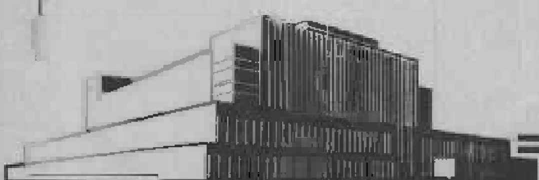
EFFECT OF CLAMP SPACING ON THE QUALITY OF GLUE BOND IN LAMINATED WHITE OAK TIMBERS GLUED WITH AN INTERMEDIATE-TEMPERATURE-SETTING PHENOL-RESIN GLUE

Information Reviewed and Reaffirmed

March 1956

No. 1670



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UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE

In Cooperation with the University of Wisconsin

EFFECT OF CLAMP SPACING ON THE QUALITY OF GLUE BOND IN LAMINATED WHITE OAK TIMBERS GLUED WITH AN INTERMEDIATE-TEMPERATURE-SETTING PHENOL-RESIN GLUE[1]

By

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To obtain good bonds in glued laminated timbers the pressure over the glued areas should be uniform and adequate. Thin laminations do not distribute pressure effectively very far from the point of application, while thick laminations distribute gluing pressure over a larger area and make the whole assembly stiffer. Even with thick laminations, however, it is common practice to employ cauls on the tops and bottoms of the assemblies to provide better distribution of gluing pressure. Clamps are placed at regular spacings over the cauls. By this means the pressure is more uniformly distributed over the glued areas, but the pressure immediately under the clamps is higher than at areas between clamps.

When a wide assembly is clamped, it is usually necessary to use narrow clamp spacings to obtain the required average pressure. When the clamps are spaced sufficiently close together there is no need to use heavy cauls. For a narrow assembly, however, the clamps may be spaced relatively far apart and still furnish the required total pressure if heavy cauls are used to distribute the pressure. Use of heavy cauls, which necessitates fewer clamps, reduces the clamping time. Heavy cauls, on the other hand, slightly delay the transfer of heat to a beam being cured at elevated temperature in a heated chamber.

It is important to know how far apart the clamps may be placed, when cauls and laminations of a certain thickness are used, without decreasing the quality of the glue bond. This report gives the results of studies on that question conducted at the Forest Products Laboratory.

Material Glued

Eleven straight beams were glued, each consisting of 14 laminations, 3/8 by 5-1/2 inches in cross section and long enough to allow for clamp spacings as shown in table 1. The laminations were of white oak lumber averaging approximately 0.61 in density based on weight when oven dry and volume at 12 percent moisture content; the cauls were also of white oak.

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[1]The work here reported was conducted in cooperation with the Bureau of Ships, U. S. Navy.

The wood was conditioned to approximately 12 percent moisture content before gluing.

Glue and Gluing Conditions

An intermediate-temperature-setting phenol resin was applied by double spreading on a mechanical spreader at approximately 60 pounds per 1,000 square feet of single glue line. Three thicknesses of cauls were used. The beams were assembled in pressure-equalizing-head retaining clamps 3 inches wide. An average pressure of 150 pounds per square inch was applied after a closed assembly period of about 60 minutes. Three retaining clamps were used for each beam. The distribution of the clamps is illustrated in figure 1. The caul thickness and clamp spacings are given in table 1. One beam was glued for each caul and spacing condition.

Curing

To cure the glue, the clamped assemblies were held in a chamber heated at 210° F. with 80 percent relative humidity for 18 hours.

Testing

The glued beams were conditioned at 80° F. and 65 percent relative humidity for 2 weeks, and then five sections were cut from each beam, three from directly under clamps and two from mid-points between clamps. These sections were cut into 13 shear blocks each, so that a total of 65 shear tests were made on each beam.

The remaining sections of each beam were subjected to cyclic soaking-drying tests, each cycle consisting of 30 days' soaking in fresh water at room temperature followed by 30 days' drying at 80° F. and 30 percent relative humidity.

The thickness of each beam directly under the clamps and at mid-points between clamps was also measured after the conditioning period.

Results

The average results of the shear tests and of the measurements of the thickness variations in the beams are given in table 2.

For 8 of the 11 beams, the shear strengths and percentage of wood failure of joints under the clamps were higher than those of joints between the clamps. For all 11 beams the joints under the clamps averaged about 80 pounds per square inch more in shear strength and 8 percent more in wood failure than the joints between the clamps.

For each caul thickness, excellent wood failures were obtained at the high pressure points (under the clamps). At the low pressure points (between the clamps) there was a gradual decrease in wood failure values with increase in clamp spacing (decrease in pressure). This was most pronounced with the thinnest caul.

With the 3/8-inch caul, percentages of wood failure at the low-pressure points were about the same for the 4-inch and 6-inch clamp spacing. With the 3/4-inch caul, the wood failures were very high with a clamp spacing of both 6 and 9 inches; and with the 2-inch caul with 6, 12, and 18 inch spacings.

