

AD-A044 579

FOREST PRODUCTS LAB MADISON WIS
YIELD AND STRENGTH OF SOFTWOOD DIMENSION LUMBER PRODUCED BY EGA--ETC(U)
1977 K C COMPTON, H HALLOCK, C GERHARDS
FSRP-FPL-293

F/G 11/12
EGA--ETC(U)

UNCLASSIFIED

NL

| OF |
AD
A044579



END
DATE
FILMED
10 -77
DDC

AD A 044579

**YIELD AND STRENGTH
OF SOFTWOOD DIMENSION
LUMBER PRODUCED
BY EGAR SYSTEM**

12
B.S.

USDA FOREST SERVICE
RESEARCH PAPER
FPL 293
1977

U.S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE
✓ FOREST PRODUCTS LABORATORY
MADISON, WIS.

AD No. _____
DDC FILE COPY



DISTRIBUTION STATEMENT A
Approved for public release;
Distribution Unlimited

ABSTRACT

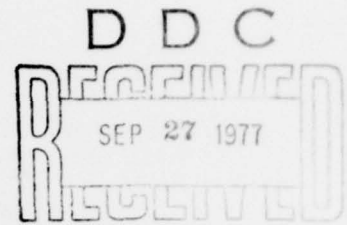
Approximately 20 billion board feet of softwood dimension lumber is manufactured annually in the United States by systems that waste considerable potentially usable material in ripping and edging of cants and flitches to fixed widths.

The Edge-Glue-and-Rip (EGAR) system is designed to use the full width of each flitch sawn from a log by live sawing logs, drying round-edge flitches, ripping to the widest possible usable width, edge gluing into panels 36 to 48 inches wide, and ripping the panels to final dry widths for softwood dimension lumber. The panels are ripped to yield lumber that reflects the highest grade and strength potential within the panel. The effect of knots is minimized by placing them away from the edges and containing the large knots in wider lumber.

With the EGAR system, size of log does not restrict the width of lumber. The system lends itself well to automated scanning and computer ripping decisionmaking. A significant increase in overall yield of 10 percent was recorded for lumber produced by the EGAR system over standard lumber. It was also significantly higher in modulus of rupture than standard. EGAR lumber showed less warp and was of higher visual grade than standard lumber, but in neither case was the difference statistically significant. Data indicate that EGAR had slightly higher stiffness properties, but the difference was not significant.

ACCESSION No.		
NTIS	Full Text	<input checked="" type="checkbox"/>
NTIS	WFO Summary	<input type="checkbox"/>
NTIS	Summary	<input type="checkbox"/>
PER LETTER		
BY		
DISTRIBUTION/AVAILABILITY CODES		
Dist.	INT.	SPECIAL
A		

6
**YIELD AND STRENGTH
OF SOFTWOOD DIMENSION
LUMBER PRODUCED
BY EGAR SYSTEM.**



By

10
KENNETH C. COMPTON, Forest Products Technologist
HIRAM/HALLOCK, Forest Products Technologist
CHARLES/GERHARDS, Engineer

~~250~~
RONALD/JOKERST, Forest Products Technologist
Forest Products Laboratory,¹ Forest Service
U.S. Department of Agriculture

9 Forest Service research paper

11 1977

12 15 P.

14 FSRP-FPL-293

INTRODUCTION

Some 20 billion board feet of softwood dimension lumber is now used annually in the United States for housing, commercial construction, and industrial uses. If consumption continues to increase annually at the present rate, a shortage of softwood lumber before the year 2000 is forecast. If that rate rises even faster, a shortage could occur in the next decade. The U.S. Forest Products Laboratory is involved in a national effort to increase the supply of softwood timber products. At the same time, the timber resource must not be destroyed and the quality of the environment must be enhanced.

To improve manufacturing efficiency that will better utilize the timber resource and extend the supply, research in new and improved systems of sawing and secondary processing is underway.

EGAR System

One of the systems tested for processing timber into lumber has been named Edge-Glue-and-Rip (EGAR). Basically, EGAR attempts to eliminate the losses that occur during the conventional manufacturing system of edging green flitches to standard widths. In the EGAR system the green, round-edged flitches are dried, ripped to the widest width possible, and edge-glued into panels that are ripped to finished dimension widths.

A modification of the system would be to rough-edge green flitches with rip-saws or chipper-edgers, dry, re-edge, and glue into panels. Either way, the entire EGAR system for manufacturing softwood dimension lumber is technically feasible with present equipment.

In addition to the anticipated benefit from increased volume yield of softwood dimension lumber, a potential exists to increase quality. Panels can be ripped to minimize the effect of knots and other defects. Warp can be reduced and the width of lumber is no longer restricted by log diameter. Panels can be stored and cut to customers' orders. The potential for a defect scanner and computer control of ripping presents a further possibility for control of product mix and quality.

Objectives and Scope

The study was designed to examine the feasibility of gluing square-edge softwood flitches, nominally 8/4 thick, to:

Compare volume yields of 8/4 softwood dimension lumber manufactured by the standard process and by the EGAR system.

¹Maintained at Madison, Wis., in cooperation with the University of Wisconsin.
EPL 293

DISTRIBUTION STATEMENT A

Approved for public release;
Distribution Unlimited

141 700

mt

Examine yield by grade, degree of warp, and comparative mechanical characteristics of solid lumber and lumber manufactured by the EGAR system.

