

STRENGTH OF SCARF AND LAP JOINTS IN GLASS-FABRIC-BASE PLASTIC LAMINATES

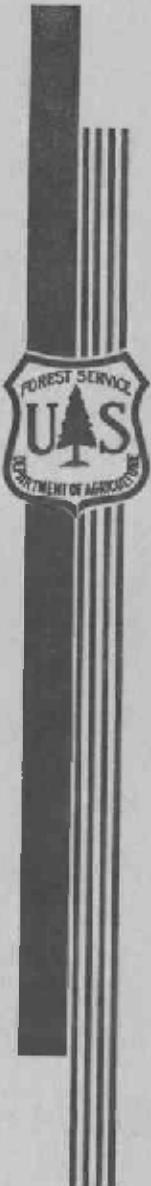
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UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE

In Cooperation with the University of Wisconsin

STRENGTH OF SCARF AND LAP JOINTS IN
GLASS-FABRIC-BASE PLASTIC LAMINATES¹

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Summary

Scarf joints and lap joints in two glass-fabric-base plastic laminates were tested in tension and in compression. In each case the joints were made between sections of the cured laminate. The scarf-joint tests involved a variety of gluing techniques and adhesives as well as a range of scarf slopes. The lap joints were made with several gluing techniques and in lengths up to 3-1/2 inches.

The scarf-joint tests indicated that the efficiencies that could be attained depended on the adhesive used and the technique of using it as well as on scarf slope. For a given slope, efficiencies appear to be higher in compression than in tension. Efficiencies in tension ranging up to 70 to 80 percent at a scarf slope of 1 in 28 were obtained with one adhesive when tested in the dry condition. After exposure to high humidity, efficiencies were about 10 percent

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²Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

lower than for joints tested in the dry conditions. Choice of a different adhesive permitted attainment of efficiencies as high as 90 percent in the dry condition and 80 percent in the wet condition at a slope of 1 in 20.

Lap joints are inefficient in transmitting tensile stress. Even with lap lengths of 3-1/2 inches, only about one-fourth to one-third of the tensile strength of the laminate could be developed. In compression, however, efficiencies of 60 to 80 percent were found at this lap length. At the 3-1/2-inch length, the majority of the specimens did not fail in the joint when tested in compression.

Introduction

The structural application of glass-fabric-base plastic laminates sometimes requires the joining, end to end, of two sheets of the cured laminate. Two of the methods available for making such joints are: (1) scarf joints, in which the feathered ends of two sheets are bonded with an adhesive; and (2) lap joints, in which overlapping surfaces of two sheets are bonded with an adhesive.

This report presents the results of tests to determine the strength in tension and in compression of joints of these types when used with laminates made from each of two different glass fabrics.

Scarf joints and lap joints made by "wet laminating" have been tested in other programs. For example, FPL Report No. 1584, "Repair of Aircraft Sandwich Constructions," discusses the results of tests in which glass cloth sandwich facings were repaired by wet laminating a patch to scarfed surfaces in a cured laminate. Similar tests are described in a supplementary report, No. 1584-A. In fabrication of glass cloth panels, fabric laps in one or more layers may occur corresponding to some extent to the lap joints tested in the program reported herein. Such tests are reported in FPL Report No. 1809, "Effect of Defects on Strength of Aircraft-Type Sandwich Panels" and FPL Report No. 1814, "Effect of Defects on the Tensile and Compressive Properties of a Glass-Fabric-Base Plastic Laminate." Wet laminating, to which these four reports refer, is not always practical, especially in repair, so that joints between cured laminates, as in the tests reported herein, become necessary.

Description of Material

Laminated panels were made from each of two types of glass fabric, 112-114 and 181-114, at the Forest Products Laboratory. Two 1/8- by 36- by 36-inch

panels and one 1/16- by 36- by 36-inch panel were made from each fabric. For all panels, the fabric was parallel-laminated and assembled with a typical polyester resin conforming with U.S. Air Force Specification 12049, Types I, II, and III. The resin, referred to herein as resin 2, was a high-temperature-setting, low-viscosity, laminating resin of the polyester (styrene-alkyd) type. It was catalyzed by the addition of 0.8 percent benzoyl peroxide by weight. The lay-up of fabric and resin was made between cellophane-covered aluminum cauls that were 1/4 inch thick. After impregnation and lay-up, each panel was cured at a pressure of 14 pounds per square inch for 1 hour and 40 minutes in a press at a temperature gradually increasing from 220° to 250° F. Pressure was applied by means of an oil-filled steel bladder located on the bottom platen of the press.

Upon completion of pressing, each panel was trimmed to size with a metal-cutting band saw. The panel was carefully weighed and measured, and the overall average resin content and specific gravity were calculated. Barcol hardness readings were made at various positions on each face of the panel. General information on each panel is summarized in table 1.

Preparation of Specimens

The cutting of each panel was arranged so that the warp of the laminations would be parallel to the long direction of the final specimen. The laminate was cut with a 1/8-inch emery wheel rotated at 1,770 revolutions per minute in the arbor of a variable-speed table saw.

