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EVALUATION OF NON-WOVEN GLASS FIBER REINFORCEMENTS FOR LOW PRESSURE MOLDED POLYESTER RESINS FOR AIRCRAFT APPLICATIONS

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FOREWORD

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This report covers work conducted from November 1952 to April 1955.

ABSTRACT

The strength properties of several glass-fiber reinforced polyester moldings and sheets made from similar materials were determined. The constructions tested were: tote boxes made from glass mat, and from glass fiber roving preforms with no filler, and with filler; flat sheets made from the same combinations of resin, glass fiber and filler as used in the tote boxes; window frames made from glass fiber roving preforms; and small panels made from glass fiber reinforced molding compound. The results indicate that the bottoms of the tote boxes made from preforms with no filler had slightly higher strength properties than the corresponding sheets. The bottoms of the tote boxes made from glass mat had strength properties approximately equal to the corresponding sheets, and the bottoms made from preforms with filler had lower strength properties than the corresponding sheets. The strength properties of the bottoms of the window frames were approximately equivalent to those of the corresponding tote boxes with no filler and were, in general, higher than those of the corresponding flat sheets. The sides of the tote boxes and the flanges of the window frames had lower strength properties than corresponding construction in the flat sheets. The panels made from the glass fiber reinforced molding compound had much lower strength properties than the other moldings tested. In general, the strength properties of the moldings decreased after immersion in water.

PUBLICATION REVIEW

This report has been reviewed and is approved.

FOR THE COMMANDER:

M. R. WHITMORE
Technical Director
Materials Laboratory
Directorate of Research

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SUMMARY

Strength properties of several glass-fiber reinforced polyester moldings were determined both dry and after 30 days' immersion in water at 23°C. The moldings tested were: tote boxes made from glass mat, from glass fiber roving preforms with no filler, and from glass fiber roving preforms with filler; flat sheets made from the same combinations of resin, glass fiber and filler; window frames made from glass fiber preforms; and small panels made from glass fiber reinforced molding compounds.

Flexure, tensile, compression and Izod impact tests were conducted, and resin content, specific gravity and Barcol hardness were determined.

The results indicate that in most cases, the sides of the tote boxes and the flanges of the window frames had lower strength properties than the respective bottoms. The tote boxes made from the preforms with no filler had higher strength properties, in general, than the other two types. The strength properties of the window frames, also made from preforms with no filler, were similar to those of the corresponding tote boxes. For the flat sheets which were made from glass roving preforms similar to those used in the tote boxes, there was no significant difference in the strength properties with or without filler, and both types were superior to the sheets made from glass mat.

The bottoms of the tote boxes made from preforms with no filler and those made from glass mat had strength properties approximately equal to the corresponding flat sheets; those made from preforms with filler had lower strength properties. The bottoms of the window frames had strength properties equivalent to those of the tote boxes with no filler.

The panels made from the glass fiber reinforced molding compound had much lower strength properties than the other moldings tested.

In general, the strength properties of the moldings decreased after immersion in water.

INTRODUCTION

There are several types of unoriented non-woven glass fibers that are used as reinforcement for polyester resins. These include products such as chopped glass fiber filler in molding compounds, glass-fiber preforms, and glass mat. Because of the relative ease of preparing large moldings from these materials as well as favorable cost and production factors for non-woven glass fiber compared to glass fabric, these materials are finding many applications in military as well as civilian fields. However, little comparative data are available on these non-woven glass fiber reinforced plastics, and this investigation was undertaken to determine the mechanical properties of representative moldings and sheets made of unoriented non-woven glass fiber reinforced polyester plastics.

MATERIALS

The representative moldings of unoriented glass fiber reinforced polyester plastics used in this investigation consisted of the following:

1. Twelve tote boxes made of three different combinations of resin, glass fiber and filler.

2. Twelve flat sheets made of the same combinations of resins, glass fiber and filler used in the tote boxes.

3. Four window frames made of glass-fiber preforms.

4. Twelve flat panels made of glass fiber reinforced molding compound.

A tote box is shown in figure 1, a window frame in figure 2, and both are shown in figure 3. The weights of the sample moldings are listed in table 1, and the code used in referring to the test materials is given in table 2.

Tote boxes

The tote boxes were rectangular shaped boxes with rounded corners and molded-in feet. The boxes were approximately 27 inches long, 12 inches wide, and 8 inches deep. There was an indented area in the center of one long side, which extended from the top of the side to the bottom and was approximately 5 inches wide and 0.5 inch deep.

The boxes were made by Structurlite Plastics Corporation, and the details of fabrication are listed below.

No. of boxes	Type of Reinforcement	Filler	Pigment
4	Fiberglas Mat, M503 - treatment 17, 2 oz/ft^2, 3 layers	None	None
4	Preforms of Fiberglas glass roving, code R14A01-007 with 863 sizing, 2 inch strands; Plaskon 920 emulsion binder	None	None
4	Preforms of Fiberglas glass roving, code R14A01-007 with 863 sizing, 2 inch strands; Plaskon 920 emulsion binder	25% Surfex	1% Selectron 5537 olive drab

Resin:	Selectron 5003
Catalyst:	One percent Lucidol B.P.O.
Filler:	Surfex regular filler, precipitated calcium carbonate
Mold release:	DuPont Ortholeum 162
Molding pressure:	18 tons total molding force
Molding temperature:	225°F
Time in press:	5 minutes

The impregnation and layup procedure are described as follows:

"In all cases the reinforcing material, either mat or preform, was placed on the mold dry and a weighed amount of resin was poured on the bottom surface of the box and the mold closed immediately. The mold shear edges trimmed the reinforcing material and confined the resin so that fluid pressure was built up inside the mold thus forcing the resin through the reinforcement and into all areas of the molding.

"The mat was cut in patterns to fit the mold with joints only on the vertical corners of the box. The mat patterns were then placed in position and molded as described above." (Reference 1).

The edges along the bottoms of these boxes were resin-starved; these areas contained unbonded glass fibers.

The edges up the sides contained little or no glass fiber, as might be expected from the manner in which they were made. The resin in these areas was cracked when the boxes were received.

Flat sheets

The flat sheets were manufactured by the Glastic Corporation and were made of the same types and compositions of resin, glass fiber and filler as were used in the tote boxes. Two sheets of each of the three groups of four sheets were made using the same batches of resin used in making the tote boxes; the other two sheets in each group were bonded with a fresh batch of Selectron 5003 resin. The odd-numbered sheets, or units, were made with the original batch of resin, and the even-numbered sheets were made with the fresh batch of resin. The sheets were molded at 230°F for from four to five minutes. The catalyst was Lucidol benzoyl peroxide in granular form and a concentration of 0.75 percent was used.