In the last column of table 2 are given the results of the measurements of the thickness of the beams under and between the clamps. The greater the clamp spacing, the greater was this difference. It is interesting to note that at the clamp spacing limits of 4, 9, and 18 inches for the 3/8, 3/4, and 2-inch caul thicknesses, respectively, the thickness of the laminated block was approximately 0.07 inch greater at mid-points between clamps than at the clamps. The blocks contained 14 laminations and 13 glue lines, so that the average difference in glue line thickness between high- and low-pressure points at the designated spacings would have been approximately 0.005 inch, if there had been no compression of the wood. Inasmuch as there probably was some compression of the wood, the difference in glue line thickness was actually less.

In figure 2 the percentage of wood failure obtained in shear blocks taken at mid-points between clamps is plotted against caul thickness for three different clamp spacings. With 6-inch clamp spacing, the wood failures were more than 90 percent for all three caul thicknesses, although there was a slight decrease with the thinnest caul. With 12-inch clamp spacing, there was a sharp decrease in wood failure with the thinnest caul. Only two sizes of cauls were used with 9-inch spacing and the curve was extrapolated to the 2-inch caul thickness in accordance with the values for 6- and 12-inch clamp spacings.

In general, the graphs show that when it is necessary to increase the clamp spacing by reducing the number of clamps, the thickness of the cauls must be increased in order to achieve the required distribution of pressure.

In figures 3 to 8 are shown sections of the white oak beams prepared in this study after exposure to 6 cycles of soaking and drying.

In figure 3 are shown sections from a beam that was clamped at the time of gluing in 3/8-inch cauls, using 6 inches clear spacing between clamps. The sections in the upper part of the picture (marked H) were taken from high-pressure points (adjacent to clamps), and the sections in the lower part of the picture were taken from low-pressure points (near mid-points between clamps). After a year of soaking and drying the glue bond showed no evidence of deterioration in any of these sections, and it may be concluded that with a 6-inch spacing the pressure was sufficiently uniform to produce durable bonds throughout the beam.

In figure 4 similar sections taken from a beam made with 12-inch clamp spacing and 3/8-inch cauls are shown. The glue joints are intact in the sections taken from high-pressure points in the beam (upper part of picture), while those taken from low-pressure points had developed considerable delamination of glue joints. Consequently, a 12-inch clamp spacing did not furnish sufficiently uniform pressure to produce durable glue bonds throughout the beam.

In figures 5 and 6, sections are shown that were taken from beams made with 3/4-inch cauls and with 9- and 15-inch clamp spacings, respectively. With the 9-inch spacing (fig. 5) there is no noticeable difference in appearance of glue bonds between sections from high- and low-pressure points. With the 15-inch spacing, however, the integrity of the glue bonds in sections from high-pressure points appears superior to that in the sections from the low-pressure points.

In figures 7 and 8, sections are shown that were taken from beams made with 2-inch cauls and with 12- and 18-inch clamp spacings. With this caul thickness there is no appreciable difference between the performance of glue bonds in sections from high- and low-pressure points with either of the two clamp spacings.

A comparison of results from shear tests and cyclic . tests indicates that wood failures are far better criteria of adequate glue joints than shear strength. Even where the clamps were spaced too far apart to furnish adequate pressure at mid-points between clamps there was no consistent decrease in shear strength. The wood failures, however, showed a definite decrease (as shown in table 2 and fig. 2), and the inadequacy of the glue joints was confirmed in the cyclical tests (figs. 4 and 5).

Conclusions

The study herein reported indicates that in laminating straight members an average gluing pressure of 150 pounds per square inch gives uniformly good glue bonds provided the clamp spacings are not greater than the following values:

Thickness of caul (white oak)	Clamp spacing
Inches	Inches
2	18
3/4	9
3/8	6

While the particular phenol-resin glue used in these tests gave good glue bonds with the maximum spacings shown in the foregoing tabulation, it is possible that other glues might require or permit somewhat different spacings for satisfactory gluing, and that the use of somewhat shorter spacings might be desirable for better insurance of uniformity of glue bond.

Table 1.--Schedule of beams glued

Beam number	Caul thickness	Clear spacings between clamps (a)	Length of beam
	Inches	Inches	Inches
CS-1	2	18	63
CS-2	2	12	45
CS-3	2	6	27
CS-4	3/4	15	54
CS-5	3/4	12	45
CS-6	3/4	9	36
CS-7	3/4	6	27
CS-8	3/8	12	45
CS-9	3/8	9	36
CS-10	3/8	6	27
CS-11	3/8	4	21

All laminations 3/8 by 5-1/2 inches in cross section.

Table 2.--Results of shear tests on glue joints under clamps and at mid-points between clamps in laminated white oak beams[1] made with various caul thicknesses and clamp spacings

Clear spacing between clamps	Caul thickness	Average shear strength and wood failure under clamps[2]		Average shear strength and wood failure between clamps[3]		Thickness of beam between clamps minus thickness under clamps
Inches	Inches	Lb. per sq. in.	Percent	Lb. per sq. in.	Percent	Inch
18	2	2,003	97	1,927	94	0.067
12	2	1,774	92	1,797	95	.041
6	2	2,154	99	2,049	100	.004
15	3/4	2,062	93	1,956	79	.116
12	3/4	2,214	93	2,125	85	.107
9	3/4	2,424	95	2,477	94	.066
6	3/4	2,301	99	2,275	98	.052
12	3/8	2,199	97	1,907	65	.205
9	3/8	2,453	98	2,365	83	.197
6	3/8	2,243	99	2,154	92	.086
4	3/8	2,090	97	2,026	90	.067

[1]Each beam made of 14 laminations, 3/8 by 5-1/2 inches in cross section.

