, there is a net reduction in the moment of inertia due to the presence of butt joints in some plies. The average ratio of I_{net}/I_{gross} was calculated to be about 70 percent. Inclusion of this butt joint factor reduces the expected average MOR to 5,460 psi, exactly the average value if the defective tie is not included. This procedure demonstrates the predictability of obtained strength values.

Bending Stiffness

The results of static and dynamic determinations of MOE for crossties of 8.5-foot veneer are given in tables 8 and 9. As expected from clear wood strength data, the hickory ties had the highest stiffness; the gum and beech had the lowest. All crossties exceeded the 1.1 million psi MOE level suggested as a design level. The stiffness obtained from the bending tests correlated reasonably well with the "stress-wave" values. A 95 percent confidence interval for predicted MOE in bending (unadjusted full span) using "stress-wave" values was ± 18 percent.

The results of static bending determinations of MOE for red oak crossties composed of 4-foot veneer indicate a mean MOE of 1.2 million psi and coefficient of variation of 10 percent for these crossties. This exceeded the 1.1 million psi level suggested for solid-sawn red oak ties, but is considerably less than crossties from 8.5-foot veneer. MOE values determined by "stress-wave" techniques were 25 to 70 percent higher (average, 40 pct) than those determined by bending tests and are not reported here. During the test period, this type of stress-wave equipment was being evaluated (12) and the causes of the differences were not pursued as part of this study.

Shear Bond

Shear strengths of small glue-bond test specimens removed from the Press-Lam crossties were evaluated. Comparison of actual shear strengths of many small test specimens to shear

requirements developed for full-size timbers present problems in analysis of data. Local variation in shear strength could be easily detected in the small specimens, while this variation would tend to "average out" over the gross cross-section of a railroad tie. To account for a portion of this discrepancy, average allowable cross-section shear stresses with an assumed coefficient of variation of 14 percent (23) are compared with group averages of test data from the shear bond specimens. Statements regarding the adequacy of shear strengths in the two phases of this study are based primarily on apparent tie performance. A design shear stress of 120 psi used by AREA is derived from red oak clear wood properties. By multiplying by a factor of 4.5 (5), the expected near-minimum shear strength is 540 psi.

Shear weakness was common throughout the 8.5-foot-veneer cross-ties of several species, as evidenced by the shear failures of a narrow red oak tie and one other red oak specimen. Shear tests were performed on 1-inch cores as removed from specimens of the other seven narrow ties (20).

Tie performance indicating inadequate shear strength is substantiated by test results (table 10). Only the blackgum, beech, and hickory ties had average shear bond strengths exceeding the average expected of a minimum-quality tie. Results generally indicate that precure was the principal factor affecting bond strength. This was one result of working with an experimental adhesive (16) for which little previous experience was available. The highest frequency of bond weakness seemed to be at the platen-reheated interface occurring at every third ply (table 2) (fig. 9), perhaps a result of the high temperature (200° F) at this intermediate surface between sets as assembled.

Other possible factors which may contribute to poor bonding are the nonuniform pressure upon the glue bond caused by extreme variation in veneer width (overhang, indentation in stack and thickness), and unknown influence of surface fungi on some veneers.

For the ties produced from 4-foot veneer average shear strength was 1,120 psi with coefficient of variation of 30 percent. Wood failure averaged 79 percent. This average shear strength substantially exceeded the expected average of a minimum-quality tie. Even