Two series of panels molded from preforms were made using box shaped preforms. They were cut along the corners, laid flat, and then the tongues which had been the narrow sides were cut off, leaving a practically square flat mat made up of the former bottom and long sides of the box. An extra piece of mat was placed in the press to fill out the mold to facilitate making the panels. The portion of the extra mat was cut off the molded sheet, leaving a test panel 24 inches by 26 inches (Reference 2).

Window frames

The window frames were rectangular shaped boxes with rounded corners, resembling trays, with a rectangular flange running along the entire perimeter of the edge of the tray. Two opposite sides were curved inward slightly, and the flanges on these sides were depressed slightly as shown in figures 2 and 5. The frame proper had a length of approximately 18 inches, a width of 15 3/4 inches, and a depth of 3 1/2 inches. The flange extended 2 inches beyond the limits of the frame proper.

The frames were fabricated by the Zenith Plastics Company, and the details of fabrication are listed below:

Reinforcement:	Preforms of Fiberglas roving, 60 ends, 863 sizing, 2 inch strands
Resin:	Selectron 5084
Catalyst:	12 g/lb Garan benzoyl peroxide
Binder:	American Cyanamid 4022 emulsion binder
Mold release:	Garan B-12
Molding pressure:	2300 lb/in^2
Molding temperature:	240°F
Time in press:	3 minutes
Other details:	Four frames were molded on four different days (Reference 3).

Small flat panels

Small flat panels molded from a glass reinforced molding compound by the Glastic Corporation were also tested. These panels were 6 inches by 8 inches and had a nominal thickness of 3/16 inch.

Molding compound:	Glastic MG 508C
Reinforcement:	33 percent 1/2-inch chopped glass fibers with chrome sizing
Resin:	38 percent Laminac 4120 and 4 percent Paraplex P-13
Catalyst:	2 percent benzoyl peroxide
Filler:	25 percent inorganic, finer than 325 mesh
Additional:	Suitable mold release and inorganic pigment were used (Reference 2)
Molding pressure:	1000 lb/in^2
Molding temperature:	240°F
Time in press:	3 minutes
Other details:	No limiting stops were used in molding, so that thickness could be expected to vary considerably from sheet to sheet.

Materials suppliers

American Cyanamid binder:	American Cyanamid Co. New York, N. Y.
DuPont mold release:	E. I. duPont de Nemours & Co., Inc. Wilmington, Delaware
Fiberglas mat and roving:	Owens-Corning Fiberglas Corp. New York, N. Y.
Garan catalyst and mold release:	Garan Chemical Corp. Los Angeles, Calif.
Laminac resin:	American Cyanamid Co. New York, N. Y.
Lucidol catalyst:	Lucidol Div., Novadel-Agene Corp. Buffalo, New York
Paraplex resin:	Rohm and Haas Co. Philadelphia, Pa.
Plaskon binder:	Libbey-Owens-Ford Glass Co. Toledo, Ohio
Selectron resins and pigment:	Pittsburgh Plate Glass Co. Pittsburgh, Pa.
Surfex filler:	Diamond Alkali Co. Painesville, Ohio

PROCEDURES

Sampling

A sampling pattern was drawn up indicating the location of the flexural, compression, tensile and impact specimens to be cut from the tote boxes. It was possible to test for directional variations for all properties except tensile strength in the sides and bottoms of the boxes. The sides of the boxes were too shallow to obtain tensile specimens in a direction perpendicular to the bottom of the box.

Two sampling patterns, shown in figure 4, were used for the tote boxes. Pattern "A" was used on the bottoms; each bottom provided enough specimens for two replicates of this pattern. Thus duplicate specimens for each test were available which could be used for an evaluation of reproducibility in the statistical analysis. Pattern "B" was used for each side of the boxes. Because of the depression in the middle of side number 1 of the boxes, the specimens were cut from the area to the left of the depression in the even numbered boxes, and from the area to the right of the depression in the odd numbered boxes. Table 3 gives the numerical distribution of the test specimens obtained from the tote boxes.

Sampling pattern "A" in figure 4 was also used in cutting the specimens from the flat sheets made from the same materials as were used in the tote boxes. Two patterns were cut from each sheet. Table 4 shows the numerical distribution of the specimens from the sheets.

Figure 5 shows the sampling pattern used for the window frames. It was possible to identify the sides of the frames with respect to their position in the mold. Sides 2 and 4 were curved inward as shown and the flanges on these sides were slightly curved. Therefore, test specimens were not taken from the flanges on these sides. Test were made only on specimens cut from the bottoms and from the flanges of sides 1 and 3. Table 5 shows the numerical distribution of these specimens.

Figure 6 shows the sampling pattern used for the small flat panels.

The Barcol hardness, resin content, and specific gravity were determined on randomly selected specimens cut from all the molded pieces of each material.

Preparation and conditioning of specimens

The rough cutting of all specimens was done with a diamond tip rotary disk saw. After being rough cut, the specimens were machined with carbide cutters to the required tolerances in width and parallelism.

All specimens were conditioned at 23 ± 1°C (73.4 ± 2°F) and 50 ± 4 percent relative humidity for at least 7 days prior to test. The specimens that were tested wet were immersed in distilled water for 30 days at 23 ± 1°C (73.4 ± 2°F). The specimens were removed from the water immediately before testing, and were wiped with absorbent paper to remove any surface moisture prior to test.

It was originally planned to replace the 30-day immersion period in water at room temperature with an equivalent immersion in boiling water for a shorter period. To determine this equivalent boiling period, flexure specimens were prepared from sheets SM1 and SP5. Four specimens from each sheet were immersed in boiling water for periods of 1, 1 1/2, 2, 2 1/2, and 3 hours, respectively. In addition, four specimens from each sheet were immersed in water at 23°C for 30 days and four specimens were conditioned for 30 days at 23°C and 50 percent relative humidity. Flexural strength and modulus of elasticity were determined on each specimen. The averages of the results obtained and the range for each condition are plotted in figures 7 and 8. The irregular shapes of the curves may be due to a combination of volatilization of residual styrene monomer, postcuring, and degradation of the laminate. The results indicate that the boiling period equivalent to 30 days' immersion at 23°C is quite variable, depending on the type of material and on the property to be measured. For this reason, the 30-day immersion period at 23°C was used rather than the shorter boiling period, prior to determining the properties of the wet laminates.

Tensile test

The dry and wet tensile properties were determined in accordance with Method 1011 of Federal Specification L-P-406 (Reference 4). A standard dumbbell specimen, Type 1, having a reduced test section width of 0.50 inch was used. Military Specification MIL-P-8013A (Reference 5) specifies that the tensile tests shall be conducted using a Type 2 specimen, having a reduced section 0.25 inch wide. However, a number of specimens of this type broke in the reduced section during the machining operation and therefore the Type 1 specimen with a wider reduced section was used. The testing speed was 0.05 inch per minute. A load-extension graph was made of each specimen, and the modulus of elasticity was calculated from this graph.