[2]Each value for shear strength and wood failure is the average of 39 tests.

[3]Each value for shear strength and wood failure is the average of 26 tests.

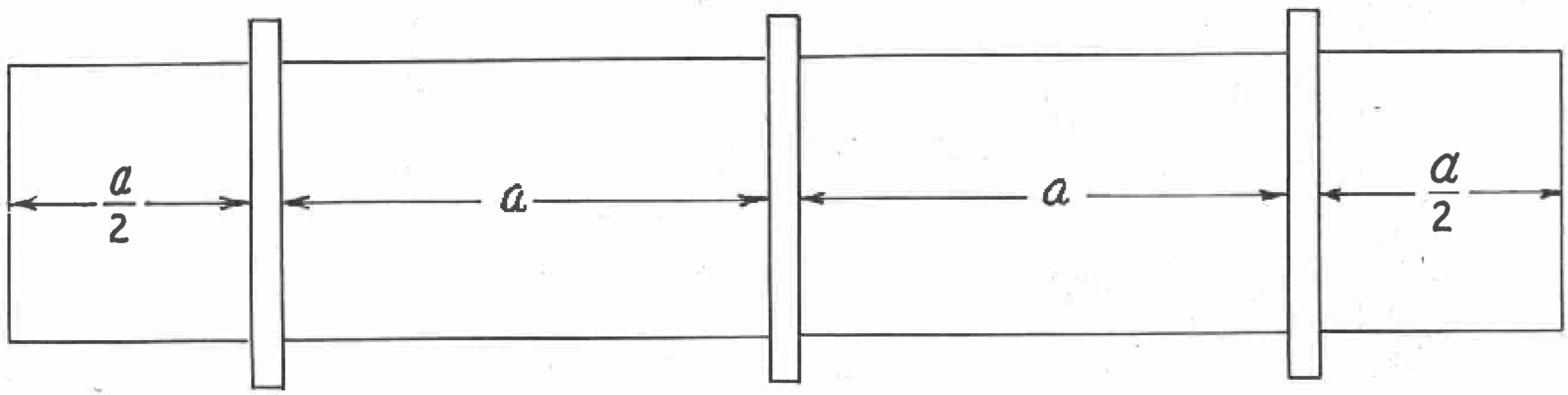

Figure 1.--Distribution of retaining clamps on beams (plan view). Values of a are given in the third column of table 1.

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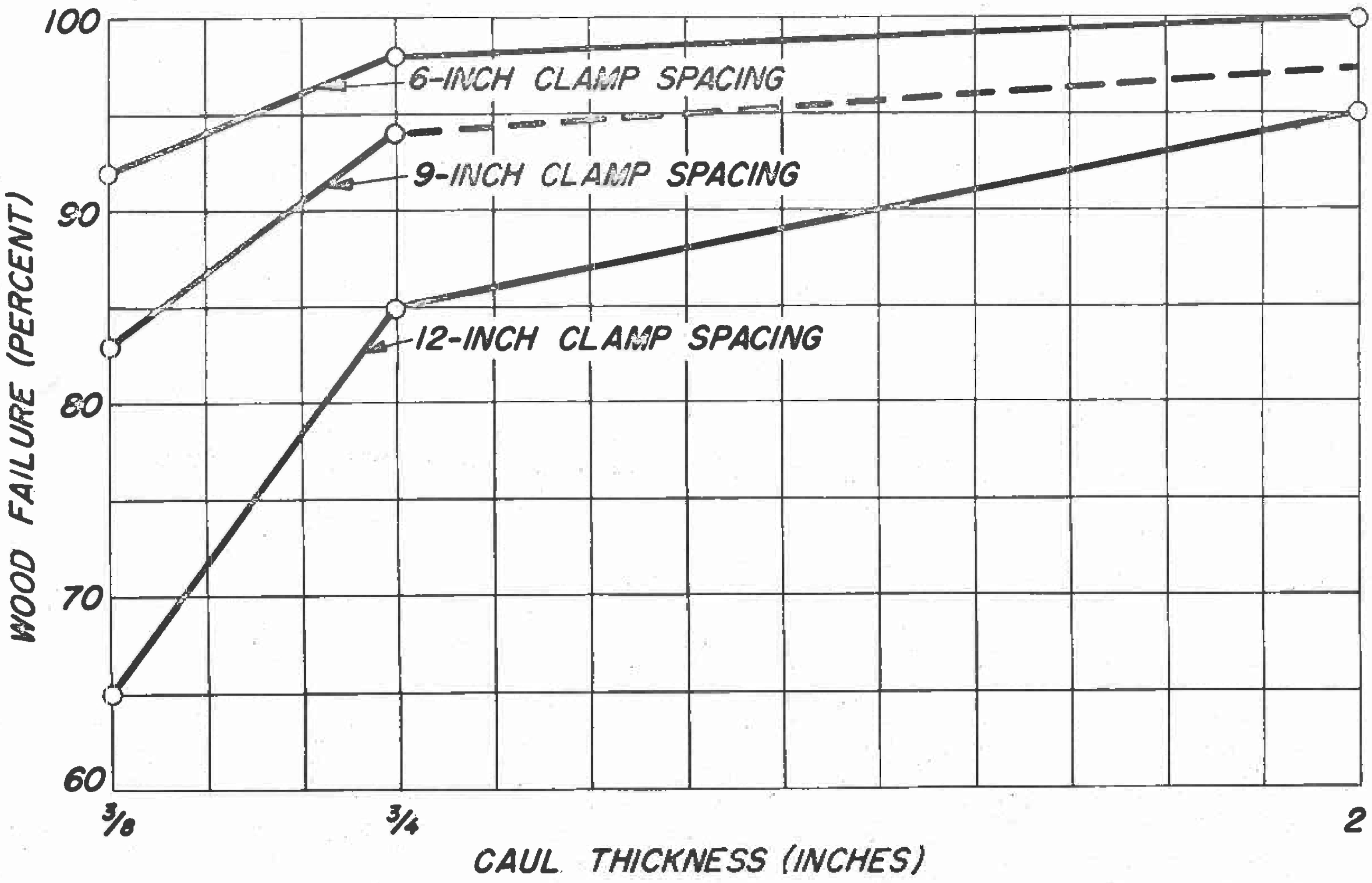

