Armed Services Technical Information Agency

Because of our limited supply, you are requested to return this copy WHEN IT HAS SERVED YOUR PURPOSE so that it may be made available to other requesters. Your cooperation will be appreciated.

AD 38648

Reproduced by
DOCUMENT SERVICE CENTER
KNOTT BUILDING, DAYTON, 2, OHIO

UNCLASSIFIED

NAVORD REPORT 2689

EVALUATION OF GLASS FABRIC REINFORCED PLASTIC LAMINATES

30 JANUARY 1953

U. S. NAVAL ORDNANCE LABORATORY
WHITE OAK, MARYLAND

EVALUATION OF GLASS FABRIC REINFORCED PLASTIC LAMINATES

Prepared by:

F. Robert Barnet

ABSTRACT: Use of reinforced plastics as materials of construction for naval ordnance requires that specifications be established to control the quality of these materials. Many such material specifications already exist and are used as a basis for the procurement of plastics. However, further information and exact data are required if these materials are to be properly used and specified in ordnance design. Properties of laminates made with different reinforcements and tested under various environmental conditions peculiar to the ordnance field must be made available.

To provide a limited amount of specialized data, a program of evaluation of numerous materials and process variables on the physical, electrical and mechanical properties of glass cloth laminates was undertaken by the Naval Ordnance Laboratory. Included were the variables of fabric weave, yarn weight, fabric finish, type resin, test panel thickness, resin content, and temperature at the time of test. Test panels were molded under precise conditions, and the properties of the laminates were measured after storage for one week at 75°F and 50% RH. No data were taken after sea water immersion, outdoor exposure or other conditions of service.

U. S. NAVAL ORDNANCE LABORATORY
WHITE OAK, MARYLAND

NAVORD Report 2669 30 January 1953

NAVORD Report 2669 presents data on plastic laminates which are necessary for the specification of reinforced plastic materials to be employed in the manufacture of structures for naval ordnance devices. It is believed that they are sufficient for the specification of design models and prototypes. However, concurrent with tests on these units, considerable data must still be gathered on the influence of such factors as sea water immersion, transportation vibration, impact, dead loads, and outdoor exposure and or variable storage temperatures and humidities. These further data are necessary before satisfactory service life can be assured on materials subject to the more stringent environmental conditions. Test panels for the program discussed in this Report were prepared at the Naval Ordnance Laboratory on its precision molding press and were then sent to the Forest Products Laboratory, Madison, Wisconsin, for preparation of the test specimens, testing, and reporting of the data. The work at the Forest Products Laboratory was carried out by K. H. Boller and L. E. Downs, engineers. Excerpts from their report to the Naval Ordnance Laboratory are incorporated in this Report. The work was originated at the request of the Naval Ordnance Test Station, Inyokern, California, and was concluded as authorized by task NOL-Re6a-268-18-53. The data reported herein are applicable to all those applications where glass fabric reinforced laminated plastics are materials of consideration in the production of ordnance. They do not, however, represent the sum total of the data needed for this purpose.

EDWARD L. WOODYARD
Captain, USN
Commander

D. S. MUZZEY, JR.
By direction

CONTENTS

ILLUSTRATIONS

EVALUATION OF GLASS FABRIC REINFORCED PLASTIC LAMINATES

INTRODUCTION

1. The program to investigate the properties of glass-fabric-reinforced plastic includes an evaluation of the physical, mechanical, and electrical properties of specific laminates as molded, as well as the effects of a number of variables on these properties.

2. It is the purpose of this investigation to evaluate the properties of laminates made of two resin types, polyester and phenolic; five different glass-fabric weaves; two different types of yarn; two different finishes; four different thicknesses; five different resin contents; and tested at seven different temperatures.

Preparation Of Test Panels

3. All of the laminates for this investigation were supplied by the Naval Ordnance Laboratory. The panels were all parallel laminated with glass fabrics using either a polyester or phenolic-type resin as follows:

All polyester-resin laminates were made using a wet lay up procedure and an effort was made to eliminate the air from the piece. Six hundred PT Cellophane was used to contain the wet panel. After lay up the Cellophane was sealed with scotch tape, after which the panel was rolled with a steel roller until the air had been eliminated. The entire operation required approximately 1 hour. The panel was then placed in a Baldwin-Southwark precision laminating press and pressure was applied. Approximately 5 hours were required to produce a good solid gel at room temperature. At completion of this preliminary curing condition under pressure, the laminate was removed from the press and placed in an oven operating at 110°F for 24 hours to complete the cure. The resin and catalyst system used was as follows:

Resin: Paraplex P-43 (Rohm and Haas Co.)
Catalyst: 1.25 percent DDM (Methyl ethyl ketone peroxide)
Accelerator: 1.00 percent Nuodex (6 percent) (Cobalt Naphthenate)

All phenolic laminates were made using a dry lay up procedure. The required number of plies of preimpregnated glass cloth were cut and laid in position on Cellophane (600 PT) after which they were sealed in with scotch tape. The piece was then placed in the Baldwin-Southwark precision laminating press and pressure was applied. After the desired pressure had been reached, heat was applied to the platens and the piece was maintained at a temperature of 300° ± 5°F for 1 hour to effect cure. At the end of this heating period the press was cooled to ambient temperature and the panel was removed. The impregnated cloth* had the following characteristics before cure:

*Phenolic impregnated glass cloth was treated by Fabricon Products, Inc., Plastics Division, River Range, Michigan

Resin: Bakelite BV 17085
Resin content: Approximately 35 percent
Volatile matter: 6-1/2 percent volatile matter (determined by 10-minute exposure at 160°C)

Further molding data are given in Table 1.

Test Methods

4. The test procedures, in general, conformed to the methods specified in Federal Specification for Plastics, Organic: General Specifications, Test Methods, No. L-P-406a and amendments thereto. The following mechanical, physical, and electrical tests were made on the specimens from each of the panels referred to in Table 1.

Mechanical tests
Tension - Method 1011
Compression - Method 1021
Flexure - Method 1031
Shear (double) - Method 1041
Izod impact - Method 1071

Physical tests
Water Absorption - Method 7031
Dimensional change - Method 7031
Specific gravity - Method 5012

Resin content [2]

Electrical properties
Power factor [3]
Dielectric constant [3]

5. The specimens for the mechanical and physical tests were cut from the panels by means of a carborundum saw, and when further shaping was necessary, a fine emery wheel on a vertical spindle was used. The specimens so machined were stored for at least a week prior to test at 75°F ± 2°F,

---

[2] L-P-406a has no method so USAF Specification 12049, paragraph F-6b(4) was used.

[3] The dielectric constant and power factor were determined at a frequency of 8,530 megacycles per second, by use of a "Microwave Dielectrometer", Model 2, manufactured by Central Research Laboratories, Inc., Red Wing, Minnesota. Actually the loss tangent was determined, rather than power factor, but for low-loss materials such as these plastic laminates the difference between loss tangent and power factor does not exceed 3 units in the fifth decimal place, which is less than the experimental error or the error introduced by rounding off the results to four decimal places.

50 ± 2 percent relative humidity. Mechanical test specimens in Group 3 were held at the test temperature for 1/2 hour before test. Temperature measurements with a thermocouple showed that the test temperature was attained after 10 minutes exposure; however, an additional 20 minutes was allowed before testing. The specimens for the electrical tests were roughly shaped on a Doall band saw and then finally shaped with machine tools and emery paper.

Discussion Of Results

A. Evaluation of Laminates Made of Fabrics of Different Weaves and Yarn Types

Variations in Fabrics

6. General. The investigation was concerned with the variation in physical, mechanical, and electrical properties of laminates made with fabrics of different weaves. Five cloth styles which included three types of weaves were investigated.

7. Resin content. The resin contents of the polyester-type laminates are greater than those of the phenolic type having resin contents which range from 32.7 to 44.7 percent as compared with the phenolic-type laminates which range from 22.3 to 29.3 percent. A comparison of the laminate with 114 finish shows that the 128-type fabric has the highest resin content in its particular resin class. In each resin class there is a duplication of panels made with 181-114-225 fabric. The resin contents of these duplicate panels are very nearly equal.

8. Specific gravity. The majority of the panels in Group 1 have specific gravities which vary from 1.685 to 1.910 (Table 2, Column 4). There are two panels, however, (panels 1.2 and 1.6, Table 1) which are considerably below this range. Both of them were made of phenolic resin, one with 128-114 and the other with 164-114 fabric. Except for these two panels, the values are within the range usually found in glass-fabric-base laminates. It was found, however, that duplicate panels made of these two fabrics and phenolic resin had about the same specific gravities as those tabulated so it was concluded that this low specific gravity was because of insufficient resin on the fabric thus allowing too little compression of the plies in the fabrication technique employed.

9. Water absorption and dimensional change. There were considerably more pores or voids in the laminates (panels 1.2 and 1.6) having low specific gravity than in the other laminates, which were void-free. This fact accounts for the high values of water absorption for these two panels (Table 2, Column 5). A comparison of values shows that the water absorption of laminates fabricated with polyester resin is under 0.14 percent and that the values from phenolic laminates are over 0.62 percent.

10. Table 2, Columns 6 to 8, which presents the dimensional change due to water absorption shows that the greatest change is 0.52 percent. The small values are typical of glass-fabric-base laminates.

11. Compression, shear, and Izod impact strengths. Figure 1 also shows graphically the average strength values for compression, shear, and Izod impact. Since all of the panels were parallel laminated, these strength values show the relative strengths at 0° and 90° to the warp. The 143-114 fabric is, of course, the strongest of the fabrics in the 0° direction and the weakest in the 90° direction. The other fabrics are not so unidirectional. The laminates made with 181-type fabric have higher strength values in compression and shear than do the other laminates tested but are weaker in impact strength. The compressive and shear strengths of a given fabric fabricated with phenolic resin are generally lower than for the same fabric laminated with a polyester; however, the reverse is true of their impact strengths. The laminates having voids, that is, the 128 and 164 fabrics having phenolic resin binder, are definitely weaker in all properties.

12. Tension. The tensile properties of the various glass-fabric-base laminates, as shown in Group 1 of Table 3, are listed under two major headings, modulus of elasticity and stress. These values serve to define an average stress-strain curve for the material in question. Such an average curve has been reproduced (Figure 2) for each material in its two principal directions. A comparison of these stress-strain curves shows that the 143 fabric is highly unidirectional and that even though all panels were parallel laminated, the 0° and 90° properties of the other laminates are nearly equal. The proportional limit values of all the laminates are a small percentage of the maximum stress. The meaning of this low value is questionable since the portion of the stress-strain curve above it is also a straight line for most of the materials. There was, however, a definite break at this point for most of the materials. Previous experiments have shown that if these materials are prestressed beyond the apparent initial proportional limit, a new modulus of elasticity and proportional limit are established.[4] The new modulus of elasticity has a lower value than the first one and might be about equal to the second straight line or a secant modulus, depending on the amount of prestressing. For this reason, the secant modulus at 0.2 percent strain offset has been computed. Secant modulus at 0.2 percent strain offset was not obtainable for all materials so that the secant modulus at 0.1 percent strain offset was also computed.

13. The laminates which had the lowest strength are again those which were made of phenolic resin and either 128 or 164 fabric. These laminates contained voids which caused poor bonds between the laminations of fabric. The fracture of specimens from these laminates was a splintering, brooming type, which delaminated from the break toward the grip. The void-free specimens had, in general, cleaner breaks across the net section.

14. Flexure. The results of the flexural tests, Group 1 of Table 5, show strength values comparable to those shown for the tensile tests. The flexural properties, however, show higher proportional-limit values and the average load-deflection curves (Figure 3) do not exhibit dual

---

[4] Werren, Fred, Effect of Prestressing in Tension or Compression on the Mechanical Properties of two Glass-fabric-base Plastic Laminates. Forest Products Laboratory Report No. 1811. September 1950.

straight lines. The flexural stresses, being a combination of tension and compression stresses show by a detailed comparison about the same relation among materials as the tensile tests.

15. Electrical properties. Any variation in electrical properties attributable to variations in fabrics was too small to be detected in the presence of the normal experimental errors.

Series 2. Variations in Yarns

16. Series 2 of this investigation deals with variations in the physical, mechanical, and electrical properties resulting from a variation in yarn "count", which is an indication of the number of yards of basic strand per pound of yarn. The evaluation of these properties was obtained from panels made of 181-114 fabric with both polyester and phenolic-type resin. The yarn count of one set of panels was 150 (15,000 yards of basic filament per pound) and that of the second set was 225 (22,500 yards of basic filament per pound).

17. The results show that a difference in yarn count did not greatly affect the specific gravity, percentage water absorption, ultimate compressive strength, or flexural strength of laminates made with either type of resin. Neither did this difference significantly affect either the flatwise shear strength of polyester-type laminates or the Izod impact and tensile strengths of the phenolic-type laminates. This difference in yarn count seemed to affect only the flatwise shear strength of the phenolic-type laminate and the Izod impact and tensile strengths of the polyester-type laminate. These strengths were affected to the extent that the laminate with 150-count yarn was stronger in impact and tension but weaker in shear.

18. Electrical properties. No variations in electrical properties due to variations in yarn count could be detected, because if present, they are smaller than experimental error and variations attributable to differences in resin content.