Flexural test

The flexural properties were determined, dry and wet, in accordance with Method 1031 of Federal Specification L-P-406 (Reference 4). The specimens were 1 inch by 4 inches by the thickness of the material, approximately 0.10 to 0.15 inch. A span-depth ratio of 16:1 was used, and the speed of testing was 0.05 inch per minute. A load-deflection graph was made of each test specimen, and the modulus of elasticity was calculated from this graph.

Compression test

The compressive strength, dry and wet, was determined in accordance with Method 1021 of Federal Specification L-P-406 (Reference 4). The supporting compression jig described in this test method was used with all test specimens. The specimens were 3 1/8 inch by 1/2 inch by the thickness of the material, approximately 0.10 to 0.15 inch. The speed of testing was 0.05 inch per minute.

Impact strength

The Izod impact strength was determined in accordance with Method 1071 of Federal Specification L-P-406 (Reference 4). Standard notched test specimens were used. The specimens were tested in groups of three or four to obtain a composite specimen approximately 0.5 inch in thickness. Thus the number of impact tests is approximately one-fourth of the number of specimens prepared. The individual specimens making up a composite test specimen were from the same direction within a test area.

Resin content

The resin content was determined in accordance with Military Specification MIL-P-8013A (Reference 5) for the samples which did not contain a filler other than glass or inorganic fillers stable at 600°C. The four tote boxes and the four corresponding flat sheets, designated as BR9, BR10, BR11, BR12, SR9, SR10, SR11, and SR12, contained a calcium carbonate filler.

The loss of carbon dioxide from the calcium carbonate filler during the ignition of the laminate specimens introduces an error in the determination of resin content. A method was developed to compensate for this loss. Briefly, this method consists of completely saturating the residue with a concentrated solution of ammonium carbonate in distilled water. The specimens are evaporated to dryness at 80°-85°C and then heated at 110°C to constant weight. The specimens are then cooled to room temperature in a desiccator and reweighed. The weight gained by the residue is due to the carbon dioxide replacing that which was driven off during ignition. This method is described in detail with supporting data in WADC Technical Report 54-326 (Reference 6).

One specimen was tested from each test area of each unit, initially. After the strength tests were completed, an additional resin content specimen was cut from a flexural or impact specimen from each test area of each unit and the resin content determined.

Specific gravity

The specific gravity was determined in accordance with Method 5011 of Federal Specification L-P-406 (Reference 4). One specimen was tested from each test area of each unit.

Barcol hardness

The Barcol hardness was determined by direct reading on the Barcol Impressor. One specimen was tested from each test area of each test unit, and four measurements were made on each specimen.

RESULTS AND DISCUSSION

Mechanical tests

The results of the tensile tests are given in tables 6, 7, 8, and 9, the flexural tests in tables 10, 11, 12, and 13, the compression tests in tables 14 and 15, and the impact tests in table 16. A summary of the results of these mechanical tests for the tote boxes is given in table 17, for the flat sheets in table 18, and for the window frames in table 19.

Standard deviations measuring the variability of single measurements for each property are given in table 20. These are based on the duplicate specimens which were cut from the bottoms of the tote boxes and window frames, and from the flat sheets. The standard errors given in the summary tables were calculated by taking into account the variability between the four units of each type of reinforcement tested for each of the three types of moldings. The level of significance used to judge the differences was 5 percent.

Tote boxes. In the tests on the boxes in groups BM and BP, the results for the sides were consistently lower than those for the bottoms. For group BR there was no consistent difference between sides and bottoms.

The values obtained for tensile, flexural, and impact strengths of the sides were higher for group P than for groups M and R. However, the number of units tested was insufficient to make the observed differences statistically significant in most cases. Even if the differences are significant, they are so small as to be of questionable practical importance. There was no consistent difference between BM and BR.

For the bottoms of the boxes, the results from group BP were significantly and appreciably higher than for BM and BR for all properties except compressive strength and wet flexural strength. In most cases, the differences in the results obtained for the bottoms of groups BM and BR were not appreciable.

Flat sheets. There was no significant difference between the properties of the sheets made with the same batch of resin as was used for the tote boxes and those sheets made from a fresh batch of resin.

The flat sheets in groups SP and SR had approximately equal strength properties; those in group SM had appreciably lower strength properties than the other two groups except for compressive strength and wet flexural strength.

The strength values obtained for the sheets were compared to those obtained for the bottoms of the tote boxes made from corresponding materials. The differences between the boxes and the sheets in group M and in group P were very slight. In group R, however, the values obtained for the sheets were much higher than those obtained for the boxes, except for compressive strength which was lower.

Window frames. The strength values obtained for the flanges were much lower than those for the bottoms of the frames. The values obtained on the frame bottoms were similar to those obtained for group BP of the tote boxes. This group had the highest strength properties of the three groups of tote boxes and was made from preforms with no filler as were the window frames.

Small panels. The strength values for the small molded panels were much lower than those obtained for the other molded pieces. Accurate tangent moduli of elasticity values could not be calculated for the tensile tests, dry or wet, or for the wet flexural tests from the load-extension graphs because they exhibited some curvature over the entire range.

Unit-to-unit variations. The data obtained in the mechanical tests were analyzed statistically to determine if there was significant unit-to-unit variation in the various types of moldings. The results are summarized in table 21.

The results obtained in the tests on the tote boxes indicate that the variation between boxes was not significant in group BM but was significant for most properties in groups BP and BR.

For the flat sheets, there was no significant sheet-to-sheet variation in the properties of group SM except for tensile modulus whereas the variation was significant for all properties of group SP except for compression strength. In group SR, the sheet-to-sheet variation was significant for tensile and impact properties but not for flexure and compressive properties.

There was a significant unit-to-unit variation for all properties of the window frames except for the tensile properties of the flanges.

In general, both the tote boxes and the flat sheets made from glass mat did not show unit-to-unit variations. The boxes and sheets made from preforms with no filler exhibited significant unit-to-unit variations in most cases, as did the window frames which were also made from preforms with no filler. The tote boxes made from preforms with filler also showed unit-to-unit variations for most properties whereas the corresponding flat sheets showed significant variations for half of the properties only.

Directional effects. The results of the mechanical tests were analyzed statistically to determine if the moldings exhibited directional effects. For the tote boxes made from glass mat, the tensile properties of the bottoms were greater in the lengthwise direction than in the crosswise, the flexural properties of the sides were greater in the horizontal direction than in the vertical, and the flexural modulus and impact strength of the ends were greater in the vertical direction than in the horizontal. There were no significant directional effects observed in the other properties. Since these boxes were each made from single pieces of mat laid on top of one another, the variations observed give some indication that the mat was stronger in one direction, i.e., parallel to the longest side, than in the other.