Figure 2.--Percentage wood failure in shear blocks taken from mid-points between clamps in laminated white oak beams pressed between white oak cauls of three different thicknesses with clamps at different spacings.

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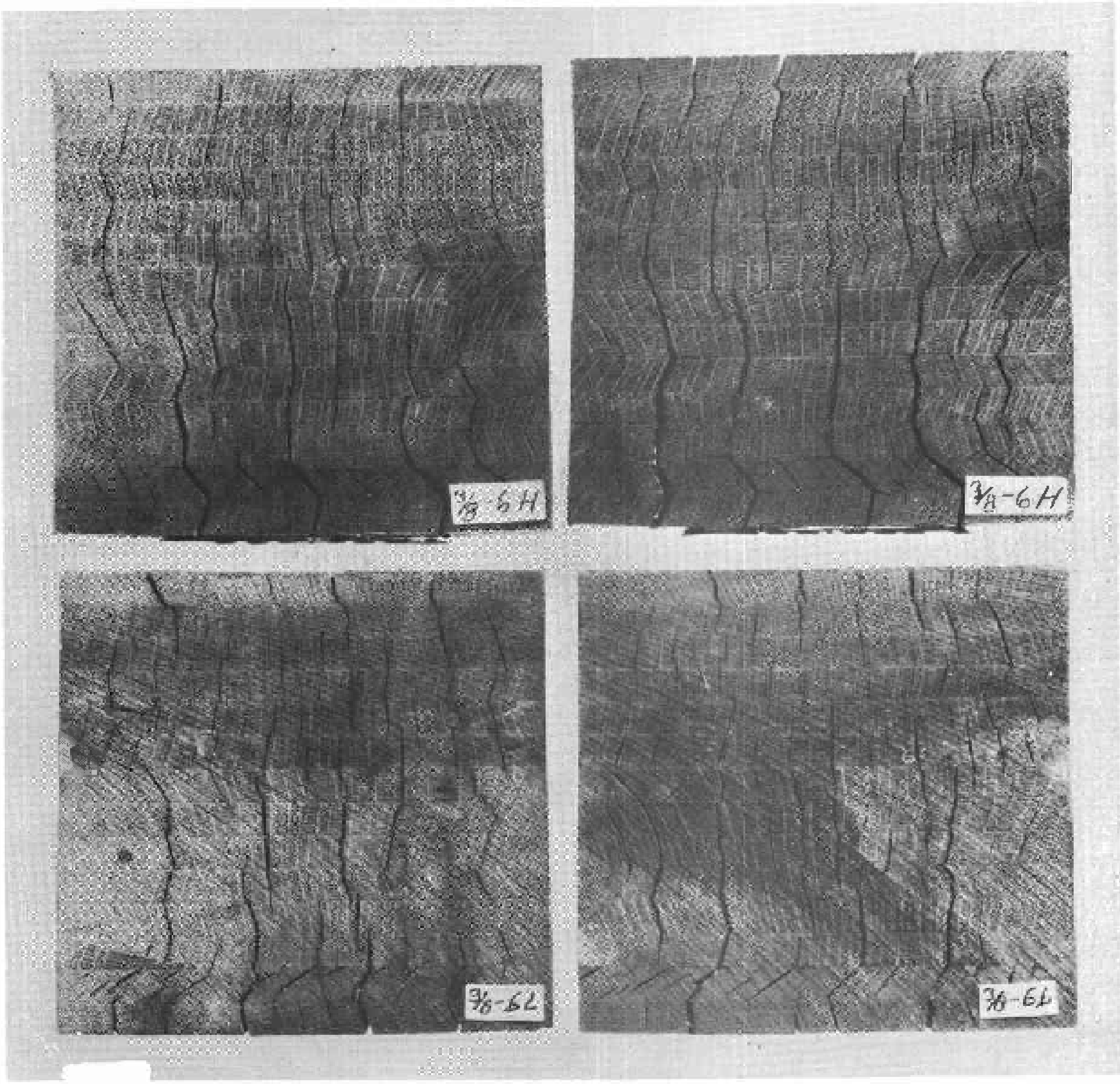

Figure 3.--Sections of laminated white oak beam pressed in retaining clamps using 3/8-inch oak cauls and 6-inch clear spacings between clamps.