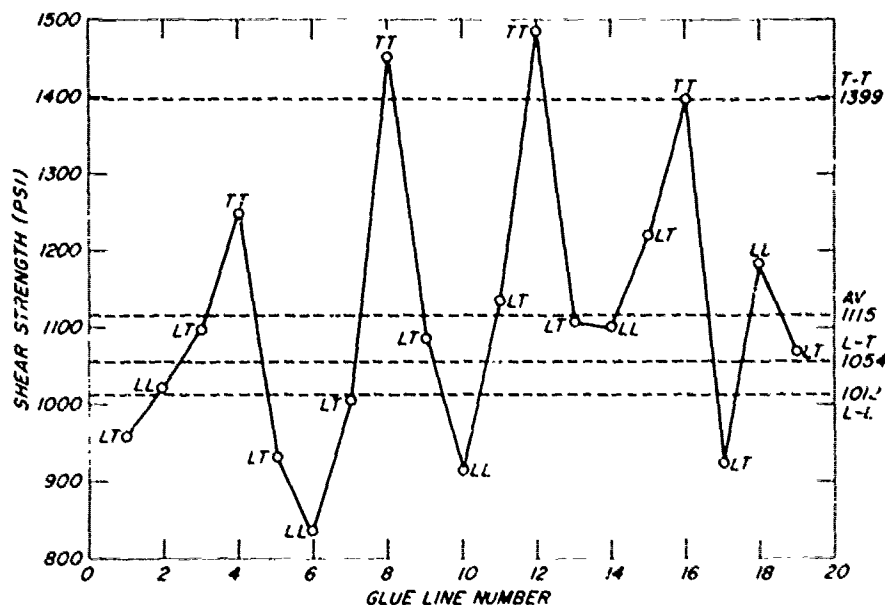


Figure 17.—Periodic shear bond strengths as a function of tight-to-tight (T-T), loose-to-tight (L-T), and loose-to-loose (L-L) types within the tie. Average for six red oak ties (each point 18-test average; 72 observations for T-T, 180 observations for L-T, 90 observations for L-L).

(M 145 352)

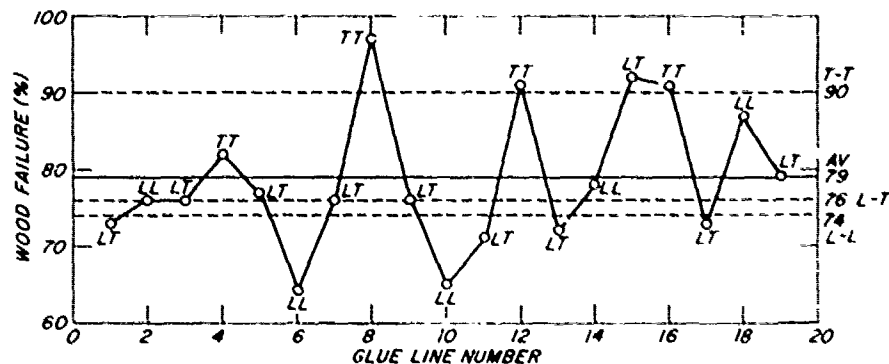


Figure 18.—Periodic percent wood failure as a function of T-T, L-T, and L-L surface types within the tie. Average for six red oak ties (each point 18-test average; 72 observations for T-T, 180 observations for L-T, 90 observations for L-L).

(M 145 351)

the tie that failed during proofloading exhibited adequate shear strength, indicating that the precure condition that caused the failure was probably localized.

The variability in the test data is partially a function of the test procedure itself (19), and partially due to the nature of a bond between two pieces of veneer (figs. 17 and 18).

Bonding the loose side of the veneer considerably reduces the average shear strength and percent wood failures obtained. There are several reasons for this. The loose side is rougher and its

surface less sound than the tight side. Also, a portion of the adhesive applied is absorbed into the lathe checks where it does little to improve bond quality. Conversely, bonds between tight faces of veneer are substantially stronger. In spite of these factors, the results of the tests on the full-size members were considered satisfactory, and the ties were pressure treated with preservative with very little glue-line separation.

Tie Wear

One blackgum and one red oak tie made from 8.5-foot veneer were tested

in the AAR tie wear machine after creosote treatment. The overall performances of these specimens under a 14-inch steel tie plate was adequate during the 2.5 million cycles in the tie wear machine (figs. 19 and 20). The tie plate was fastened to the ties with conventional $\frac{3}{8}$ -inch spikes driven into $\frac{3}{8}$ -inch holes. The surface wear was low on both specimens. These results compared favorably with the performances and wear on treated solid oak crosstie specimens tested under the same conditions.