For the boxes made from preforms with no filler, the flexural properties of the sides and the ends were greater in the vertical direction than in the horizontal, as was the impact strength of the ends. This would tend to indicate a directional effect probably associated with the molding process in which the resin is poured onto the bottom of the preform and forced up the sides in a vertical direction by fluid pressure built up after the mold is closed.

For the tote boxes made from preforms with filler, the impact strength was greater in the horizontal direction for the ends and sides, and the compressive strength was greater in the lengthwise direction for the bottoms.

The analysis of the data obtained on the flat sheets corroborates the results observed with the tote boxes fairly well. For the sheets made from glass mat, the flexural, impact, and compression properties were greater in a lengthwise direction than in the crosswise, denoting a directional variation as indicated in the corresponding tote boxes. For the sheets made from preforms with no filler, a directional effect was observed in the flexural strength only, which would tend to indicate that there was no general effect of direction associated with the glass preform or with the molding of the flat sheet. The sheets made from preforms with filler indicated directional effects in tensile and impact properties only, in which case the lengthwise direction was stronger than the crosswise.

The frame bottoms, also made from preforms with no filler, did not indicate any consistent directional effects, corroborating the results obtained for the bottoms of the tote boxes and for the flat sheets made from preforms with no filler.

Wet tests. Immersion of the test specimens in water at 23°C for 30 days decreased all of the strength properties of all the materials except the tensile properties of the flanges of the window frames. The largest decreases were observed in the compression tests in which the strength decreased approximately 50 percent in most cases.

Resin content

The results of the resin content determinations are given in table 22. The resin content was slightly higher for the tote boxes than for the corresponding sheets. The resin content for the tote boxes made from preforms with no filler was approximately equal to that of the window frames which were also made from preforms and no filler. For box group BP and for the window frames the results for the sides were higher than for the bottoms.

Specific gravity

The data obtained in the specific gravity tests are presented in table 23. The results for the tote boxes indicate that there is a significant box-to-box variability within each group, based on the specimen-to-specimen variability. There is also a significant group-to-group difference based on the box-to-box variability. The boxes made with preforms containing pigment and filler had the highest specific gravity, those made with preforms with no pigment and filler were next highest, and those made from the glass mat had the lowest specific gravity.

Although the group averages for the flat sheets were in the same order as those for the tote boxes, the group-to-group differences were not statistically significant for the sheets. The data for the flat sheets indicate a significant sheet-to-sheet difference based on the specimen-to-specimen variability. However, the three groups do not differ significantly when compared to the sheet variability.

The four window frames do not differ significantly from one another in specific gravity when compared to the specimen-to-specimen variation.

Barcol hardness

The Barcol hardness numbers are given in table 24. The data for the tote boxes indicate that the greatest source of variability comes from the four readings on a specimen. Compared to the differences between readings on a specimen, there is no significant specimen-to-specimen variation or box-to-box variation. However, based on the box-to-box variation within each group, there is a significant difference between the three groups. The boxes made with glass mat had the lowest hardness number, those made with preforms and having no pigment or filler were slightly higher, and those made with preforms and having pigment and filler were **highest** .

Analysis of the data for the flat sheets, based on the reading-to-reading variability within a specimen, indicates no significant specimen-to-specimen variation within a sheet but a significant sheet-to-sheet difference within a group. However, the three groups do not differ significantly from each other.

The window frames show a significant specimen-to-specimen difference based on the variation of readings within a specimen but do not differ significantly from one another when compared to the specimen-to-specimen difference within each frame.

For the molded flat panels, the sheet-to-sheet difference is not significant when compared to the variation of the individual readings.

CONCLUSIONS

The following detailed conclusions can be made on the basis of the tests conducted on specimens from the representative moldings of unoriented glass fiber reinforced polyester plastics:

1. In general, the strength properties of the tote boxes made from preforms with no filler are greater than those of the boxes made from glass mat or from preforms with filler. The differences between the strength properties of the tote boxes made from glass mat and those made from preforms with filler are not appreciable.

2. For the flat sheets made from materials corresponding to those used in the tote boxes, the strength properties of the sheets made from the preforms with filler are approximately equal to those of the sheets made from preforms with no filler. The strength properties of the sheets made from glass mat are less than those of the other two types of sheets in most cases.

3. In general, the strength properties of the sides of the tote boxes and the flanges of the window frames are lower than those of the respective bottoms.

4. The strength properties of the bottoms of the tote boxes made from glass mat and from preforms with no filler are approximately equal to those of the corresponding sheets. For the materials made from preforms with filler, the flat sheets are stronger than the bottoms of the corresponding tote boxes. The strength properties of the bottoms of the window frames, also made from glass fiber preforms with no filler, are equivalent to those of the tote boxes made from preforms with no filler which are the strongest of the tote boxes.

5. In general, both the tote boxes and the flat sheets made from glass mat do not show unit-to-unit variations. The boxes and the sheets made from preforms with no filler exhibit significant unit-to-unit variations in most cases, as do the window frames which are also made from preforms with no filler. The tote boxes made from preforms with filler also show unit-to-unit variations for most properties whereas the corresponding flat sheets show significant variations for half of the properties only.

6. There is some indication of directional effect in the strength properties of the tote boxes and flat sheets made from glass mat, probably resulting from directional variation in the glass mat itself. Directional variations in strength properties of the tote boxes made from preforms with no filler, as evidenced by greater strength in the vertical direction than in the horizontal for the ends and sides, is probably associated with the molding process. No significant variations are observed for the corresponding flat sheets, or for the window frames which are also made from preforms with no filler. The tote boxes and the sheets made from the preforms with filler exhibit directional variations for some properties only and are inconsistent.

7. In general, the strength properties of the moldings decrease after immersion in water. The decrease is greatest for the compressive strength.

8. The resin content of the tote boxes is slightly higher than that of the corresponding sheets. The resin content of the tote boxes made from preforms with no filler is equal to that of the window frames, also made from preforms with no filler.

9. The specific gravity is slightly higher for the sheets than for the corresponding tote boxes. The specific gravity of the window frames is higher than that of the corresponding tote boxes made from preforms with no filler.

10. The Barcol hardness of the tote boxes is slightly higher than that of the corresponding flat sheets. The hardness of the boxes made of preforms with no filler is slightly higher than that of the window frames.

The above detailed conclusions can be summarized into two general conclusions, as follows: (a) The strength properties of the flat sheets agree fairly well with those of pieces cut from the bottoms and sides of the tote boxes and window frames except for those made with preforms containing calcium carbonate filler. The agreement between the properties of the bottoms of the boxes and frames, and those of the sheets, is good with the same exception. Although the differences between the sides of the boxes and frames, and the sheets are statistically significant, they are not large in most cases when judged on the usual basis for selecting specification limits. (b) Visual examination of the boxes indicates that the corners are defective. The edges along the bottom where the reinforcement is bent to a small radius of curvature contain insufficient resin to obtain maximum strength properties. The edges of the sides contain little or no reinforcement; the resin in these areas in most cases was cracked when the boxes were received. It would be expected that the properties of the flat sheets would not correspond to even a fair degree to the properties of the edges of the molded boxes.