The study was limited to one species--shortleaf pine.

STUDY PROCEDURE

Material

Eighteen shortleaf pine logs, 33 feet (ft) long, were purchased from the Weyerhaeuser Company at Mt. Pine, Ark. To eliminate the effect that variables such as rot, shake, and scars have on yield and quality of dimension lumber, logs were chosen that were free of defects except for knots. Straightness was also a criterion, but here effect of moderate sweep would be minimal because the 33-ft logs were bucked to nominal 8-ft lengths. The only other criterion applied in selecting logs was top diameter (6-13 in.).

The logs were stored under water spray at the Forest Products Laboratory before bucking to 8-ft 3-in. lengths. As the logs were delivered to the sawmill log deck, the sawing pattern was stenciled with indelible pencil on the small end of each log using a template (fig. 1).

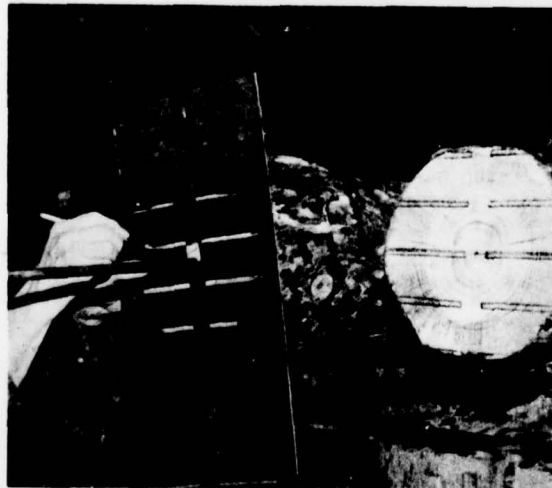


Figure 1.--Stenciling the sawing pattern on the small end of the logs. Log already marked has sawline through middle of log perpendicular to the short axis.

(M 141 260-3)

The template was made of thin fiberboard with parallel sawline slots 9/32 in. wide, separated by strips 1-25/32 in. wide, which represented the green target thickness for 8/4 southern pine dimension lumber. The template was placed on the face with the sawlines perpendicular to the short axis. It was moved to one side or the other until equal slab faces at least 4 in. wide were visible in the outer sawline slots in the template. This method resulted in two patterns. One sawline was through the center of the log, or a sawline on each side was equidistant from the center of the log. Results of mathematical modeling² indicate that this method yields the greatest possible total width of flitches when live sawing the log (through and through).

Sawing and Drying

The logs were sawed on the Forest Products Laboratory's circular sawmill, cutting 1-25/32-in. thickness for each flitch and 9/32 in. for saw kerf (fig. 2). Flitches were numbered consecutively, beginning with the first flitch from the first log and ending with the last flitch from the last log. All were measured on the narrow face at the narrowest point between the bark. By coin flip, the even-numbered flitches were chosen for standard manufacturing procedure, and they were edged (fig. 3) to green target widths to yield standard dry softwood dimension lumber according to the American Softwood Lumber Standards.³

Nominal Width (In.)	Green Target Width (In.)	ALS Dry-Dressed Width ³ (In.)
4	3.9	3-1/2
6	6.0	5-1/2
8	7.8	7-1/4
10	9.9	9-1/4
12	12.0	11-1/4

For this study no wane was permitted on edged standard lumber nor was it permitted in measuring EGAR flitch widths. This was done to eliminate wane as a variable since it could be a subjective element in measuring total

²Unpublished research at FPL to evaluate EGAR potential.

³American Softwood Lumber Standard, NBS Voluntary Product Standard PS 20-70, U.S. Department of Commerce, January 1970.

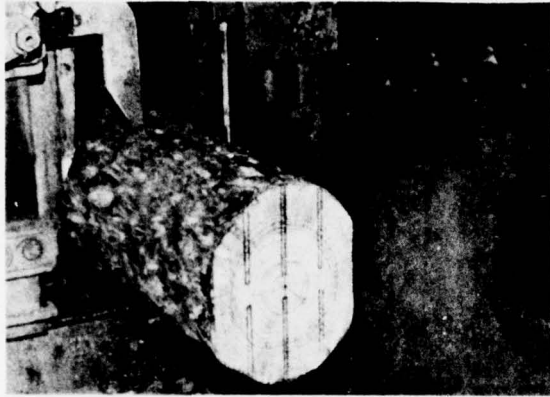


Figure 2.--Marked logs were sawed live with opposite faces at least 4 in. wide and parallel to the long axis.

(M 141 260-9)

yield and establishing the grade. The narrowest EGAR flitch width that was accepted was 3.9 in., the same as the green target size for standard 4-in. lumber. After eliminating pieces with less than the allowable width, there were 121 EGAR and 127 standard flitches.

The EGAR flitches and standard lumber were kiln dried to 12 percent (pct) moisture content. Because the round-edge flitches occupied approximately 60 pct more space in the dry kiln, a piling arrangement alternating two layers of them to one layer of edged standard lumber was used (fig. 4). Approximately 2,000 pounds (lb) of iron weights (about 30 lbs/ft²) were laid on top of the pile.

