

REPAIR OF AIRCRAFT SANDWICH CONSTRUCTIONS

May 1948



This Report is One of a Series
Issued in Cooperation with the
ARMY-NAVY-CIVILCOMMITTEE
on
AIRCRAFT DESIGN CRITERIA
Under the Supervision of the
AERONAUTICAL BOARD

No. 1584

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
FOREST PRODUCTS LABORATORY
Madison 5, Wisconsin
In Cooperation with the University of Wisconsin

REPAIR OF AIRCRAFT SANDWICH CONSTRUCTIONS¹

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Introduction

The purpose of this study was to attempt to devise repair techniques for various sandwich type constructions. The work was done at the Forest Products Laboratory in cooperation with the Army-Navy-Civil Technical Subcommittee on Sandwich Construction.

Three facing materials -- aluminum, glass-cloth fabric, and plywood- and five core materials -- cellular cellulose acetate, cellular hard rubber, end-grain balsa, glass-cloth honeycomb, and paper honeycomb -- were used in the study.

Repair work was divided into three parts: A, damage to facings only; B, damage to one facing and core; and C, fracture of both facings and core, Parts B and C were further subdivided as to accessibility from one or both sides.

The work was restricted to flat panels with the exception of the glass-cloth - glass-cloth honeycomb combination on which some work was done on single-curvature panels having a radius of 30 inches.

Repair Techniques

General

The repairs were developed with the objective of equaling, as nearly as possible, the strength of the original panel. In order to eliminate dangerous stress concentrations, abrupt changes in cross-sectional area were avoided wherever practicable by tapering joints, making small patches round or oval-shaped instead of rectangular, and rounding corners on all large patches. Because smoothness of outside surfaces of high-speed aircraft is a necessity for proper performance, patches that projected above the original surfaces were avoided whenever practicable. When this was impossible the

¹This progress report is one of a series prepared and distributed by the Forest Products Laboratory under U. S. Navy, Bureau of Aeronautics No. NBA-PO-NAer 00619 Amend. No. 1, and U. S. Air Force No. USAF-PO-(33-038)48-41E, Results here reported are preliminary and may be revised as additional data become available,

edges were tapered. Uniformity of thickness and the continuity of the core are also necessary where radar equipment is involved. Repairs involving punctured facings and fractured cores therefore necessitated removal of all of the damaged material and its replacement with the same type of materials and in the same thicknesses as the original.

Damages were assumed to vary in size from small holes the size of a pencil to large holes extending over several square feet. Three types of patches -- round, oval, and square or rectangular -- were devised to repair holes of various sizes.

Cutting and treatment of the core were done according to methods described in Forest Products Laboratory Report No. 1574.²

Plywood-faced Panels

Repair tools and equipment, discussed in Sections IV and V of AN-01-1A-7, "Repair of Wood Aircraft Structures," November 1944, were found to be applicable.

Scarf joints having a slope of 1 in 12 were used for repairs to the facings. Pressure was applied to the joint by No. 5 roundhead wood screws driven through 1/4-inch plywood backing strips or pressure plates. Grain direction of the patch matched that of the original. A room-temperature-setting resorcinol glue, adhesive D,³ was used for all patches. Two rows of screws were used on the round and oval patches. The first row followed a line drawn around the hole in the center of the scarf. The second row was 3/8 inch in from the edge of the hole. Screws in the rows were spaced 1 inch apart. For the square patch, four rows of screws were used. Suggested details are shown in figures 1, 2, and 3. The steps in making an oval repair when one side only is accessible are shown in figure 4.

No satisfactory method was found to repair damages to one facing and core when only one facing of the panel was accessible. Damage of this nature was treated the same as damage where both facings and core were damaged.

Aluminum-faced Panels

The technique for the oval patch when the core and both facings were damaged was developed (figs. 5 and 6), but the bonds made with the glues available were erratic in quality. Further work, therefore, was stopped pending development of a better glue for bonding metal to metal at low pressures (vacuum pressure) and at temperatures of 250° F. or less. To date, however, no such glue has been made available for test.

²"Fabrication of Lightweight Sandwich Panels of the Aircraft Type," Forest Products Laboratory Report No. 1574, June 1947.

³Appendix I, Note 4.

The details of making an oval-shaped repair when only one side of the panel is accessible are shown in figure 7.

Cutting of the panels was accomplished with a plug cutter on round Cuts, using a template whenever possible, and with a reciprocating-saw attachment to a 1/4-inch electric drill, using a 24-tooth hacksaw blade, on straight cuts. The hole was filled with a plug made of the same material and having the same thickness of core and facings as the original. Plates were glued to both faces. A hot-press thermosetting glue, adhesive E,⁴ was used for the patches.

All surfaces to which glue was applied were etched. They were first sanded lightly with 320A paper, then cleaned with acetone. Etching of the plates was done by submerging in a hot sulfuric acid-sodium dichromate bath (10 parts by weight of concentrated sulfuric acid, 1 part of sodium dichromate, and 30 parts of water) for 20 minutes at 145° F. The plates were rinsed and, if necessary, rerinsed until a smooth unbroken water film was obtained. The panel and plug covers were etched by swabbing cold (75° F.) sulfuric acid - sodium dichromate solution on the faces, taking precautions to prevent any of it from getting on the core. Fresh solution was added several times during the treatment, and after 30 minutes it was removed by wiping with a clean cloth saturated with water and dried with a clean dry cloth.

After etching, two coats of adhesive E⁴ were applied to all surfaces. One hour was allowed between coats at 75° F., and 16 to 24 hours were allowed between the last coat and curing. When both faces were accessible, 0.012-inch 24ST aluminum plates 1-1/2 inches wider on all edges than the hole were glued to both faces. The patch was applied in one operation, using a heated vacuum blanket on each side to supply pressure and heat.

When only one side was accessible, a backing plate of 0.064-inch 24ST aluminum was used on the back and a 0.012-inch 24ST aluminum plate was used on the front face. The edges of the 0.012-inch plates were tapered with a file. Three major steps were required to complete the patch. First, the backing plate was glued to the back face, No. 8 self-tapping screws (sheet-metal screws) with lock washers under the heads were used to apply pressure, and a rubber electric heating pad supplied the heat. Temperature on the surface of the panel was not allowed to exceed 260° F. At an air temperature of 75° F., temperatures of 185° to 190° F. were obtained at the glue line. Heat was applied for 3 hours. Second, the sandwich plug was glued to the backing ring. Self-tapping screws were used for pressure as in step one. Heat was again applied with an electric heating pad. With the temperature not exceeding 260° F. on the panel surface, temperatures of 175° to 185° F. were obtained at the glue line. Heat was again applied for 3 hours. Third, the front cover was glued to the plug and original facing. A heated vacuum blanket was used for pressure and heat for a period of 3 hours, again with the temperature on the face of the patch limited to 250° to 260° F.

⁴Appendix I, Note 5.

Screw holes drilled through the facings and plug were equal in size to the major diameter of the No. 8 self-tapping screws. The holes through the backing plate were equal to the minor diameter of the screws. Three rows of screws were used. The first row was located 3/8 inch and the second row 1-1/8 inches in from the edge of the backing plate. The holes were spaced 1-1/2 inches apart in the rows. The first two rows of screws were used when the backing ring was glued to the back cover. The third row was used when the plug was glued to the backing plate. The screws were long enough to pass through the backing plate and project 1/4 inch beyond. Screw-hole location and drilling were done on the backing ring first. The backing ring was used as a template to locate the screws on the plug, panel, and pressure ring. Before the front face plate was applied, all screw holes were filled with patching putty.⁵ A 4-hour drying period was allowed before the glue was spread on the top facing.

Glass-cloth-faced Panels

Several attempts were made to make repairs to glass-cloth-faced panels when only one side was accessible, but no satisfactory technique has been devised to date. A repair technique for the oval patch when both sides were accessible was developed. The results were somewhat erratic, however, due primarily to the quality of the scarfing. The method used for scarfing the faces was not too successful. No better method has been tried to date.

Suggested details for the preparation of an oval repair when both sides are accessible are shown in figure 8, and the steps in making this repair in figure 9.

When round cuts were necessary in removing the damaged portion of a panel, a plug cutter in a hand brace was employed. A template was used whenever possible. Straight cuts were made with a 24-tooth hacksaw blade in a reciprocating-saw attachment on a 1/4-inch portable electric drill. The facings were scarfed for a distance of 2 inches around the hole with a flexible disk sander using medium-grit cloth. Extreme care was taken to get the scarf uniform and not to gouge out pieces of the core. The core plug was cut from material having the same thickness as the original core. Face patches were made using the same number of plies as were used in the original face. Starting with a ply the size of the opening, each successive ply was slightly larger with the final ply 2 inches larger on all sides. Before cutting the patches, the glass cloth was impregnated with a long-assembly, high-viscosity resin, such as resin A,⁶ which was used for this study. Methods for impregnating the cloth are discussed in Forest Products Laboratory Report No. 1574.² The impregnated cloth was stretched out and laid on a sheet of cellophane with a second sheet of cellophane laid on top of the cloth to facilitate handling and storing. The outlines of the patches (two of each size) were then drawn on the cellophane, and the patches cut with a pair of 9-inch office shears.

⁵Appendix I, Note 11.

⁶Appendix I, Note 1.

Cellophane was placed on a sheet of smooth aluminum, both slightly larger in dimensions than the largest patch. The cellophane was removed from one side of the largest patch, which was then laid (exposed glass-cloth face down) on the cellophane-covered sheet of aluminum. The cellophane was removed from the top side of the patch and all wrinkles and air bubbles were worked out. This procedure was repeated until the entire patch was laid up. Care was taken to center each ply. The whole assembly was then removed from the sheet of aluminum by cutting the cellophane with a knife leaving a 1-inch border around the patch. Before positioning the patch on the panel, the scarfed portion of the panel around the hole was coated by brush with the same resin as that used for Impregnating the cloth to a spread of 10 grams per square foot. When necessary, as in the case of glass-cloth honeycomb, the resin was also applied to the core plug. The patch was then positioned over the core plug with the glass-cloth face down. The air bubbles were worked out of the cover with the hands and the cellophane was punctured at about 1-inch spacing with a needle. The procedure was repeated for the patch on the opposite side. Electrically heated vacuum blankets were taped to both sides over the patches. Vacuum was applied and the temperature was raised to 125° F. for 10 minutes, then increased to 230° F. and held there for 1 hour.