Examination of the test specimens revealed significantly different internal checking patterns in red oak and blackgum laminated crossties. The red oak laminate contained well ordered lathe checks. The checks were intensified in the areas of spiking as observed on cutting the tie specimen close to the spike across the load-bearing area (fig. 21).

On driving a $\frac{3}{8}$ -inch spike 3 inches into a 9.16-inch hole in the red oak laminate, the specimen split. A piece of solid red oak of comparable moisture content, specimen size, and spike hole location did not split on driving a $\frac{3}{8}$ -inch spike into a 9.16-inch hole. These results are indicative of a potential problem, but are inconclusive.

In contrast, the blackgum laminate showed no open lathe checks either at the ends or internally. When the spike was driven into a 9.16-inch hole, no internal cracks were developed in the blackgum laminate (figs. 22 and 23).

Cyclic Delamination

Cyclic delamination tests performed on test blocks taken from five ties laminated from 4-foot red oak veneer tested previously in bending disclosed that three specimens exceeded AITC 201-73 (1) requirements on the first cycle. It was decided at this point to check one specimen by splitting it apart with a chisel at the gluelines to investigate the wood surface and/or adhesive condition.

Between laminates 7 and 8, where the longest open time occurred, starved and precured adhesive was prevalent, and approximately 25 percent of the surface showed wood failure. The glueline between laminates 11 and 12 showed precure along with delamination due to lack of bond at a large knot. Wood failure resulting from the chisel test was approximately 30 percent of the bond area. Another major opening appeared between laminates 17 and 18 where extensive crossgrain

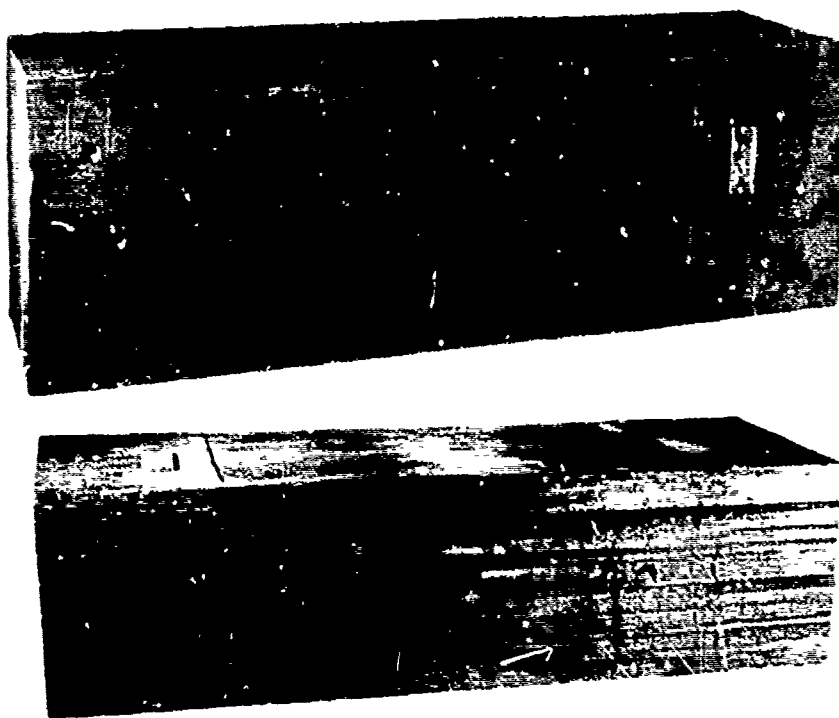


Figure 19 —Blackgum veneer tie sections after 2.5 million cycles in the wear machine under a 14-inch steel tie plate
Upper Surface Average wear, 0.09 inch (M 146-056)
Lower General appearance (M 146-057)