An elevated-temperature schedule was used for drying. Maximum temperature was 205° F and maximum depression was 85° F. After drying, all lumber was conditioned and equalized at 190° F dry bulb and 185° F wet bulb for an EMC of 14 pct.

In practice, kiln space could be saved by rough-edging the EGAR flitches either by sawing or chipping. This would require another step in the process, however, because it would still be necessary to re-edge the flitches before assembly in the glueup process.

Preparing Standard Lumber

The rough, dry standard lumber was assigned randomly from the kiln to 23 subgroups, with each subgroup having a total surface width of 36 to 48 in. The number of subgroups was reduced by random selection to 20 for statistical comparison with EGAR



Figure 3.--Illustrates loss of material when edging green flitches to widths for standard lumber with allowances for shrinkage, planing, and sawing variation.

(M 141 261-8)

lumber. Each piece was measured to the nearest 0.01 in. in width and surfaced to American Lumber Standard dimensions for dry-dressed softwood lumber. The lumber was then placed in a controlled atmosphere to attain an EMC of 12 pct until it was graded, measured for warp, and tested mechanically.

Preparing EGAR Lumber

After drying, the EGAR flitches were edged on a straight-line rip saw using a carbide-tipped, smooth-cutting saw. Care was used to place the rip line kerf in the wane so that the widest possible square-edged flitch resulted. The edge surface produced by the smooth-cutting saw was judged good enough for strong glue joints so no further surfacing was done.

Panels were glued up by assembling flitches at random as they came from the pile. Width of each flitch was measured to the nearest 0.1 in. and enough flitches were accumulated to make a panel at least 36 in. but not over 48 in. wide. By this procedure, the panels became the equivalent of a standard lumber subgroup for use in the analysis. Twenty-two panels were assembled, of which 20 were

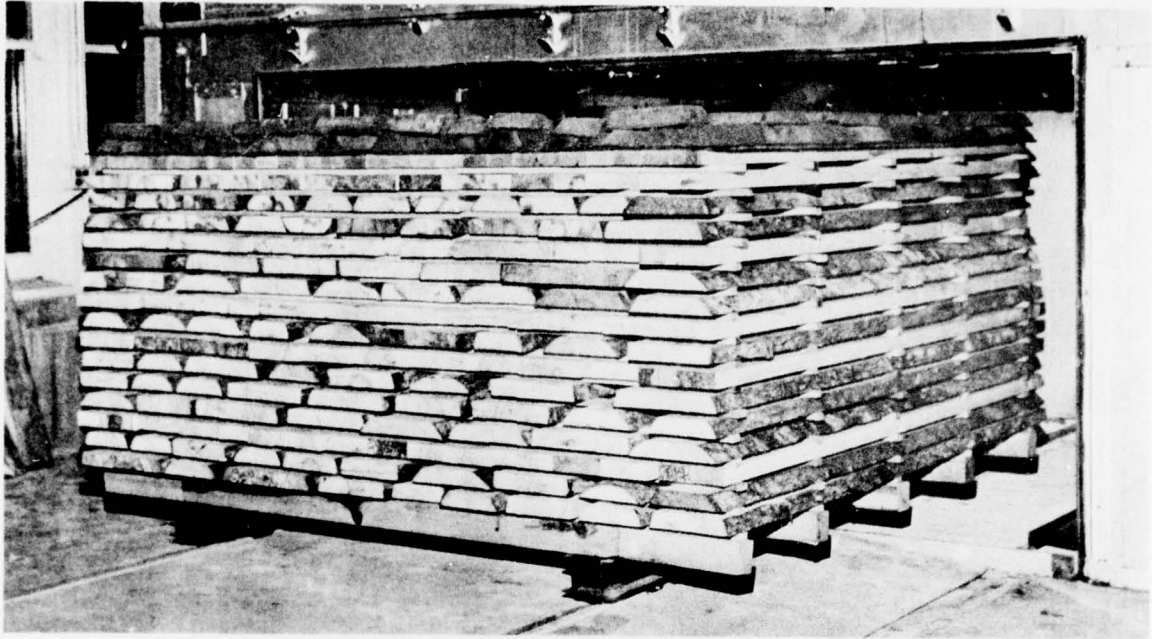


Figure 4.--Standard lumber and unedged EGAR flitches piled for kiln drying. EGAR flitches occupied 60 pct more space than edged lumber.

(M 141 141-5)

selected by random method to match the 20 standard lumber subgroups.

The adhesive was spread by hand using a paint roller, and no special effort was made to control or determine spread rate. The assembly time was a minimum of 20 minutes and was measured from the time the first surface was spread until pressure was applied to the layup. Overhead screw clamps and heavy timbers applied vertical pressure to keep the panels as flat as possible. Horizontal pressure was applied by inserting a section of fire hose between a side pressure bar that ran the full length of the edge of the panel (fig. 5). An air compressor with automatic pressure control supplied air through fittings to the fire hose at between 105 and 125 lb/in.² This system proved satisfactory and resulted in relatively flat panels and good glue joints. The adhesive was a commercially available room-temperature-curing phenol resorcinol and was permitted to cure for 20 to 24 hours (h) at temperatures of 70° to 85° F.