Each large panel was cut into smaller segments of sufficient size for a few specimens of each group. This may be demonstrated by an example, as follows. A segment, 10-1/2 inches wide and 18 inches long, was cut from the basic panel. This segment was cut at the center to form two pieces 10-1/2 inches wide and 9 inches long. These two pieces of the cured laminate were then scarf'd to 2 inches at the center edges, and were glued together as described later. Upon completion of gluing, the assembled segment was ripped into 10 specimens 3/4 inch wide and 16 inches long. Alternate specimens were dry conditioned and the others wet conditioned for tests at a later date. Similar procedures were used in preparing other tensile and compression specimens for both scarf and lap joints.

The scarf joints were made with the apparatus used for preparing scarf joints in veneers for plywood. This device consists of a sanding drum mounted to machine accurately cut scarf's on the material. The scarf'd surfaces appeared to be well suited for gluing. The surfaces to be joined in lap-joint assemblies were sanded lightly by hand. The two prepared surfaces were then coated

with adhesive, carefully alined and taped to the proper position, and pressed in a hydraulic press. Fabrication conditions for the various joints are shown in table 2.

Testing

Prior to test, some specimens were conditioned to constant weight at 73° F. and 50 percent relative humidity and others at 100° F. and approximately 100 percent relative humidity. For convenience hereafter, the first condition will be referred to as "dry" and the second as "wet." Testing was done under conditions of 74° F. and 65 percent relative humidity, with the specimens being exposed to these conditions for as short a time as possible.

Tension Tests

The tension specimens were 16 inches long and were 3/4 inch wide over their full length. They were held in Templin-type grips and loaded with a rate of head movement of 0.035 inch per minute. Strain was not measured; maximum load only was measured and recorded.

Compression Tests

The compression specimens were 4 inches long and 1 inch wide over their full length. They were supported laterally to prevent buckling by an appratus similar to that shown in figure 2, American Society for Testing Materials Standard Designation D805-47. Inserts were placed between the fingers of the apparatus and the lap-joint specimens to compensate for the offset. They were loaded through a spherically seated bearing with a rate of head movement of 0.012 inch per minute. Strain was not measured; maximum load only was measured and recorded.

Presentation and Discussion of Results

Scarf Joints

Data from the results of tension tests of scarf joints between sections of the cured laminates are given in tables 3, 4, and 5.

Tests on material from panels 37 and 39 (table 3) indicated efficiencies in the neighborhood of 50 percent in the dry condition at the flattest slope used (1 in 16) and of less than 40 percent in the wet condition. Since a scarf slope of 1 in 16 had been expected to give considerably higher efficiencies than actually resulted, it was considered possible that the gluing technique was at fault.

Accordingly, a number of scarf joints were fabricated by using six gluing techniques and tested in tension (series 2). The results, shown in table 4, indicated that method IV was the best. That method had been used in making the scarf joints previously tested.

An additional set of scarf joints was then made by using the gluing technique found to be best, and the range of scarf slopes was extended to 1 in 28. The data are shown in table 3 (panels 75 and 76). Prior to fabricating the full series of scarf joints for these two panels, a few exploratory tests had been made to verify the assumption that higher efficiencies could be attained at flat slopes. These values also are shown in table 3.

The data of table 3 are shown also in figure 1. It is apparent that the efficiency of a scarf joint increases as the slope of the scarf becomes flatter. While the data are somewhat erratic, the efficiency of scarf joints appears to vary linearly with slope of scarf within the range tested when slope is expressed as a ratio of scarf thickness to scarf length. Straight lines approximately representing the averages have been drawn on figure 1. The results from the specimens tested in the wet condition are more erratic than those from the dry specimens. However, it appears that a reasonable representation is obtained by a straight line having the same slope as that for the dry condition, but at a level about 10 percent lower.

While scarf-joint efficiencies on the order of 70 to 80 percent may be attained in the dry condition, at a scarf slope of about 1 in 28, a scarf joint having that slope is somewhat long for practical use. A number of scarf joints glued with various adhesives were, therefore, tested in tension to determine whether greater efficiency could be obtained with an adhesive other than that used for the tests previously discussed. The adhesives chosen are shown in table 2, and the test results are shown in table 5 and in figure 1. Scarf joints made with adhesives 28 and 36 show efficiencies generally in the range shown by those made with resin 2 as the adhesive. Adhesive 35 shows efficiencies considerably higher than the others, particularly for the 112-114 laminate. It should be noted that only contact pressure was used with adhesive 28 as compared with 75 or 200 pounds per square inch with the other adhesives. Scarf joints in the 112-114 laminate showed generally higher efficiencies than those in the 181-114 laminate.

A limited number of tests of scarf joints in compression were made. While the data are erratic, the values of table 6 indicate that somewhat higher efficiencies are attained than in tension. The data indicate also that the efficiency may vary relatively little with slope of scarf. The majority of the specimens failed in the scarf joint. At the flattest slope, the failures were evenly divided between compression failures in the material and joint failures.

The wet laminated scarf joints described in reports 1584 and 1584-A are extremely flat (slopes of about 1 in 70 to about 1 in 160) as compared with those involved in the study reported herein. No conclusions as to differences in scarf joint efficiency between the two methods of making the joints is possible because of the differences in scarf slope involved.

Lap Joints

Lap joints, between sections of the cured laminates, made with several lengths of lap were tested in tension and compression. The data are shown in tables 7 and 8 and in figures 2 and 3.