An additional step, found applicable only when the sandwich had a honeycomb core, was to use a thin (0.005- to 0.012-inch) aluminum caul over the cellophane. This caul gave a smoother outer surface.

Attempts were made to repair a curved panel having a 30-inch radius but the results were not satisfactory. Blisters developed in the patches, especially on the concave side, due probably to the thermal distortion of the 0.005-inch aluminum cauls used. In later trials the aluminum caul was eliminated from the concave side; but, although results were somewhat more satisfactory, blisters were not entirely eliminated.

Test Procedures and Test Results

Glue and Resin Selection

Plywood facings.--A room-temperature-setting resorcinol glue, adhesive D,³ was selected and used for all patches. A spread of 35 grams per square foot of glue line was used, one-half applied to each contacting surface.

Aluminum facings.--Tension tests were made on 0.012-inch 24ST Alclad aluminum. Two pieces 6-3/4 inches by 12 inches were joined together using a 1-1/2-inch lap joint. Both pieces were first sanded lightly with 320A paper and cleaned with acetone, then etched. Piece No. 1, representing the standing part of the plane, was etched by the cold method. Piece No. 2, representing the patch, was etched in the sulfuric acid-dichromate hot bath. Glue was spread on both surfaces to be joined, and the two pieces were assembled on a smooth sheet of aluminum with cellophane placed on top and beneath the joint. A heated vacuum blanket was taped down over the assembly, and heat and pressure were applied for a specified period, depending on the glue used.

The glues or combinations of glues tested follow:

(1) Adhesive F⁷ + adhesive G⁸ with 6 percent accelerator⁹.--Adhesive F was spread as a primary costing on both surfaces with a brush. Adhesive F on piece No. 1 was cured under a heating pad at about 275° F. for 1 hour. Adhesive F on piece No. 2 was cured in an oven at 325° F, for 15 minutes. Both surfaces were sanded lightly with 320A paper to remove irregularities. Then adhesive G was spread as a secondary coating with a brush at a rate of 10 grams per square foot on each surface. Adhesive G was allowed to air dry at room temperature for 1 hour. The pieces were assembled and cured under a heated vacuum blanket at about 230° F. for 1 hour.

(2) Adhesive F⁷ + adhesive G⁸ with 20 percent accelerator⁹.--Same procedure used as in (1), except cure was accomplished at room temperature (75° F.) in 8 hours.

(3) Adhesive H¹⁰.--The adhesive H liquid was spread with a brush at a rate of 20 grams per square foot on each surface. While the liquid was still wet, the thermoplastic powder was sifted on and, after drying, the excess was removed. The joints were cured under a heated vacuum blanket for 1 hour at 275° F.

(4) Adhesive E⁴.--Adhesive E was thinned 50 percent with adhesive E thinner¹¹ and brushed on both surfaces. Two coats were applied, allowing 1 hour between coats and 16 to 24 hours between the second coat and curing. Dry-film thickness varied between 0.004 to 0.006 inch. The joints were cured under a heated vacuum blanket for 1-1/2 hours at 275° F.

(5) Forest Products Laboratory Glue No. M-249 (Adhesive I¹²) .--Two coats of glue M-249 were applied to each surface with a brush, allowing 1 hour air drying at room temperature, open assembly between coats and 1 hour between second cost and curing. The joints were cured under a heated vacuum blanket at 250° to 260° F. for 2 hours. The dry-film thickness was 0.004 to 0.006 inch-

(6) Forest Products Laboratory Glue M-432 (Adhesive J¹³) .--Two coats of glue M-432 were applied with a brush allowing 2 hours of air drying at room temperature between coats and 30 minutes between second coat and curing. The joints were cured under a heated vacuum blanket at 250° to 260° F. for 15 minutes. The dry film thickness was approximately 0.005 inch.

After curing, five 1- by 12-inch specimens were cut from each panel and tested in a universal testing machine. Results are shown in table 1.

⁷Appendix I, Note 6.

⁸Appendix I, Note 7.

⁹Appendix I, Note 13.

¹⁰Appendix I, Note 8.

¹¹Appendix I, Note 14.

¹²Appendix I, Note 9.

¹³Appendix I, Note 10.

All bonds were somewhat spotty, indicating a lack of adequate pressure. The adhesive H¹⁰ bond was the poorest, as indicated by the joint efficiency of 58.5 percent. The adhesive E⁴ bond, although spotty, was the best of the six glues tested, as indicated by the joint efficiency of 90.7 percent.

Although the adhesive E bond was not considered entirely satisfactory, it was used for the repair of the metal-faced panels,

Glass-cloth faces. --A high-viscosity resin having a long assembly time was found to be most suitable for repair work. Glass cloth impregnated with a low-viscosity resin having a short assembly time usually was fairly dry and stiff before the lay-up of the patches was completed and usually resulted in blistered patches.

Since it is often impossible to determine what resin was originally used in fabricating the panel, a compatibility test was conducted to check whether or not a resin would cure in the presence of the same or a different cured resin.

Panels (12- by 12-inch) were bag molded of 10 plies of glass cloth¹⁴ impregnated with one of the following resins: resin A,⁶ resin B,¹⁵ or resin C.¹⁶ Resin A and resin B are high-viscosity, long-assembly resins, while resin C is a low-viscosity, short-assembly resin. These panels were cut in half and three 1- by 12-inch specimens were cut from one of the pieces for controls. The second half was again divided into two equal parts and one edge of each of the 6- by 6-inch pieces was scarfed with an accurate machine-cut scarf for a distance of 2 inches.

Six- by 8-inch patches were wet-laminated to the scarfed edge using cloth impregnated with a high-viscosity, long-assembly-time resin. The scarfed edge was first coated with the same resin used for impregnating the cloth applied at a rate of 10 grams per square foot. Then the first ply of the patch was butted against the lower edge of the scarf. This was found to be necessary in actual repair to produce uniform thickness across the patch. The other nine plies of glass cloth were spaced equidistant along the scarf, each being placed farther up with the last ply approximately 2 inches from the edge. The lay-up was made on a sheet of aluminum covered with cellophane. A second sheet of cellophane was placed over the assembly and perforated with pin holes. A heated vacuum blanket was then taped down over the assembly. Vacuum pressure was applied and the temperature raised to 125° F. After 10 minutes it was raised to the curing temperature and held for 1 hour. The curing temperature for resin A⁶ was 230° F., and for resin B¹⁵ it was 240° F. After curing, the panel was trimmed to 6 by 12 inches and three 1- by 12-inch specimens were cut. These specimens along with the three control specimens were tested in tension on a universal testing machine. The results are given in table 2.

¹⁴Appendix I, Note 12.

¹⁵Appendix I, Note 2.

¹⁶Appendix I, Note 3.

An examination of the broken specimens revealed no indication of non-compatibility, as all of the failures were tension breaks at the end of the scarfed piece. A few additional tests on specimens made by overlapping all the plies (instead of the butt joint between the edge of the first ply) revealed an increase of about 10 percent in joint efficiency. This increase in strength could be realized if thickness of facing was not the primary consideration.

Repair Strength Tests

Oval patches 2-1/2 by 8 inches in size were cut in panels 24 by 24 inches in size and repaired by the recommended procedures. All cores were 1/4 inch thick. Facing thickness varied with the material: A, plywood -- 0.070-inch three-ply birch manufactured in accordance with Specification AN-P-69a; B, aluminum -- 0.012-inch 24ST Alclad; C, glass cloth¹⁴ -- six plies, cross laminated. Preparation of the core, face material, and fabrication of the panels was in accordance with methods described in Forest Products Laboratory Report No. 1574.2

Sandwich combinations used in the study were as follows.

Patches made when both sides were accessible:

- Plywood - End-grain balsa
- Aluminum - End-grain balsa
- Aluminum - Paper honeycomb¹⁷
- Glass cloth - Cellular hard rubber¹⁸
- Glass cloth - Cellular cellulose acetate¹⁹
- Glass cloth - Glass-cloth honeycomb²⁰
- Glass cloth - End-grain balsa

Patches made when only one size was accessible:

- Plywood - End-grain balsa
- Aluminum - End-grain balsa
- Aluminum - Paper honeycomb¹⁷

Three panels were used for each combination for each type of repair. Tension and compression specimens were cut (fig. 10) and tested in a universal testing machine. Compression specimens, 2 by 3 inches, were substituted for the 1- by 4-inch specimens shown in figure 10 in all of the aluminum-faced panels and the plywood-faced panels where only one side was accessible. The results are recorded in table 3.

¹⁷Appendix I, Note 15.

¹⁸Appendix I, Note 16.

¹⁹Appendix I, Note 17.

²⁰Appendix I, Note 18.

Plywood-faced specimens usually failed in the patch either over the plug or in the scarf joint. Aluminum-faced specimens usually failed in the glue joint. The glass-cloth-faced specimens failed at or near the outer edge of the scarfed joint. The joint strength values for the glass-cloth-faced panels, as shown in table 3, were somewhat erratic due mostly to the quality of the scarfing operation. Where the scarfing exceeded the 2-inch limit a decrease in strength proportional to the decrease in thickness of the faces resulted.

Uniformity in thickness is essential to the satisfactory performance of a sandwich radar housing; therefore, repairs to these housings are subject to the same close thickness tolerances. Thicknesses of typical repairs and panels were measured at the stations shown in figure 11. These measurements, presented in table 4, show a greater variation in thickness across the repaired section, in most cases, than across the panel. The maximum variation in the case of a repair to the glass-cloth - glass-cloth-honeycomb combination was 0.038 inch, or about 14 percent, on the patch, and 0.033 inch, or about 12 percent, on the panel itself. On the glass-cloth-cellular-hard-rubber combination the maximum variations were about 13 percent and 7 percent, respectively. In most cases the patch was slightly thicker than the panel.