Series 3. Variations in Finish

19. The evaluation of the effects of different fabric finishes on the properties was obtained from laminates made with both polyester and phenolic-type resins in combination with the 181-136 fabric for comparison with those obtained from laminates made of 181-114-225 fabric. The results of the physical tests show that the specific gravities of the laminates with 136-type finish are less than those with 114-type finish. The phenolic laminate with 136 finish contained some voids which caused greater water absorption and dimensional changes than were experienced in either the polyester laminate or the laminate with 114 finish and phenolic resin. It should be noted that the 136-type finish was intended primarily to improve the wet strength of a laminate but wet strength tests were not a part of this evaluation. The results of the dry strength tests show, however, that the 136-type finish with polyester-type resin had compressive, shear, tensile, and flexural strengths equal to or less than the 114-type finish. The Izod impact strength showed a slight improvement.

All of the strengths, however, from the phenolic panel with 136 finish were less than those with 114 finish. Some of this deficiency may be a result of the low specific gravity.

20. Electrical properties. Any effect of variations in finish on electrical properties was small, and negligible in comparison to the effects of resin content and the normal experimental error inherent in determinations of this kind.

B. Group 2. Effect of Laminating Conditions on the Strength of Plastics

21. General. The evaluation of the effect of certain laminating and fabricating conditions on properties of glass-fabric-base plastics was conducted on one combination of materials, 181-114-225 fabric plus a polyester-type resin. This evaluation includes (1) the fabrication variable of thickness and (2) the combined effect of varying the resin content and pressure during fabrication. To evaluate these effects, the same physical, mechanical, and electrical tests were conducted on laminates in Group 2 as were conducted on laminates in Group 1.

22. Resin content. The resin content of the panels in Series 5 varies from 21.8 to 41.6 percent. The desired range for this series was from 20 to 50 percent which was to be accomplished by a pressure variation from 395 to 2 pounds per square inch. The 2 pounds per square inch pressure, however, resulted in 39.5 instead of 50 percent resin content. It may be noted also that the 61 pounds per square inch laminating pressure (panels 1.7 and 1.9) resulted in a 33.2 percent resin content which is greater than the 30.0 percent resulting from a pressure of 45 pounds per square inch, all of which means that the resin content is dependent upon factors other than pressure.

23. Specific gravity. As the resin content increases, the specific gravity decreases, which is as expected, since glass is heavier than resin.

24. Water absorption and dimensional stability. A comparison of the water absorption values as shown in Table 2, Column 5, indicates that the percentage of water absorbed increases when the thickness of the laminate is decreased. The values range from 0.05 percent for 1/2-inch-thick material to 0.22 percent for 1/16-inch-thick material.

25. It appears, by a comparison of values on Series 5, that the resin content has little effect on the water absorption except that at 21.8 percent resin content the percentage is higher than normal, with a value of 0.36 percent.

26. The values for dimensional change appear to be unaffected by size or resin content as shown by Table 2, Columns 6 to 8 for Series 4 and 5.

27. Compression, shear and Izod impact strengths. The effects that laminating conditions have on the compression, shear, and Izod impact strength are shown in Figure 4. Even though the strength of these laminates may be affected by their molding pressure as well as by their resin contents, the combination of these effects is shown plotted as a function of resin content only.

28. This visual comparison of values and those presented in Tables 4, 6, and 7 shows the following trends:

a. The edgewise compressive strength increases with increases in thickness from 1/16 inch to 1/4 inch; the strength of the 1/2-inch-thick laminate is about the same as that of the 1/4-inch laminate.

b. The flatwise shear strength of these laminates shows very little increase in strength with increases in thickness.

c. The edgewise Izod impact strength also increases with increase in thickness, having values of about 11 foot-pounds per inch of width at 1/8 inch and 17 foot-pounds at 1/2 inch of thickness.

d. The edgewise compressive strength appears unaffected by resin content.

e. The flatwise shear strength decreases slightly with increase in resin content.

f. The edgewise Izod impact strength decreases with increase in resin content.

29. Tension. Figure 5 presents graphically the results of tensile tests, which are tabulated in Table 3, to show the effect of laminating conditions on tensile properties of plastics. This figure shows that both the maximum tensile strength and the secant modulus at 0.2 percent strain offset are reduced by an increase in resin content. The tensile strength decreases from 53,000 pounds per square inch at 21.8 percent resin content to 29,380 pounds per square inch at 41.6 percent resin content or about 1,250 pounds per square inch change in stress per percent change in resin content. The secant modulus decreases about 37,000 pounds per square inch per percent change in resin content.

The proportional limit stress appears to be unaffected by either resin content or thickness of the laminate. Due to the scatter of points, it is difficult to determine the trend indicated by the points for effect of thickness on secant modulus or maximum tensile strength, although there is some indication that tensile strength increases with increasing thickness.

30. Flexure. The results of the flexural tests as shown on Figure 6 indicate decreases in modulus of rupture and secant modulus as a result of increases in either thickness or resin content. Slight increases in compressive and tensile strength were observed with increases in thickness, yet these flexure tests show a decrease in strength with increases in thickness. The decrease in modulus of rupture with increase in resin content is in agreement with the tensile test results.

31. Electrical properties. No effect of panel thickness on dielectric constant and power factor was discernible.

32. The dielectric constant of the polyester laminates had a striking relation to their resin content, as illustrated in Figure 10. The dielectric constant decreased as the resin content increased, which would be expected if the dielectric constant of glass is higher than that of the polyester resin. There is a certain amount of scattering of the points, but it appears that the resin content - dielectric constant curve follows an approximately straight line over the range investigated.

33. The power factor of the polyester laminates was approximately constant over the range of resin content investigated, suggesting that the power factor of the polyester resin may be approximately equal to that of the glass used. The power factor of panel 4.3 appears very low (and a low power factor is desirable) but this may not indicate a real superiority of this panel in this respect. The data on this panel turned out in such a way that in the course of calculation of power factor most data were not usable because they were outside the range of certain curves used for calculation purposes, hence the figure reported is one single value rather than the average of several, and it is believed to be too low.

34. The points for dielectric constant and power factor of the phenolic resin laminates would be crowded both on Figures 10 and 11, and there appears to be little relation between resin content and electrical properties. No attempt was made, therefore, to plot the points but instead a circle was drawn on each figure, which would enclose all points for phenolic laminates except a few representing panels of abnormally low specific gravity and which in some cases contained voids.

35. If a low dielectric constant and power factor are considered desirable, then of the materials tested all polyester laminates tested having resin contents of 30 percent or over were superior to the phenolics in respect to dielectric constant, and all polyester panels regardless of resin content were superior to the phenolics in power factor.

36. From the results on both polyester and phenolic laminates, it appears that a certain weight or percentage of glass has a certain effect on electrical properties, irrespective of the manner in which the glass is present (weave, yarn count, finish).

C. Group 3. Variation of Strength Properties Because of Evaluation Conditions

37. General. The third group of tests was conducted to determine the effect of a specific evaluation condition — temperature at the time of test. Mechanical tests were conducted on test specimens at temperatures of -65°F, -30°F, 0°F, 30°F, 75°F, 120°F and 160°F. Specimens were held at the respective temperatures for 1/2 hour before test. Physical and electrical tests were, however, conducted at room temperature. Average values of strengths obtained are shown on the various tables. These values are shown also in Figures 7, 8, and 9.

38. Physical properties. The results of the physical tests, as shown in Table 2 for Group 3, which were obtained at room temperature, show how nearly identical the panels are to each other. The panels having polyester-type resin, for example, have resin contents between 30.0 and 36.4 percent. The pair of control panels in Group 1 had resin contents of 33.4 and 33.7 percent, respectively. The panels having phenolic-type resin show even less variation — the range is 23.3 to 23.9 percent. The specific gravity and water absorption values in Table 2 also show a uniformity of results.

39. Mechanical properties. All of the mechanical tests in Group 3 may be discussed together because they show the same trend. The data on Figures 7, 8, and 9 show that for increases in temperature from -65°F to 160°F there is a decrease in strength. That decrease in strength is greater for the laminates having polyester-type resin than for the laminates having phenolic-type resin. The trends are shown by broken lines through the scattered points. The scatter is, of course, due to the method of matching the specimens in this series of tests. Each point represents the average value from five specimens from a given panel so that the scatter includes the variation between panels. The trends, however, are well defined, except for tensile stress below maximum. The stresses at intermediate points on the stress-strain curve in tension show no trend (Table 3, Group 3, Column 7) or slight upward trends (Columns 8 and 9 or Figure 8). No particular significance is attached to this behavior because the initial tangent modulus (Column 4) decreases with increases in temperature the same as the other strength properties. This decrease in modulus indicates a flatter initial slope and hence a greater strain and stress at the 0.1 or 0.2 percent strain offset than experienced at the low temperatures.

CONCLUSIONS

A. Group 1. Evaluation of Laminates Made of Fabrics of Different Weaves and Yarn Types

40. The tables and charts show major differences among the materials such as: (1) The unidirectional property of 143 weave; (2) the detrimental effect of voids and low specific gravity; and (3) the small change in strength due to a difference in yarn type. The effect of 136-type finish is not conclusive because of the low glass content of the panels tested.

41. The results show also the reproducibility of values from two identical panels. This reproducibility may be seen by comparing the values in Series 1 obtained from panel 1.7 with those of 1.9 or the values obtained from panel 1.8 with those of 1.10. The average test values obtained from identical panels are in such close agreement that they were averaged to give a value which represents the strength for that particular combination of materials. This representative value was then used for comparative purposes in each series which followed.

42. Electrical properties. The dielectric constant and power factor appeared to be affected little, if any, by variations in fabrics, yarn count, or finish. Any differences in these electrical properties that may have resulted from variations in these factors were so small that they are within the limits of experimental error.

B. Group 2. Effect of Laminating Conditions on the Strength of Plastics

43. The data obtained in Group 2 show that the fabrication variables, thickness and resin content, do affect the mechanical properties. Tests of laminates which varied in thickness from 1/16 to 1/2 inch indicate that increases in thickness caused increases in the compression, shear, Izod impact, and tensile strength. Flexural strength was the only one which showed a decrease. Tests of laminates which varied in resin content from 21.8 to 41.6 percent showed that the shear, tensile, flexural, and Izod impact strengths decreases with increases in resin content. The compressive strength appeared to be unaffected by resin content.

C. Group 3. Variation of Strength Properties Because of Evaluation Conditions

44. The results show that the strength of glass-fabric-base laminates fabricated with either a polyester- or phenolic-type resin decreases with increases in temperatures at time of test; also, that those with polyester-type resin decrease more than those with phenolic-type resin. The exact amounts of these decreases vary with the mechanical test. The amounts are shown in the tables for particular applications.

Table 1.—Fabrication methods used in making laminated panels of glass fabric with typical polyester and phenolic resins

Panel No.		Resin[1] type	Type of glass fabric[2]	Number of plies[3]	Thickness[4]	Cure cycle		
Naval Ordnance Laboratory	F.P.L.					Time	Temperature	Pressure
					In.	Hr.	°F.	P.s.i.
GROUP 1 — VARIATIONS IN FABRICS								
Series 1 — Variations in Weaves								
269GP12131	1.1	Polyester	128-114	18	0.127	5	75	10
						24	110	0
269GP1472	1.3	.....do......	143-114	14	.146	5	75	6
						24	110	0
269GP1373	1.5	.....do......	164-114	9	.137	5	75	5
						24	110	0
269GP1396	1.7	.....do......	181-114-225	15	.139	5	75	61
						24	110	0
269GP1397	1.9	.....do......	181-114-225	15	.142	5	75	61
						24	110	0
269GP12129	1.11	.....do......	182-114	10	.131	5	75	16
						24	110	0
269GB13144	1.2	Phenolic	128-114	19	.136	1	300	10
269GB13142	1.4	.....do......	143-114	15	.136	1	300	7
269GB14146	1.6	.....do......	164-114	9	.144	1	300	5
269GB12140	1.8	.....do......	181-114-225	15	.128	1	300	37
269GB 12142	1.10	.....do......	181-114-225	15	.127	1	300	37
269GB12145	1.12	.....do......	182-114	10	.130	1	300	20
Series 2 — Variations in Yarns								
269GP1395	2.1	Polyester	181-114-150	15	.137	5	75	61
						24	110	0
269GB13143	2.2	Phenolic	181-114-150	15	.131	1	300	37

Table 1.--Fabrication methods used in making laminated panels of glass fabric with typical polyester and phenolic resins (Continued)

Panel No.		Resin type[1]	Type of glass fabric[2]	Number of plies[3]	Thickness[4]	Cure cycle		
Naval Ordnance Laboratory	F.P.L.					Time	Temperature	Pressure
					In.	Hr.	°F.	P.s.i.
			Series 3 -- Variations in Finish					
269GP12149	3.1	Polyester	181-136	15	0.179	5	75	61
						24	110	0
269GB12154	3.2	Phenolic	181-136	15	.163	1	300	40
			Group 2 -- VARIATIONS IN FABRICATION PROCEDURE					
			Series 4 -- Variation in Thickness					
269GP5394	4.1	Polyester	181-114-225	64	.532	5	75	61
						24	110	0
269GP2675	4.3	....do......	181-114-225	32	.266	5	75	61
						24	110	0
269GP0674	4.5	....do......	181-114-225	8	.066	5	75	61
						24	110	0
			Series 5 -- Variation in Molding Pressure and Resin Content					
269GP11132	5.1	Polyester	181-114-225	10	.111	5	75	2
						24	110	0
269GP12103	5.3	.....do......	181-114-225	12	.130	5	75	10
						24	110	0
269GP11104	5.5	.....do......	181-114-225	14	.119	5	75	45
						24	110	0
269GP13130	5.7	.....do......	181-114-225	17	.136	5	75	395
						24	110	0

Table 1.--Fabrication methods used in making laminated panels of glass fabric with typical polyester and phenolic resins (Continued)

Panel No. Naval Ordnance Laboratory	Panel No. F.P.L.	Resin[1] type	Type of glass fabric[2]	Number of plies[3]	Thickness[4]	Cure cycle Time	Cure cycle Temperature	Cure cycle Pressure
					In.	Hr.	°F.	P.s.i.
GROUP 3 -- VARIATIONS IN EVALUATION CONDITIONS								
Series 6 -- Variation in Temperature at Time of Test[5]								
269GP13133	6.1	Polyester	181-114-225	15	0.138	5	75	61
						24	110	0
269GP13100	6.3	....do......	181-114-225	15	.143	5	75	61
						24	110	0
269GP1398	6.5	....do......	181-114-225	15	.132	5	75	61
						24	110	0
269GP13102	6.7	....do......	181-114-225	15	.135	5	75	61
						24	110	0
269GP14101	6.9	....do......	181-114-225	15	.145	5	75	61
						24	110	0
269GP1399	6.11	....do......	181-114-225	15	.136	5	75	61
						24	110	0
269GB12139	6.2	Phenolic	181-114-225	15	.127	1	300	37
269GB12138	6.4	....do......	181-114-225	15	.125	1	300	37
269GB12137	6.6	....do......	181-114-225	15	.126	1	300	37
269GB12136	6.8	....do......	181-114-225	15	.126	1	300	37
269GB12135	6.10	....do......	181-114-225	15	.125	1	300	37
269GB12134	6.12	....do......	181-114-225	15	.127	1	300	37

[1] Polyester resin was Paraplex P-43 (Catalyst System of 1.25 percent DDM and 1 percent Nuodex). Phenolic resin was Bakelite BV17085.