The following description applies to figures 3 to 8 inclusive: Sections marked L were taken near the mid-points between clamps from low-pressure areas; those marked H were taken near the clamps from high-pressure areas. All sections were exposed to 6 cycles of soaking and drying. Each cycle consisted of 30 days' soaking at room temperature followed by 30 days' drying at 80° F. and 30 percent relative humidity.

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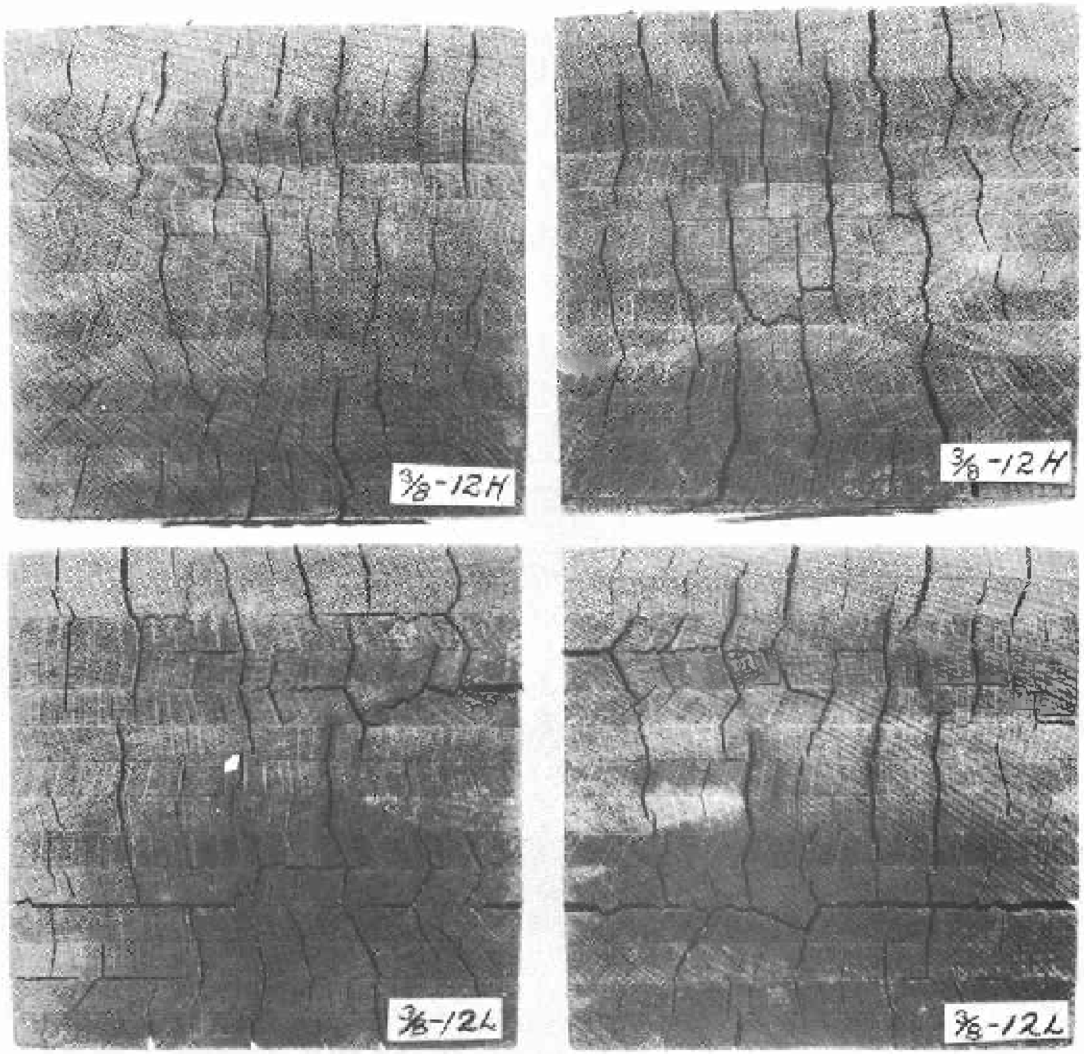

Figure 4.--Sections of laminated white oak beam pressed in retaining clamps using 3/8-inch oak cauls and 12-inch clear spacings between clamps. (L signifies low pressure; H, high pressure. See caption of fig. 3.)