Patching Putty for Aluminum-faced Panels

Two unpainted aluminum-faced panels each having four dents filled with putty were subjected to a repeating cycle of 8 hours at 200° F. followed by 16 hours at -20° F. This cycle was repeated 20 times. No deterioration of the putty was observed at the end of the period. The panels were then exposed to 80° F. and 97 percent relative humidity for 3 months. By the end of this exposure scaling of the putty occurred where it was less than 1/32 inch thick, apparently due to the breakdown of the putty and to the corrosion of the metal.

APPENDIX I

Description of Resins and Adhesives.

- Note 1. Resin A. A high-temperature-setting, high viscosity, contact-pressure, laminating resin of the polyester type.
- Note 2. Resin B. A high-temperature-setting, high-viscosity, contact-pressure, laminating resin of the polyester type.
- Note 3. Resin C. A high-temperature-setting, low-viscosity, laminating resin of the styrene monomer, polyester type.
- Note 4. Adhesive D. A room-temperature-setting resorcinol resin.
- Note 5. Adhesive E. A high-temperature-setting mixture of thermoplastic and thermosetting resins.
- Note 6. Adhesive F. A high-temperature-setting mixture of thermosetting resin and synthetic rubber.
- Note 7. Adhesive G. A high-temperature-setting, acid-catalyzed, phenolic resin.
- Note 8. Adhesive H. A high-temperature-setting, two-component resin with a thermosetting liquid and thermoplastic powder.
- Note 9. Adhesive I. A high-temperature-setting mixture of thermoplastic and thermosetting resin. Developed at the U. S. Forest Products Laboratory, Madison, Wis.
- Note 10. Adhesive J. A room-temperature-setting mixture of thermoplastic and thermosetting resins. Developed at the U. S. Forest Products Laboratory, Madison, Wis.
- Note 11. Patching putty. A synthetic putty or crack filler used for filling dents in aluminum.
- Note 12. Glass cloth. Heat-cleaned cloth chemically treated with a chrome complex bath.
- Note 13. Accelerator. An acid catalyst for use with adhesive G.
- Note 14. Thinner. A specially formulated thinner for use with adhesive E.

- Note 15. Paper honeycomb. Honeycomb core material (approximately 1/8-inch cell size) developed at the U. S. Forest Products Laboratory in cooperation with the National Advisory Committee for Aeronautics. Made by impregnating with resin 4.5-mil kraft paper, corrugated by passing between B-flute corrugating rolls, as described in Forest Products Laboratory Report No. 1574.²
- Note 16. Cellular hard rubber. A core material, black in color, 8 pounds per cubic foot density (including skin).
- Note 17. Cellular cellulose acetate. An extruded, unoriented, multi-cellular form of cellulose acetate containing a small percentage of glass fiber as a filler, 7-8 pounds per cubic foot density (including skin).
- Note 18. Glass-cloth honeycomb, Honeycomb core material with 3/16-inch hexagonal cells, made by impregnating glass cloth (note 12) with resin to give a density of 9 pounds per cubic foot.

Table 1.—Results of tension tests -- aluminum to aluminum

Glue ¹	Average ultimate load ²	Joint efficiency
	<u>Pounds</u>	<u>Percent</u>
Control (no joint)	740	---
Adhesive F - adhesive G + 6 percent accelerator	584	79.0
Adhesive F - adhesive G + 20 percent accelerator	553	74.8
Adhesive H	433	58.5
Adhesive E	671	90.7
Adhesive I	577	78.0
Adhesive J	622	84.0

¹Adhesives in table are described in Appendix I.

²Average of 10 specimens.

Table 2.—Results of tension tests on scarfed, wet-laminated joints in glass-cloth panels using different resins

Panel resin ¹	Wet-laminated patch resin	Average joint strength ²	Average control strength ²	Joint efficiency
		<u>Pounds</u>	<u>Pounds</u>	<u>Percent</u>
Resin A	Resin A	975	1,160	84
Resin A	Resin B	922	1,157	80
Resin B	Resin B	975	1,177	83
Resin B	Resin A	890	1,243	72
Resin C	Resin A	807	1,165	69
Resin C	Resin B	940	1,162	81

¹Resins in table are described in Appendix I.

²Average of three specimens.

Table 3.--Strength of repairs in sandwich panels

Sandwich construction	One side accessible:	Both sides accessible:	Panel number:	Tension			Compression			Joint efficiency: Percent
				Patch specimens	Average maximum load in lbs.	Control specimens	Patch specimens	Average maximum load in lbs.	Control specimens	
Plywood - End grain balsa		X	1	832	1566	1566	1017	1034	98.2	
		X	2	867	1800	1800	995	1066	93.3	
		X	3	905	1765	1765	1005	1003	100.2	
Aluminum - End grain balsa	X		1	883	1932	1932	2037	2078	98.0	
	X		2	917	1783	1783	2027	2165	93.6	
	X		3	1045	1729	1729	1877	2088	89.9	
Aluminum - End grain balsa		X	1	1112	1509	1509	2568	2488	103.0	
		X	2	1045	1515	1515	2365	2500	94.6	
		X	3	532	1543	1543	1435	2190	65.5	
Aluminum - Paper honeycomb	X		1	1267	1378	1378	2315	2155	107.5	
	X		2	1317	1273	1273	2585	2370	109.0	
	X		3	1352	1355	1355	2565	2300	111.5	
Aluminum - Paper honeycomb		X	1	449	1446	1446	815	1570	51.3	
		X	2	673	1460	1460	1420	2290	62.0	
		X	3	370	1443	1443	1050	2230	47.1	
Glass cloth - Glass cloth honeycomb	X		1	1183	1305	1305	2105	2275	92.5	
	X		2	1210	1378	1378	2040	2400	85.0	
	X		3	1327	1379	1379	2555	2380	107.3	
Glass cloth - Cellular cellulose acetate		X	1	992	1159	1159	652	631	103.3	
		X	2	845	1088	1088	612	695	88.1	
		X	3	953	1063	1063	652	725	89.9	
Glass cloth - Cellular cellulose acetate		X	1	796	1284	1284	672	792	84.8	
		X	2	327	1304	1304	307	642	47.8	
		X	3	638	1259	1259	537	634	84.7	
Glass cloth - Cellular hard rubber		X	1	759	1334	1334	297	406	73.1	
		X	2	669	1211	1211	217	217	100.0	
		X	3	993	1360	1360	342	342	100.0	
Glass cloth - End grain balsa		X	1	548	1193	1193	487	833	58.6	
		X	2	449	1121	1121	387	585	66.2	
		X	3	710	926	926	607	869	69.8	

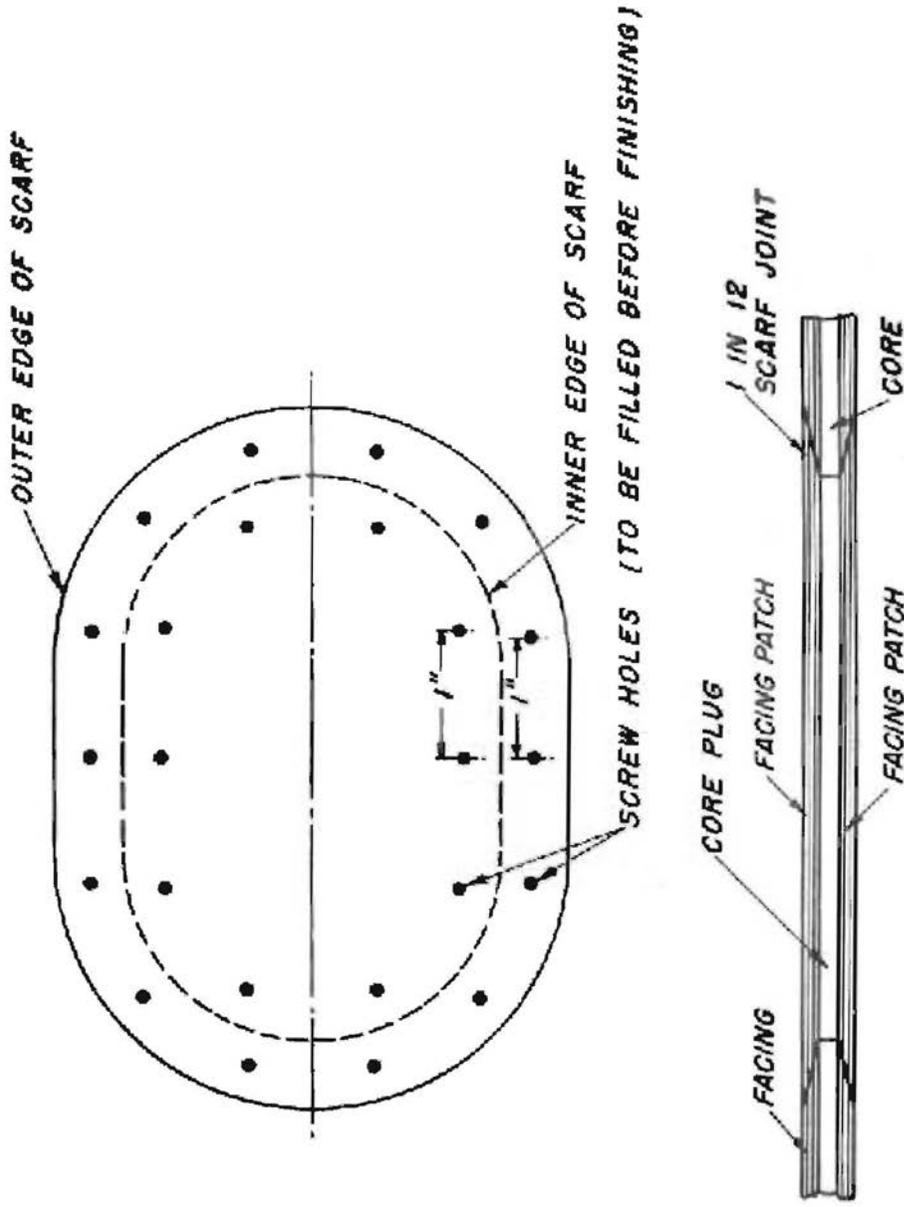
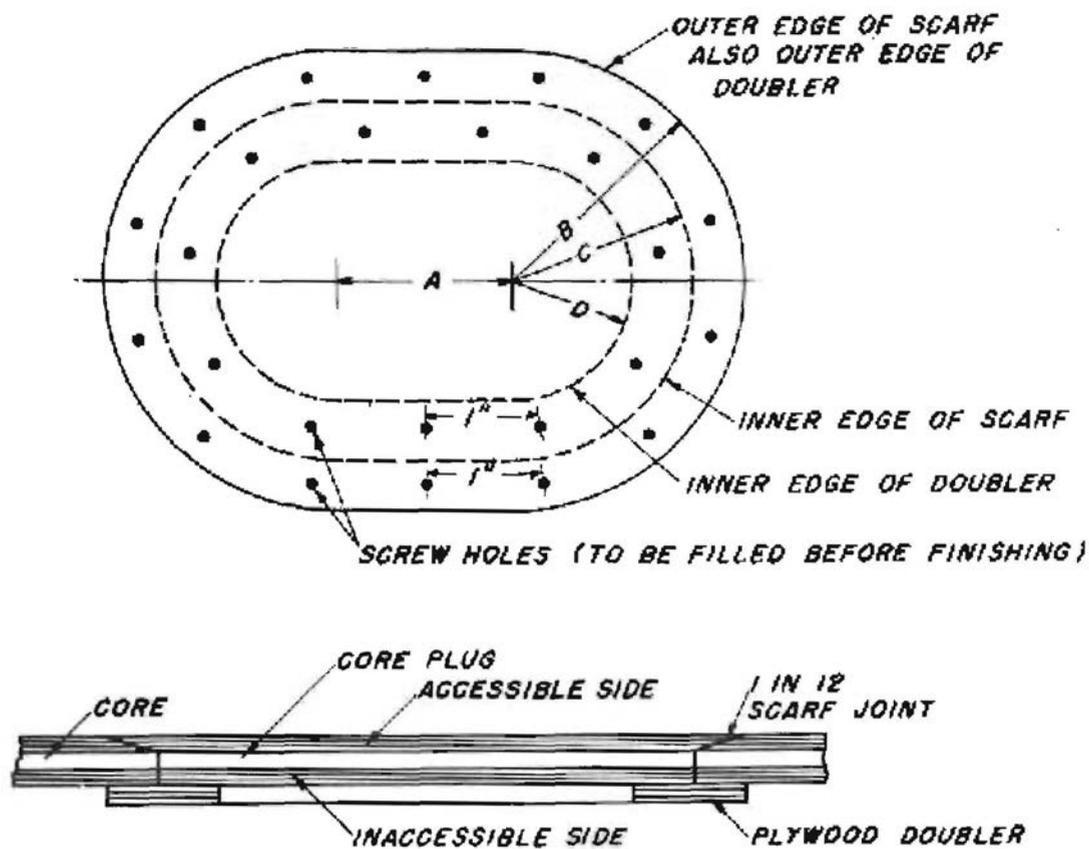