[2] Detailed descriptions of fabrics in U. S. Air Force Specification No. 12051.

[3] Plies parallel laminated for approximate 1/8-inch thickness except series 4 which has 1/2-, 1/4-, and 1/16-inch thicknesses for 64, 32, and 8 ply constructions, respectively.

[4] Average of 30 measurements.

[5] The temperatures at time of test are listed on subsequent tables where the effect of temperature on the properties is shown.

Table 2.--Physical properties of glass-fabric-base plastic laminates

F.P.L. panel No.	Factors investigated	Resin content[1]	Specific gravity[2]	Water absorption[3]	Increase in dimensions due to water absorption[2]: Length	Width	Thickness
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
		Percent		Percent	Percent	Percent	Percent
	GROUP 1 -- VARIATIONS IN FABRICS						
	Series 1 -- Variations in weaves						
1.1	128-114 - polyester	38.1	1.815	0.13	-0.04	0.00	0.26
1.3	143-114 - polyester	37.2	1.805	.07	-.09	.00	.00
1.5	164-114 - polyester	38.1	1.805	.14	-.09	.03	-.24
1.7	181-114-225 - polyester	33.4	1.892	.09	-.03	.00	-.24
1.9	181-114-225 - polyester	33.7	1.878	.09	.03	.03	-.47
1.11	182-114 - polyester	32.7	1.910	.10	-.01	-.03	-.51
1.2	128-114 - phenolic	29.3	1.485	1.57	-.02	.13	.25
1.4	143-114 - phenolic	24.5	1.733	.74	.01	.05	.00
1.6	164-114 - phenolic	24.8	1.410	2.29	.04	.03	[illegible]
1.8	181-114-225 - phenolic	23.2	1.815	.94	.02	.07	.00
1.10	181-114-225 - phenolic	24.5	1.848	.62	.03	.00	.26
1.12	182-114 - phenolic	22.7	1.726	.81	.04	.00	.52
	Series 2 -- Variations in Yarns						
2.1	181-114-150 - polyester	33.1	1.893	.13	-.03	.00	.00
2.2	181-114-150 - phenolic	22.3	1.811	.71	.00	.02	.00
	Series 3 -- Variations in Finish						
3.1	181-136 - polyester	44.7	1.758	.14	.00	.00	.00
3.2	181-136 - phenolic	36.5	1.685	1.57	.02	.10	.61
	GROUP 2 -- VARIATIONS IN FABRICATION PROCEDURE						
	Series 4 -- Variation in Thickness						
4.1	1/2 inch	27.0	1.975	.05	-.04	.03	.00
4.3	1/4 inch	28.3	1.957	.09	.00	.00	.00
4.5	1/16 inch	27.9	1.987	.22	-.02	.03	.00
	Series 5 -- Variation in Molding Pressure and Resin Content						
5.1	2 p.s.i.	39.5	1.796	.15	-.01	-.05	.00
5.3	10 p.s.i.	41.6	1.786	.13	-.01	.00	-.15
5.5	45 p.s.i.	30.0	1.936	.17	-.01	.00	.00
5.7	395 p.s.i.	21.8	2.038	.36	-.02	.00	.00
	GROUP 3 -- VARIATIONS IN EVALUATION CONDITIONS						
	Series 6 -- Variation in Temperature at Time of Test						
6.1	-65° F.	32.1	1.916	.12	.03	.00	.00
6.3	-30° F.	33.3	1.880	.12	.00	.00	.00
6.5	0° F.	30.0	1.908	.13	.00	.03	.00
6.7	30° F.	31.5	1.912	.16	.03	.00	.00
6.9	120° F.	36.4	1.878	.14	.01	.02	.12
6.11	160° F.	32.1	1.912	.13	.00	.02	.00
6.2	-65° F.	23.6	1.822	.69	.08	.07	.00
6.4	-30° F.	23.6	1.855	.66	.04	.05	.33
6.6	0° F.	23.5	1.859	.83	.04	.00	.40
6.8	30° F.	23.8	1.840	.75	-.01	.02	.13
6.10	120° F.	23.3	1.857	.75	.00	.03	.00
6.12	160° F.	23.9	1.840	.96	-.01	.05	.40

[1]Determined by burning as described in paragraph F-6b(4) of U. S. Air Force Specification 12049. Average of two specimens.

[2]Weight and dimensions taken on each 17- by 22-inch panel.

[3]Weights and dimensions taken according to Method 7031 of Federal Specification L-P-406a. Length of specimen was parallel to warp direction. Average of three specimens.

Z M 90644 F

Table 3.--Results of tensile tests of glass-fabric-base plastic laminates

F.P.L. panel No.	Factors investigated	Relation of loaded direction to warp	Modulus of elasticity: Initial tangent	Modulus of elasticity: Secant at 0.1 percent strain offset	Modulus of elasticity: Secant at 0.2 percent strain offset	Stress at - Proportional limit	Stress at - 0.1 percent strain offset	Stress at - 0.2 percent strain offset	Stress at - Maximum
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
		Degrees	1,000 p.s.i.	1,000 p.s.i.	1,000 p.s.i.	1,000 p.s.i.	1,000 p.s.i.	1,000 p.s.i.	1,000 p.s.i.
		GROUP 1 -- VARIATIONS IN FABRICS							
		Series 1 -- Variations in Weaves							
1.1	128-114 - polyester	0	4,120	3,237	3,008	9.98	19.46	26.81	47.23
		90	2,382	2,116	2,016	11.56	20.80	26.50	41.65
1.3	143-114 - polyester	0	4,370	4,112	....	40.35	70.35	....	78.52
		90	1,718	1,329	1,103	4.45	5.88	6.11	9.64
1.5	164-114 - polyester	0	2,758	2,561	2,216	6.76	17.03	22.60	35.67
		90	2,271	2,002	1,870	8.79	15.76	20.15	29.94
1.7	181-114-225 - polyester	0	3,315	2,936	2,781	11.66	22.33	30.96	41.24
		90	2,922	2,510	2,366	10.64	17.45	23.96	36.17
6.1	181-114-225 - polyester	0	3,236	2,866	2,757	15.02	25.28	35.74	50.16
		90	3,087	2,739	2,598	11.83	22.52	30.61	46.82
1.11	182-114 - polyester	0	3,413	2,890	2,750	10.05	20.39	29.31	51.20
		90	3,461	2,897	2,728	9.00	18.02	25.94	51.72
1.2	128-114 - phenolic	0	2,782	2,454	2,345	10.74	20.30	28.59	37.48
		90	2,218	1,902	1,766	6.85	12.79	17.21	27.63
1.4	143-114 - phenolic	0	4,601	4,469	....	38.52	71.50	....	79.60
		90	1,701	1,256	1,026	3.50	4.75	5.23	9.56
1.6	164-114 - phenolic	0	2,005	1,765	1,636	8.17	14.81	17.19	19.96
		90	2,143	1,859	1,706	7.21	13.11	15.80	21.29
1.8	181-114-225 - phenolic	0	3,427	2,990	2,845	12.58	23.74	31.86	52.26
		90	3,304	3,058	2,729	12.31	21.19	29.30	49.44
1.10	181-114-225 - phenolic	0	3,582	3,132	2,976	12.91	23.24	31.79	51.37
		90	3,425	2,903	2,715	10.39	18.43	24.84	48.65
1.12	182-114 - phenolic	0	3,227	2,788	2,628	10.49	20.92	28.23	43.64
		90	3,288	2,762	2,598	9.09	18.28	25.45	47.38
		Series 2 -- Variations in Yarns							
1.7 & 6.1	181-114-225 - polyester	0	3,275	2,901	2,769	13.09	23.81	33.35	45.70
		90	3,004	2,624	2,482	11.23	19.98	27.28	41.49
2.1	181-114-150 - polyester	0	3,390	2,890	2,757	11.41	20.92	29.42	50.94
		90	3,192	2,699	2,564	10.69	19.63	27.53	50.28
1.8 & 1.10	181-114-225 - phenolic	0	3,504	3,061	2,910	12.74	23.49	31.82	51.81
		90	3,364	2,995	2,722	11.35	19.81	27.07	49.02
2.2	181-114-150 - phenolic	0	3,483	3,265	3,110	10.92	21.87	31.32	50.95
		90	3,761	3,140	2,951	9.48	20.57	28.48	47.35
		Series 3 -- Variations in Finish							
1.7 & 6.1	181-114-225 - polyester	0	3,275	2,901	2,769	13.09	23.81	33.35	45.70
		90	3,004	2,624	2,482	11.23	19.98	27.28	41.49
3.1	181-136 - polyester	0	2,677	2,456	2,343	8.55	17.87	25.09	40.42
		90	2,533	2,171	2,053	8.52	15.61	20.09	38.49
1.8 & 1.10	181-114-225 - phenolic	0	3,504	3,061	2,910	12.74	23.49	31.82	51.81
		90	3,364	2,995	2,722	11.35	19.81	27.07	49.02
3.2	181-136 - phenolic	0	2,696	2,365	....	11.06	25.69	....	33.84
		90	2,276	2,105	....	15.08	26.33	....	30.10

Z M 93645 F

Table 5.--Results of tensile tests of glass-fabric-base plastic laminates (Continued)

F.P.L. panel No.	Factors investigated	Relation of loaded direction to warp	Modulus of elasticity: Initial tangent	Modulus of elasticity: Secant at 0.1 percent strain offset	Modulus of elasticity: Secant at 0.2 percent strain offset	Stress at - Proportional limit	Stress at - 0.1 percent strain offset	Stress at - 0.2 percent strain offset	Stress at - Maximum
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
		Degrees	1,000 p.s.i.	1,000 p.s.i.	1,000 p.s.i.	1,000 p.s.i.	1,000 p.s.i.	1,000 p.s.i.	1,000 p.s.i.
GROUP 2 -- VARIATIONS IN FABRICATION PROCEDURE									
Series 4 -- Variation in Thickness									
4.1	1/2 inch thick	0	3,721	3,226	3,037	13.51	24.02	33.11	51.88
		90	3,733	3,134	2,939	10.46	19.49	27.72	53.88
4.3	1/4 inch thick	0	3,619	3,153	3,015	12.25	25.37	35.43	41.50
		90	3,465	2,911	2,737	8.87	18.77	26.68	35.84
1.7 & 6.1	1/8 inch thick	0	3,275	2,901	2,769	13.09	23.81	33.35	45.70
		90	3,004	2,624	2,482	11.23	19.98	27.28	41.49
4.5	1/16 inch thick	0	3,959	3,294	3,133	11.68	20.84	30.82	43.77
		90	3,428	2,848	2,711	10.57	18.94	27.07	40.25
Series 5 -- Variation in Molding Pressure and Resin Content									
5.1	39.5 percent	0	2,381	2,336	2,226	14.57	24.75	32.81	45.02
		90	2,785	2,476	2,362	12.26	23.20	31.43	47.11
5.3	41.6 percent	0	2,821	2,475	2,410	11.70	21.56	28.01	31.39
		90	2,597	2,266	2,126	10.85	19.34	24.24	29.38
1.7 & 6.1	33.5 percent	0	3,275	2,901	2,769	13.09	23.81	35.35	45.70
		90	3,004	2,624	2,482	11.23	19.98	27.28	41.49
5.5	30.0 percent	0	3,538	3,100	2,935	12.55	25.10	34.78	41.55
		90	3,552	2,997	2,800	9.82	18.71	26.33	37.54
5.7	21.8 percent	0	3,846	3,320	3,141	11.44	24.19	34.64	53.86
		90	3,911	3,236	3,055	9.86	20.74	30.10	53.08
GROUP 3 -- VARIATIONS IN EVALUATION CONDITIONS									
Series 6 -- Variation in Temperature at Time of Test									
1.9	-65° F.	0	4,077	3,367	3,193	12.01	20.39	29.92	57.10
		90	4,048	3,703	3,357	9.46	15.43	21.88	48.60
6.3	-30° F.	0	4,371	3,528	3,286	9.41	17.44	26.46	54.00
		90	4,064	3,274	3,118	8.97	16.62	26.73	52.30
6.5	0° F.	0	4,595	3,742	3,469	11.95	26.68	39.13	60.84
		90	3,839	3,252	3,101	10.30	20.58	31.14	59.32
6.7	30° F.	0	3,864	3,254	3,115	11.90	22.39	36.17	46.86
		90	4,225	3,389	3,097	11.77	17.34	25.16	40.64
1.7 & 6.1	75° F.	0	3,275	2,901	2,769	13.09	23.81	35.35	45.70
		90	3,004	2,624	2,482	11.23	19.98	27.28	41.49
6.9	120° F.	0	2,765	2,521	2,452	14.15	28.22	36.57	40.86
		90	2,765	2,548	2,437	13.94	30.11	36.17	44.76
6.11	160° F.	0	2,753	2,526	....	13.37	26.86	....	27.34
		90	2,192	1,943	....	8.41	16.73	....	21.27
6.2	-65° F.	0	4,390	3,731	3,519	12.64	24.49	34.93	66.30
		90	4,313	3,626	3,373	12.45	22.48	30.64	59.80
6.4	-30° F.	0	4,379	3,711	3,486	12.94	22.78	32.18	65.50
		90	4,054	3,253	3,018	13.81	22.93	30.24	54.40
6.6	0° F.	0	3,912	3,394	3,222	13.30	24.63	38.16	59.74
		90	3,574	3,050	2,853	11.65	19.07	26.07	44.18
6.8	30° F.	0	4,183	3,612	3,443	13.98	25.85	38.42	59.98
		90	3,964	3,332	3,153	11.14	20.12	29.85	52.24
1.8 & 1.10	75° F.	0	3,504	3,061	2,910	12.74	23.49	31.82	51.81
		90	3,364	2,995	2,722	11.35	19.81	27.07	49.02
6.10	120° F.	0	3,704	3,195	3,068	11.30	24.26	34.80	47.78
		90	3,450	2,952	2,786	10.62	19.79	27.17	46.97
6.12	160° F.	0	3,224	2,938	....	12.52	30.18	....	45.48
		90	3,192	2,851	2,742	11.87	26.04	36.43	46.21