After assembly, the panels were stored at room temperature. Lumber ripping lines were laid off by using blocks that were cut to exact

widths of standard softwood dimension plus kerf of the rip saw (fig. 6). Blocks were matched for length at the ends of the panels, and strings were stretched tightly between kerf notches at the ends of the blocks. The position of the strings established the position of the sawlines that divided the panels into standard-width softwood dimension lumber. The criteria used to position the sawlines were to minimize visually the effect of defects in bending as a joist, and to obtain as nearly as possible the same number and mix of pieces of lumber that were obtained by the standard process.

Although it was unnecessary to plane the edges, the lumber was planed on both wide faces to the standard softwood dimension lumber thickness of 1-1/2 in. Table I shows the number of pieces of dimension lumber the 20 panels yielded and the number of gluelines.

After machining, the EGAR lumber was stored under conditions to maintain an EMC of 12 pct.

Glue Bond Quality

The quality of the bonds developed in the EGAR lumber was evaluated with a slightly

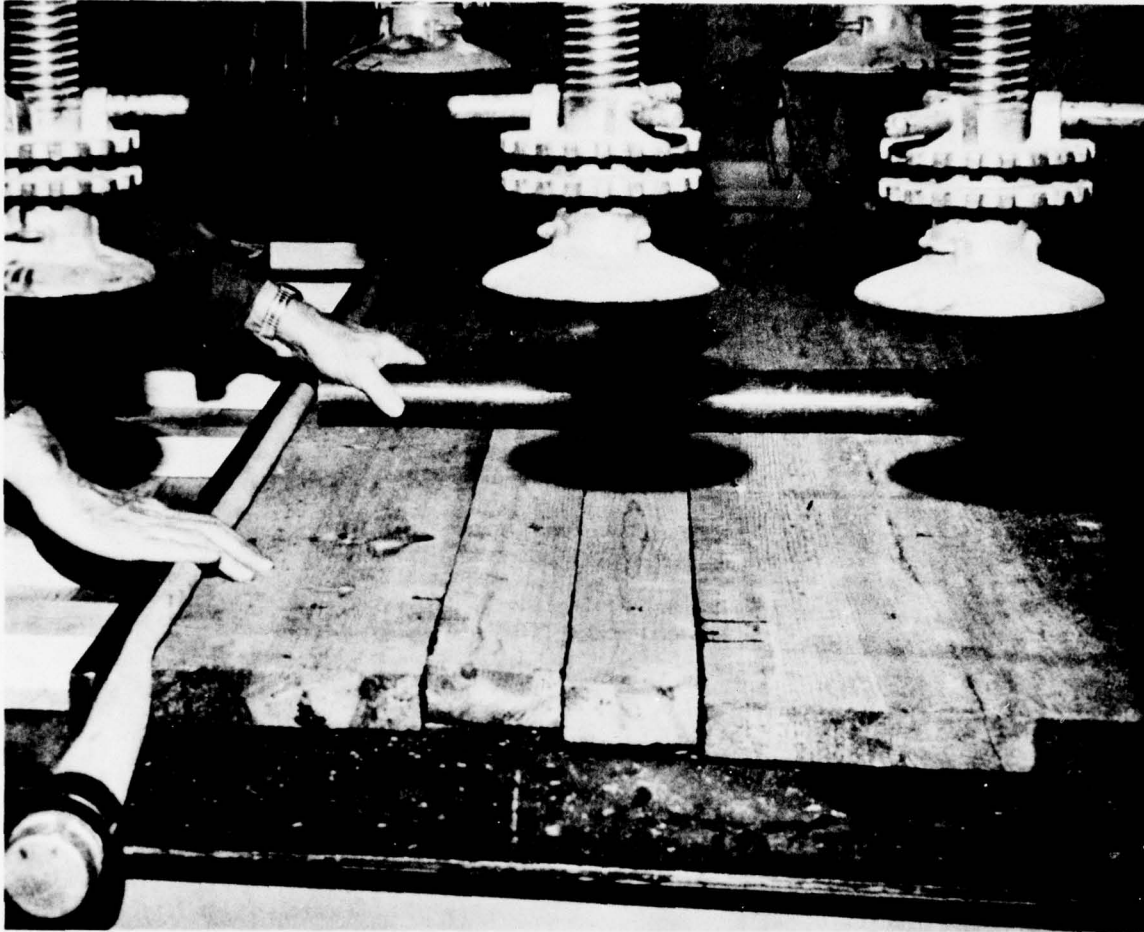


Figure 5.--Assembly of dry and edged EGAR flitches in glue press. Fire hose at left side of panel applied 100 to 125 lb/in.² of air pressure. Overhead clamps restrained tendency to buckle.