Figure 1.--Oval-shaped scarf patch assembly used in plywood-faced panels when both sides are accessible.

2 X 75913 Y



DIMENSIONS (INCHES):

	<u>A</u>	<u>B</u>	<u>C</u>	<u>D</u>
SMALL OVAL PATCH	$1\frac{1}{2}$	$2\frac{1}{4}$	$1\frac{1}{2}$	$\frac{3}{4}$
LARGE OVAL PATCH	2	$3\frac{1}{4}$	$2\frac{1}{2}$	$1\frac{3}{4}$

Figure 2.--Oval-shaped patch assembly need in plywood-faced panels when one side only is accessible.

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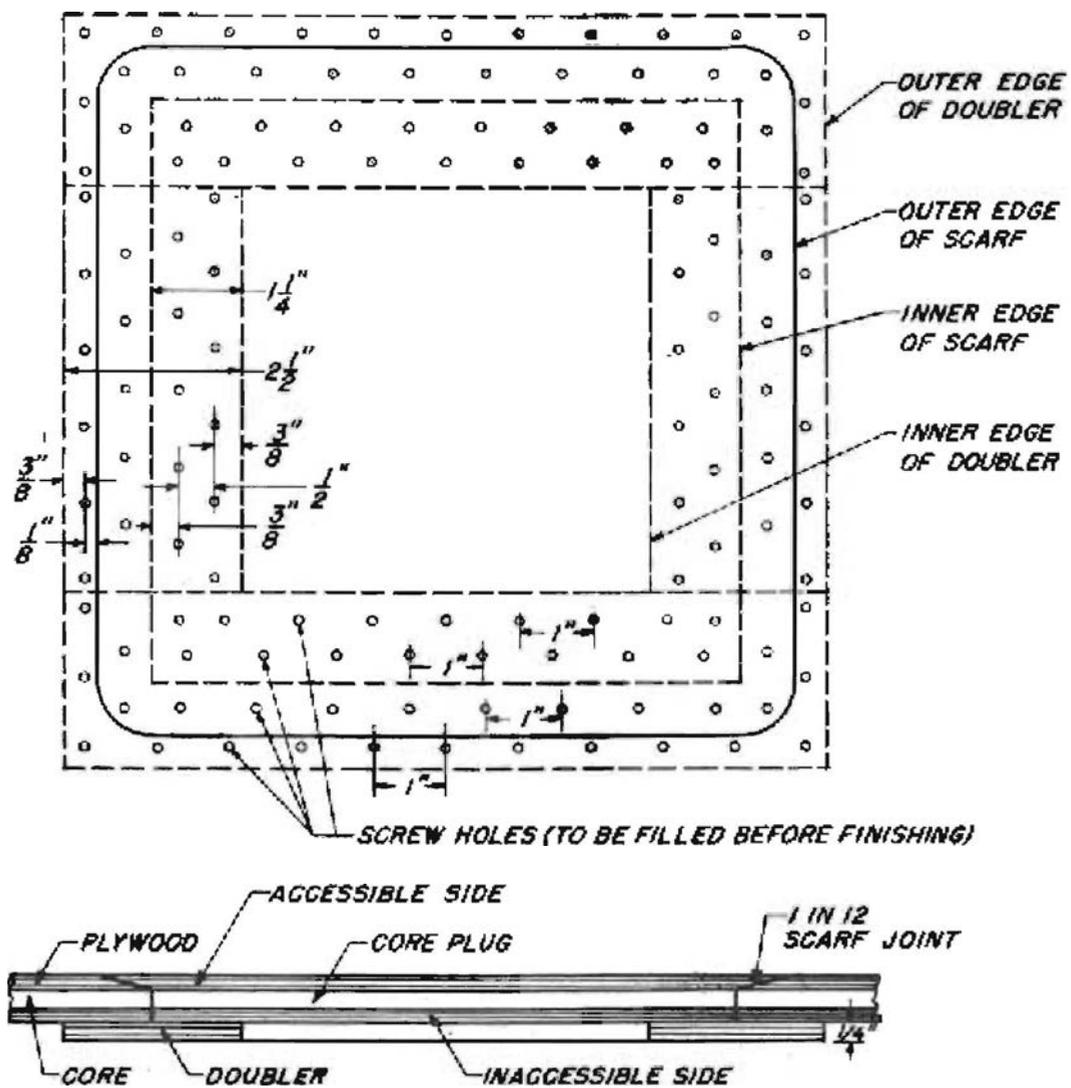


Figure 3.--Square or rectangular patch assembly used in plywood-faced panels when one side only is accessible.

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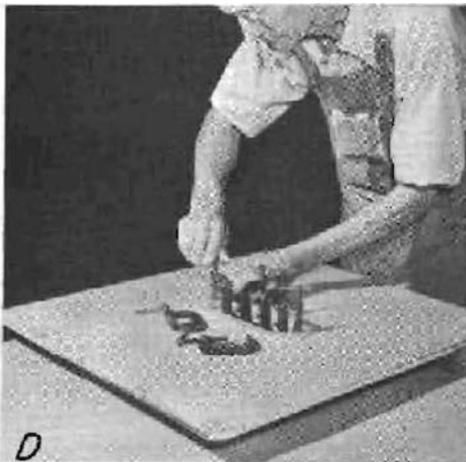
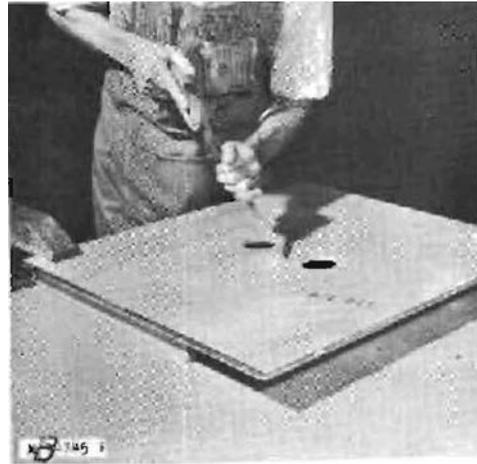


Figure 4.--Steps used in making an oval-shaped scarfed patch in a sandwich panel having plywood facings and end-grain balsa core when one side only is accessible. A, cutting holes at the end of the oval repair by means of a centerless hole saw in a hand brace; B, sawing out the area between the holes; C, spreading glue on the backing ring to be glued to the back side of the panel; D, clamping backing ring to panel; E, scarfing face side of repair.