The data of table 7 show that lap joints are inefficient in transmitting tensile stress. The shear strength developed in the lap was low, and even at a length of 3-1/2 inches was sufficient to develop only about one-fourth to one-third of the tensile strength of the 1/8-inch laminates tested. Approximately the same strengths were developed in both the dry and wet conditions.

In an effort to improve the properties, two additional sets of lap joints (series 2) were made, one with somewhat higher gluing pressures than had previously been used, the other incorporating a layer of 112-114 fabric in the joint. The data from this series are shown in table 8 and in figures 2 and 3. Some improvement resulted from the modified procedures with the shorter lap lengths, but at the 3-1/2-inch length, only slight improvement was evident.

In compression, somewhat higher shear strengths were developed than in tension. In the original series, shear strengths were as much as 3 to 4 times as high as those that were developed in tension. Consequently, the lap joints developed higher efficiencies in compression than in tension. At a lap length of 3-1/2 inches, for example, the joints developed from about 60 to 80 percent of the compressive strength.

Failures were, in general, in the joint. Of the specimens with the larger laps (2-3/4 and 3-1/2 inches), the majority failed in compression outside the lap area at stresses lower than the compressive strength of the control

panels. The reason for this is not known, but it may possibly have been due to failure of the equipment to provide adequate lateral support to the portions of the specimen beyond the lap, although every effort was made to insure support along the full length.

It is not believed that the data from FPL Reports 1809 and 1814 are directly comparable with the data of this report. However, it is interesting to note that a very short lap (1/4 inch long) appeared to develop an efficiency in tension of about 75 percent when the lapped layers alternated with continuous layers in a laminated panel (FPL Report 1814). When tested in compression both as sandwich facings and as straight laminates, lap joints in the fabric layers appeared to cause no reduction in compressive strength.

Conclusions

The following conclusions apply to the results of tests reported herein, based on scarf and lap joints made between sections of cured laminates with a limited number of adhesives and techniques.

1. Scarf joints stressed in tension increase in efficiency as the scarf slope becomes flatter. The rate of increase is about the same in the wet as in the dry condition, but efficiencies in the wet condition are on the order of 10 percent lower than those in the dry condition.
2. Scarf-joint efficiencies in tension at a given slope vary with the choice of adhesive and the technique of using it.
3. Relatively flat scarfs are necessary to obtain efficiencies in tension higher than about 50 percent.
4. Scarf-joint efficiencies in compression at a given scarf slope appear to be somewhat higher than in tension and to vary less with slope of scarf.
5. Lap joints are inefficient in tension, but relatively high efficiencies may be attained in compression.

Table 1.--Resin content, specific gravity, and Barcol hardness values for glass-fabric-base plastic laminate panels

Panel No.	:	Number of plies	:	Average thickness	:	Resin content ¹	:	Specific gravity	:	Average Barcol hardness
	:		:	<u>Inch</u>	:	<u>Percent</u>	:		:	
<u>112-114 Laminate, Resin 2</u>										
33	:	42	:	0.127	:	44.1	:	1.69	:	69
37	:	42	:	.127	:	44.5	:	1.70	:	69
75	:	21	:	.062	:	44.1	:	1.73	:	66
5 (control) ²	:	84	:	.250	:	43.5	:	1.71	:	69
6 (control) ²	:	84	:	.250	:	43.4	:	1.70	:	69
<u>181-114 Laminate, Resin 2</u>										
35	:	12	:	.119	:	34.5	:	1.83	:	69
39	:	12	:	.125	:	36.2	:	1.79	:	67
76	:	6	:	.064	:	38.0	:	1.79	:	67
16 (control) ²	:	23	:	.249	:	37.8	:	1.77	:	69
17 (control) ²	:	23	:	.244	:	36.8	:	1.77	:	70
	:		:		:		:		:	

¹Based on weight of cured panel.

²Panels 1/4 inch thick made by same methods as panels used for joint tests.

Table 2--Fabrication details for scarf and lap joints

Series	Adhesive No.	Slope of scarf	Length of lap	Conditions of cure			Remarks
				Temperature	Pressure	Time	
				°F.	psi.	hrs.	min.
<u>Scarf Joints</u>							
1	Resin 2	: 1:8 to 1:28	:	220 to 250	: 75	: 1	: 30 : Regular spread; 30-minute open assembly.
2-I	Resin 2	: 1:17	:	220 to 250	: 75	: 1	: 30 : Regular spread; 5-1/2 hour open assembly.
2-II	Resin 2	: 1:17	:	220 to 250	: 75	: 1	: 30 : 20 percent glass fibers in resin; 3-1/2-hour open assembly.
2-III	Resin 2	: 1:17	:	220 to 250	: 75	: 1	: 30 : 20 percent glass fibers in resin; 30-minute open assembly.
2-IV	Resin 2	: 1:17	:	220 to 250	: 75	: 1	: 30 : Regular spread; 30-minute open assembly.
2-V	Resin 2	: 1:17	:	220 to 250	: 75	: 1	: 30 : Regular spread on scarf; 5-1/2-hour open assembly; sheet of 112-114 fabric, impregnated with resin 2, laid in joint.
2-VI	Resin 2	: 1:17	:	220 to 250	: 75	: 1	: 30 : Thinned-out (50 percent acetone) spread of resin cured on scarf surfaces; then same as series 2-I.
3-I	Adhesive 36	: 1:20	:	250	: 200	: 16	: 35 : Adhesive sprayed on; 20-hour open assembly.
3-II	Adhesive 28	: 1:20	:	75	: Contact	: 16	: Brush spread; 5-minute open assembly.
3-III	Adhesive 35	: 1:20	:	300	: 200	: 16	: Brush spread; 20-hour open assembly.
<u>Lap Joints</u>							
1	Resin 2	: 1/2 to 3-1/2	: 200 to 250	: 75	: 1	: 30	: Regular spread; 30-minute open assembly.
2-I	Resin 2	: 1/2 to 3-1/2	: 200 to 250	: 200	: 1	: 30	: Regular spread; 30-minute open assembly.
2-II	Resin 2	: 1/2 to 3-1/2	: 200 to 250	: 15	: 1	: 30	: One sheet of 112-114 fabric in joint.