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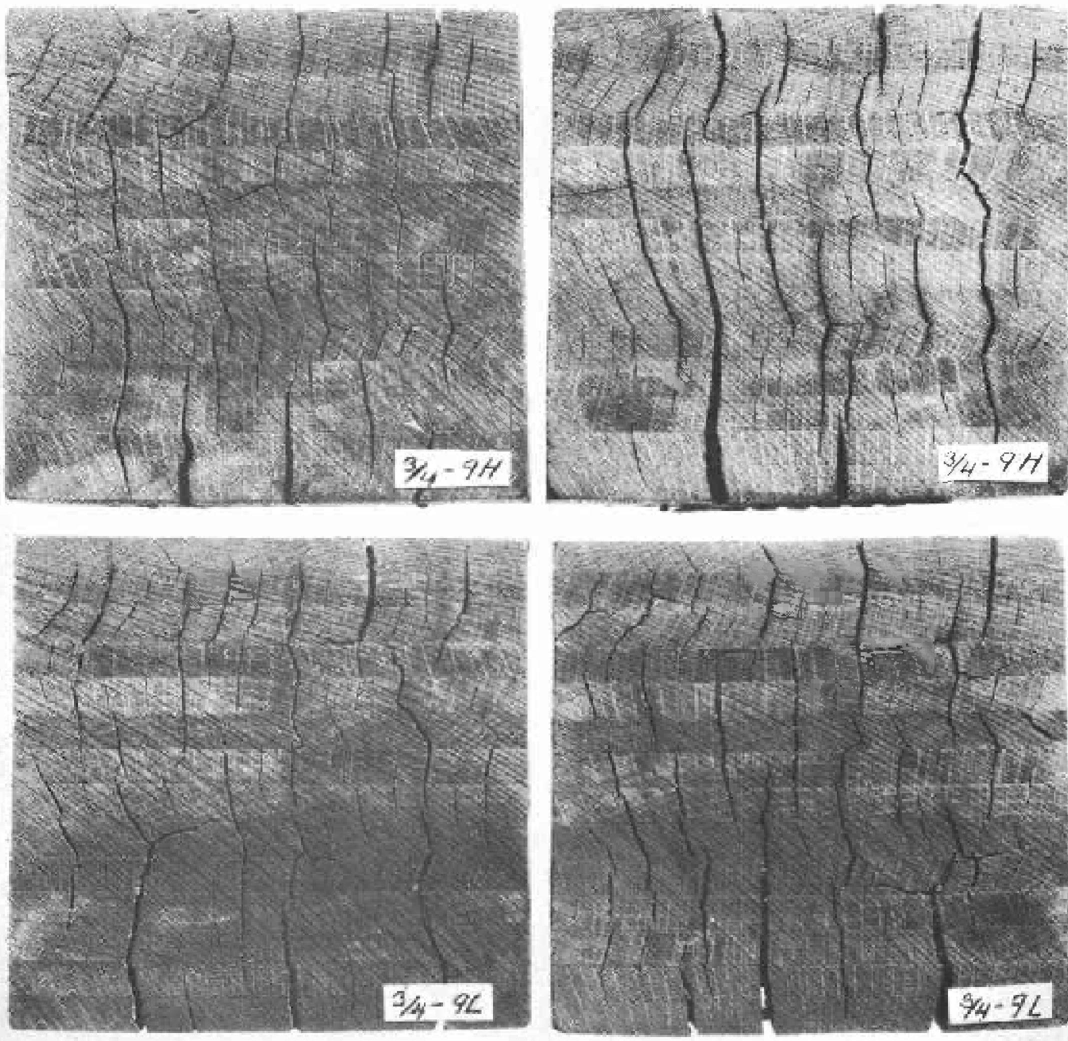

Figure 5.--Sections of laminated white oak beam pressed in retaining clamps using 3/4-inch oak cauls and 9-inch clear spacings between clamps. (L signifies low pressure; H, high pressure. See caption of fig. 3.)