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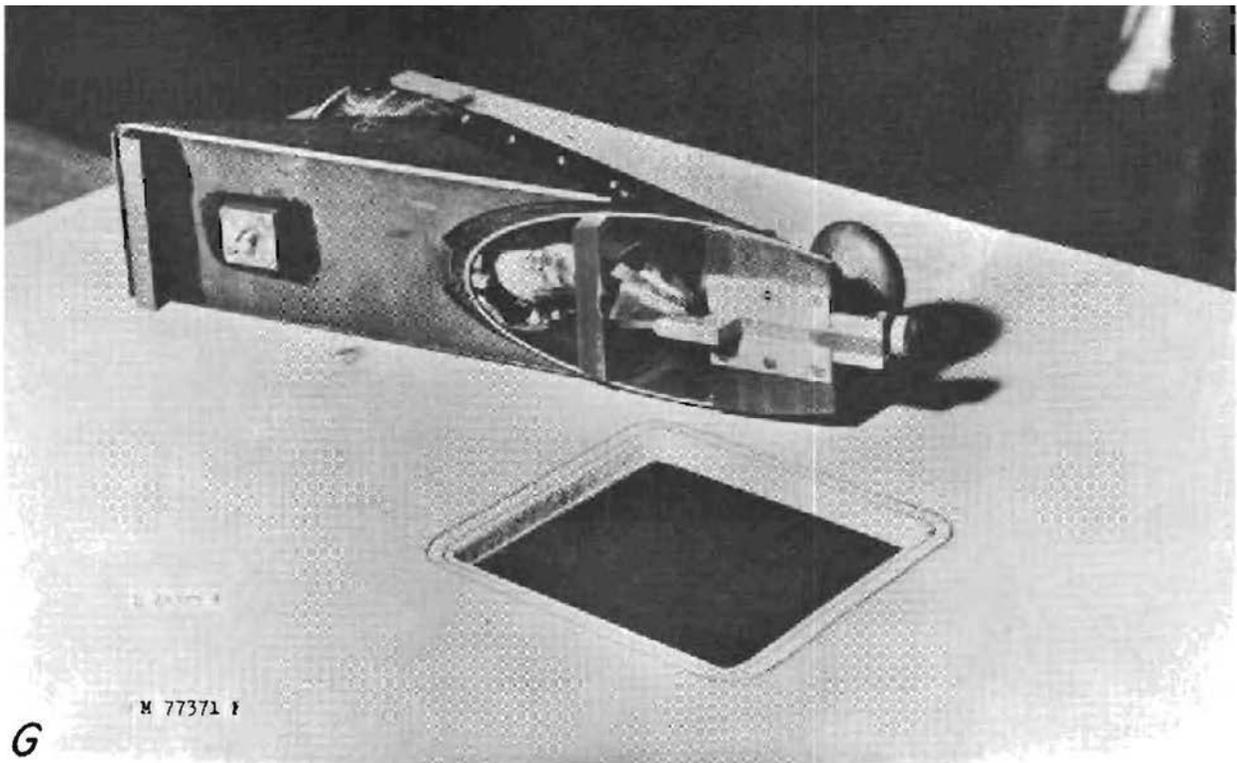
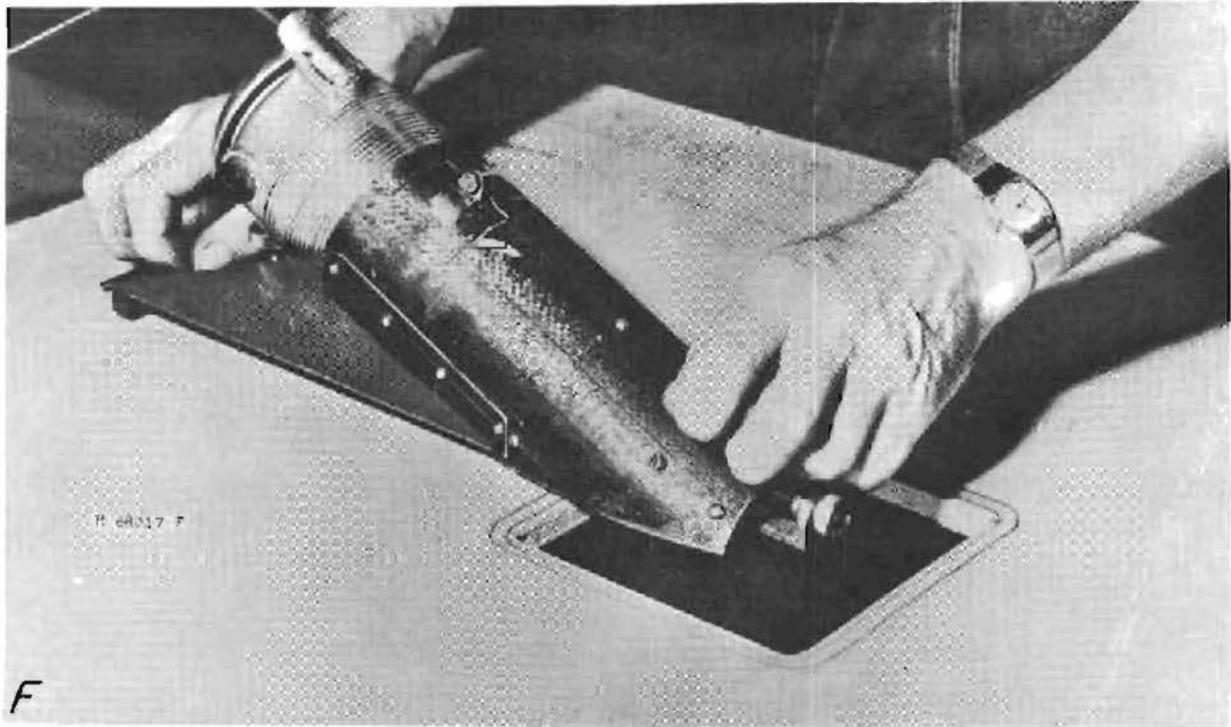


Figure 4 (continued) .-F, alternate method of scarfing plywood, using an electric router in a special adapter; G, underside of scarfing device showing details of construction.

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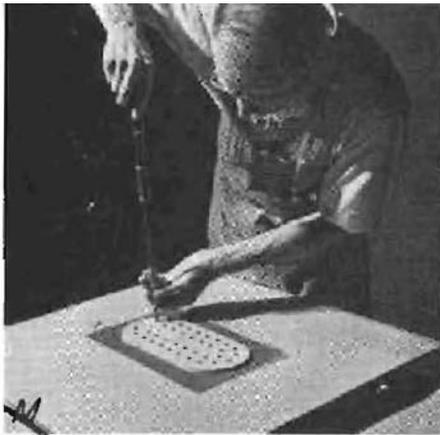


Figure 4 (continued).—H, scarfed face patch prepared (Note back face and core filler.); I, spreading glue on parts preparatory to assembling; J, completing glue-spreading operation on face patch; K, laying cellophane parting film over repair; L, drilling screw holes through repair; M, screwing pressure plate in place; and N, scraping glue from finished repair.

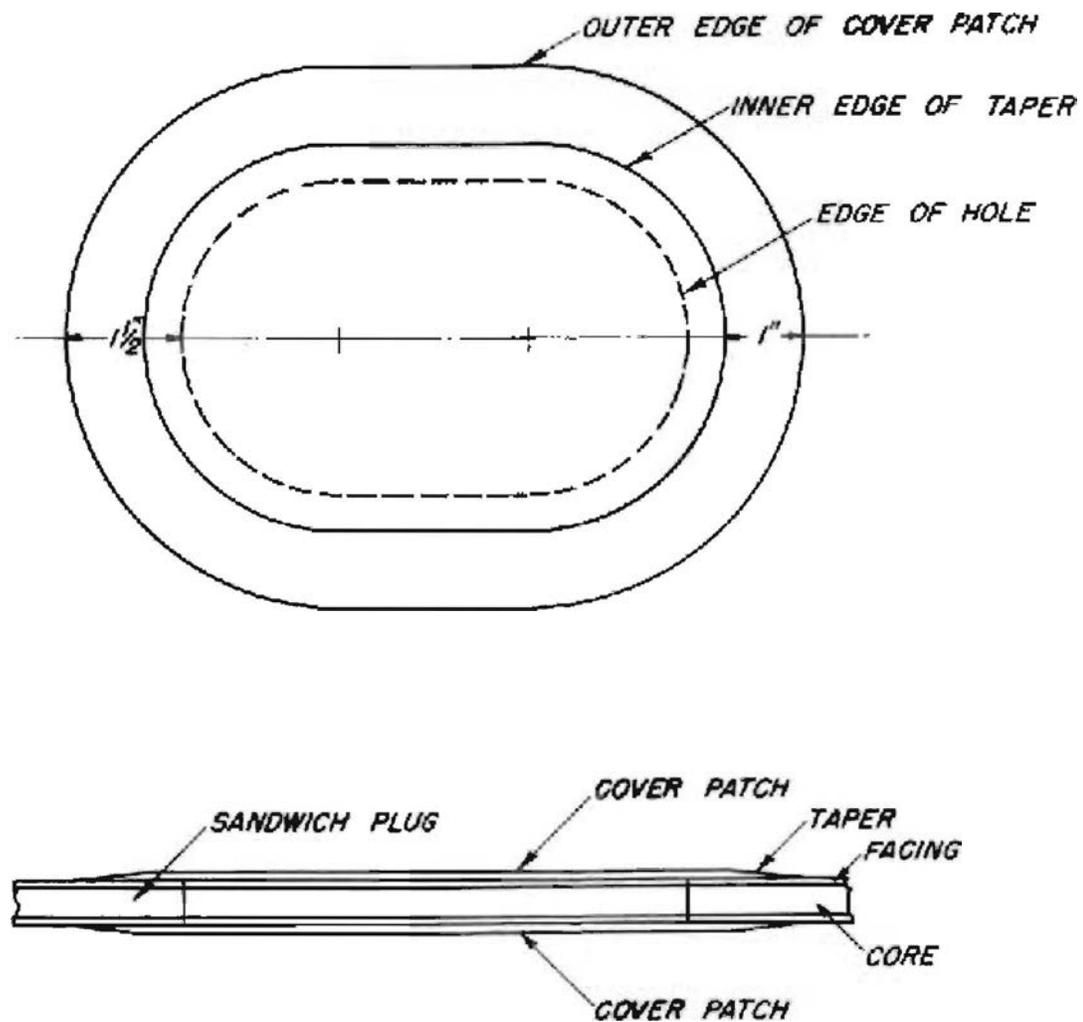


Figure 5.--Oval-shaped patch assembly used in aluminum-faced panels when both sides are accessible.