¹Resin 2 - A high-temperature-setting, low-viscosity, laminating resin of the polyester (styrene-alkyd) type.

Adhesive 28 - A room-temperature-setting formulation of epichlorohydrin resin.

Adhesive 35 - A high-temperature-setting formulation of thermoplastic and thermosetting resins.

Adhesive 36 - A high-temperature-setting formulation of thermosetting resin and synthetic rubber.

Table 3.--Results of tension tests of scarf joints (series 1)

Slope of scarf	Number of speci- mens	Tensile strength					
		Dry			Wet		
		Average	Maximum	Minimum	Ratio	Average	Maximum
		:Dry:Wet:	:	:	:to con-	:	:
		:	:	:	:trols :	:	:
		P.s.i.	P.s.i.	P.s.i.		P.s.i.	P.s.i.

Panel 37; 112-114 Fabric

Controls: 6 : 6 : 42,700: 44,380: 40,980: 1.00 : 31,900: 35,650: 26,480: 1.00
1:9 : 5 : 5 : 19,100: 22,800: 15,100: .45 : 11,500: 12,200: 10,600: .36
1:13 : 5 : 5 : 15,500: 18,400: 12,900: .36 : 11,400: 15,100: 9,500: .36
1:16 : 5 : 5 : 22,500: 26,800: 18,000: .53 : 12,900: 18,100: 10,700: .40

Panel 39: 181-114 Fabric

Controls: 6 : 6 : 49,100: 51,680: 46,930: 1.00 : 40,940: 44,010: 38,750: 1.00
1:9 : 5 : 5 : 16,700: 18,500: 15,200: .34 : 9,500: 11,000: 7,200: .23
1:13 : 5 : 5 : 15,600: 16,700: 14,000: .32 : 10,300: 12,100: 8,900: .25
1:16 : 5 : 5 : 22,100: 25,400: 18,500: .45 : 15,000: 17,300: 13,800: .37

Panel 75; 112-114 Fabric

Controls: 6 : 6 : 42,700: 44,380: 40,980: 1.00 : 31,900: 35,650: 26,480: 1.00
1:8 : 6 : 6 : 17,800: 20,300: 15,700: .42 : 13,200: 14,000: 12,300: .41
1:13 : 6 : 6 : 18,300: 23,200: 15,300: .43 : 14,000: 17,300: 11,600: .44
1:20 : 6 : 6 : 24,400: 29,800: 15,200: .57 : 18,900: 22,900: 13,400: .59
1:28 : 6 : 6 : 34,100: 38,100: 30,600: .80 : 29,100: 32,100: 26,700: .91

Panel 76; 181-114 Fabric

Controls: 6 : 6 : 49,100: 51,680: 46,930: 1.00 : 40,940: 44,010: 38,750: 1.00
1:8 : 6 : 6 : 18,900: 20,100: 17,800: .38 : 12,700: 14,000: 9,600: .31
1:13 : 6 : 6 : 24,700: 26,700: 23,200: .50 : 18,100: 19,300: 15,800: .44
1:20 : 6 : 6 : 24,100: 28,100: 21,300: .49 : 16,300: 19,100: 12,100: .40
1:28 : 6 : 6 : 32,000: 33,700: 27,500: .65 : 23,600: 27,700: 20,400: .58

Exploratory Panels; 112-114 Fabric

Controls: 6 :: 42,700: 44,380: 40,980: 1.00 ::::
1:20 : 4 :: 16,700: 19,200: 15,400: .39 ::::
1:22-1/2: 4 :: 28,900: 29,500: 28,100: .66 ::::
1:27 : 4 :: 33,400: 34,600: 30,500: .78 ::::
..... : : : : : : :

Table 4.--Results of tension tests of scarf joints glued with resin 2
by different methods (series 2). Slope of scarf 1:17