Table 4.--Edgewise compressive strength of glass-fabric-base plastic laminates

Factors investigated	Molded with polyester resin: F.P.L. panel No.	Molded with polyester resin: Maximum strength Lengthwise	Molded with polyester resin: Maximum strength Crosswise	Molded with phenolic resin: F.P.L. panel No.	Molded with phenolic resin: Maximum strength Lengthwise	Molded with phenolic resin: Maximum strength Crosswise
(1)	(2)	(3)	(4)	(5)	(6)	(7)
		1,000 p.s.i.	1,000 p.s.i.		1,000 p.s.i.	1,000 p.s.i.
GROUP 1 -- VARIATIONS IN FABRICS						
Series 1 -- Variations in Weaves						
128-114	1.1	23,890	29,570	1.2	20,290	24,770
143-114	1.3	50,650	24,100	1.4	40,900	17,850
164-114	1.5	24,370	22,940	1.6	12,460	16,020
181-114-225	1.7	33,970	33,640	1.8	32,890	40,280
181-114-225	1.9	34,190	38,190	1.10	38,600	35,720
182-114	1.11	32,460	39,550	1.12	30,300	35,420
Series 2 -- Variations in Yarns						
181-114-225	1.7 & 1.9	34,080	35,920	1.8 & 1.10	35,740	38,000
181-114-150	2.1	33,480	37,420	2.2	35,410	37,820
Series 3 -- Variations in Finish						
181-114-225	1.7 & 1.9	34,080	35,920	1.8 & 1.10	35,740	38,000
181-136	3.1	35,630	34,580	3.2	20,100	16,440
GROUP 2 -- VARIATIONS IN FABRICATION PROCEDURE						
Series 4 -- Variation in Thickness						
64 ply - 1/2 inch	4.1	42,910	38,260	....	....	....
32 ply - 1/4 inch	4.3	39,870	39,340	....	....	....
16 ply - 1/8 inch	1.7 & 1.9	34,080	35,920	....	....	....
8 ply - 1/16 inch	4.5	23,370	28,990	....	....	....
Series 5 -- Variation in Molding Pressure and Resin Content						
39.5 percent	5.1	33,160	32,500	....	....	....
41.6 percent	5.3	32,700	35,340	....	....	....
30.0 percent	5.5	29,930	37,540	....	....	....
33.5 percent	1.7 & 1.9	34,080	35,920	....	....	....
21.8 percent	5.7	30,000	35,160	....	....	....
GROUP 3 -- VARIATIONS IN EVALUATION CONDITIONS						
Series 6 -- Variation in Temperature at Time of Test						
-65° F.	6.1	44,340	38,080	6.2	44,100	42,000
-30° F.	6.3	30,700	37,380	6.4	48,560	43,580
0° F.	6.5	40,420	38,440	6.6	38,680	33,340
30° F.	6.7	41,940	39,260	6.8	41,360	37,180
77° F.	1.7 & 1.9	34,080	35,920	1.8 & 1.10	35,740	38,000
120° F.	6.9	30,060	29,000	6.10	37,560	36,840
160° F.	6.11	17,130	12,760	6.12	35,790	31,990

Z M 90647 F

Table 5.--Results of flexural tests on glass-fabric-base plastic laminates

F.P.L. panel No.	Factors investigated	Relation of span direction to warp	Modulus of elasticity: Initial tangent	Modulus of elasticity: Secant to 0.1 per-cent strain offset	Modulus of elasticity: Secant to 0.2 per-cent strain offset	Fiber stress at - Propor-tional limit	Fiber stress at - 0.1 per-cent strain offset	Fiber stress at - 0.2 per-cent strain offset	Modulus of rupture
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
		Degrees	1,000 p.s.i.	1,000 p.s.i.	1,000 p.s.i.	1,000 p.s.i.	1,000 p.s.i.	1,000 p.s.i.	1,000 p.s.i.
				GROUP 1 -- VARIATIONS IN FABRICS					
				Series 1 -- Variations in weaves					
1.1	128-114 - polyester	0	3,009	2,814	2,674	28.0	59.6	44.7	46.0
		90	2,710	2,510	2,378	20.2	31.3	37.9	42.8
1.3	143-114 - polyester	0	4,383	4,194	....	80.0	106.4	....	106.5
		90	1,724	1,484	1,351	9.0	12.4	14.2	18.4
1.5	164-114 - polyester	0	2,688	2,451	2,295	23.0	33.3	37.4	43.7
		90	2,485	2,253	2,107	17.4	27.0	31.4	40.0
1.7	181-114-225 - polyester	0	3,347	3,122	....	35.2	55.2	....	57.5
		90	3,364	3,082	....	25.2	45.0	....	52.9
1.9	181-114-225 - polyester	0	3,392	3,163	....	26.8	53.0	....	59.2
		90	3,301	3,018	2,874	26.2	44.4	52.9	54.1
1.11	182-114 - polyester	0	3,384	3,147	2,984	27.5	47.2	54.4	56.7
		90	3,355	3,119	2,939	25.0	46.9	52.0	59.6
1.2	128-114 - phenolic	0	2,646	2,472	....	22.9	33.9	....	34.8
		90	2,260	2,103	1,935	21.0	30.2	33.7	34.9
1.4	143-114 - phenolic	0	4,955	4,739	4,478	75.4	94.0	97.9	98.4
		90	1,717	1,472	1,353	7.8	11.2	13.4	18.7
1.6	164-114 - phenolic	0	2,037	1,869	1,706	17.6	21.6	23.4	24.3
		90	2,054	1,956	1,732	15.9	21.9	23.5	24.1
1.8	181-114-225 - phenolic	0	3,358	3,167	3,037	31.5	50.8	58.9	65.5
		90	3,521	3,334	3,169	34.1	51.4	58.8	59.8
1.10	181-114-225 - phenolic	0	3,583	3,376	3,258	31.4	53.0	67.3	69.7
		90	3,319	3,095	2,946	26.9	43.0	50.4	58.2
1.12	182-114 - phenolic	0	3,296	3,068	2,914	31.0	45.8	51.6	54.6
		90	3,065	2,868	2,717	30.5	46.1	49.1	49.9
				Series 2 -- Variations in Yarns					
1.7 & 1.9	181-114-225 - polyester	0	3,369	3,142	....	31.0	54.1	....	58.3
		90	3,332	3,050	....	25.7	44.7	....	53.5
2.1	181-114-150 - polyester	0	3,416	3,207	3,034	29.8	54.1	60.4	60.8
		90	3,332	3,119	2,974	31.5	48.1	57.7	61.4
1.8 & 1.10	181-114-225 - phenolic	0	3,470	3,271	3,147	31.4	51.9	63.1	67.6
		90	3,420	3,215	3,057	30.5	47.2	54.6	58.5
2.2	181-114-150 - phenolic	0	3,787	3,544	3,370	32.6	52.1	61.3	63.9
		90	3,571	3,373	3,205	30.9	50.8	58.0	59.1
				Series 3 -- Variations in Finish					
1.7 & 1.9	181-114-225 - polyester	0	3,369	3,142	....	31.0	54.1	....	58.3
		90	3,332	3,050	....	25.7	44.7	....	53.6
3.1	181-136 - polyester	0	2,555	2,423	....	30.7	55.2	....	59.5
		90	2,280	2,155	....	33.3	46.0	....	50.9
1.8 & 1.10	181-114-225 - phenolic	0	3,470	3,271	3,147	31.4	51.9	63.1	67.6
		90	3,420	3,215	3,057	30.5	47.2	54.6	58.5
3.2	181-136 - phenolic	0	2,550	2,330	....	27.9	34.1	....	34.3
		90	2,175	2,026	1,954	18.8	26.1	29.0	31.3

Z M 90648 F

Table 5.--Results of flexural tests on glass-fabric base plastic laminates (Continued)

F.P.L. panel No.	Factors investigated	Relation of span direction to warp	Modulus of elasticity: Initial tangent	Modulus of elasticity: Secant to 0.1 percent strain offset	Modulus of elasticity: Secant to 0.2 percent strain offset	Fiber stress at - Proportional limit	Fiber stress at - 0.1 percent strain offset	Fiber stress at - 0.2 percent strain offset	Modulus of rupture
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
		Degrees	1,000 p.s.i.	1,000 p.s.i.	1,000 p.s.i.	1,000 p.s.i.	1,000 p.s.i.	1,000 p.s.i.	1,000 p.s.i.
				GROUP 2 -- VARIATIONS IN FABRICATION PROCEDURE					
				Series 4 -- Variation in Thickness					
4.1	1/2 inch	0	3,892	3,623	....	26.8	53.3	....	56.2
		90	3,782	3,504	....	22.2	47.2	....	51.9
4.3	1/4 inch	0	3,969	3,719	....	24.9	56.7	....	61.0
		90	3,825	3,563	....	20.7	47.8	....	55.5
1.7 & 1.9	1/8 inch	0	3,369	3,142	....	31.0	54.1	....	58.3
		90	3,332	3,050	....	25.7	44.7	....	53.5
4.5	1/16 inch	0	3,707	3,491	3,326	32.3	56.6	65.4	66.2
		90	4,002	3,693	3,484	24.4	43.8	53.0	62.2
				Series 5 -- Variation in Molding Pressure and Resin Content					
5.1	39.5 percent	0	2,886	2,761	2,654	30.8	47.6	54.5	57.2
		90	2,888	2,755	2,635	28.9	45.6	51.2	58.5
5.3	41.6 percent	0	3,189	3,017	....	26.3	45.1	....	50.8
		90	3,017	2,839	2,708	25.7	41.3	48.7	49.4
1.7 & 1.9	33.5 percent	0	3,369	3,142	....	31.0	54.1	....	58.3
		90	3,332	3,050	....	25.7	44.7	....	53.6
5.5	30.0 percent	0	3,985	3,756	3,596	27.4	47.1	59.8	63.1
		90	3,610	3,379	3,221	26.1	46.6	52.6	54.1
5.7	21.8 percent	0	4,137	3,797	3,585	22.4	45.4	53.7	54.8
		90	3,879	3,587	....	25.9	48.9	....	51.6
				GROUP 3 -- VARIATIONS IN EVALUATION CONDITIONS					
				Series 6 -- Variation in Temperature at Time of Test					
6.1	-65° F.	0	3,562	3,370	3,218	52.4	67.0	73.2	73.8
		90	3,521	3,323	....	46.0	68.6	....	72.0
6.3	-30° F.	0	3,608	3,433	....	45.3	67.8	....	70.4
		90	3,334	3,188	....	49.3	73.6	....	77.4
6.5	0° F.	0	3,800	3,608	....	48.9	66.2	....	71.2
		90	3,513	3,313	....	44.6	61.8	....	66.6
6.7	30° F.	0	3,869	3,620	3,434	45.7	59.6	64.2	64.9
		90	3,532	3,322	3,160	35.7	55.0	61.8	63.3
1.7 & 1.9	75° F.	0	3,369	3,142	....	31.0	54.1	....	58.3
		90	3,332	3,050	....	25.7	44.7	....	53.6
6.9	120° F.	0	3,031	2,798	2,648	19.7	33.9	41.9	45.1
		90	2,959	2,674	2,529	20.3	31.2	39.3	43.1
6.11	160° F.	0	2,278	2,011	1,863	10.8	18.8	22.4	24.2
		90	1,888	1,709	1,591	9.9	16.7	20.4	24.2
6.2	-65° F.	0	3,619	3,467	....	60.2	80.3	....	85.1
		90	3,478	3,294	....	44.4	62.4	....	66.9
6.4	-30° F.	0	3,810	3,642	....	59.3	78.9	....	82.0
		90	3,478	3,326	3,202	42.2	64.4	57.3	74.7
6.6	0° F.	0	3,626	3,466	....	44.5	68.1	....	76.8
		90	3,514	3,275	3,163	33.6	52.2	63.1	69.3
6.8	30° F.	0	4,363	4,051	3,878	37.7	62.5	74.0	78.4
		90	3,330	3,273	3,128	29.4	47.1	56.5	67.2
1.8 & 1.10	75° F.	0	3,470	3,271	3,147	31.4	51.9	63.1	67.6
		90	3,420	3,215	3,057	30.5	47.2	54.6	58.5
6.10	120° F.	0	3,713	3,475	3,335	29.7	47.9	61.0	66.7
		90	3,606	3,364	3,216	27.4	43.8	53.9	58.5
6.12	160° F.	0	3,360	3,156	3,012	28.6	48.0	55.3	57.1
		90	3,217	2,974	2,840	26.8	39.3	46.8	52.4