(M 144 852-7)

Table 1.--Finished 8-ft EGAR lumber from 20 panels

Size	Number of pieces	Number of gluelines			
		0	1	2	3
2 by 4	35	23	12	--	--
2 by 6	30	13	12	5	--
2 by 8	24	8	14	2	--
2 by 10	22	3	12	6	1
2 by 12	6	1	1	3	1
Total	117	48	51	16	2

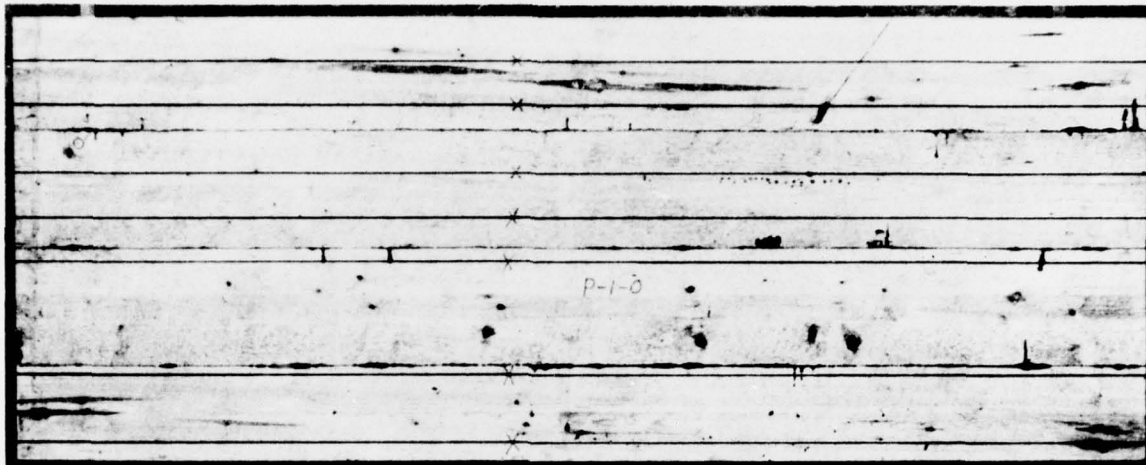


Figure 6.--Edge-glued panel marked for ripping to standard softwood dimension widths of four 4-in., two 6-in., one 10-in. and a recyclable strip 1-1/2-in. wide.

(M 141 703)

modified version of ASTM D-905.⁴ Normally the test specimen would be cut so that the shear area under test is 2 in. across the grain and 1-1/2 in. along the grain. However, the best that could be done in this instance with EGAR material was a specimen 1-1/2 in. across the grain and 2 in. along the grain. This slight modification is expected to yield slightly higher shear stresses than the standard shear block results, but there should be no effect on wood failure.

The material for evaluation was obtained by selecting at random 15 pieces containing gluelines, with at least 1 in. of wood on either side of the glueline. The 1-1/2-in. strip with the glueline centrally located was ripped from each piece. Rough blocks were then crosscut from this strip--one near each end, one at the center of the length, and two more at the third points. In a few cases, these positions had to be changed slightly to avoid knots and local grain deviations. A total of five blocks were thus cut from each strip. The blocks were then notched to fit the test apparatus and stored at 80° F and 65 percent relative humidity (RH) until tested. The moisture content of the wood at the time of testing was approximately 12 pct.

The block shear specimens were tested to failure. The maximum load attained and the estimated percentage wood failure were recorded for each specimen.

Mechanical Properties

Mechanical properties examined to permit comparison between EGAR and standard lumber were limited to modulus of rupture and modulus of elasticity. Additional properties of the lumber measured included: weight, dimensions, and estimated visual grading bending strength ratio.

In addition to visual grading, other non-destructive techniques for grading EGAR lumber may become of interest. One is machine stress grading (MSR) which uses static bending modulus of elasticity as the normal standard for quality control. Therefore modulus of elasticity measurements using different techniques of current interest were made to estimate static bending modulus of elasticity (ESB). These included two dynamic measurements: Flexural vibration flatwise (EDB) and impact stress waves lengthwise (ESW) as defined previously.⁵

⁴American Society for Testing and Materials. 1949. Strength properties of adhesives in shear by compression loading. ASTM D 905-49.

⁵Gerhards, C. C. 1975. Stress wave speed and MOE of sweetgum ranging from 150 to 15 percent MC. For. Prod. J. 25(4) :51-57.

Bending strength ratio (SR) was determined by the displacement method of ASTM D 245.⁶ Modulus of rupture was measured in a static bending test according to ASTM D 198.⁷ In the static bending test, specimens were loaded edgewise at the third-points on an 84-in. support span. Because the wider widths would likely have failed in shear, only the 2 by 4's and 2 by 6's were statically tested. Each 2 by 4 or 2 by 6 was randomly oriented so that the "worst edge" had an equal chance of being stressed in tension or compression. The 2 by 6's were also laterally supported during the static test.

ESB was determined in conjunction with the static bending tests of 2 by 4's and 2 by 6's. EDB and ESW were determined on all widths.

After the 2 by 4 and 2 by 6 specimens were tested in bending, a 1-in. thick wafer, free of knots and pitch, was cut from a point near the failure area to determine the moisture content (MC).

⁶ American Society for Testing and Materials. 1974. Standard methods for establishing structural grades and related allowable properties for visually graded lumber. ASTM D 245-70.

⁷ American Society for Testing and Materials. 1974. Standard methods of static tests of timbers and structural sizes. ASTM D 198-67.

RESULTS AND DISCUSSION

Yield of Green Dimension

The green flitches from the 20 subgroups yielded 35 pieces of 2 by 4, 26 pieces of 2 by 6, 23 pieces of 2 by 8, 20 pieces of 2 by 10, and six pieces of 2 by 12, for a total of 110 pieces of standard lumber.