Gluing method	Number of speci- mens	Tensile strength		
		Average	Maximum	Minimum
		P.s.i.	P.s.i.	P.s.i.
I - Regular spread; 3-1/2-hour open assembly; pressure, 75 pounds per square inch	4	12,800	14,000	11,800
II - 20 percent glass fibers in resin; 3-1/2-hour open assembly; pressure, 75 pounds per square inch	4	16,000	18,000	14,900
III - 20 percent glass fibers in resin; 30-minute open assembly; pressure, 75 pounds per square inch	4	17,700	21,400	14,400
IV - Regular spread; 30-minute open assembly; pressure, 75 pounds per square inch	4	24,200	25,600	21,800
V - Regular spread on scarf; 3-1/2-hour open assembly; sheet of 112-114 cloth in scarf; pressure, 75 pounds per square inch	4	16,000	18,300	11,300
VI - Thinned-out spread of resin cured on scarf surfaces; then same as method I	4	14,600	18,800	12,700

Table 5.--Results of tension tests of scarf joints glued with various adhesives (series 3). Slope of scarf 1:20

Adhesive ¹	Number of specimens	Tensile strength					
		Dry	to controls	Wet	to controls	Ratio	
36	5	25,600	26,100	25,000	0.60		
28	5	23,200	24,400	21,200	.54		
35	5 : 7	39,800	42,300	37,500	.93	25,300	26,000 : 24,700 : 0.79
		P.s.i.	P.s.i.	P.s.i.	P.s.i.	P.s.i.	P.s.i.

<u>Panel 75; 112-114 Fabric</u>							
36	5	23,800	24,400	22,800	.48		
28	5	27,300	30,000	24,800	.56		
35	5 : 7	34,300	36,400	32,200	.70	20,900	23,100 : 20,100 : .51
		:	:	:	:	:	:

<u>Panel 76; 181-114 Fabric</u>							
36	5	23,800	24,400	22,800	.48		
28	5	27,300	30,000	24,800	.56		
35	5 : 7	34,300	36,400	32,200	.70	20,900	23,100 : 20,100 : .51
		:	:	:	:	:	:

¹Adhesives described in table 2.

Table 6.--Results of compression tests of scarf joints; panels 37 and 39

Slope	Number	Compressive strength					
of	of	Dry	:	Wet			
scarf	speci-						
: mens	-----	-----	-----	-----	-----	-----	-----
-----	Average	Maximum	Minimum	Ratio	Average	Maximum	Minimum
Dry:Wet:	:	:	:	:to con-	:	:	:to con-
:	:	:	:	:trols	:	:	:trols
-----	-----	-----	-----	-----	-----	-----	-----
:	:	P.s.i.	P.s.i.	P.s.i.	P.s.i.	P.s.i.	P.s.i.
<u>Panel 37; 112-114 Fabric</u>							
Controls:	6 : 6 :	36,840:	41,510:	34,270:	1.00 :	28,360:	29,850:
1:9	: 3 : 3 :	19,500:	22,000:	16,900:	.53 :	11,500:	13,400:
1:13	: 3 : 3 :	27,900:	35,700:	20,600:	.76 :	16,000:	17,300:
1:16	: 3 : 3 :	26,500:	27,600:	24,900:	.72 :	18,000:	18,500:
<u>Panel 39; 181-114 Fabric</u>							
Controls:	6 : 6 :	34,510:	36,860:	30,760:	1.00 :	23,940:	25,140:
1:9	: 3 : 3 :	28,500:	32,500:	21,400:	.83 :	11,700:	13,800:
1:13	: 3 : 3 :	19,000:	27,800:	11,500:	.55 :	11,300:	12,500:
1:16	: 3 : 3 :	27,400:	28,600:	25,700:	.79 :	15,800:	16,300:

Table 7.--Results of tests of lac joints (sample 1)

Length of lap	Number of specimens	Shear stress on lap at failure						Stress on net section at failure										
		Dry			Wet			Dry			Wet							
		Dry	Wet	Average	Maximum	Minimum	Average	Maximum	Minimum	Ratio to controls	Average	Maximum	Minimum					
<u>Inch</u> : <u>P.s.i.</u>																		
Controls	6	6	560	680	430	680	850	540	42,700	44,380	40,980	1.00	31,900	35,650	26,480	1.00		
1/2	5	5	560	570	410	460	370	370	3,120	3,790	2,520	.07	2,830	3,450	2,270	.09		
1	5	5	480	520	360	410	370	370	3,940	4,380	2,960	.09	3,340	3,650	2,990	.10		
2	5	5	350	340	250	320	390	260	5,690	7,180	3,870	.13	5,110	6,200	4,230	.16		
3-1/2	5	5	510	560	470	420	490	320	13,800	15,000	12,600	.32	11,300	13,400	8,400	.36		
<u>Panel 11: 112-114 Fabric: Tension</u>																		
Controls	6	6	760	840	670	730	810	670	49,100	51,680	46,930	1.00	40,940	44,010	38,750	1.00		
1/2	5	5	340	360	320	400	450	350	3,180	3,480	2,860	.07	3,390	3,880	3,020	.08		
1	5	5	280	300	230	330	320	670	4,940	5,530	5,960	.06	3,550	3,950	3,220	.09		
2	5	5	370	400	350	440	440	670	360	11,000	12,100	10,500	.10	5,780	6,870	4,370	.14	
3-1/2	4	3	1,110	1,180	1,080	740	800	980	1,010	1,330	30,200	32,200	29,200	.22	11,900	13,200	10,500	.29
<u>Panel 15: 181-114 Fabric: Tension</u>																		
Controls	6	6	2,180	2,710	1,580	990	1,420	600	9,200	11,500	6,600	1.00	28,360	29,850	25,650	1.00		
1/2	3	3	1,930	2,070	1,750	910	980	670	15,700	16,900	14,400	.25	4,110	5,900	2,470	.14		
1	3	3	1,310	1,500	1,190	720	760	670	20,800	23,800	18,900	.43	7,310	7,880	7,020	.26		
2	3	3	1,400	1,430	1,330	980	980	940	30,200	30,800	29,000	.57	11,700	13,100	10,600	.41		
2-3/4	4	3	1,310	1,420	1,200	740	800	870	620	30,300	32,200	29,200	.82	21,000	21,700	20,200	.74	
3-1/2	4	3	1,010	1,060	940	600	690	690	460	28,400	30,800	26,800	.52	20,200	22,000	17,600	.71	
<u>Panel 11: 112-114 Fabric: Compression</u>																		
Controls	6	6	2,050	2,460	1,750	1,330	1,420	1,270	9,030	11,100	7,800	1.00	23,940	25,140	23,000	1.00		
1/2	3	3	1,810	1,900	1,670	870	950	800	15,100	15,800	11,900	.26	5,790	6,110	5,470	.24		
1	3	3	1,050	1,090	920	860	900	810	17,200	18,300	15,500	.44	7,200	7,850	6,680	.30		
2	3	3	1,310	1,420	1,200	810	870	760	29,900	32,600	27,400	.50	14,400	15,000	13,400	.60		
2-3/4	4	3	1,010	1,060	940	600	690	690	460	28,400	30,800	26,800	.57	19,000	20,400	17,900	.79	
3-1/2	4	3	1,010	1,060	940	600	690	690	460	28,400	30,800	26,800	.52	16,200	18,600	12,400	.68	