Z M 90649 F

Table 6.--Flatwise shear strength of glass-fabric-base laminates (Johnson-type shear)

Factors investigated	Molded with polyester resin			Molded with phenolic resin		
	F.P.L. panel No.	Flatwise strength		F.P.L. panel No.	Flatwise strength	
		Lengthwise	Crosswise		Lengthwise	Crosswise
(1)	(2)	(3)	(4)	(5)	(6)	(7)
		1,000 p.s.i.	1,000 p.s.i.		1,000 p.s.i.	1,000 p.s.i.
GROUP 1 -- VARIATIONS IN FABRICS						
Series 1 -- Variations in Weaves						
128-114	1.1	19.98	21.78	1.2	10.11	9.26
143-114	1.3	10.21	27.15	1.4	6.89	21.09
164-114	1.5	19.51	20.15	1.6	7.22	7.21
181-114-225	1.7	20.30	21.88	1.8	15.00	17.26
181-114-225	1.9	20.07	21.01	1.10	16.46	18.12
182-114	1.11	22.37	21.24	1.12	12.53	12.51
Series 2 -- Variations in Yarns						
181-114-225	1.7 & 1.9	20.18	21.44	1.8 & 1.10	15.73	17.69
181-114-150	2.1	22.22	21.94	2.2	14.89	13.99
Series 3 -- Variations in Finish						
181-114-225	1.7 & 1.9	20.18	21.44	1.8 & 1.0	15.73	17.69
181-136	3.1	16.68	17.62	3.2	11.64	11.98
GROUP 2 -- VARIATIONS IN FABRICATION PROCEDURE						
Series 4 -- Variation in Thickness						
64 ply - 1/2 inch	4.1	21.90	23.72	...	...	...
32 ply - 1/4 inch	4.3	20.49	22.60	...	...	...
16 ply - 1/8 inch	1.7 & 1.9	20.18	21.44	...	...	...
8 ply - 1/10 inch	4.5	21.25	23.19	...	...	...
Series 5 -- Variation in Molding Pressure and Resin Content						
39.5 percent	5.1	19.15	19.02	...	...	...
41.6 percent	5.3	18.21	19.78	...	...	...
30.0 percent	5.5	21.46	23.13	...	...	...
33.5 percent	1.7 & 1.9	20.18	21.44	...	...	...
21.8 percent	5.7	21.27	21.22	...	...	...
GROUP 3 -- VARIATIONS IN EVALUATION CONDITIONS						
Series 6 -- Variation in Temperature at Time of Test						
-65° F.	6.1	30.04	30.20	6.2	20.55	24.94
-30° F.	6.3	27.28	28.05	6.4	19.85	22.69
0° F.	6.5	27.80	25.95	6.6	19.01	23.21
30° F.	6.7	22.93	25.90	6.8	17.81	18.03
77° F.	1.7 & 1.9	20.18	21.44	1.8 & 1.10	15.73	17.69
120° F.	6.9	17.65	18.45	6.10	15.67	17.03
160° F.	6.11	14.41	16.45	6.12	13.43	15.74

Z M 90650 F

Table 7.--Edgewise Izod impact strength of glass-fabric laminates

Factors investigated	Molded with polyester resin			Molded with phenolic resin		
	F.P.L. panel No.	Edgewise notch: Lengthwise	Edgewise notch: Crosswise	F.P.L. panel No.	Edgewise notch: Lengthwise	Edgewise notch: Crosswise
(1)	(2)	(3)	(4)	(5)	(6)	(7)
		Ft.-lb. per in. of width	Ft.-lb. per in. of width		Ft.-lb. per in. of width	Ft.-lb. per in. of width
GROUP 1 -- VARIATIONS IN FABRICS						
Series 1 -- Variations in Weaves						
128-114	1.1	20.4	15.9	1.2	12.9	10.0
143-114	1.3	36.1	2.3	1.4	43.9	2.4
164-114	1.5	23.8	20.1	1.6	11.3	11.0
181-114-225	1.7	12.7	10.5	1.8	21.0	18.1
181-114-225	1.9	11.0	9.8	1.10	19.9	16.5
182-114	1.11	20.6	21.0	1.12	20.9	20.9
Series 2 -- Variations in Yarns						
181-114-150	2.1	19.0	18.5	2.2	19.5	16.9
181-114-225	1.7 & 1.9	11.8	10.2	1.8 & 1.10	20.4	17.3
Series 3 -- Variations in Finish						
181-136	3.1	13.9	12.0	3.2	10.1	7.2
181-114-225	1.7 & 1.9	11.8	10.2	1.8 & 1.10	20.4	17.3
GROUP 2 -- VARIATIONS IN FABRICATION PROCEDURE						
Series 4 -- Variation in Thickness						
64 ply - 1/2 inch	4.1	18.4	17.0	....	....	....
32 ply - 1/4 inch	4.3	11.8	10.0	....	....	....
16 ply - 1/8 inch	1.7 & 1.9	11.8	10.2	....	....	....
8 ply - 1/16 inch	4.5	13.9	12.3	....	....	....
Series 5 -- Variation in Molding Pressure and Resin Content						
39.5 percent	5.1	17.3	16.3	....	....	....
41.6 percent	5.3	8.6	7.0	....	....	....
30.0 percent	5.5	11.2	9.5	....	....	....
35.5 percent	1.7 & 1.9	11.8	10.2	....	....	....
21.8 percent	5.7	23.4	22.1	....	....	....
GROUP 3 -- VARIATIONS IN EVALUATION CONDITIONS						
Series 6 -- Variation in Temperature at Time of Test						
-65° F.	6.1	26.4	24.7	6.2	28.8	25.8
-30° F.	6.3	18.5	16.8	6.4	28.0	22.2
0° F.	6.5	23.5	22.5	6.6	26.8	22.0
30° F.	6.7	13.7	10.8	6.8	24.1	20.5
77° F.	1.7 & 1.9	11.8	10.2	1.8 & 1.10	20.4	17.3
120° F.	6.9	17.7	16.8	6.10	18.5	16.7
160° F.	6.11	10.8	8.8	6.12	16.1	16.0

Z M 90651 F

Table 8. — Dielectric constant and power factor of glass-cloth laminates

P.P.L. panel No.	Factors investigated	Resin content	Specific gravity	Dielectric constant	Power factor
		Percent			
	GROUP 1 — VARIATIONS IN FABRICS				
	Series 1 — Variations in Weaves				
1.1	128-114 - polyester	38.1	1.815	4.03	0.0100
1.3	143-114 - polyester	37.2	1.805	4.04	.0119
1.5	164-114 - polyester	38.1	1.805	4.16	.0116
1.7	181-114-225 - polyester	33.4	1.892	4.42	.0102
1.9	181-114-225 - polyester	33.7	1.878	4.32	.0113
1.11	182-114 - polyester	32.7	1.910	4.47	.0106
1.2	128-114 - phenolic	29.3	1.485	3.79	.0266
1.4	143-114 - phenolic	24.5	1.733	4.30	.0288
1.6	164-114 - phenolic	24.8	1.410	3.60	.0237
1.8	181-114-225 - phenolic	23.2	1.815	4.55	.0248
1.10	181-114-225 - phenolic	24.5	1.848	4.71	.0246
1.12	182-114 - phenolic	22.7	1.726	4.35	.0237
	Series 2 — Variations in Yarns				
2.1	181-114-150 - polyester	35.1	1.893	4.42	.0086
2.2	181-114-150 - phenolic	22.9	1.8[illegible]	4.48	.0230
	Series 3 — Variations in Finish				
3.1	181-136 - polyester	44.7	1.758	4.05	.0095
3.2	181-136 - phenolic	36.5	1.685	4.56	.0415
	GROUP 2 — VARIATIONS IN FABRICATION PROCEDURE				
	Series 4 — Variation in Thickness				
4.1	1/2 inch - polyester	27.0	1.975	4.67	.0084
4.3	1/4 inch - polyester	28.3	1.957	4.56	.0045
4.5	1/16 inch - polyester	27.9	1.987	4.61	.0097
	Series 5 — Variation in Molding Pressure and Resin Content				
5.1	2 p.s.i. - polyester	39.5	1.796	4.16	.0101
5.3	10 p.s.i. - polyester	41.6	1.786	4.12	.0107

(Page 1 of 2)

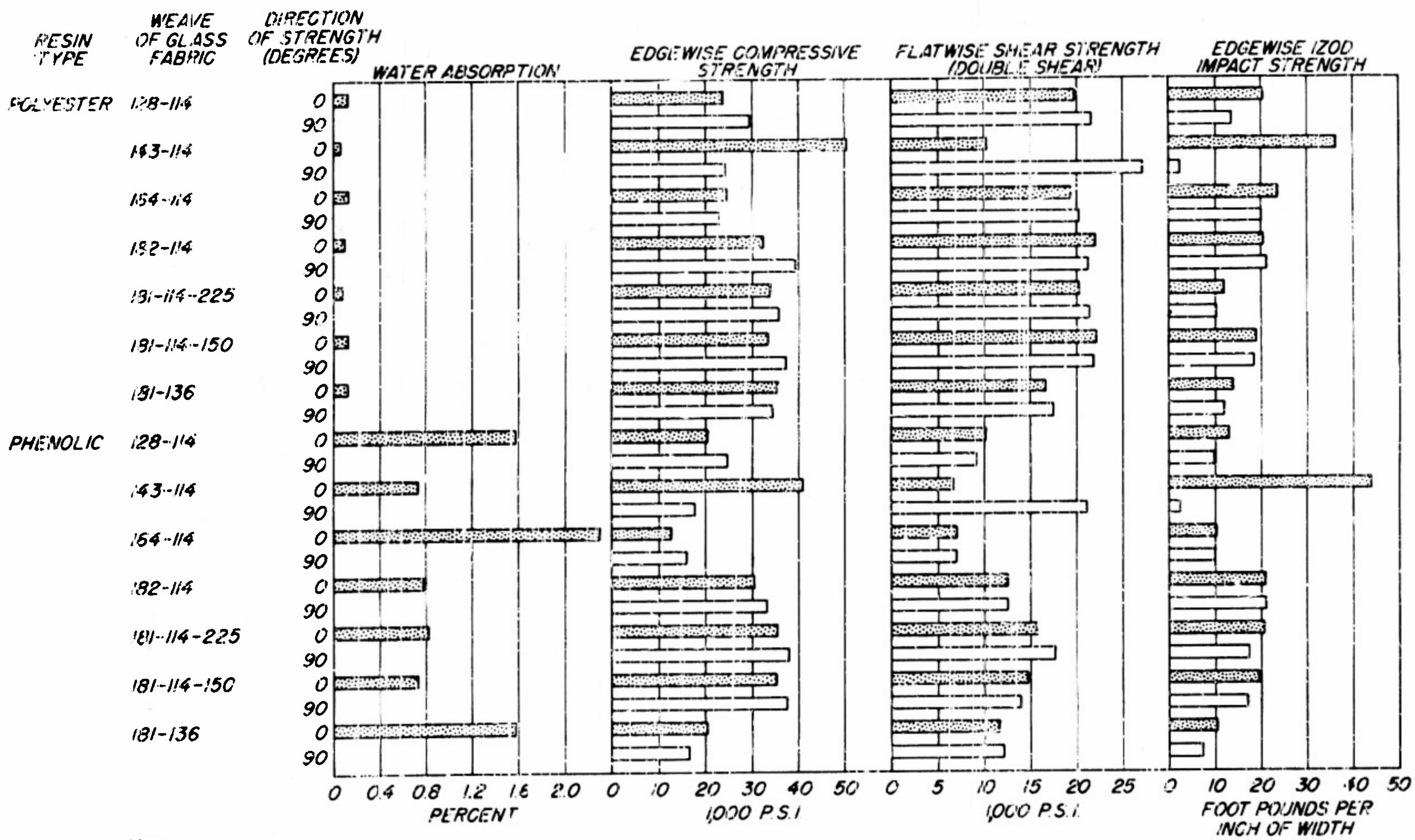
Table 8.-- Dielectric constant and power factor of glass-cloth laminates (Continued)

F.P.L. panel No.	Factors investigated	Resin content	Specific gravity	Dielectric constant	Power factor
		Percent			
5.5	45 p.s.i. - polyester	30.0	1.936	4.52	.0117
5.7	395 p.s.i. - polyester	21.8	2.038	4.74	.0098
	GROUP 3 -- VARIATIONS IN EVALUATION CONDITIONS				
	Series 6 -- Variation in Temperature at Time of Test[2]				
6.1	Polyester	32.1	1.916	4.43	0.0109
6.3	......do................	33.3	1.880	4.39	.0109
6.5	......do................	30.0	1.908	4.48	.0096
6.7	......do................	31.5	1.912	4.36	.0104
6.9	......do................	36.4	1.878	4.44	.0108
6.11	......do................	32.1	1.912	4.41	.0100
6.2	Phenolic	23.6	1.822	4.47	.0249
6.4	......do................	23.6	1.855	4.51	.0247
6.6	......do................	23.5	1.859	4.63	.0240
6.8	......do................	23.8	1.840	4.65	.0248
6.10	......do................	23.3	1.857	4.58	.0228
6.12	......do................	23.9	1.840	4.57	.0232

[1] Abnormally low specific gravity.