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2. Private communications from M. A. Leeds, The Glastic Corporation.

3. Private communication from I. Green, Zenith Plastics Company.

4. Federal Specification L-P-406 for Plastics, Organic: General Specifications, Tests Methods. Federal Standard Stock Catalog Section IV, Part 5, Item L-P-406b, 27 September 1951, and Amendment - 1, 25 September 1952.

5. Military Specification MIL-P-8013A for Plastic Materials, Glass Fabric Base, Low Pressure Laminated, Aircraft Structural, September 19, 1952.

6. S. D. Toner, Determination of Resin Content of Glass Fiber-Polyester Laminates Containing a Calcium Carbonate Filler. WADC Technical Report 54-326 (June 1954).

Table 1. - Weights of Sample moldings

Sample Number	Weight (g)	Description
1	2653	Tote box: Glass fiber mat
2	2686	
3	2625	
4	2642	
5	2774	Tote box: Glass fiber roving preform
6	2693	
7	3021	
8	2771	
9	3097	Tote box: Glass fiber roving preform, 25% filler, 1% pigment
10	3099	
11	3083	
12	3198	
1	1663	Window frame: Glass fiber preform
2	1783	
3	1689	
4	1752	

Table 2. - Code used for test materials

Type	Group	Units	Test areas per unit	Description
B	M	1 to 4	1 to 6	Tote box, glass fiber mat reinforcement
B	P	5 to 8	1 to 6	Tote box, glass fiber roving preform reinforcement
B	R	9 to 12	1 to 6	Tote box, glass fiber roving preform reinforcement with filler and pigment
S	M	1 to 4	7 and 8	Flat sheets, similar in composition to BM
S	P	5 to 8	7 and 8	Flat sheets, similar in composition to BP
S	R	9 to 12	7 and 8	Flat sheets, similar in composition to BR
F	P	21 to 24	1 to 5	Window frames, glass fiber roving preform reinforcement
P	G	31 to 38	1 only	Flat panels, made from a glass reinforced molding compound

Table 3. - Numerical distribution of test specimens from tote boxes

Type of test	Direction of specimens	Test condition	Number of specimens: Per side	Per bottom	Per box	Per type[a] of box	Total for all boxes
Compression	Parallel	Dry	1	2	6	24	
	do.	Wet	1	2	6	24	
	Perpendicular	Dry	1	2	6	24	
	do.	Wet	1	2	6	24	
	Both directions	Wet and dry	4	8	24	96	288
Flexure	Both directions	Wet and dry	4	8	24	96	288
	(Distribution is the same as for the compression specimens).						
Tension	Parallel	Dry	1	2	6	24	
	do.	Wet	1	2	6	24	
	Perpendicular	Dry	0	2	2	8	
	do.	Wet	0	2	2	8	
	Both directions	Wet and dry	2	8	16	64	192
Impact	Parallel	Dry	1	2	6	24	
	Perpendicular	Dry	1	2	6	24	
	Both directions	Dry	2	4	12	48	144

a. The type of box refers to one of the three combinations of reinforcement and filler: A. Glass Mat; B. Preforms; C. Preforms with filler and pigment.

Table 4. - Numerical distribution of test specimens from flat sheets

Direction of specimen	Test condition[a]	Number of specimens per group[b]: Bonded with aged resin, Per sheet	Bonded with aged resin, Per group of two duplicate sheets	Bonded with fresh resin, Per sheet	Bonded with fresh resin, Per group of two duplicate sheets	Total for three groups of each test[c]
Perpendicular	Dry	2	4	2	4	24
Do.	Wet	2	4	2	4	24
Parallel	Dry	2	4	2	4	24
Do.	Wet	2	4	2	4	24
Both directions	Wet and dry	8	16	8	16	96

a. The distribution of the impact specimens is the same as for the other tests except that no wet impact specimens were tested.

b. The group refers to one of the three combinations of reinforcement and filler: A. Glass Mat; B. Preforms; C. Preforms with filler and pigment

c. The types of test are: 1) flexure, 2) tension, 3) compression, 4) impact.

Table 5. - Numerical distribution of test specimens from window frames[a]

Direction of specimens	Test condition[a]	Number of specimens: Per flange	Per two flanges (sides 1 and 3)	Per bottom	Per frame	Total per type of test[b]
Perpendicular	Dry	0	0	2	2	8
Do.	Wet	0	0	2	2	8
Parallel	Dry	1	2	2	4	16
Do.	Wet	1	2	2	4	16
Both directions	Dry and wet	2	4	8	12	48

a. The distribution of the impact specimens is the same as for the other tests except that no wet impact specimens are tested.

b. The types of tests are: 1) flexure, 2) tension, 3) compression, and 4) impact, except for the flanges. No impact test specimens were obtained from the flanges.

Table 6. - Dry tensile strengths of unoriented glass fiber reinforced polyester moldings

Type	Test Group	Unit	Tensile strength, 10^3 lb/in.^{2} Unit average Sides[a]	Bottom	Group average Sides[a]	Bottom
B	M[b]	1	13.7	14.5		
		2	12.5	14.6		
		3	12.5	14.3		
		4	13.5	13.0	13.1	14.1
B	P[b]	5	15.8	20.4		
		6	15.1	19.1		
		7	15.3	23.5		
		8	15.3	29.4	15.4	23.2
B	R[b]	9	10.5	10.3		
		10	9.0	12.1		
		11	16.6	16.9		
		12	13.2	12.4	12.3	12.9
S	M[c]	1		16.0		
		2		14.8		
		3		15.1		
		4		13.9		15.0
S	P[c]	5		21.6		
		6		18.7		
		7		17.4		
		8		26.8		21.1
S	R[c]	9		22.6		
		10		26.6		
		11		20.3		
		12		15.8		21.4
F	P[d]	21	10.5	29.6		
		22	8.2	22.4		
		23	11.4	16.8		
		24	15.3	18.6	11.4	21.8
P	G[e]	31 to 38				4.7

a. For group FP, the values are for specimens taken from the flanges.
b. Groups BM, BP, and BR; Values per unit are the average of 4 side specimens, or 4 bottom specimens.
c. Groups SM, SP, and SR; Values per unit are the average of 4 specimens.
d. Group FP; Values per unit are the average of 2 flange specimens or 4 bottom specimens.
e. Group PG; Value is average of 6 specimens, 1 from each of 6 units.