**Table 8.--Results of tension tests of lap joints (series 2)
tested in the dry condition**

Length of lap	Number of speci- mens	Shear stress on lap at failure	Stress on net section at failure				
In.	: P.s.i.	P.s.i.	P.s.i.	P.s.i.	P.s.i.	P.s.i.	P.s.i.
<u>Lap-Joint Adhesive, Resin 2</u>							
<u>Panel 37; 112-114 Fabric</u>							
1/2 :	4	1,640	1,770	1,500	6,300	6,680	5,740
2 :	4	560	610	520	8,800	9,500	8,050
3-1/2 :	4	530	540	510	14,700	15,000	14,200
<u>Panel 39; 181-114 Fabric</u>							
1/2 :	4	1,280	1,320	1,240	4,990	5,160	4,790
2 :	4	450	520	380	7,280	8,280	6,080
3-1/2 :	4	330	370	300	9,260	10,260	8,290
<u>Lap-Joint Adhesive, Resin 2; Sheet of 112-114 Fabric in Joint</u>							
<u>Panel 37; 112-114 Fabric</u>							
1/2 :	4	2,000	2,120	1,910	7,930	8,350	7,560
2 :	4	700	740	660	11,000	11,600	10,400
3-1/2 :	4	570	590	550	15,700	16,400	15,200
<u>Panel 39; 181-114 Fabric</u>							
1/2 :	4	1,850	1,880	1,820	7,320	7,440	7,180
2 :	4	690	700	680	11,000	11,200	10,900
3-1/2 :	4	520	520	500	14,600	14,900	14,100
:	:	:	:	:	:	:	:
:	:	:	:	:	:	:	:

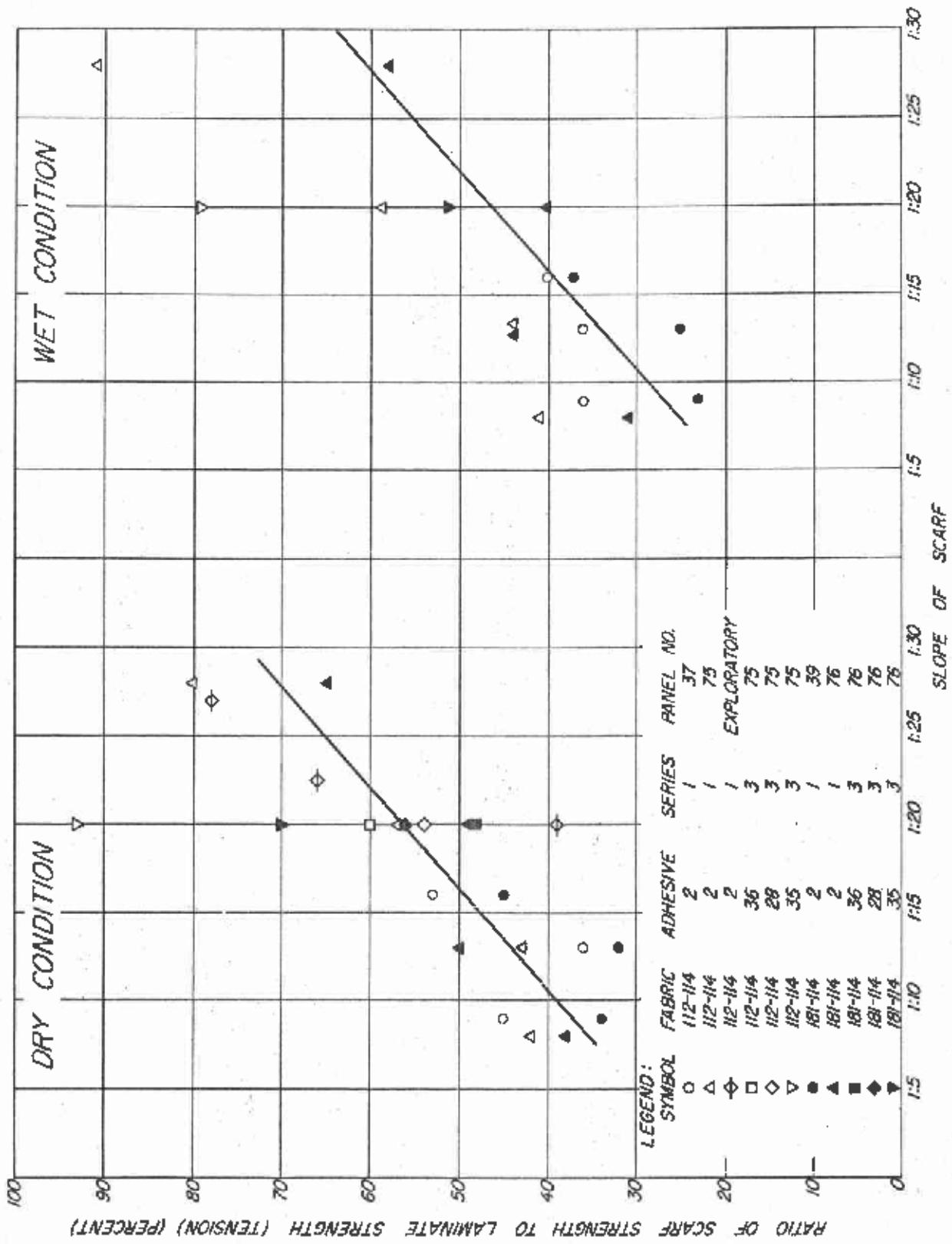


Figure 1.--Results of tension tests of scarf joints in glass-fabric-base plastic laminates.