[2] Electrical tests were made at room temperature.

Fig. 1 . Properties of Plastic Laminates Made of Different Fabrics & Resins



N 90665 F

Fig. 2 Tensile Stress-Strain Curves of Plastic Laminates Made of Different Fabrics and Resins

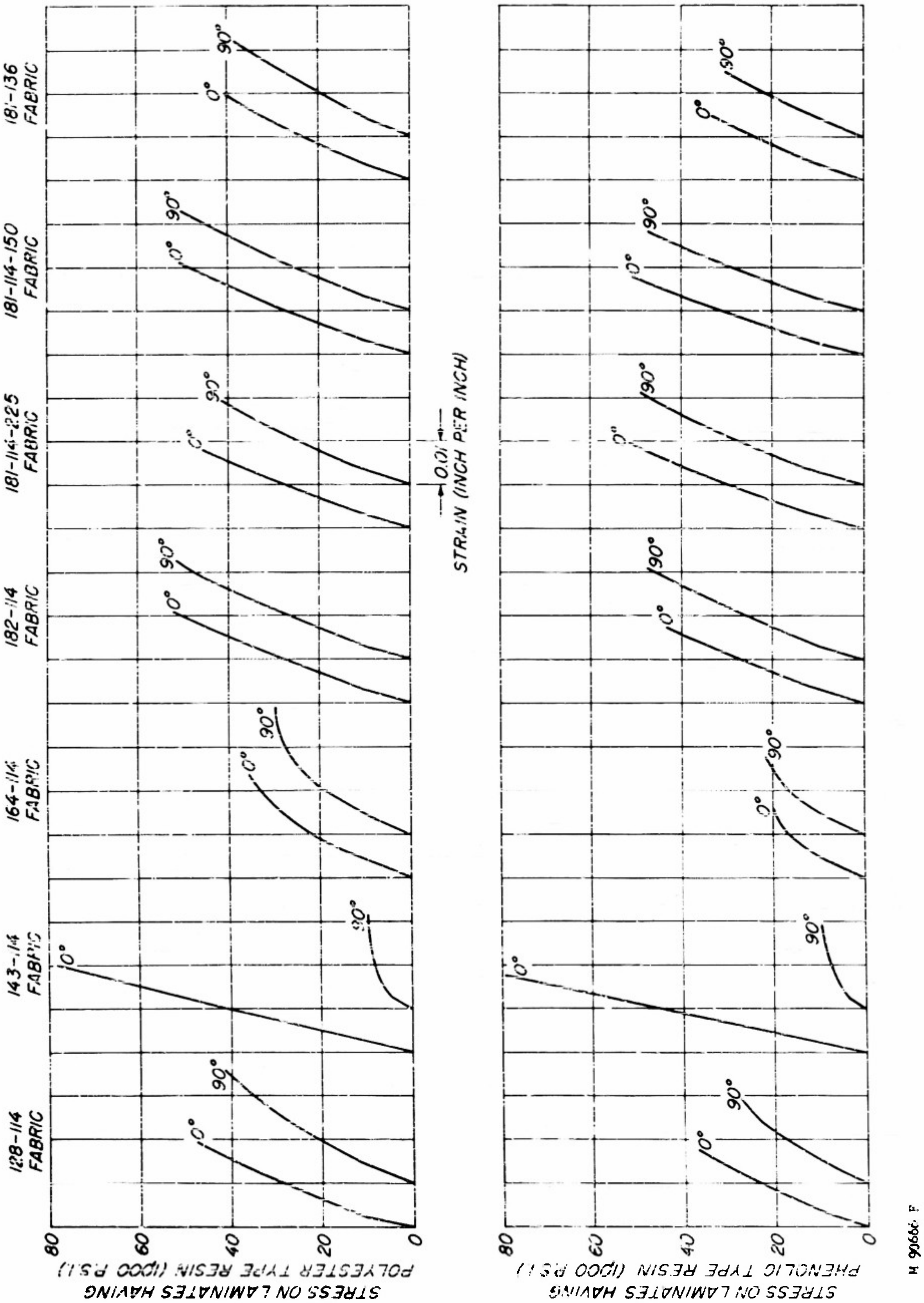


Fig. 3. Load-Deformation Curve in Flexure For Plastic Laminates Made of Different Fabrices and Resins

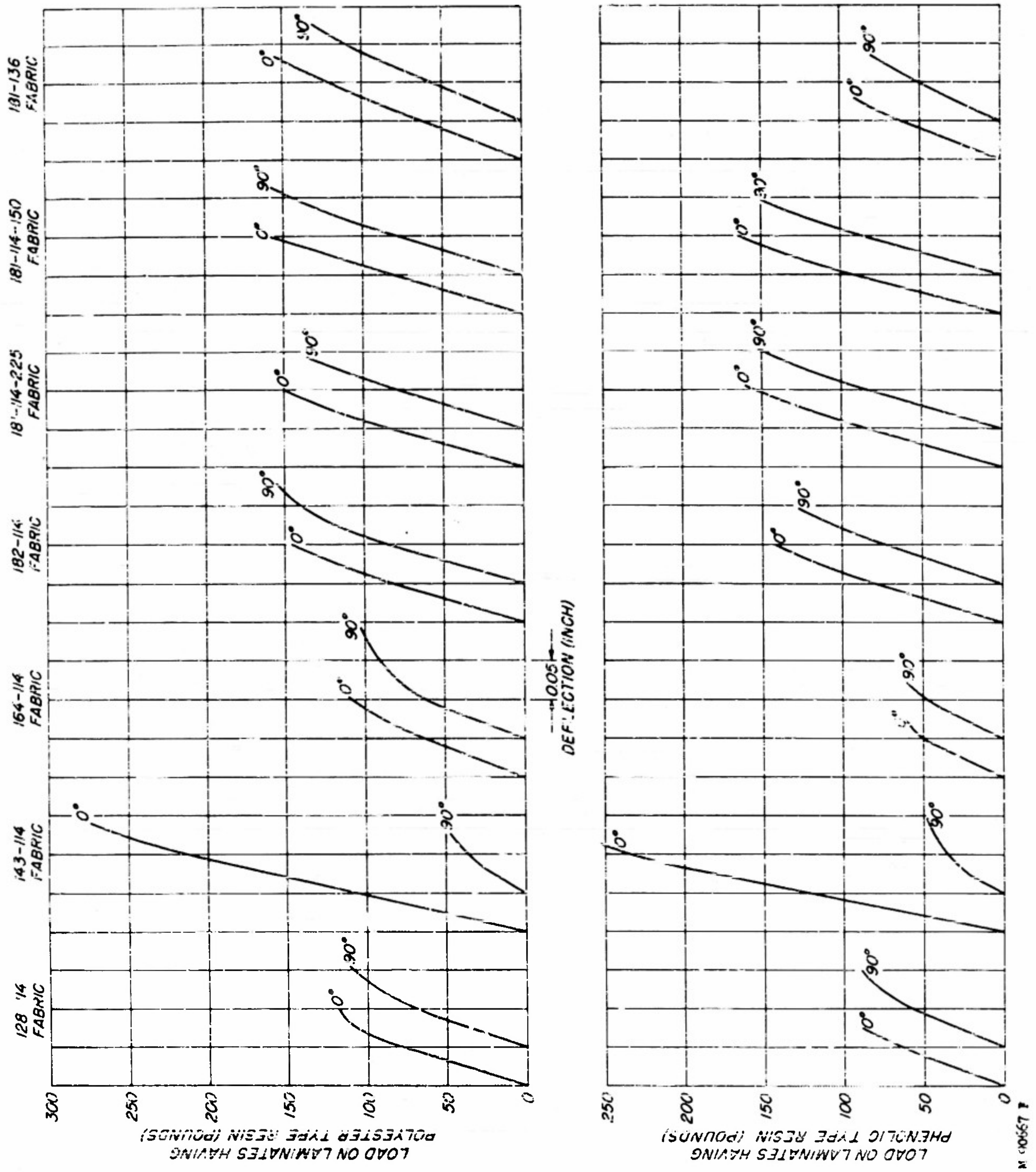


Fig. 4 Effect of Laminating Conditions on the Compressive, Sheer, and Izod Impact Strength of Plastic Laminates

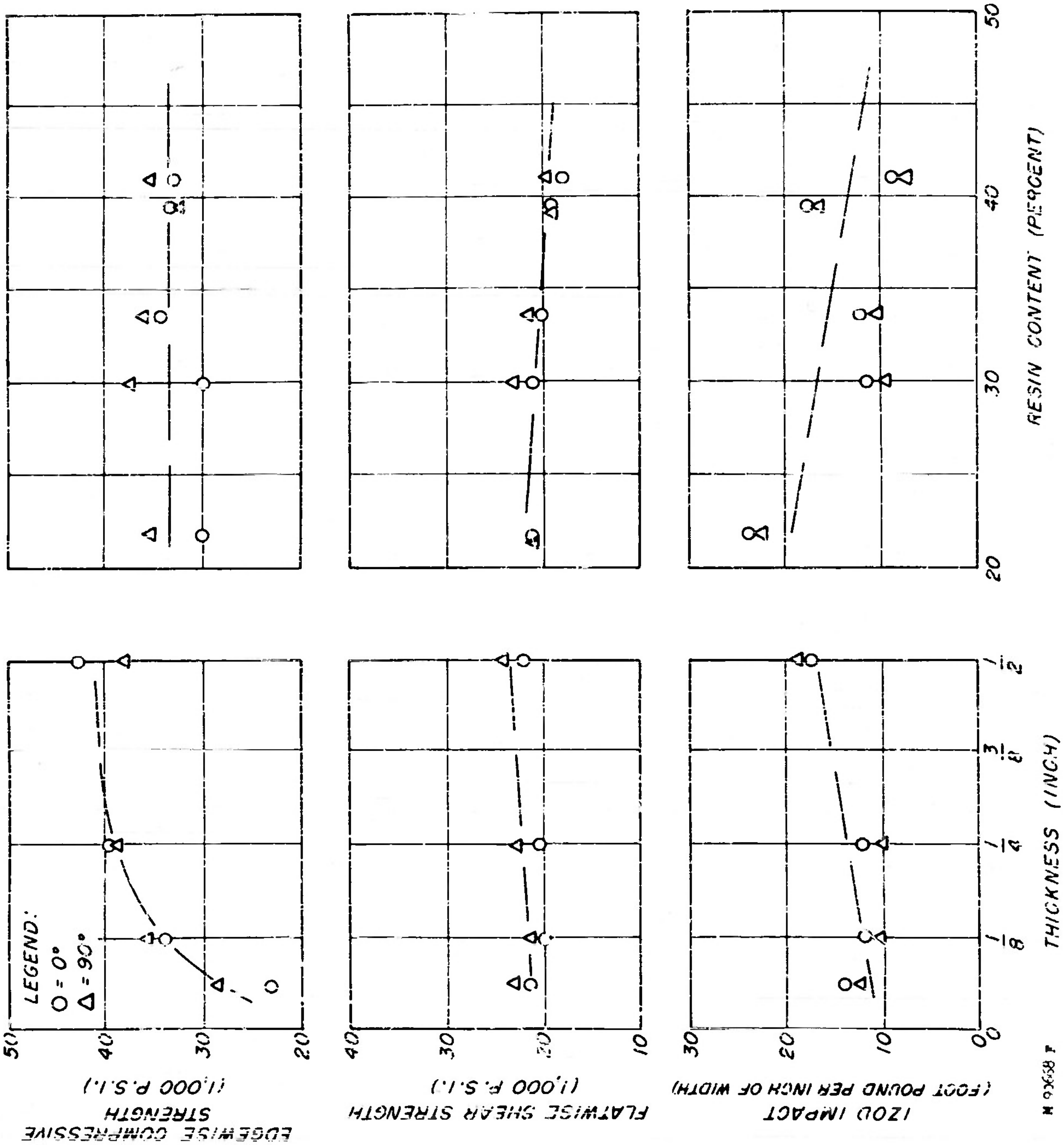


Fig. 5 Effect of Laminating Conditions on Tensile Properties of Plastic Laminates