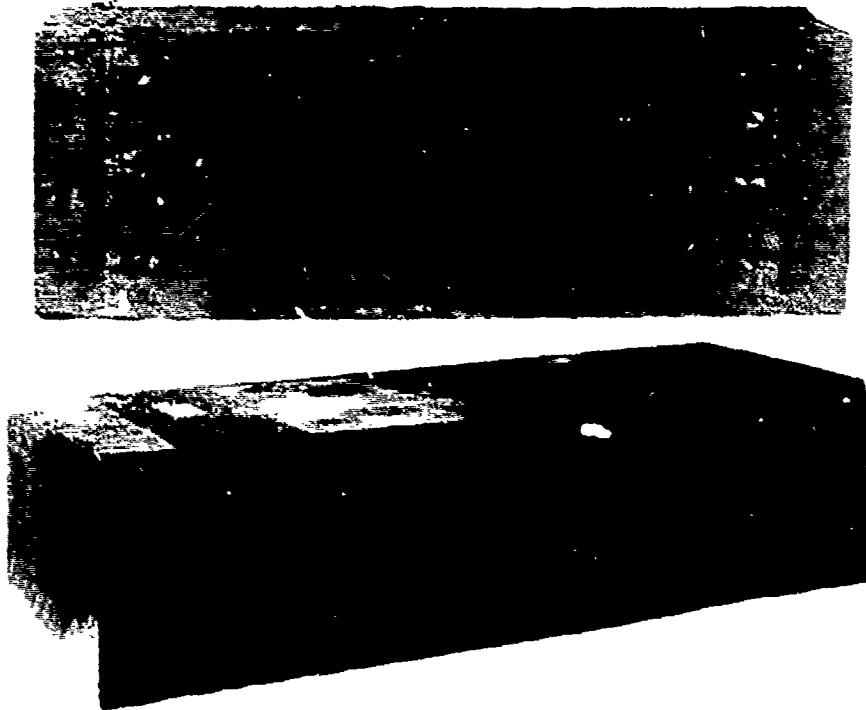


Figure 20 —Red oak veneer tie sections after 2.5 million cycles in the wear machine under a 14-inch steel tie plate
Upper Surface Average wear, 0.07 inch (M 146-060)
Lower General appearance (M 146-061)

Table 10.—Shear test data from laminated-cross-tie sections

Tie species	Number of plies	Shear		Wood handbook value ¹	Wood failure		Number of lams showing evidence of precure
		Average	Range		Average	Range	
			— Psi —		Pct	Pct	
Red oak	19	422	127-1,019	1,900	44	0-95	5
	19	546	0-1,089	1,900	44	0-90	8
Blackgum	28	854	0-1,292	1,450	68	0-100	—
White oak	28	649	0-1,184	1,600	52	0-100	9
Hickory	28	791	0-1,585	2,080	46	0-85	9
Sweetgum	28	582	0-1,732	1,600	42	0-100	12
Beech	31	1,194	0-1,903	2,010	43	0-95	11

¹For solid wood specimens at 12 pct moisture content

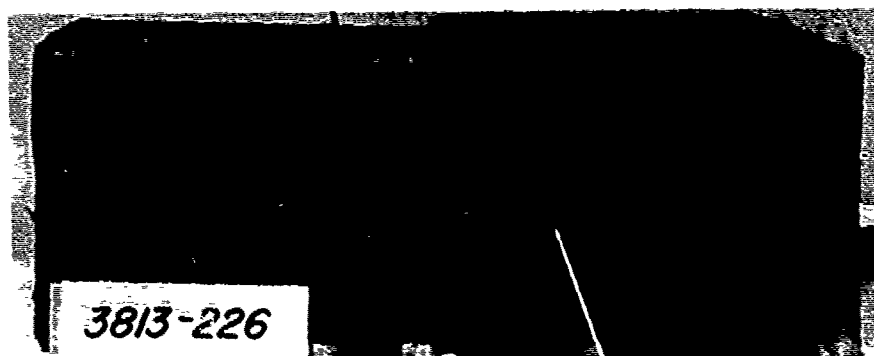


Figure 21.—The lathe checks in the red oak veneer specimen cut through the load bearing area are frequent and orderly. Damage caused by the spike is indicated by the small pointer. Several laminae are intact.