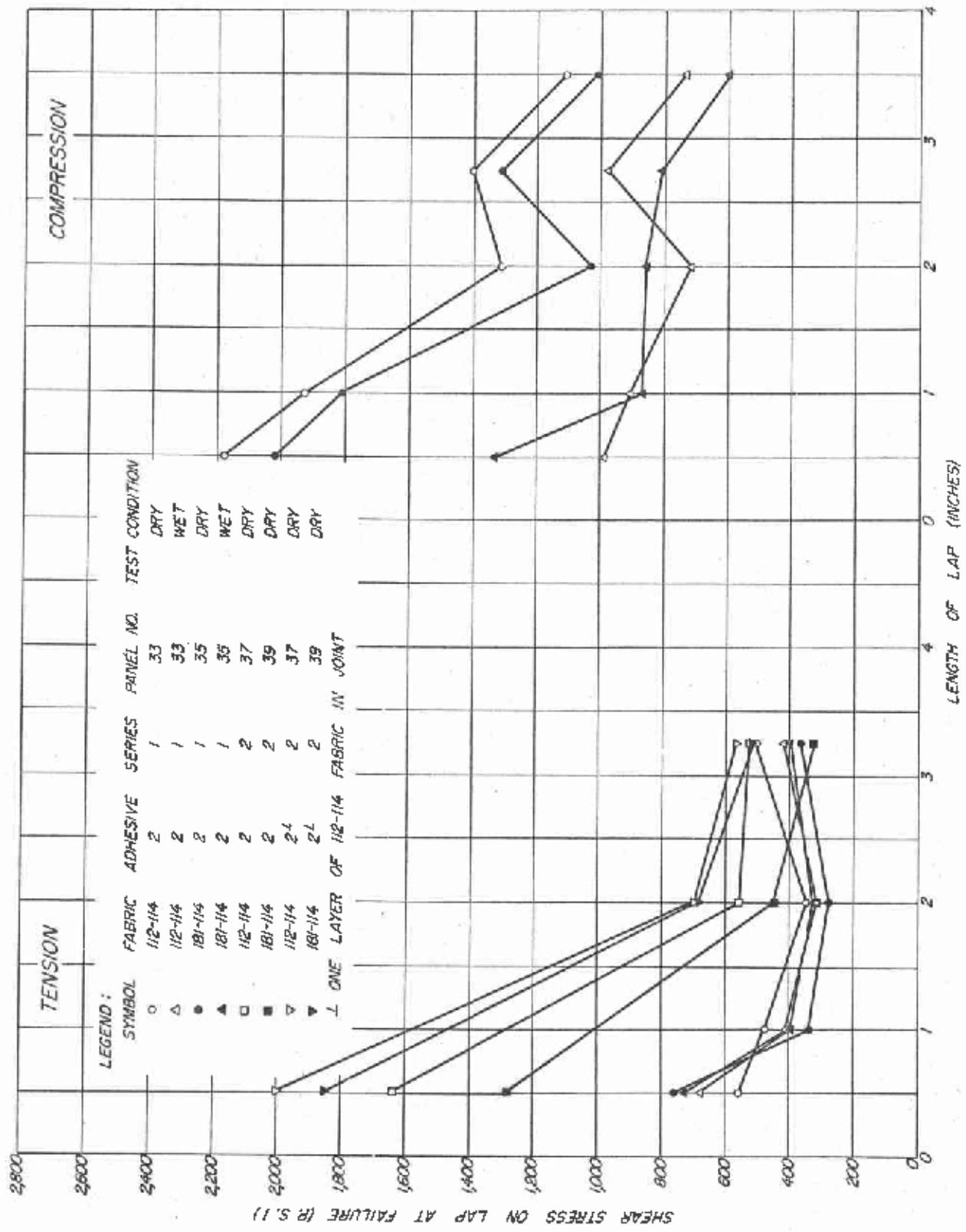


Figure 2. - Shear stresses developed in tests of lap joints in glass-fabric-base plastic laminates.

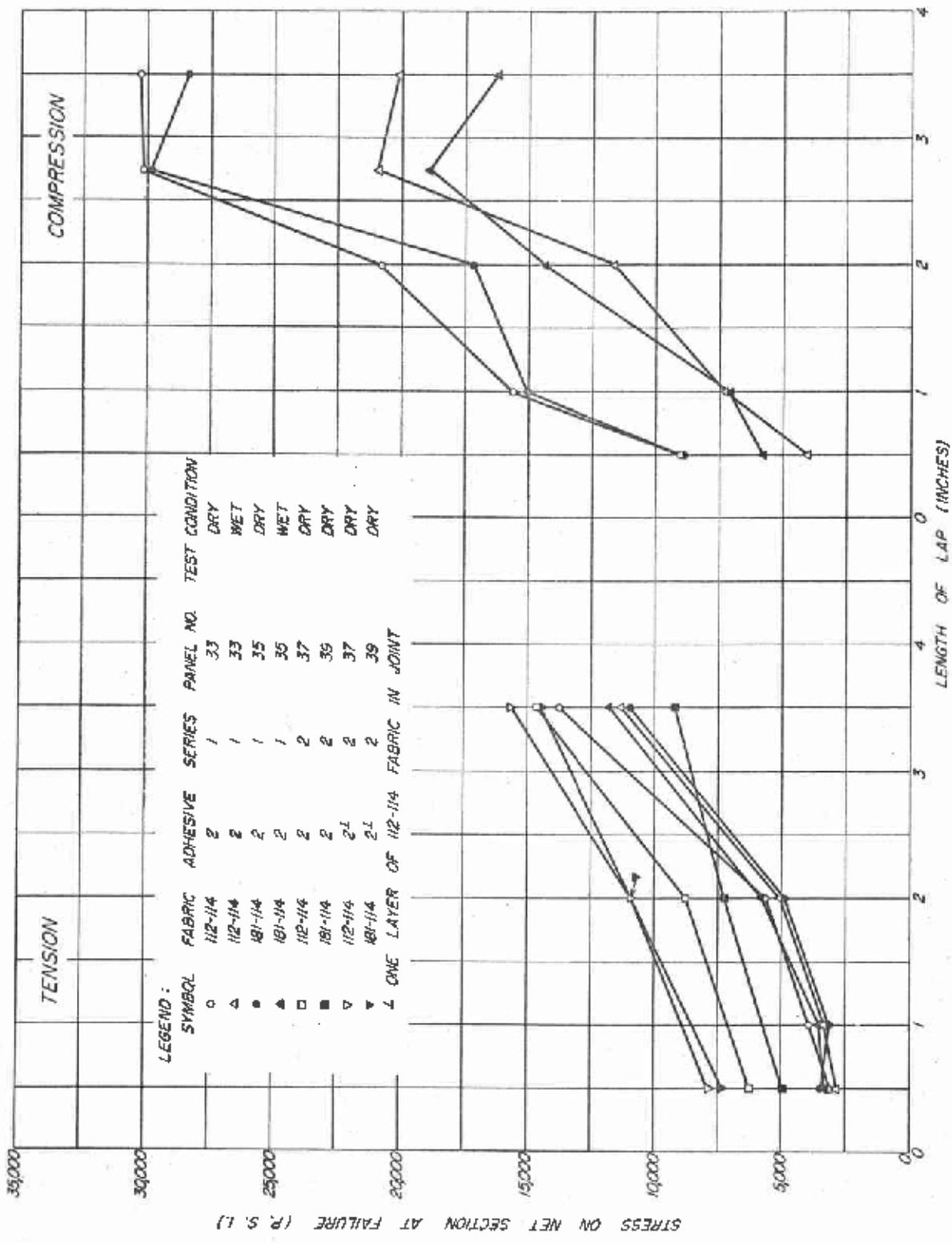


Figure 3.--Tensile and compressive stresses developed in tests of lap joints in glass-fabric-base plastic laminates.

Werren, Fred
Strength of scarf and lap joints in glass-fabric-base plastic laminates, by Fred Werren and Alan D. Freas. 2d ed.
Madison, Wis., U.S. Forest Products Laboratory, 1961.
18 p., tbls., illus. (F.P.L. rpt. no. 1818)

Reports results of tension and compression tests of scarf and lap joints in glass-fabric-base plastic laminates.

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