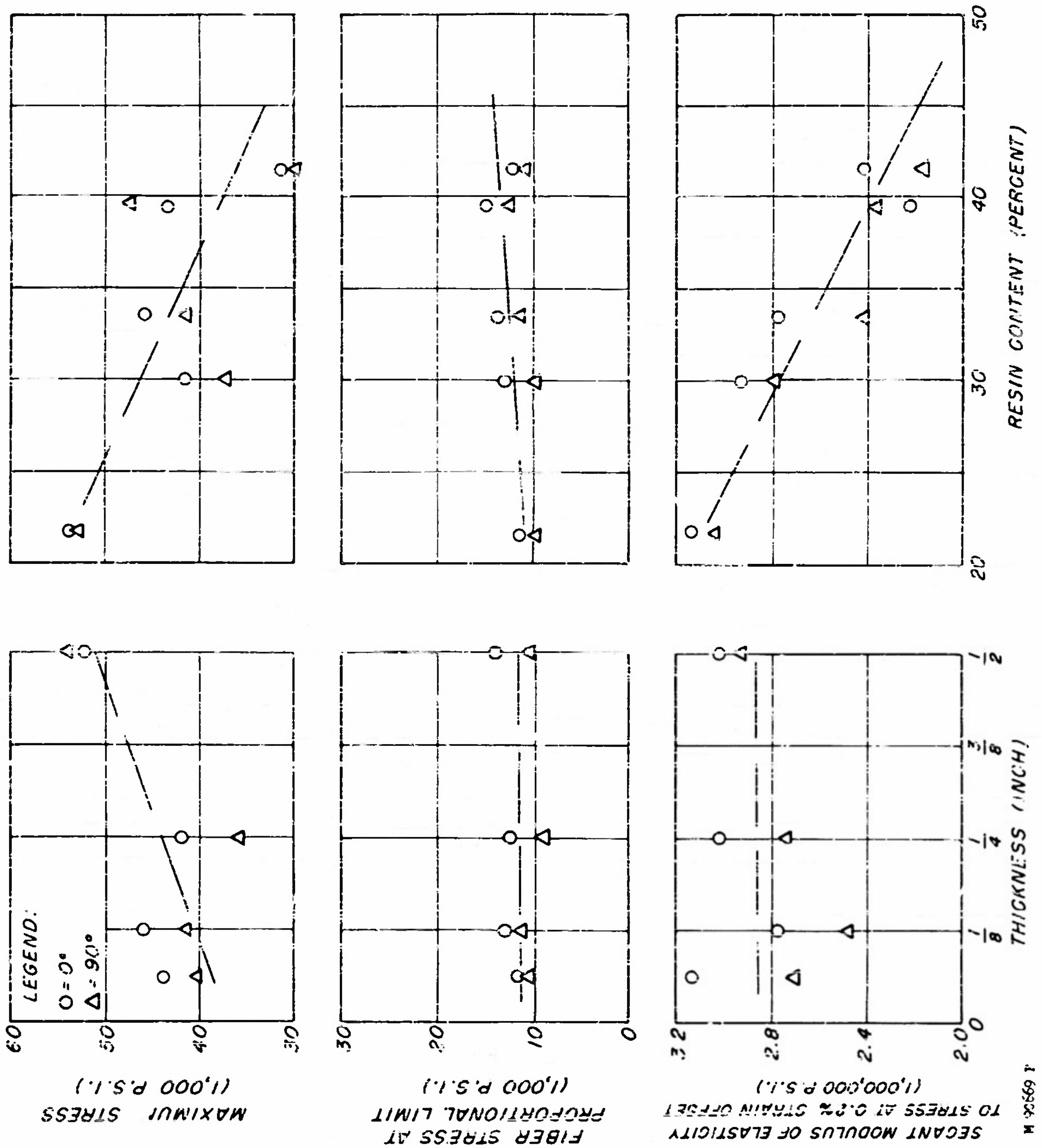


Fig. 6 Effect of Laminating Conditions on the Flexural Properties of Plastic Laminates

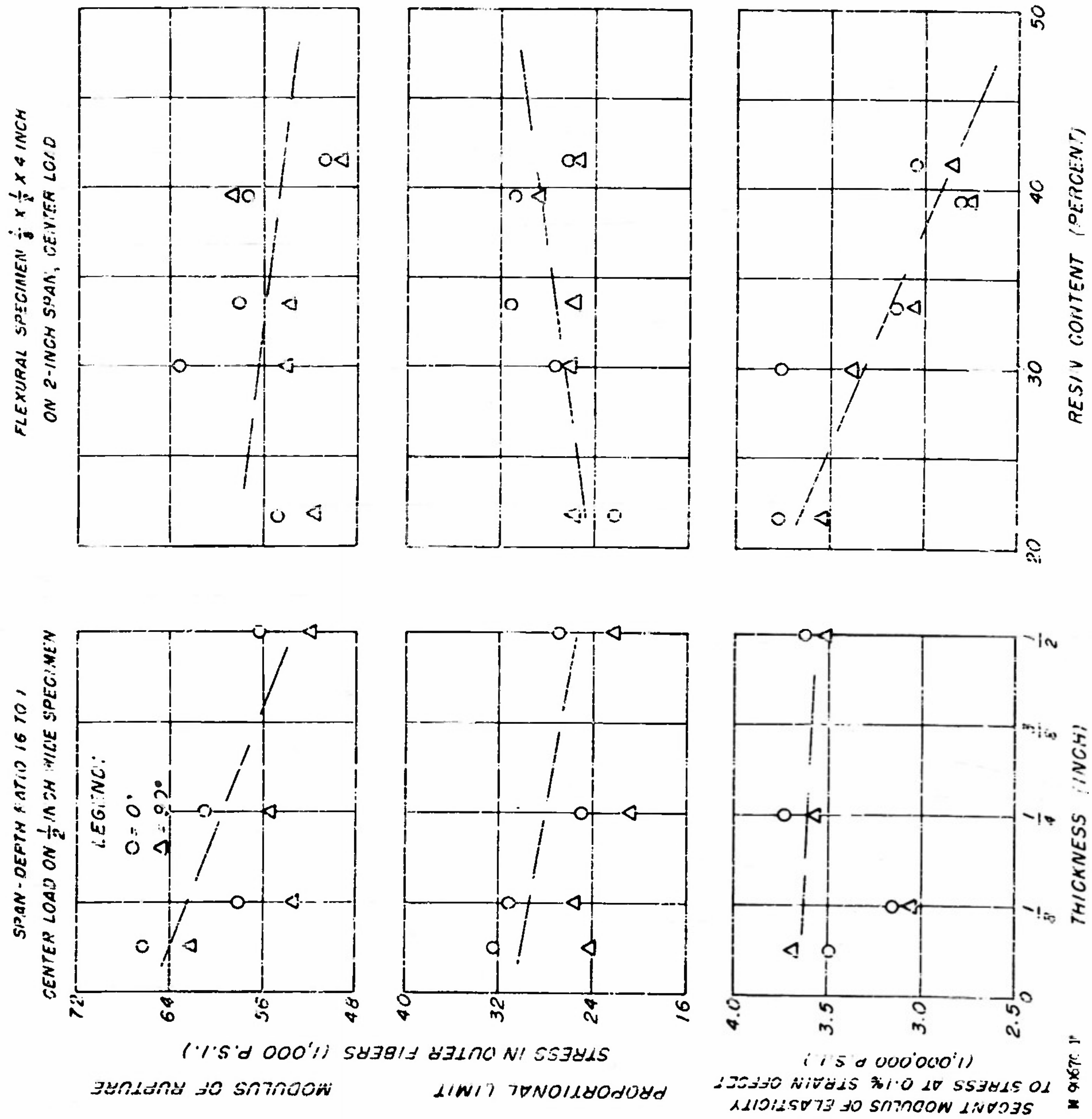


Fig. 7 Effect of Temperature at Time of Test on Compressive, Shear, and Izod Impact Strength of Plastic Laminates

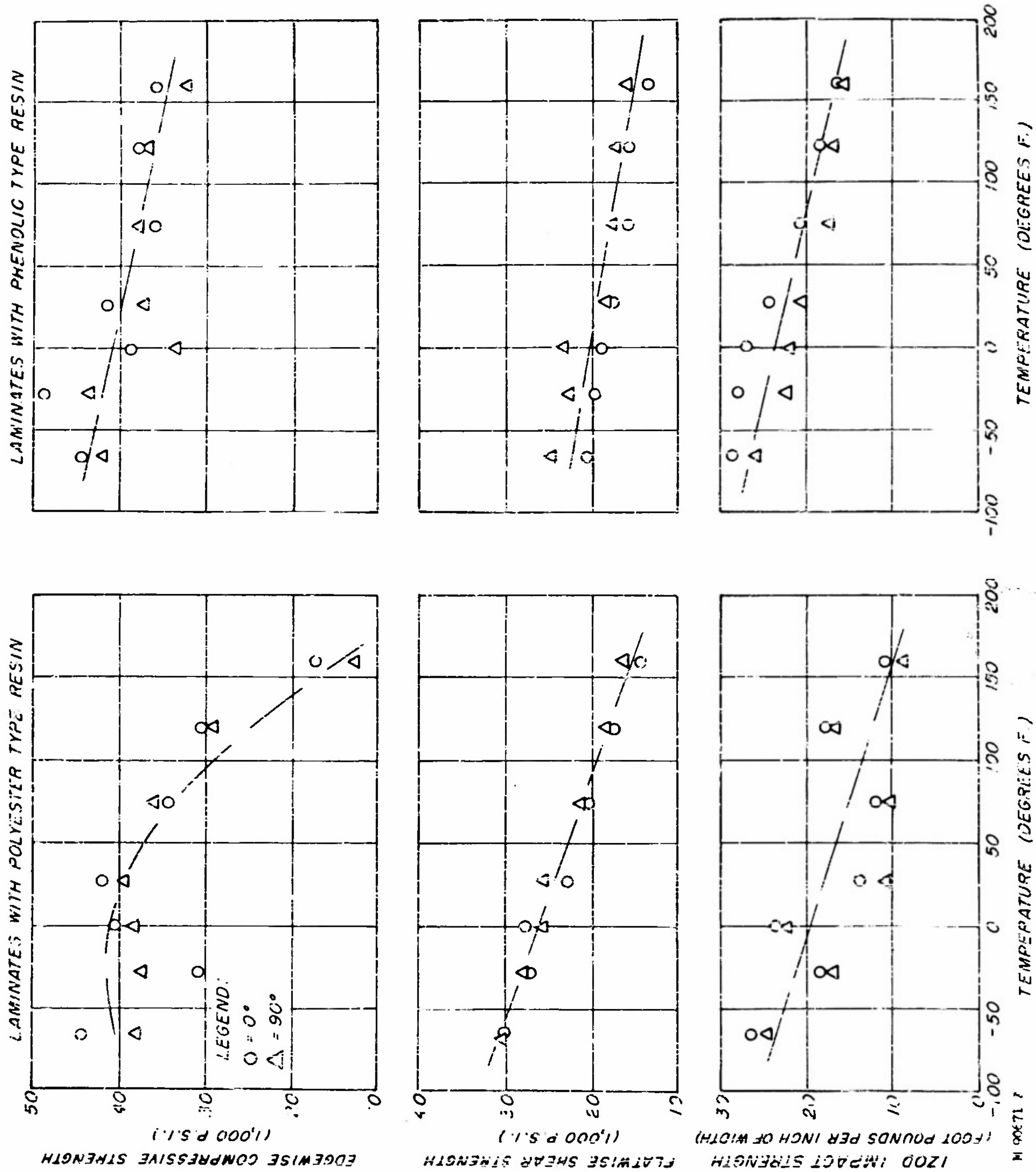


Fig. 8 Effect of Temperature at Time of Test on Tensile Properties of Plastic Laminates

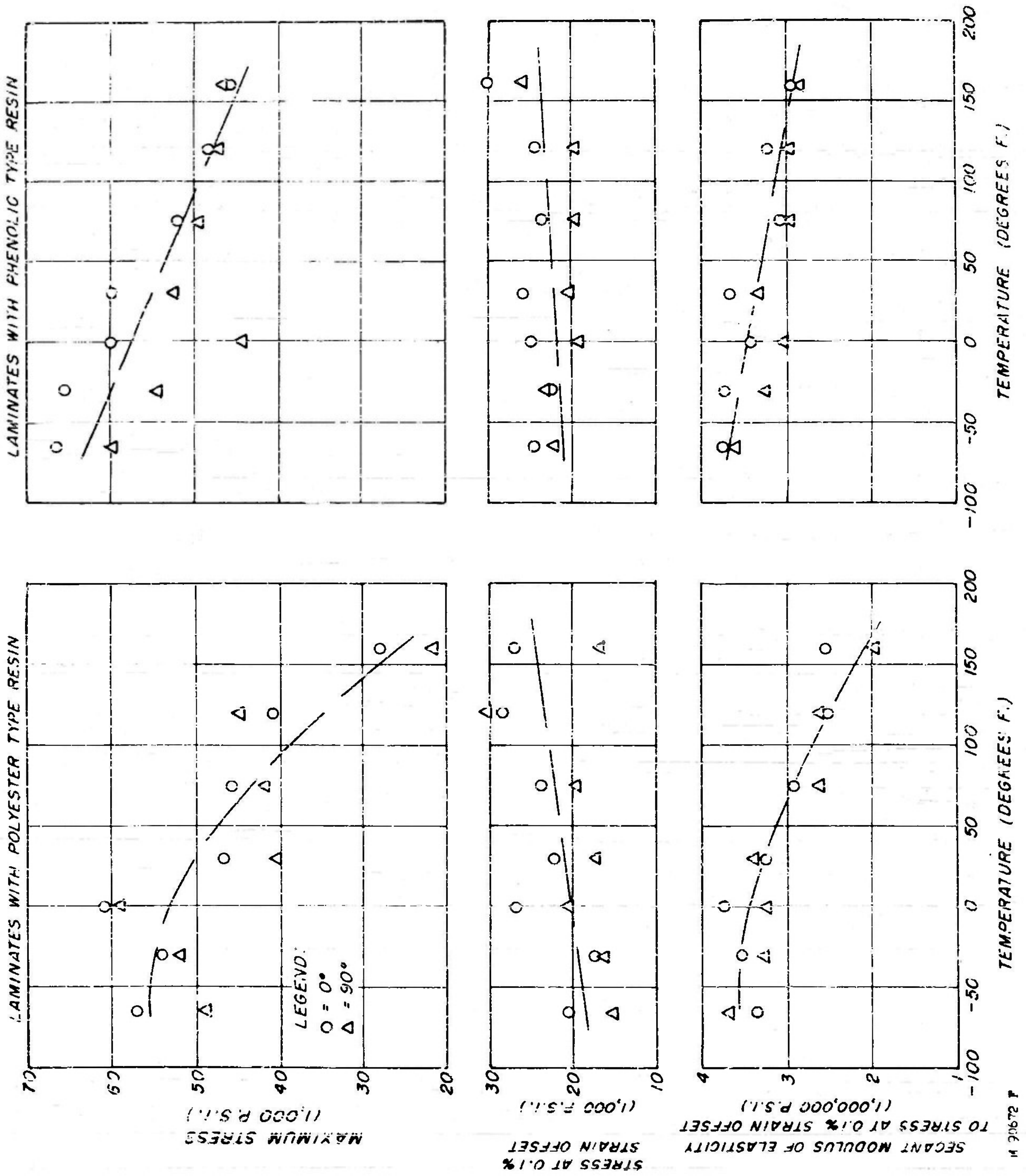


Fig. 9 Effect of Temperature at Time of Test on Flexural Properties of Plastic Laminates