Yield of Finished Lumber

The yield in dry finished lumber, plus 22 in. of usable edge strips that could be recycled in additional panels by the EGAR system, was 89 pct of the total green flitch width. The yield of dry finished lumber by the standard system was 81 pct of the total green flitch width.

Starting with the same width of green flitches, EGAR produced 10 pct more footage of finished dimension lumber than the standard system. An analysis of variance indicated that this difference in yield was significant at the 5 pct level. Even without recycling the 22 in. of edge strips, the advantage for EGAR is a 7 pct greater yield. If wider lumber were a specialty, fewer sawcuts would be made in the

EGAR panels and the advantage would be slightly higher.

By the EGAR system, shrinkage during drying accounted for most of the difference between total green flitch width and total lumber width. Total loss from ripping, including saw kerf and strips too narrow to recycle, was just under 2 pct of the total panel width before ripping. Edging to eliminate wane on EGAR flitches and standard lumber sometimes resulted in less than the measured width between bark lines, particularly when unedged flitches had some crook. This accounted for an additional small reduction in yield.

In retrospect, when determining the flitch width, it would have been better to have used long straightedges to lay out edging sawlines of the green flitches. Since both EGAR and standard flitches were treated in the same way, no bias was introduced influencing the yield by one system more than the other.

The yield of finished lumber for both the EGAR and standard systems is shown in table 2.

Lumber Grade

The lumber was graded by an inspector of the Timber Products Inspection and Testing Service, Inc.⁸

The percentage of pieces falling into each grade is shown in table 3. An analysis of variance of the grade yield indicated that the apparent superiority of EGAR lumber was not statistically significant at the 5 pct level. The EGAR lumber, however, graded 92 pct No. 1 or better compared to 86 pct for the standard lumber. Also, there was more EGAR lumber in the Select Structural grade.

When the EGAR panels were marked for ripping, location of defects was one criterion for placing riplines to reduce the effect of knots on grade. In addition, approximately the same number of pieces by width were intentionally produced from EGAR panels as were produced by the standard method. If the decisions could have been made without limitation on number of pieces by width, probably the overall grade average for lumber produced by the EGAR process could have been raised.

A higher proportion of 8-, 10-, and 12-in. widths would permit larger knots to be accepted under the knot size rules, thereby improving the grade. It is possible in practice,

⁸Timber Products Inspection and Testing Service, Inc., Eastern Division, P.O. Box 456, Lithonia, Ga. 30058.

Table 2.--Summary of yield of finished lumber from 20 subgroups of standard and EGAR systems

System	Total width		Yield of dry lumber compared to green flitch widths
	Green flitches	Dry finished lumber ¹	
	In.	In.	Pct
Standard	850.8	686.5	80.7
EGAR	850.1	756.9	89.0

¹EGAR includes usable strips and losses due to edging mistakes.

Table 3.--Percentage of total number of pieces by widths, systems, and SPIB grades

Width	System	Lumber grade					
		Select structural	No. 1	No. 2	No. 3	Standard	Economy
<u>In.</u>							
4	Standard	11.8	11.8	6.4	0.9	0.9	--
	EGAR	24.6	4.4	.9	1.8	--	--
6	Standard	16.4	4.6	2.7	--	--	--
	EGAR	18.4	2.6	1.8	1.8	--	--
8	Standard	16.4	2.7	.9	--	--	0.9
	EGAR	13.2	5.3	.9	--	--	--
10	Standard	15.5	2.7	--	--	--	--
	EGAR	15.8	2.6	.9	--	--	--
12	Standard	4.6	--	.9	--	--	--
	EGAR	3.5	1.8	--	--	--	--
Total ¹	Standard	64.5	21.8	10.9	.9	.9	.9
	EGAR	75.4	16.7	4.4	3.6	--	--

¹Total may not agree with sum of lumber grade columns because of rounding.

however, that market demand for certain widths might influence the ripping pattern and in some instances might result in a lower grade yield than the theoretical maximum.

Warp

EGAR lumber had less warp than standard lumber in most sizes and warp categories

(table 4). However, an analysis of variance indicated that differences were not significant at the 5 pct level. It had been anticipated that, because the EGAR lumber was first dried, edged, assembled into panels, and then ripped, it would be freer from warp than lumber made by the standard system (edged while green, dried, and planed).

Table 4.--Comparison of warp in 8-ft lumber produced by Standard and EGAR systems

Warp	Board Width	Average warp (per piece in 1/32-in. increments)	
		Standard	EGAR
Bow	In.		
	4	4.08	1.77
	6	3.11	1.93
	8	2.34	1.88
	10	1.95	1.18
	12	1.50	1.67
	All pieces	2.96	1.71
Crook	4	3.77	2.11
	6	2.38	1.53
	8	.70	.33
	10	.65	.09
	12	1.83	.00
	All pieces	2.13	1.11
Twist	4	1.62	1.82
	6	2.92	2.90
	8	5.48	3.25
	10	5.70	5.00
	12	6.33	8.00
	All pieces	3.73	3.30

Glue Joint Bonding Quality

Of the 15 gluelines tested, 13 met the requirements of ASTM D-2559⁹ (table 5). On this basis, gluelines 5-4 and 6-4 failed to meet the minimum average shear strength requirement, and 5-4 also failed to meet the minimum average wood failure requirement.