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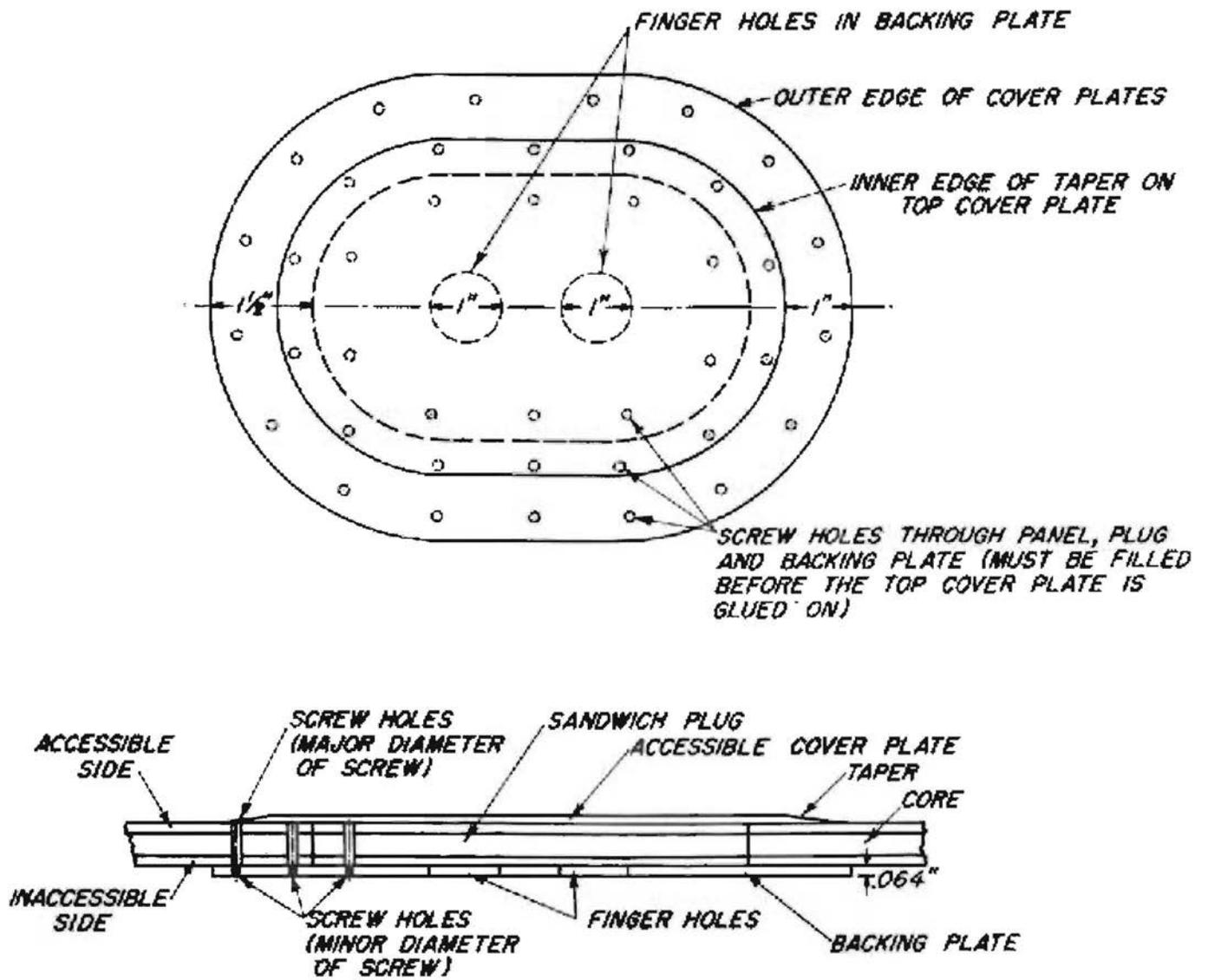


Figure 6.--Oval-shaped patch assembly used in aluminum-faced panels when one side only is accessible.

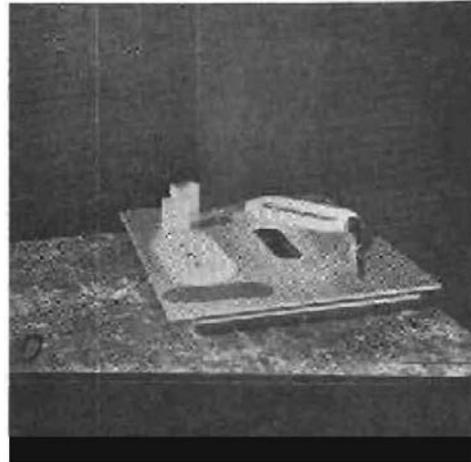


Figure 7.--Steps in making an oval-shaped repair in a sandwich panel having aluminum facings on end-grain balsa core. A, cutting holes at the ends of the oval-shaped hole; B, sawing out the damaged area, using a reciprocating-saw attachment for an electrical drill; C, removing the burr on the sawn aluminum edges; D, screw holes drilled in area around hole (Note aluminum backing plate with finger holes and plywood caul ring.) E, backing plate being screwed in place, using self-tapping screws through plywood caul ring; F, continuing to screw backing plate in place (Protector plate has been dropped in place to cover holes in backing plate increasing heat transfer to glue line.)

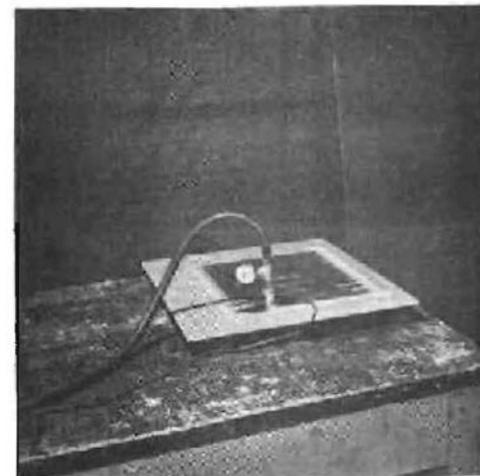
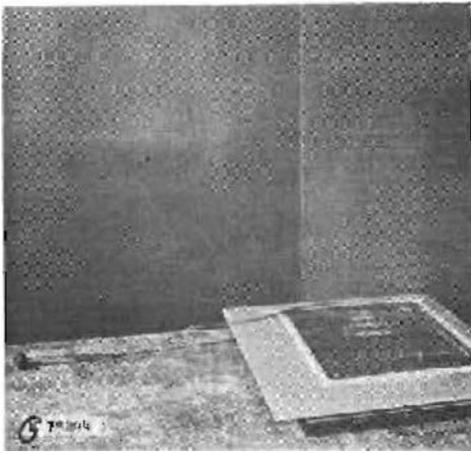


Figure 7 (continued) -- G , electrically heated blanket taped in place over patch to provide heat for curing glue; H , plug patch being screwed in place, using self-tapping screws through a plywood caul; I , heated blanket again taped over patch to cure glue between plug and backing plate; J , plugging screw holes with special filler to prevent leakage; K , glue spread on patched area and surface plate preparatory to gluing surface plate in place; and L , electrically heated vacuum blanket in place over patch in final gluing operation (Later, glue squeeze-out was cleaned off preparatory to finishing.)
 ZM 77484 F

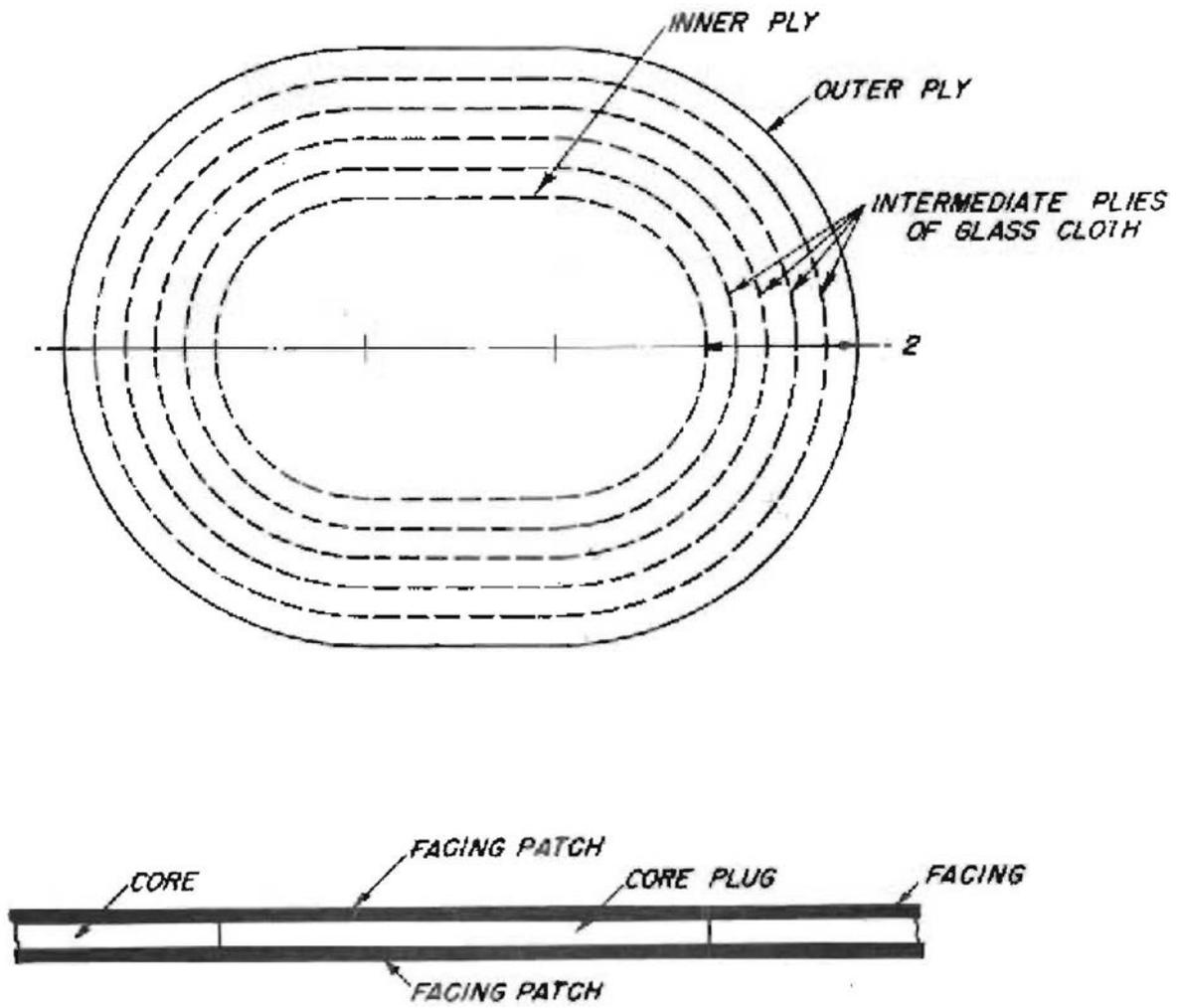


Figure 8.--Oval-shaped patch assembly used in glass-cloth-faced panels when both sides are accessible.