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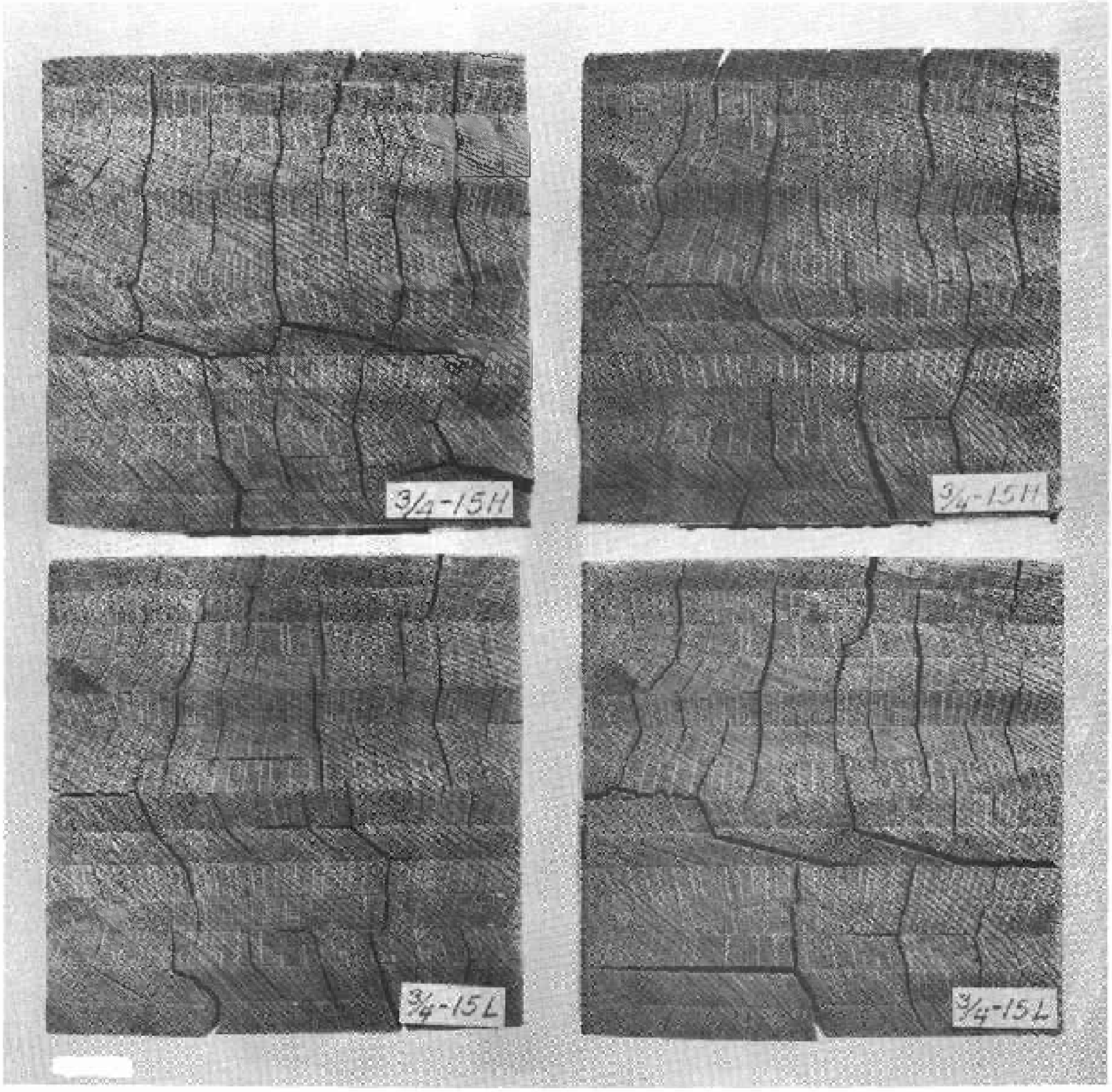

Figure 6.--Sections of laminated white oak beam pressed in retaining clamps and 3/4-inch cauls using 15-inch clear spacings between clamps. (L signifies low pressure; H, high pressure. See caption of fig. 3.)

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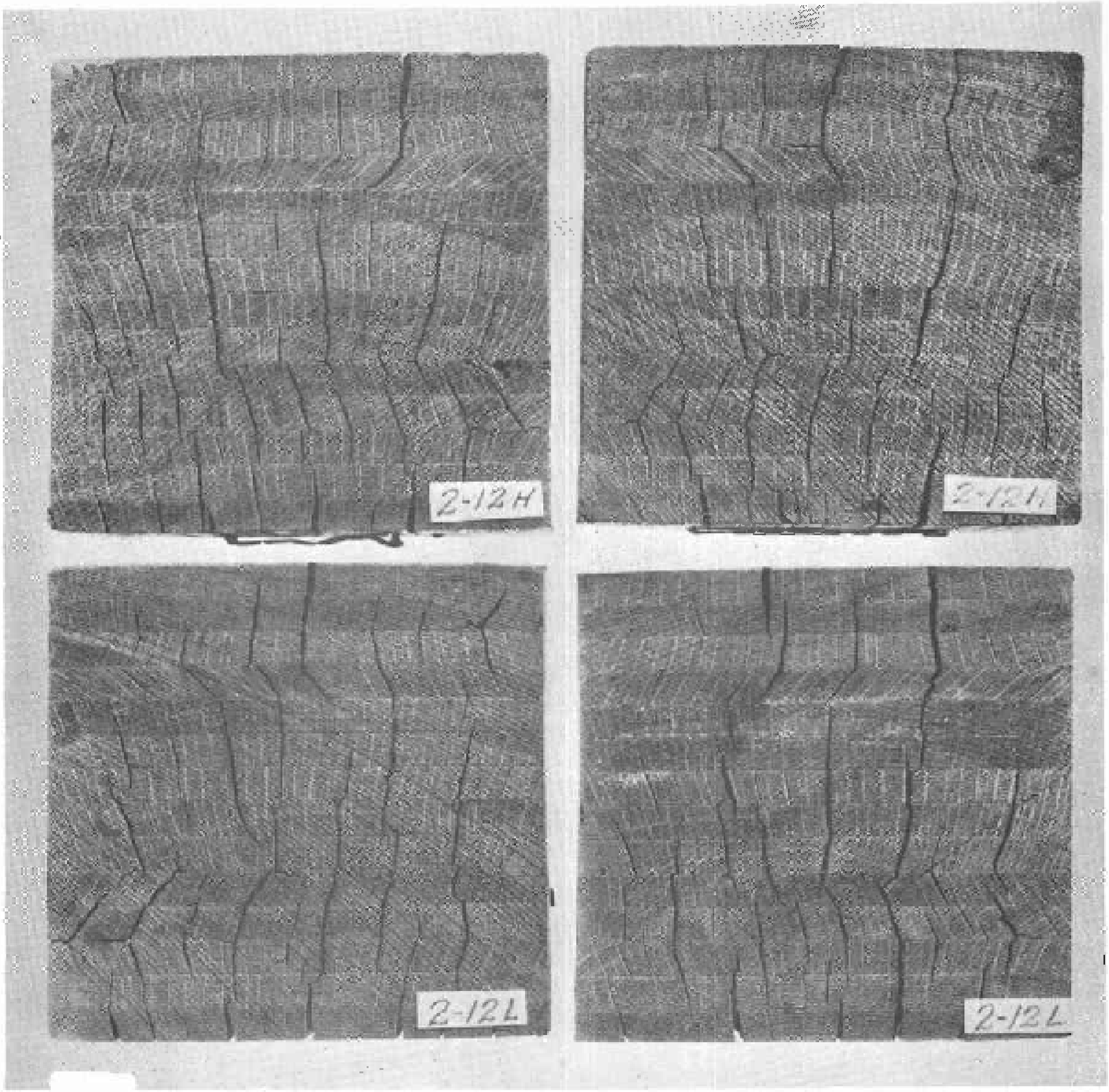