(M 146 058)

Table 11.—Intrack performance of six cross-ties of 8.5-foot veneer

Species	Length of service		
	9 months	34 months	60 months
Gum	OK	Top two laminations loose	No increase in delamination
Gum	OK	Delamination 3 in deep over middle half of tie	No increase in delamination
Red oak	Slight delamination south end	Slight delamination south end, slight tie plate cutting south end	No further tie plate wear or cutting
Red oak	OK	OK	OK
Red oak	OK	OK	OK
Red oak	OK	OK	OK

(approximately 40 degrees) was noted. Wood failure was about 80 percent, and the cause of the opening was due to shrinkage of the thin wafer of wood left between the sawn face of the specimen and a butt joint.

Of the remaining four specimens, only one did not meet the criterion of less than 5 percent delamination.

All specimens were processed through the second cycle and met the less than 10 percent delamination criterion as required by AITC (1).

Lateral Resistance

Tests on one red oak Press-Lum cross-tie of 4-foot veneer, and two solid-sawn cross-ties (one red oak and one white oak), showed comparable results¹. At 130,000 pounds total load (enough to dent the rail), the rail base displaced laterally 0.056 inch and the railhead moved an additional 0.18 inch in the Press-Lum cross-tie test, not significantly different from the white and red oak solid-sawn cross-tie tests.

Intrack Performance

8.5-Foot-Veneer Ties

Six cross-ties installed in the Penn Central track at Orrville, Ohio (May 1974) continue to perform well to date under more than 35 million gross tons of service per year (table 11). The degree of tie wear appears to be about normal after 5 years of service.

Seven ties placed in the Koppers Company yard track at the Orrville plant (May 1974) indicate that the predrilling of spike holes may not be necessary. Only one veneer in the seven ties (approximately 140 veneers) installed without predrilling split as a result of spiking. Serviceability remains excellent to date (May 1979).

4-Foot-Veneer Ties

Eight ties installed in the Burlington Northern track at Moline, Ill. (May 1976) appear to be functioning well. After nearly two years of service, it was noted that one tie had a delamination approximately 1.5 inches from the top of the tie. This delamination ran across the end of the tie and approximately one-third the length of the tie and was about 1.5 inches deep. The ties were inspected again in November 1978 and all ties were noted to be sound except for the above-mentioned delamination.

An inspection in December 1977 of the four laminated red oak 4-foot veneer

¹Joseph F. Murphy, 1979. Personal communication. Forest Products Laboratory, Madison, Wis.

crossties installed in the FRA FAST Track in Pueblo, Colo., revealed no tie plate cutting or other deterioration. At that time, 166 million gross tons of service load had been accumulated. Inspection in April 1979 showed that all ties were performing well after the accumulation of 235.4 million gross tons of load

YIELD AND ECONOMIC ANALYSIS

Log Yield

Rotary Cutting

8.5-Foot Veneer

Due to the difficulties encountered in the rotary cutting, only 27 crossties were obtained from 80 logs that should have supplied 100 or more ties. As a result of improper conditions for rotary cutting, this yield of product is considered unrealistic

4-Foot Veneer

A total of 53 bolts (50 in.) were rotary cut: average small-end diameter was 16.0 inches (cov = 17 pct); average roundup diameter was 15.3 inches (cov = 17 pct); and average core diameter was 9.1 inches (cov = 13 pct). The theoretical yield based upon log and core volumes was 66 percent (cov = 14 pct); the actual yield was 49 percent (cov = 22 pct). The overall efficiency of cutting and veneer yield was calculated to be 74 percent (cov = 15 pct). The low yield from this study is due mainly to

the large core diameter. Spinout was not a problem. Fewer small-diameter logs would also have improved the yield.

An interesting comparison can be made by examining recovery of solid-sawn 7- by 9-inch ties from these same logs. Using minimum diameter, it is estimated that 36 ties could be recovered. If these were in fact 9-foot logs, yielding one-half tie per core, then the veneer (sufficient for 33 ties) plus 13 dowel ties (27 ÷ 2) would yield 46 ties.

Neither 4- nor 6-inch chucks were considered adequate for turning 16-inch-diameter bolts of red oak without excessive bolt spin out. The first bolt was turned with 6-inch chucks and did spinout. Thus, for all other bolts except two, 8-inch chucks were used.