Table 7. - Dry tensile moduli of elasticity of unoriented glass fiber reinforced polyester moldings

Test			Tensile modulus of elasticity 10^6 lb/in.^{2}			
			Unit average		Group average	
Type	Group	Unit	Sides[a]	Bottom	Sides[a]	Bottom
B	M[b]	1	1.21	1.28		
		2	1.19	1.32		
		3	1.22	1.21		
		4	1.25	1.17	1.22	1.25
B	P[b]	5	1.37	1.61		
		6	1.32	1.52		
		7	1.17	1.60		
		8	1.24	1.95	1.28	1.67
B	R[b]	9	1.06	1.06		
		10	1.13	1.35		
		11	1.49	1.38		
		12	1.41	1.31	1.27	1.28
S	M[c]	1		1.44		
		2		1.24		
		3		1.27		
		4		1.25		1.30
S	P[c]	5		1.42		
		6		1.35		
		7		1.28		
		8		1.70		1.44
S	R[c]	9		1.53		
		10		1.78		
		11		1.47		
		12		1.15		1.48
F	P[d]	21	1.01	2.19		
		22	0.75	1.61		
		23	1.00	1.42		
		24	1.31	1.40	1.05	1.66

a. For group FP, the values are for specimens taken from the flanges.
b. Groups BM, BP, and BR; Values per unit are the average of 4 side specimens or 4 bottom specimens.
c. Groups SM, SP, and SR; Values per unit are the average of 4 specimens.
d. Group FP; Values per unit are the average of 2 flange specimens or 4 bottom specimens.

Table 8. - Wet tensile strengths of unoriented glass fiber reinforced polyester moldings

Type	Test Group	Unit	Tensile strength, 10^3 lb/in.^{2} Unit average Sides[a]	Unit average Bottom	Group average Sides[a]	Group average Bottom
B	M[b]	1	13.6	14.5		
		2	13.3	13.6		
		3	11.8	14.8		
		4	12.7	13.5	12.8	14.1
B	P[b]	5	12.9	17.4		
		6	12.2	19.8		
		7	12.4	19.6		
		8	14.1	20.0	12.9	19.2
B	R[b]	9	10.4	9.8		
		10	9.4	10.9		
		11	13.6	12.5		
		12	12.2	10.3	11.4	10.9
S	M[c]	1		15.0		
		2		14.9		
		3		15.5		
		4		13.9		14.8
S	P[c]	5		18.8		
		6		21.2		
		7		20.2		
		8		19.4		19.9
S	R[c]	9		18.9		
		10		21.1		
		11		19.1		
		12		15.5		18.7
F	P[d]	21	12.8	21.4		
		22	10.9	21.0		
		23	15.4	18.6		
		24	18.0	13.6	14.3	18.7
P	G[e]	31 to 38				2.6

a. For group FP, the values are for specimens taken from the flanges.
b. Groups BM, BP, and BR; Values per unit are the average of 4 side specimens or 4 bottom specimens.
c. Groups SM, SP, and SR; Values per unit are the average of 4 specimens.
d. Group FP; Values per unit are the average of 2 flange specimens or 4 bottom specimens.
e. Group PG; Value is average of 7 specimens, 1 from each of 7 units.

Table 9. - Wet tensile moduli of elasticity of unoriented glass fiber reinforced polyester moldings

Type	Test Group	Unit	Tensile modulus of elasticity 10^6 lb/in.^{2} Unit average Sides[a]	Unit average Bottom	Group average Sides[a]	Group average Bottom
B	M[b]	1	0.95	0.97		
		2	0.88	0.94		
		3	0.93	1.00		
		4	0.97	0.99	0.93	0.98
B	P[b]	5	0.87	1.16		
		6	0.90	1.36		
		7	0.79	1.19		
		8	0.98	1.30	0.88	1.25
B	R[b]	9	0.78	0.75		
		10	0.87	0.94		
		11	1.02	0.86		
		12	0.94	0.84	0.90	0.85
S	M[c]	1		0.94		
		2		0.97		
		3		1.06		
		4		0.94		0.98
S	P[c]	5		1.19		
		6		1.25		
		7		1.32		
		8		1.20		1.24
S	R[c]	9		1.25		
		10		1.44		
		11		1.26		
		12		1.01		1.24
F	P[d]	21	0.84	1.29		
		22	0.88	1.34		
		23	1.04	1.17		
		24	1.54	0.95	1.08	1.19

a. For group FP, the values are for specimens taken from the flanges.
b. Groups BM, BP, and BR; Values per unit are the average of 4 side specimens or 4 bottom specimens.
c. Groups SM, SP, and SR; Values per unit are the average of 4 specimens.
d. Group FP; Values per unit are the average of 2 flange specimens or 4 bottom specimens.

Table 10. - Dry flexural strengths of unoriented glass fiber reinforced polyester moldings

Test			Flexural strength, 10^3 lb/in.^{2}			
			Unit average		Group average	
Type	Group	Unit	Sides[a]	Bottom	Sides[a]	Bottom
B	M[b]	1	27.9	33.7		
		2	25.5	25.7		
		3	28.1	31.8		
		4	23.4	28.6	26.2	30.0
B	P[b]	5	32.9	34.5		
		6	28.4	34.9		
		7	31.7	36.8		
		8	29.0	45.4	30.5	37.9
B	R[b]	9	25.3	22.4		
		10	27.8	26.5		
		11	29.4	26.9		
		12	27.2	25.0	27.4	25.2
S	M[c]	1		27.8		
		2		27.4		
		3		29.8		
		4		28.9		28.5
S	P[c]	5		36.1		
		6		34.9		
		7		31.1		
		8		40.4		35.6
S	R[c]	9		37.8		
		10		39.3		
		11		35.4		
		12		33.7		36.5
F	P[d]	21	21.4	47.4		
		22	19.9	40.1		
		23	14.7	33.4		
		24	24.9	31.3	20.2	38.0
P	G[e]	31 to 38				13.0

a. For group FP, the values are for specimens taken from the flanges.
b. Groups BM, BP, and BR; Values per unit are the average of 8 side specimens or 4 bottom specimens.
c. Groups SM, SP, and SR; Values per unit are the average of 4 specimens.
d. Group FP; Values per unit are the average of 2 flange specimens or 4 bottom specimens.
e. Group PG; Value is average of 8 specimens, 1 from each of 8 units.