Both of these joints were examples of what appeared to be a primary problem in the process used. The problem arose because as the flitches dried, some cupped. When the cupped flitches were edged with the straight-line rip saw, the cut was not always at right angles to the faces, nor were the edges parallel to each other. As a result, when the flitches were laid up into panels and pressure applied to them, the bonding surfaces did not fit properly and wedge-shaped gluelines were formed. Such thick and thin gluelines are generally weaker than a properly formed joint. The joints in 5-4 and 6-4 were observed to be of the wedge type.

It is probable that the flitches can be ripped to minimize the thick and thin gluelines. Then edge gluing of the flitches into panels should present no technical gluing problems.

Although no attempts were made to measure durability, no problems are anticipated because of the type of adhesive used and the generally high strength and wood failure results obtained.

Mechanical Properties

The average static mechanical properties of the EGAR lumber sample were significantly higher than those for the standard lumber

⁹At 12 pct moisture content for southern pine, an average shear strength of 1,310 lbs/in.² and 75 pct average wood failure is required.

¹⁰American Society for Testing and Materials. Standard specification for adhesives for structural laminated wood products for use under exterior (wet use) exposure conditions. ASTM D-2559.

Table 5.--Summary of results of block shear tests¹ on gluelines in EGAR material

Board No.	Unit stress	Wood failure
	Lb/in. ²	Pct
1-0	1,360	78
2-4	1,480	76
3-0	1,420	92
4-4	1,450	76
5-4	480	61
6-4	1,260	82
7-4	1,680	99
8-3	1,580	83
10-3	1,600	95
12-3	1,360	89
13-2	1,420	97
14-2	1,690	88
15-2	1,660	94
18-1	1,400	78
20-1	1,540	89

¹Each value in the table is the average of 5 block shear tests

sample in the 2 by 4 size but not in the 2 by 6 size (tables 6 and 7). With the data from both sizes combined, modulus of rupture averaged 14 pct higher for the EGAR lumber than for the standard lumber; strength ratio was 8 pct higher and static modulus of elasticity 5 pct higher.

Based on covariance analysis, strength ratio and modulus of elasticity differences account for most of the modulus of rupture difference between the EGAR and the standard lumber specimens. In the covariance analysis with strength ratio and modulus of elasticity as covariates, common slope and common intercept hypotheses pertaining to regressions through the four sets of data (standard 2 by 4's, standard 2 by 6's, EGAR 2 by 4's, and EGAR 2 by 6's) could not be rejected at the 1 percent level of significance. The common regression for the four sets of data with modulus of rupture in 1,000 lbs/in.², modulus of elasticity in million lbs/in.², and strength ratio in pct is

$$\text{MOR} = -5.84 + 5.22 \text{ ESB} + 0.0641 \text{ SR}$$

Table 6.--Average properties of EGAR and standard lumber 2 by 4 and 2 by 6 specimens

Lumber type	Size	Number of specimens	Averages				
			Moisture content	Density	Static modulus of elasticity	Bending strength ratio	Modulus of rupture
			Pct	Lb/ft ³	Million lb/in. ²	Pct	1,000 lb/in. ²
Standard	2 by 4	41	10.3	33.1	1.75	72	7.64
EGAR	2 by 4	39	10.9	36.0	1.97	86	9.90
Standard	2 by 6	31	10.3	35.6	1.89	84	9.33
EGAR	2 by 6	31	10.7	35.6	1.81	80	9.12
Standard	2 by 4 and 2 by 6	72	10.3	34.3	1.81	77	8.37
EGAR	2 by 4 and 2 by 6	70	10.8	35.8	1.90	83	9.55

Table 7.--Pooled variances, t-values, and degrees of freedom for testing significant differences between EGAR and standard lumber specimen properties¹

Lumber size	Pooled degrees of freedom	Pooled variance (above) and student's t (below) for comparing differences in		
		Static modulus of elasticity	Bending strength ratio	Modulus of rupture
2 by 4	78	0.15990 2.460**	38.264 3.200***	12.417 2.867***
2 by 6	60	.17642 .750	30.162 .907	11.821 .240
2 by 4 and 2 by 6	138	.16708 1.302	34.741 1.904	12.158' 2.002*

¹Significance levels of t-values--*5 pct, **2 pct, and ***1 pct.

Coefficient of determination (R^2) was 0.71 and standard error of estimate was 1.94. For comparison, R^2 for the simple regressions of MOR on ESB and MOR on SR were 0.62 and 0.44, respectively.

Besides implying that the difference in modulus of rupture between EGAR and standard lumber specimens could largely be explained by strength ratio and modulus of elasticity differences, the common regression also implies comparable strength for comparable strength ratio or modulus of elasticity values regardless of lumber processing type. A further implication is that EGAR lumber strength potentially can be optimized in the EGAR process by optimizing, as noted previously, on strength ratio--a function of knot size and location.