Spinout was not a serious problem; when it did occur, a significant recovery of veneer was achieved. Although the Forest Products Laboratory lathe is not equipped with retractable chucks, it should be possible to change from 8-inch chucks to 6- or 4-inch chucks after turning to 9 inches. One can calculate yields for 6- or 4-inch chucks by assuming that the same efficiency would be obtained for smaller chucks as with 8-inch chucks (fig. 24)

Calculated Yield

From the simple geometry of peeling 8.5-foot logs (opening of the cylinder into a spiral sheet), one can calculate theoretical green yields for various log

*Hiram Hallock, 1976 Personal communication Forest Products Laboratory, Madison, Wis



Figure 22 — The laminated blackgum veneer contains only a few lathe checks. These are fine lines observed in the lamina which were not opened by spiking

(M 146 255)



Figure 23.—A brash split occurred on driving a 5.8-inch spike 3 inches into a 9 16-inch hole in the red oak laminate. Neither the solid oak control nor the blackgum laminates split on having a spike driven 5 inches into the wood

(M 146 054)

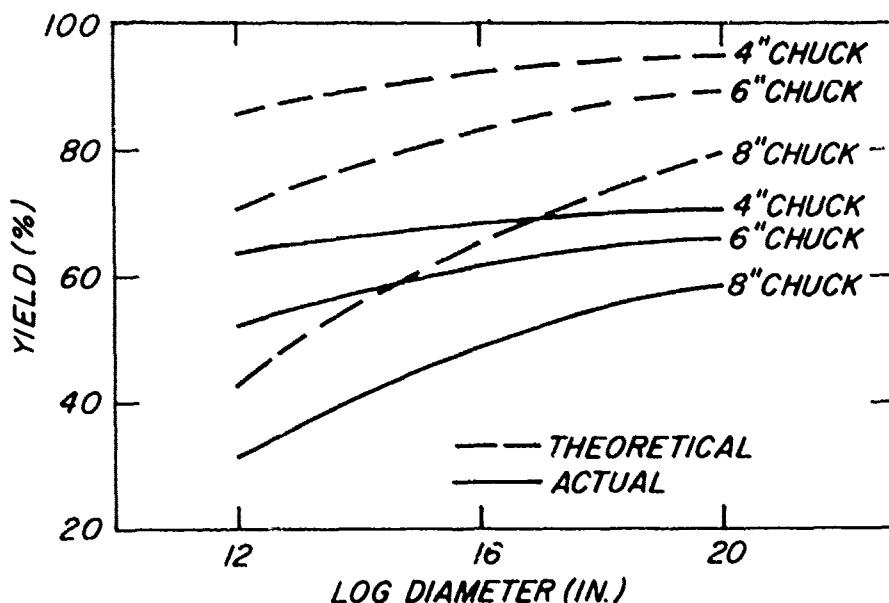


Figure 24.—Effect of log diameter on yield from three chuck sizes.

$$\text{Efficiency} = \frac{\text{Actual yield}}{\text{Theoretical yield}} \times 100 \text{ percent.}$$

74 percent efficiency is actual for 8-inch-diameter chuck, 16-inch-diameter 51-inch-long log from this study, using 54 bolts. The same efficiency is assumed for other chuck sizes.

(M 148 262)