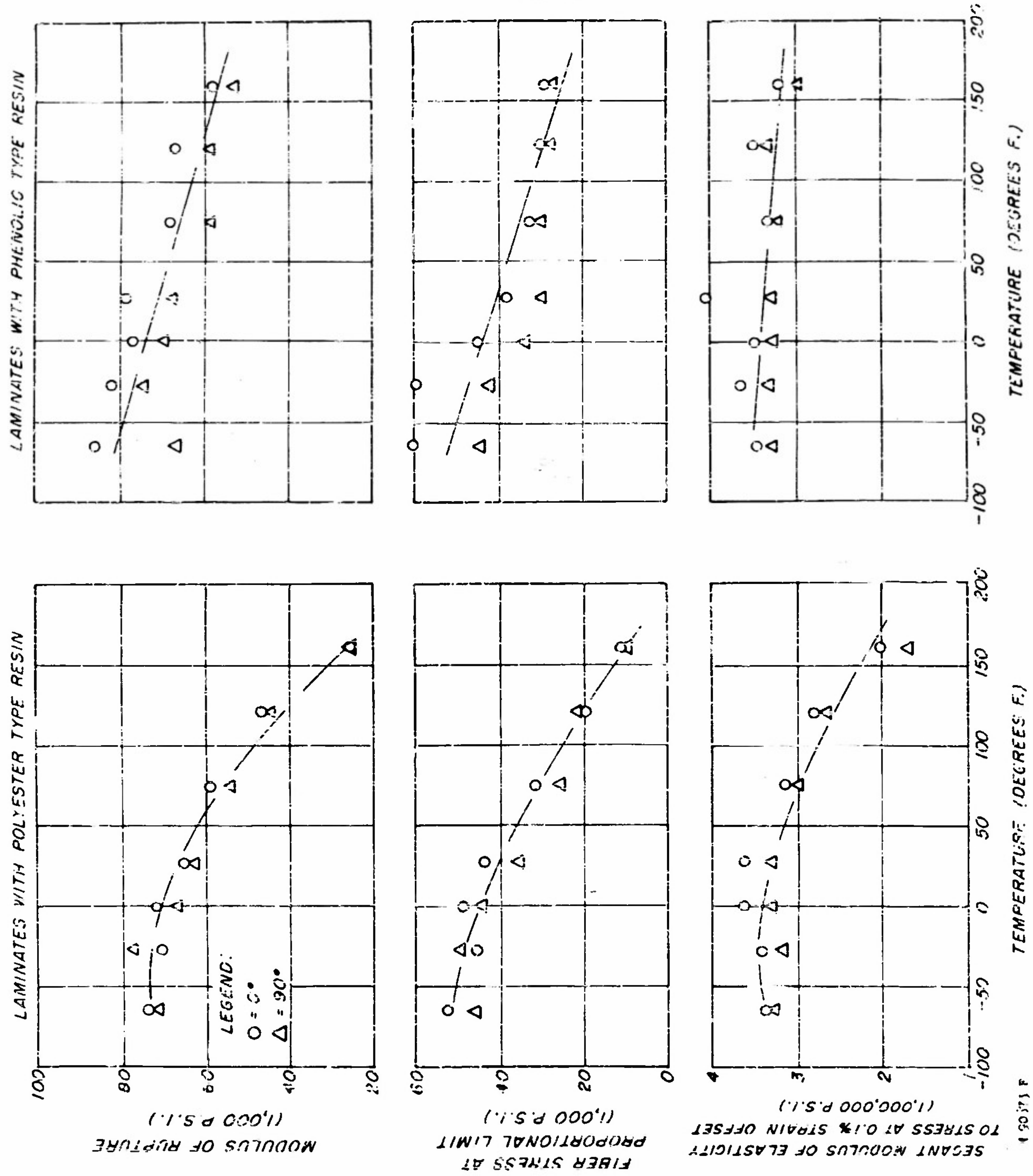


Fig. 10 Effect of Resin Content on Dielectric Constant of Plastic Laminates

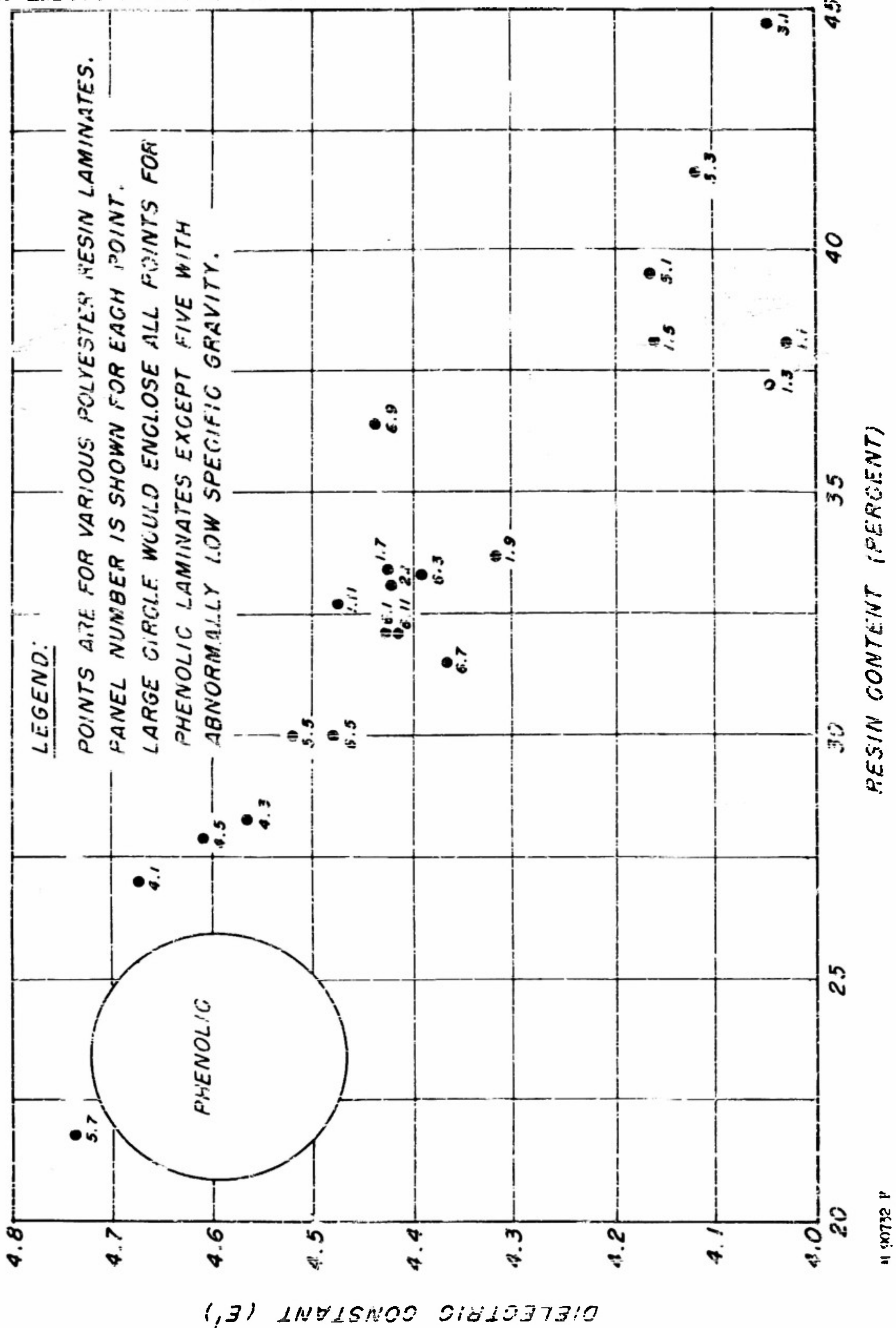
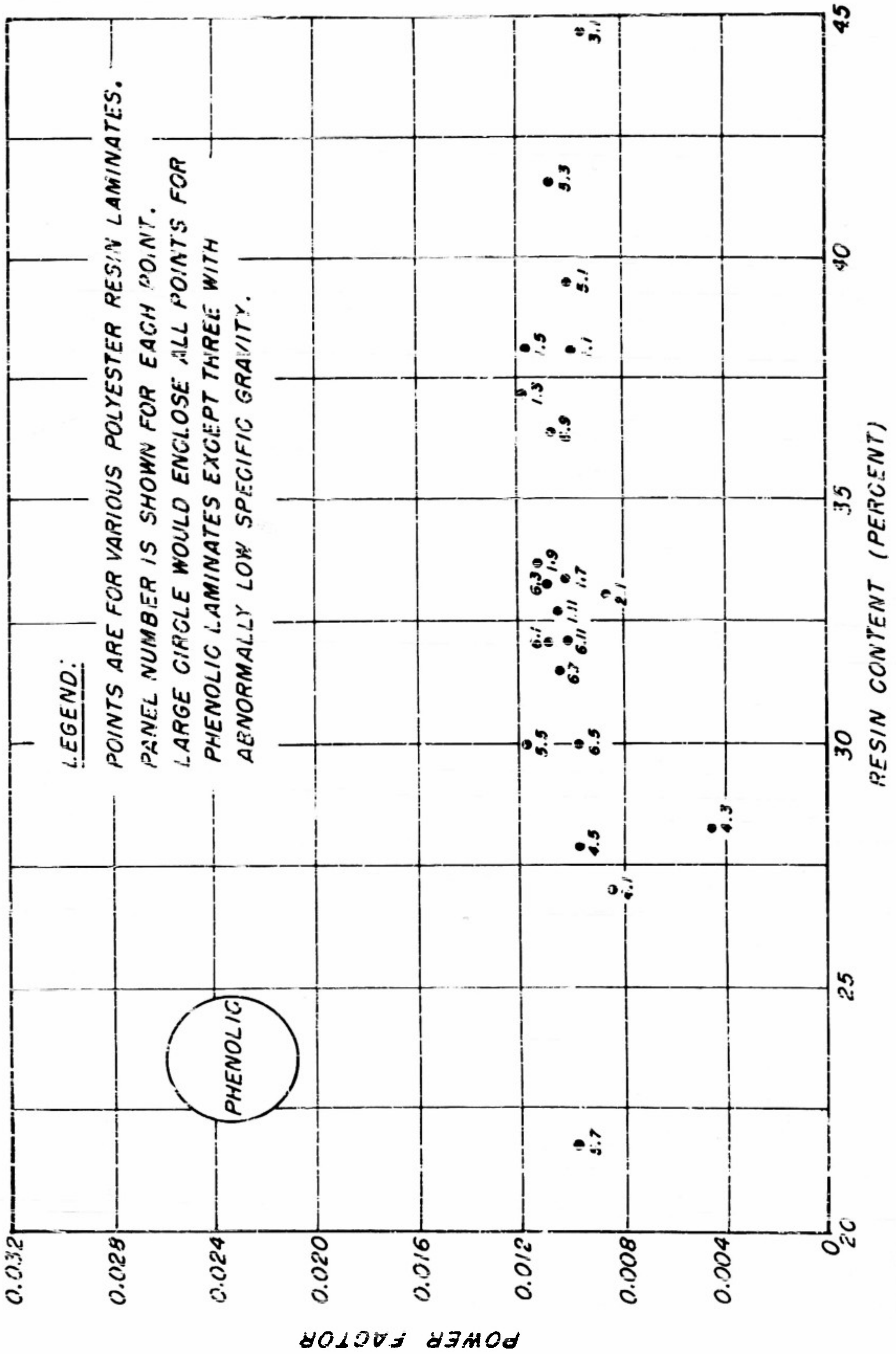


Fig. 11 Effect of Resin Content on Power Factor of Plastic Laminates



M 90733 F

Armed Services Technical Information Ag

AD 38648

Reproduced by
DOCUMENT SERVICE CENTER
KNOTT BUILDING, DAYTON, 2, OHIO

UNCLASSIFIE