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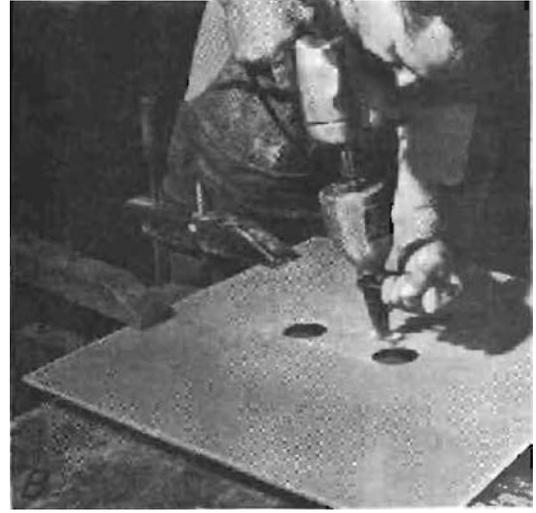


Figure 9.--The steps in making an oval-shaped patch in a sandwich panel having glass-cloth facings on glass-cloth honeycomb cores, with both sides accessible. A, cutting holes at the end of the oval repair by means of a centerless hole saw in a hand brace; B, sawing out the damaged area with a reciprocating-saw attachment for an electric drill; C, scarfing the area around the hole, using a flexible disk sander; D, core has been laid in place, and resin is being applied on scarfed face.

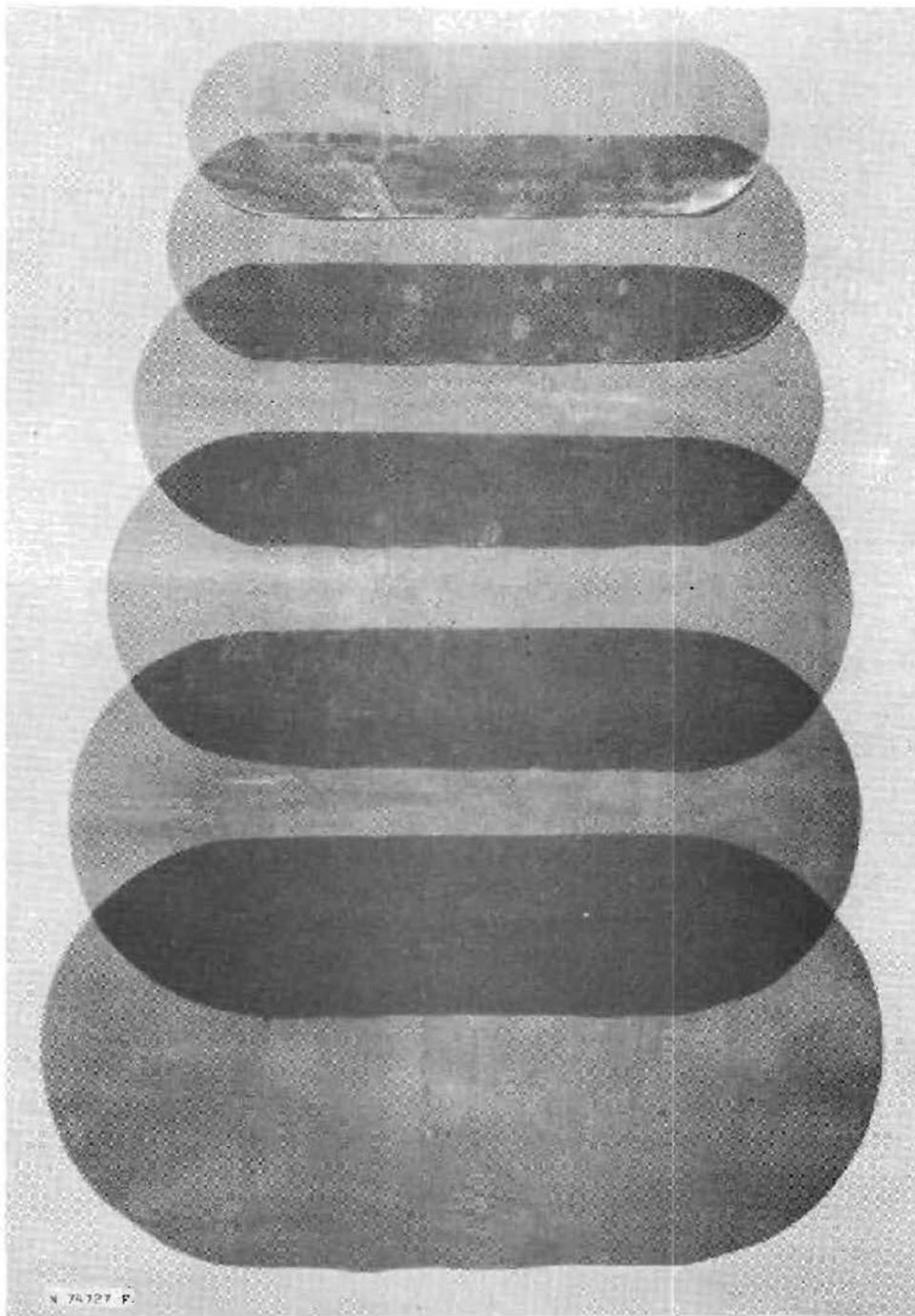


Figure 9 (continued).--E, the individual pieces of resin-impregnated, cellophane-covered glass cloth necessary to build up the repaired facing.

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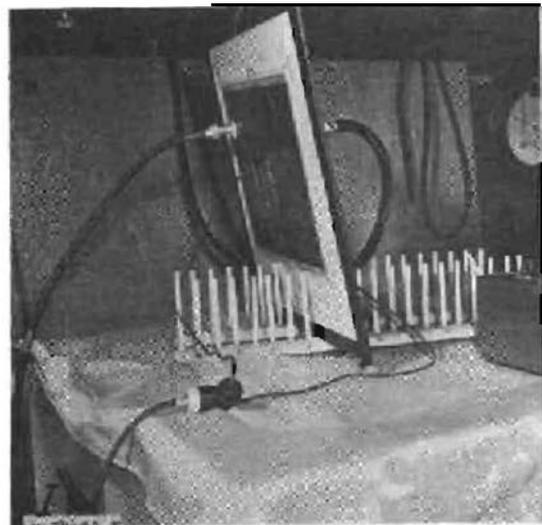


Figure 9 (continued) .-F, procedure of laying up the patch on a cellophane-covered aluminum caul; G, laying complete face lay-up in place over area to be repaired; H, pin-pricking the cellophane covering to aid escape of entrapped air; I, curing both faces of repair simultaneously under two electrically heated vacuum blankets.