Dynamic methods of determining modulus of elasticity yielded results somewhat different than the static method (table 8), with

lower values by the flatwise dynamic method (EDB) and higher values by the stress-wave method (ESW). Regardless of absolute differences, correlation was good among the three types of moduli of elasticity, suggesting the machine stress rating potential of the dynamic methods.

Either type of dynamic modulus of elasticity in conjunction with bending strength ratio yielded multiple regressions with bending strength as good as the multiple regression containing the static modulus of elasticity. Multiple regressions were

$$\text{MOR} = -6.26 + 6.14 \text{ EDB} + 0.0574 \text{ SR}$$

$$\text{MOR} = -7.73 + 5.36 \text{ ESW} + 0.0693 \text{ SR}$$

with units as before. R^2 values were 0.74 and 0.72 and standard errors of estimate were 1.84 and 1.90, respectively.

Table 8.--Comparison of modulus of elasticity measurement methods for EGAR and standard (SS) lumber specimens¹

Lumber type	Number of specimens	Averages			Ratio of averages		
		EDB	ESW	ESB	EDB ESB	ESW ESB	ESW EDB
		Million lb/in. ²	Million lb/in. ²	Million lb/in. ²			
SS 2 by 4	41	1.59	1.97	1.75	0.91	1.13	1.23
EGAR 2 by 4	39	1.81	2.16	1.97	.92	1.10	1.19
SS 2 by 6	31	1.79	2.15	1.89	.95	1.14	1.20
EGAR 2 by 6	31	1.75	2.07	1.81	.97	1.14	1.18
SS 2 by 8	25	1.75	2.11	--	--	--	1.20
EGAR 2 by 8	24	1.64	2.04	--	--	--	1.24
SS 2 by 10	24	1.78	2.16	--	--	--	1.21
EGAR 2 by 10	24	1.80	2.24	--	--	--	1.24
SS 2 by 12	7	1.94	2.22	--	--	--	1.14
EGAR 2 by 12	7	1.55	1.97	--	--	--	1.27

¹EDB, dynamic flatwise bending; ESW, stress wave; ESB, edgewise static bending

CONCLUSIONS

(1) The system for manufacturing southern yellow pine dimension lumber by the Edge-Glue-and-Rip system is entirely feasible using current technology and equipment.

(2) Analysis of variance for the two systems--standard and EGAR--for board-foot yield indicated a statistically significant increase in overall yield of 10 percent for the EGAR system. Both warp and grade showed a numerical superiority in favor of EGAR, but in neither case was the difference statistically significant.

(3) If the flitches can be edged to give surfaces that fit together properly, edge-gluing 8/4 southern pine into panels for the EGAR system will present no problem.

(4) Some of the EGAR lumber had higher static bending properties than the standard lumber. The higher bending strength of the EGAR lumber, however, was mostly attributed to higher bending strength ratios (a lumber quality characteristic that can be controlled by selective ripping of EGAR panels) and higher moduli of elasticity.

U.S. Forest Products Laboratory.

Yield and strength of softwood dimension lumber produced by EGAR system, by Kenneth C. Compton, Hiram Hallock, Charles Gerhards, and Ronald Jokerst. Madison, Wis., FPL, 1977.

13 p. (USDA For. Serv. Res. Pap. FPL 293).

The EGAR (Edge-Glue-and-Rip) system uses the full width of a flitch by live sawing logs, drying the flitches, ripping them to the widest possible width, edge gluing them into panels, and ripping the panels to final dry widths for softwood dimension lumber. A 10 percent increase in yield was recorded over standard lumber.

U.S. Forest Products Laboratory.

Yield and strength of softwood dimension lumber produced by EGAR system, by Kenneth C. Compton, Hiram Hallock, Charles Gerhards, and Ronald Jokerst. Madison, Wis., FPL 1977.

13 p. (USDA For. Serv. Res. Pap. FPL 293).

The EGAR (Edge-Glue-and-Rip) system uses the full width of a flitch by live sawing logs, drying the flitches, ripping them to the widest possible width, edge gluing them into panels, and ripping the panels to final dry widths for softwood dimension lumber. A 10 percent increase in yield was recorded over standard lumber.

U.S. Forest Products Laboratory.

Yield and strength of softwood dimension lumber produced by EGAR system, by Kenneth C. Compton, Hiram Hallock, Charles Gerhards, and Ronald Jokerst. Madison, Wis., FPL, 1977.

13 p. (USDA For. Serv. Res. Pap. FPL 293).

The EGAR (Edge-Glue-and-Rip) system uses the full width of a flitch by live sawing logs, drying the flitches, ripping them to the widest possible width, edge gluing them into panels, and ripping the panels to final dry widths for softwood dimension lumber. A 10 percent increase in yield was recorded over standard lumber.

U.S. Forest Products Laboratory.

Yield and strength of softwood dimension lumber produced by EGAR system, by Kenneth C. Compton, Hiram Hallock, Charles Gerhards, and Ronald Jokerst. Madison, Wis., FPL 1977.

13 p. (USDA For. Serv. Res. Pap. FPL 293).

The EGAR (Edge-Glue-and-Rip) system uses the full width of a flitch by live sawing logs, drying the flitches, ripping them to the widest possible width, edge gluing them into panels, and ripping the panels to final dry widths for softwood dimension lumber. A 10 percent increase in yield was recorded over standard lumber.