Table 11. - Dry flexural moduli of elasticity of unoriented glass fiber reinforced polyester moldings

Test			Flexural modulus of elasticity 10^6 lb/in.^{2}			
			Unit average		Group average	
Type	Group	Unit	Sides[a]	Bottom	Sides[a]	Bottom
B	M[b]	1	1.30	1.47		
		2	1.29	1.34		
		3	1.28	1.38		
		4	1.25	1.31	1.28	1.38
B	P[b]	5	1.42	1.51		
		6	1.12	1.46		
		7	1.26	1.59		
		8	1.28	2.10	1.27	1.66
B	R[b]	9	1.26	1.16		
		10	1.52	1.53		
		11	1.38	1.32		
		12	1.51	1.36	1.41	1.34
S	M[c]	1		1.42		
		2		1.35		
		3		1.45		
		4		1.38		1.40
S	P[c]	5		1.61		
		6		1.52		
		7		1.36		
		8		1.96		1.61
S	R[c]	9		1.66		
		10		1.98		
		11		1.69		
		12		1.72		1.76
F	P[d]	21	0.91	2.14		
		22	1.07	1.81		
		23	0.71	1.45		
		24	1.30	1.48	1.00	1.72
P	G[e]	31 to 38				1.57

a. For group FP, the values are for specimens taken from the flanges.
b. Groups BM, BP, and BR; Values per unit are the average of 8 side specimens or 4 bottom specimens.
c. Groups SM, SP, and SR; Values per unit are the average of 4 specimens.
d. Group FP; Values per unit are the average of 2 flange specimens or 4 bottom specimens.
e. Group PG; Value is average of 8 specimens, 1 from each of 8 units.

Table 12. - Wet flexural strengths of unoriented glass fiber reinforced polyester moldings

Type	Test Group	Unit	Flexural strength, 10^3 lb/in.^{2} Unit average Sides[a]	Unit average Bottom	Group average Sides[a]	Group average Bottom
B	M[b]	1	24.1	25.6		
		2	24.2	25.3		
		3	24.5	26.0		
		4	23.9	24.7	24.2	25.4
B	P[b]	5	24.5	24.9		
		6	24.8	27.0		
		7	23.3	23.9		
		8	25.8	23.5	24.6	24.8
B	R[b]	9	18.7	19.9		
		10	21.5	24.1		
		11	21.7	20.9		
		12	22.8	23.5	21.2	22.1
S	M[c]	1		24.2		
		2		23.3		
		3		24.6		
		4		23.0		23.8
S	P[c]	5		25.4		
		6		23.1		
		7		25.7		
		8		22.0		24.0
S	R[c]	9		26.4		
		10		21.2		
		11		23.3		
		12		21.7		23.1
F	P[d]	21	20.3	26.7		
		22	15.3	25.2		
		23	21.7	27.2		
		24	17.2	26.0	18.6	26.3
P	G[e]	31 to 38				7.9

a. For group FP, the values are for specimens taken from the flanges.
b. Groups BM, BP, and BR; Values per unit are the average of 8 side specimens or 4 bottom specimens.
c. Groups SM, SP, and SR; Values per unit are the average of 4 specimens.
d. Group FP; Values per unit are the average of 2 flange specimens or 4 bottom specimens.
e. Group PG; Value is average of 8 specimens, 1 from each of 8 units.

Table 13. - Wet flexural moduli of elasticity of unoriented glass fiber reinforced polyester moldings

Test			Flexural modulus of elasticity 10^6 lb/in.^{2}			
			Unit average		Group average	
Type	Group	Unit	Sides[a]	Bottom	Sides[a]	Bottom
B	M[b]	1	1.03	1.20		
		2	1.08	1.15		
		3	1.01	1.09		
		4	1.06	1.08	1.04	1.13
B	P[b]	5	1.08	1.23		
		6	0.97	1.22		
		7	1.06	1.33		
		8	1.08	1.51	1.05	1.32
B	R[b]	9	0.79	0.96		
		10	1.06	1.19		
		11	1.06	1.04		
		12	1.14	1.11	1.01	1.07
S	M[c]	1		1.25		
		2		1.12		
		3		1.22		
		4		1.13		1.18
S	P[c]	5		1.50		
		6		1.33		
		7		1.29		
		8		1.68		1.45
S	R[c]	9		1.32		
		10		1.64		
		11		1.29		
		12		1.14		1.35
F	P[d]	21	0.86	1.74		
		22	0.72	1.47		
		23	0.96	1.41		
		24	0.88	1.17	0.85	1.45

a. For group FP, the values are for specimens taken from the flanges.
b. Groups BM, BP, and BR; Values per unit are the average of 8 side specimens or 4 bottom specimens.
c. Groups SM, SP, and SR; Values per unit are the average of 4 specimens.
d. Group FP; Values per unit are the average of 2 flange specimens or 4 bottom specimens.

Table 14. - Dry compressive strengths, edgewise, of unoriented glass fiber reinforced polyester moldings

Type	Test Group	Unit	Compressive strength, 10^3 lb/in.^{2} Unit average Sides[a]	Unit average Bottom	Group average Sides[a]	Group average Bottom
B	M[b]	1	25.4	27.2		
		2	26.2	26.9		
		3	26.4	26.8		
		4	27.0	25.7	26.1	26.6
B	P[b]	5	26.7	28.4		
		6	24.4	30.4		
		7	26.1	29.8		
		8	25.7	28.2	25.8	29.2
B	R[b]	9	26.1	25.3		
		10	27.7	30.4		
		11	27.4	28.6		
		12	27.6	28.8	27.2	28.3
S	M[c]	1		24.3		
		2		25.9		
		3		24.8		
		4		25.0		25.0
S	P[c]	5		24.4		
		6		23.6		
		7		25.3		
		8		25.5		24.7
S	R[c]	9		26.8		
		10		24.9		
		11		23.3		
		12		23.7		24.7
F	P[d]	21	21.0	37.3		
		22	21.4	35.1		
		23	17.2	32.7		
		24	14.9	31.8	19.4	34.2
P	G[e]	31 to 38				18.8

a. For group FP, the values are for specimens taken from the flanges.
b. Groups BM, BP, and BR; Values per unit are the average of 8 side specimens or 4 bottom specimens.
c. Groups SM, SP, and SR; Values per unit are the average of 4 specimens.
d. Group FP; Values per unit are the average of 2 flange specimens or 4 bottom specimens.
e. Group PG; Value is average of 8 specimens; 1 from each of 8 units.

Table 15. - Wet compressive strengths, edgewise, of unoriented glass fiber reinforced polyester moldings

Type	Test Group	Unit	Compressive strength, 10^3 lb/in.^{2} Unit average Sides[a]	Unit average Bottom	Group average Sides[a]	Group average Bottom
B	M[b]	1	14.5	15.4		
		2	16.1	16.4		
		3	14.8	15.2		
		4	15.3	14.7	15.2	15.4
B	P[b]	5	12.8	14.2		
		6	14.7	16.0		
		7	12.6	15.5		
		8	14.0	11.8	13.5	14.4
B	R[b]	9	13.5	13.8		
		10	15.9	17.3		
		11	11.5	13.8		
		12	12.4	16.0	13.3	15.2
S	M[c]	1		14.6		
		2		14.8		
		3		14.4		
		4		14.4		14.6
S	P[c]	5		14.0		
		6		12.9		
		7		14.4		
		8		12.2		13.4
S	R[c]	9		13.0		
		10		11.9		
		11		13.2		
		12		13.7		13.0
F	P[d]	21	11.3	15.4		
		22	12.9	14.8		
		23	10.0	15.0		
		24	8.2	16.5	10.6	15.4
P	G[e]	31 to 38				12.0

a. For group FP, the values are for specimens taken from the flanges.
b. Groups BM, BP, and BR; Values per unit are the average of 8 side specimens or 4 bottom specimens.
c. Groups SM, SP, and SR; Values per unit are the average of 4 specimens.
d. Group FP; Values per unit are the average of 2 flange specimens or 4 bottom specimens.
e. Group PG; Value is average of 8 specimens, 1 from each of 8 units.