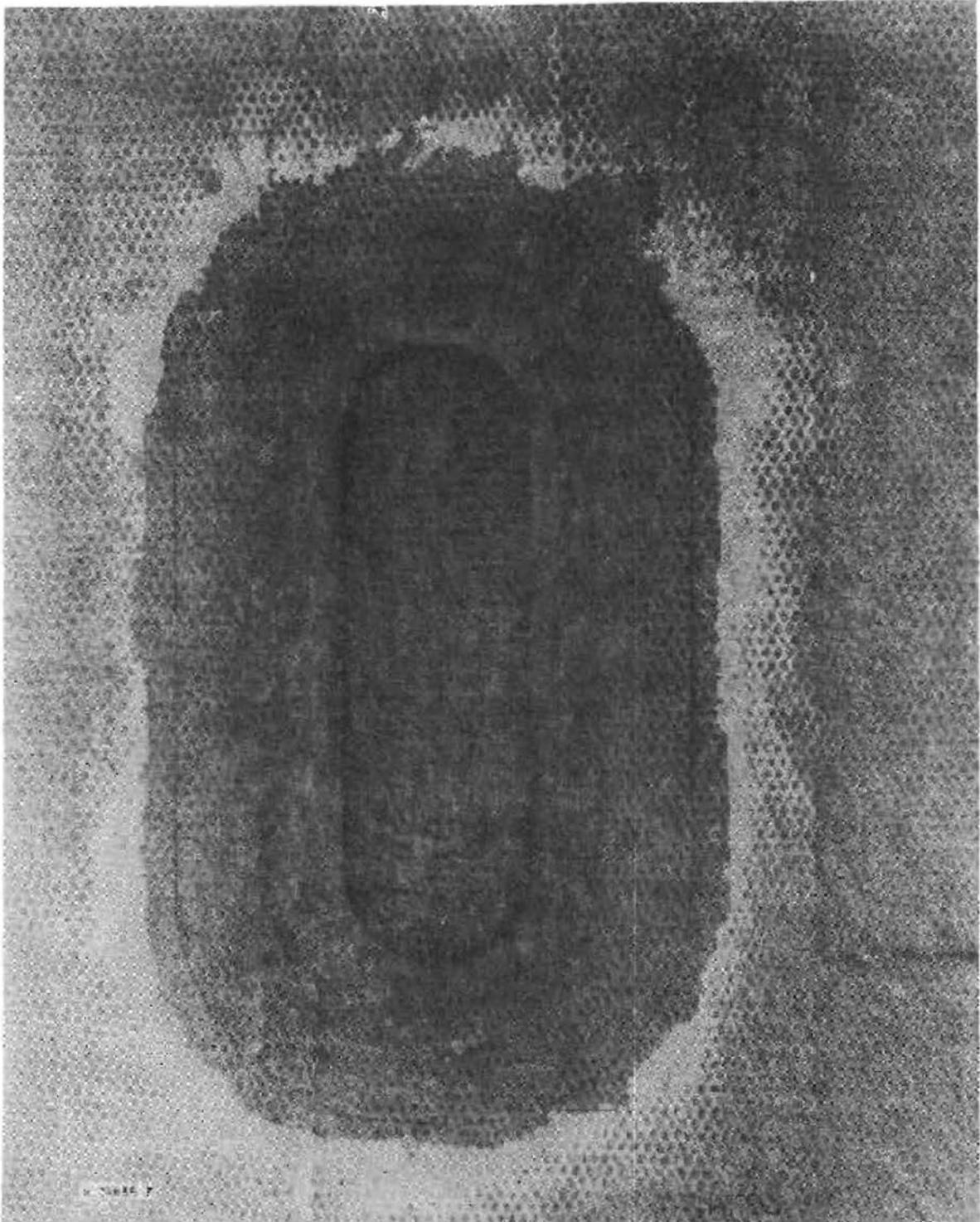
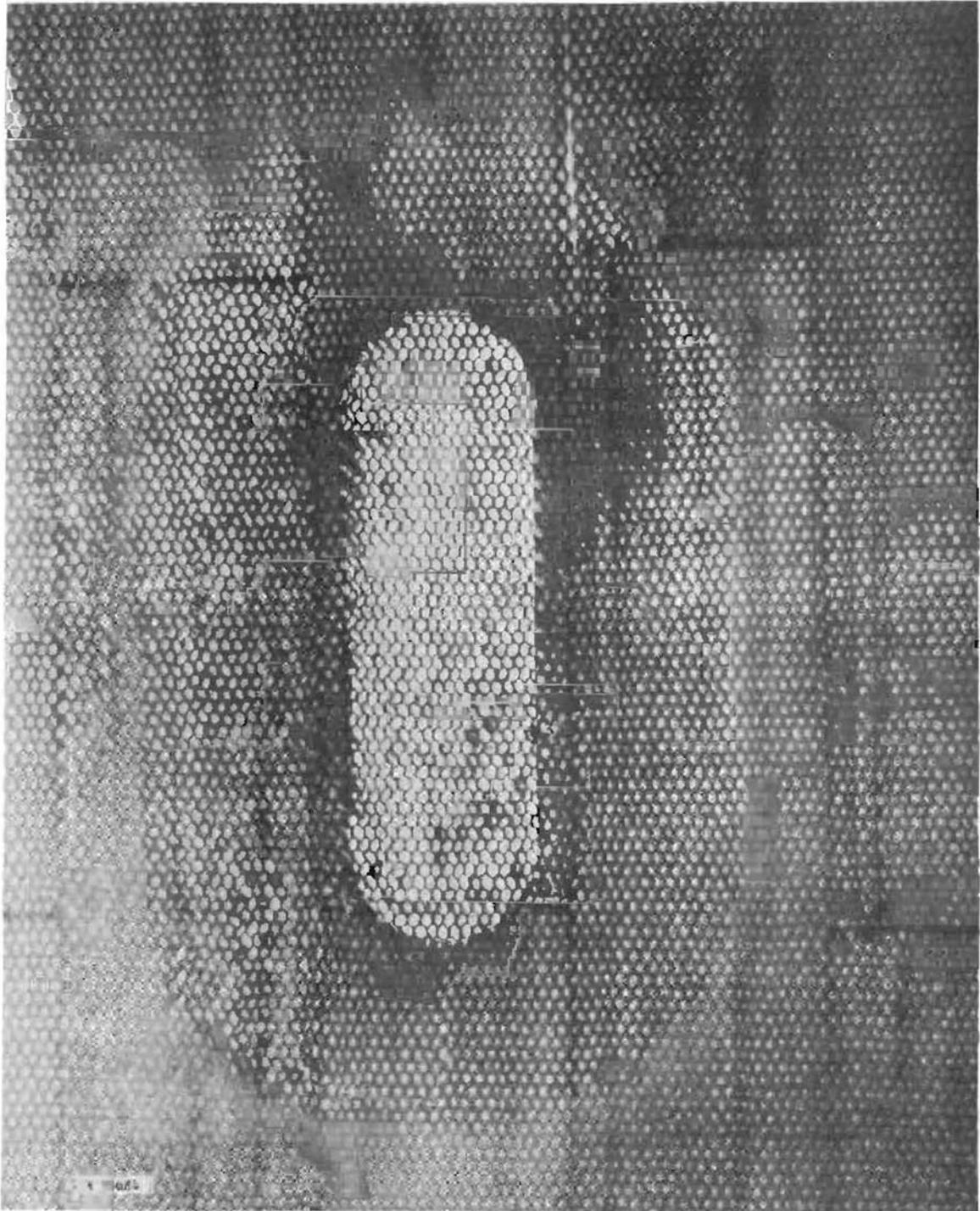


Figure 9 (continued) .--J, finished repair.

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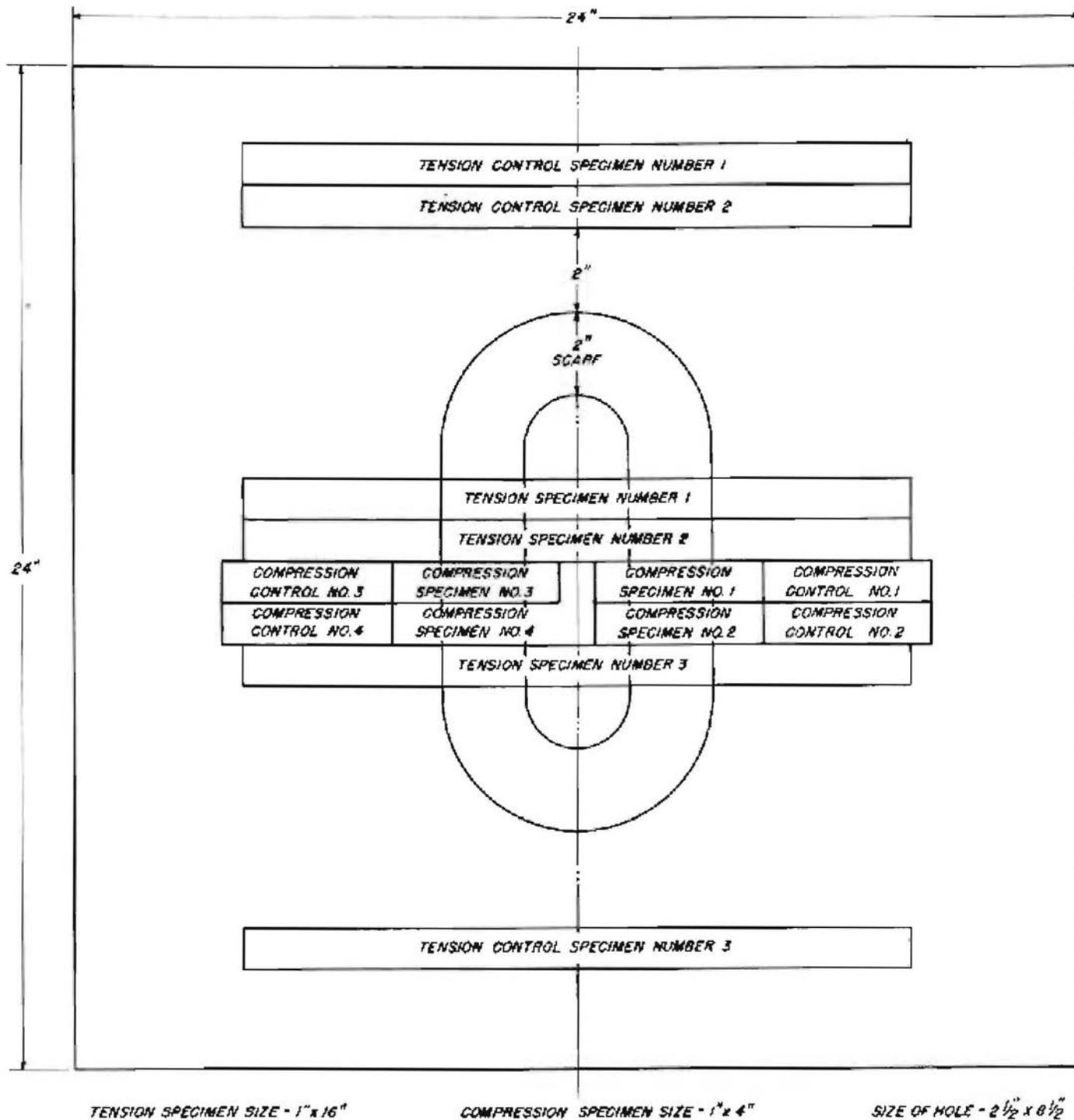


Figure 10.--Cutting diagram for test panels having glass-cloth faces.

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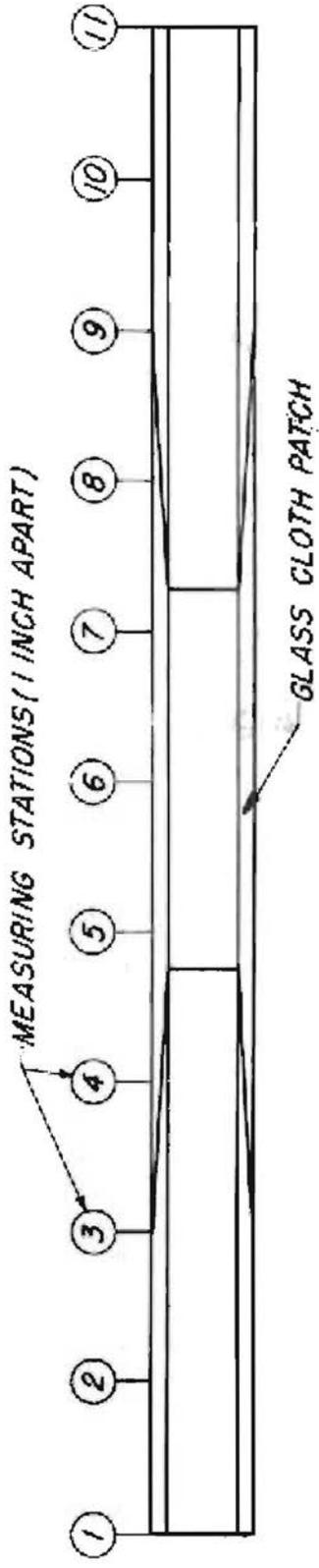


Figure 11.--Cross section of glass-cloth - glass-cloth-honeycomb sandwich showing thickness measurement stations.