DRYING SUBSET ASSEMBLY TIE LAMINATION

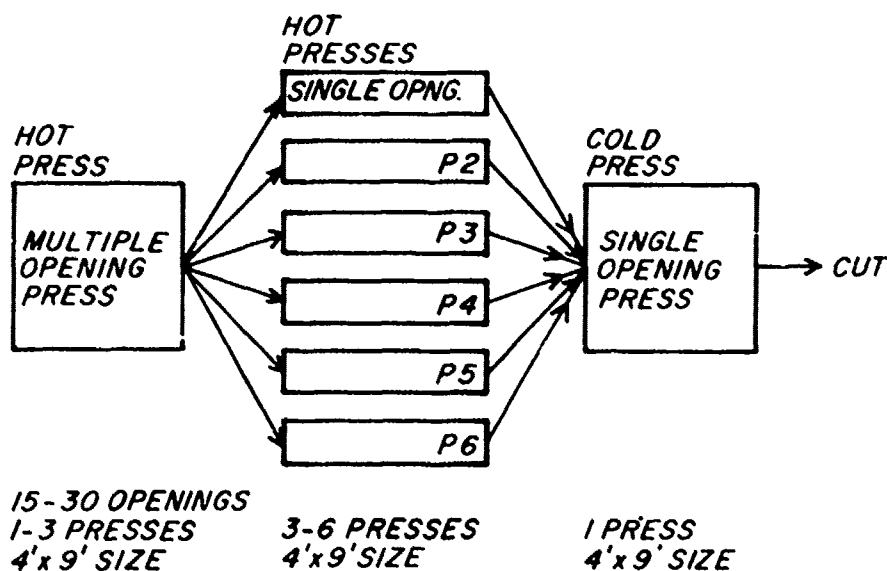


Figure 25.—One scheme for processing Press-Lam cross-ties from 8.5-foot veneer. Billets 4 by 9 feet by 7 inches thick are produced and resawn into 7- by 9-inch by 9-foot cross-ties.

(M 148 263)

diameters and final core size. Two options are available in cutting: (1) Salvaging a half tie (4.5- by 7-inch by 8.5-foot section) from a 9-inch core, and (2) cutting to 6-inch cores of low value (table 12).

Table 12.—Calculated veneer yields from 8.5-foot logs of various diameters and core sizes

Log diameter	Core diameter	Green yield (theoretical)
In	In	Pct log volume
12	9	42 (+ 1 2 tie)
	6	70
16	9	65 (+ 1 2 tie)
	6	83
20	9	79 (+ 1 2 tie)
	6	89
24	9	84 (+ 1 2 tie)
	6	92

Cost Estimates

There are several laminating schemes that might be suggested for the manufacture of Press-Lam ties, one such layout is shown in the block diagram (fig. 25). The schematic does not show conventional log preparation, rotary cutting, veneer handling, and tie cutting.

The operating cycle is assumed to be 6 minutes for production of one five-tie billet. At a rate of two 7-hour shifts per day, a manufacturer could produce 700 ties per day plus about 200 dowel ties as secondary recovery.

The capitalization of the alternative veneer thicknesses is about the same because thinner veneers dry faster (table 13).

Using the above proposed manufacturing methods, the following assumptions can be made to yield unit costs per untreated tie which in turn can be used to calculate total tie cost for specific cases (table 14):

Assume:

- Logs: Red oak (other species of similar drying rates)
- Diameter (small end) = 15 inches
- Length = 9 feet (90 BF /log Scribner scale)
- Veneer: 9.1-inch core
- 65.7 percent green yield (theoretical)
- 10 percent thickness loss in drying
- 0.41 inch lamina thickness (green)

Ties. Dimension 7- by 9-inch by 8.5 feet
Efficiency of veneer use
Actual = 75 percent (of 65.7 pct)
Theoretical = 100 percent (of 65.7 pct)
Yield = $0.75 \times 65.7 = 49.3$ percent

Core. 1-2 dowel tie (100 pct)

A Press-Lam plant is designed to press dry and laminate billets essentially 4 by 9 feet by 7 inches deep to be resawed into five ties. The total annual production of Press-Lam ties would be 175,000.

Total tie manufacture per year can be evaluated both on a theoretical and actual basis. In this context, "theoretical" implies complete utilization of the green annular volume (between the small-end diameter and core diameter) whereas "actual" assumes a 75 percent efficiency of recovery and utilization.