Figure 7.--Sections of laminated white oak beam pressed in retaining clamps using 2-inch cauls and 12-inch clear spacing between clamps. (L signifies low pressure; H, high pressure. See caption of fig. 3.)

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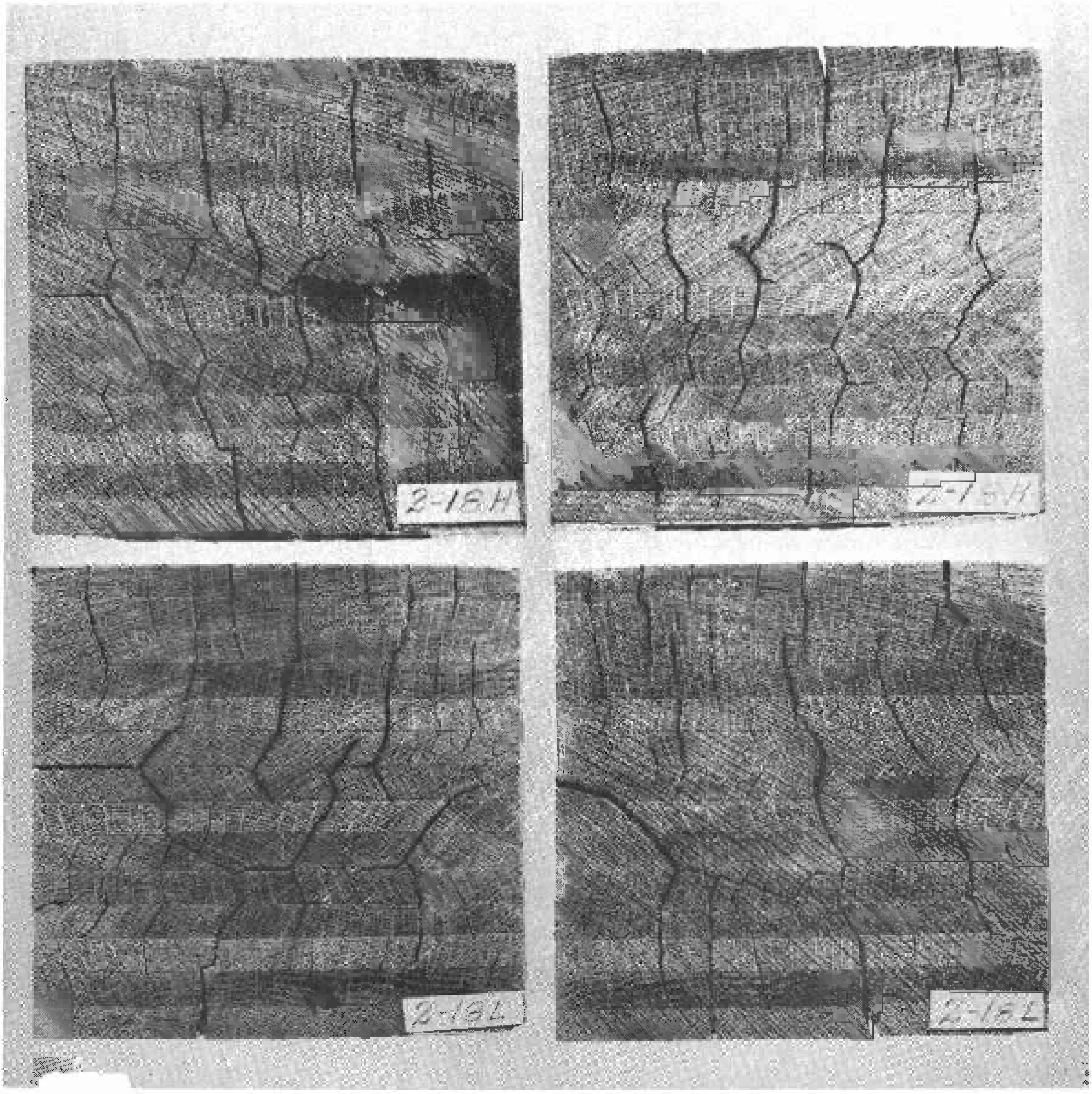

Figure 8.--Sections of laminated white oak beam pressed in retaining clamps using 2-inch cauls and 18-inch clear spacing between clamps. (L signifies low pressure; H, high pressure. See caption of fig. 3.)

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