	Theoretical	Actual
Total logs	32 740	123 653
Press-Lam ties	175 000	175 000
Dowel ties	46 370	61 827
Total ties	221 370	236 827

SUMMARY

It was found that Press-Lam (parallel laminated veneer) railroad ties—from

veneer of thicknesses up to 0.4 inches from grade 3 logs of various hardwood species with or without butt joints (8 5- and 4-foot veneer lengths)—possessed physical properties consistent with the current specifications for solid wood ties. Performance characteristics of these fabricated ties were extended to three separate intrack test groups, all of which to date (longest time interval, 5 years) have been satisfactory. As expected, creosote preservative treatment was adequate for both types and all species, with the added advantage of reducing the treating time by one half. The above intrack tests will contribute further judgments on this treating procedure.

No doubt the greatest problem in any manufacturing operation would be the maintenance of glue bond quality

(shear strength) as temperature and time have rather narrow limits within which to prevent the resin. The viability of this concept most likely will depend upon the economics of manufacture—not upon the performance characteristics, which to date seem good. In turn, the economics depend strongly upon log volumetric yield of veneer, and resin costs. One important observation was that the resin manufacturer has some latitude in developing a "new" bonding formulation to meet the needs of a non-commercial processing concept (R&D) with the primary objective of lowering resin costs. While two processing schemes are presented, others can be conceived which may reduce capital and labor costs, without reducing product quality.

Table 13.—A possible layout scheme for Press-Lam cross-ties made from 4- by 9-foot veneers (fig. 25)

Veneer thickness	Number of plies	Press-drying time (hr)	Drying presses		Number of subset presses
			Number	Number of openings	
0.46"	15	14"	3	15	3
0.350	20	8.5	2	20	4
0.233	30	3.94	1	30	6

U = 61 S (1) red oak 85 pct 20 pct 3" x 5" 50 ps.

Table 14.—Summary of unit cost factors and an example of tie cost calculation

Cost item	Unit cost factors		Tie cost calculation		
	Theoretical	Actual	Unit dimension per tie	Plant specification	Cost per untreated tie
	— Dollars tie —				— Dollars —
Log	0.377	0.470	\$ \$10 MBF (Scribner)	\$100 MBF	3.77
Capital	715	659	\$ \$10 ⁺ capital investment (10 yr 10 pct interest)	\$3 10 ⁺ yr	2.15
Labor	451	415	\$ \$10 ⁺	\$10 ⁺ yr	4.51
Glue	727	727	\$ \$0.10 lb glue increments	\$0.30 lb	2.18
Overhead					
Labor	248	232	\$ \$10 labor cost (55 pct)	55 pct	2.48
Capital	451	422	\$ \$10 ⁺ capital investment (10 pct)	10 pct	1.35
Total					16.44
					16.56

Capital investment and labor specification would be higher than shown for actual case because more half-dowel ties would be manufactured.

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APPENDIX. VENEER ACQUISITION

It had been proposed to ship the 8-foot 6-inch veneer of six species groups that had been rotary cut in Alabama via refrigerated truck to Madison, Wis. Because of shipping regulations and lack of a refrigerated truck, the material was shipped by an open truck. The veneer was stacked on plywood and was covered with plastic. The shipment arrived in Madison 12 days after rotary cutting with the plastic broken. This induced partial uneven drying and the stacks had shifted, damaging veneer plies. In addition, the veneer packages had been attacked by fungi at the surfaces.

Packages were held under cool conditions (50° F) for several days after receipt. The veneer was then resorted, wrapped in polyethylene plastic sheets,

and put on pallets. These were then transferred to a subzero warehouse for storage to arrest the already excessive mold development and to prevent further drying. Before actual process drying, the veneer was returned to room temperature. In the veneer resorting, it became apparent that there was insufficient veneer; much veneer was too narrow (badly clipped), too thin (fish tail), or too short for the 8.5-foot-long "intrack" ties having 7- by 9-inch cross sections. Therefore, before drying, another sort was made on the basis of width greater or less than 9.5 inches and on excessive variation of thickness within one of two size classes and on heavy fungal attack. The more than 9.5-inch-wide veneer was suitable for intrack ties; the lesser width could be used for the test ties (6- by 8-in. (face) by 8.5-ft). All utilizable veneer was trimmed to lengths of 8 feet 7 inches. Thin, short, and fungi-ridden material was discarded.