Table 16. - Dry impact strengths of unoriented glass fiber reinforced polyester moldings

Type	Test Group	Unit	Impact strength, ft-lb/inch of notch[a] Unit average Sides	Unit average Bottom	Group average Sides	Group average Bottom
B	M[b]	1	10.5	11.6		
		2	10.6	10.8		
		3	10.0	11.2		
		4	10.6	10.7	10.4	11.1
B	P[b]	5	15.2	17.6		
		6	13.6	19.3		
		7	15.6	18.8		
		8	15.7	21.5	15.0	19.3
B	R[b]	9	9.1	9.6		
		10	8.4	9.4		
		11	11.8	9.8		
		12	11.2	8.7	10.1	9.4
S	M[c]	1		11.3		
		2		11.0		
		3		12.2		
		4		10.5		11.2
S	P[c]	5		16.7		
		6		16.6		
		7		15.4		
		8		21.7		17.6
S	R[c]	9		17.6		
		10		21.5		
		11		17.4		
		12		14.7		17.8
F	P[d]	21		18.6		
		22		15.2		
		23		14.1		
		24		16.1		16.0
P	G[e]	31 to 38		1.9		1.9

a. Test specimens are composite specimens of several individual specimens piled up to approximately 1/2-inch thickness.
b. Groups BM, BP, and BR; Values per unit are the average of 8 side specimens or 4 bottom specimens.
c. Groups SM, SP, and SR; Values per unit are the average of 4 specimens.
d. Group FP; Values are the average of 2 bottom specimens per unit.
e. Group PG; Value is the average of 16 specimens, 2 from each of 8 units.

Table 17. - Mechanical properties of unoriented glass fiber reinforced polyester tote boxes

		Sides						Bottom					
		Group M		Group P		Group R		Group M		Group P		Group R	
			SE[a]		SE[a]		SE[a]		SE[a]		SE[a]		SE[a]
Tensile strength, 10^3 lb/in.^{2}	dry	13.1	.3	15.4	.2	12.3	1.9	14.1	.4	23.2	2.5	12.9	1.6
	wet	12.8	.4	12.9	.5	11.4	1.0	14.1	.3	19.2	.6	10.9	.7
Tensile modulus of elasticity, 10^6 lb/in.^{2}	dry	1.22	.01	1.28	.05	1.27	.11	1.25	.04	1.67	.11	1.28	.08
	wet	0.93	.02	0.88	.05	0.90	.06	0.98	.01	1.25	.05	0.85	.05
Flexural strength, 10^3 lb/in.^{2}	dry	26.2	1.2	30.5	1.1	27.4	1.0	30.0	2.0	37.9	2.7	25.2	1.1
	wet	24.2	0.1	24.6	.6	21.2	1.0	25.4	.3	24.8	.9	22.1	1.0
Flexural modulus of elasticity, 10^6 lb/in.^{2}	dry	1.28	.01	1.27	.07	1.41	.06	1.38	.04	1.66	.16	1.34	.09
	wet	1.04	.02	1.05	.03	1.01	.09	1.13	.03	1.32	.07	1.07	.06
Compressive strength, 10^3 lb/in.^{2}	dry	26.1	.4	25.8	.6	27.2	.4	26.6	.4	29.2	.5	28.3	1.2
	wet	15.2	.4	13.5	.5	13.3	1.1	15.4	.4	14.4	1.0	15.2	.9
Impact strength, ft-lb/inch of notch	dry	10.4	.1	15.0	.5	10.1	.8	11.1	.2	19.3	0.7	9.4	.3

a. Standard Error

Table 18. - Mechanical properties of unoriented glass fiber reinforced polyester flat sheets

		Group M		Group P		Group R	
			SE[a]		SE[a]		SE[a]
Tensile strength, 10^3 lb/in.^{2}	dry	15.0	.5	21.1	2.3	21.4	2.7
	wet	14.8	.4	19.9	.6	18.7	1.4
Tensile modulus of elasticity, 10^6 lb/in.^{2}	dry	1.30	.05	1.44	.10	1.48	.15
	wet	0.98	.03	1.24	.03	1.24	.11
Flexural strength, 10^3 lb/in.^{2}	dry	28.5	.6	35.6	2.3	36.5	1.4
	wet	23.8	.4	24.0	.9	23.1	1.3
Flexural modulus of elasticity, 10^6 lb/in.^{2}	dry	1.40	.02	1.61	.15	1.76	.08
	wet	1.18	.03	1.45	.10	1.35	.12
Compressive strength, 10^3 lb/in.^{2}	dry	25.0	.4	24.7	.5	24.7	.9
	wet	14.6	.1	13.4	.5	13.0	.4
Impact strength, ft-lb/inch of notch	dry	11.2	.4	17.6	1.6	17.8	1.7

a. Standard Error

Table 19. - Mechanical properties of unoriented glass fiber reinforced polyester window frames

		Flanges		Bottom	
			SE[a]		SE[a]
Tensile strength, 10^3 lb/in.^{2}	dry	11.4	1.7	21.8	3.1
	wet	14.3	1.7	18.7	1.8
Tensile modulus of elasticity, 10^6 lb/in.^{2}	dry	1.02	.14	1.66	.19
	wet	1.08	.17	1.19	.10
Flexural strength, 10^3 lb/in.^{2}	dry	20.2	2.5	38.0	4.0
	wet	18.6	1.6	26.3	0.5
Flexural modulus of elasticity, 10^6 lb/in.^{2}	dry	1.00	.14	1.72	.17
	wet	0.85	.06	1.45	.14
Compressive strength, 10^3 lb/in.^{2}	dry	19.4	1.6	34.2	1.3
	wet	10.6	1.1	15.4	.4
Impact strength, ft-lb/inch of notch	dry	------		16.0	1.1

a. Standard Error

Table 20. - Standard deviations[a] for mechanical properties of bottoms of tote boxes and window frames, and of flat sheets

Type	Group	Standard deviations										
		Tensile strength		Tensile modulus		Flexural strength		Flexural modulus		Compressive strength		Impact strength
		dry	wet	dry	wet	dry	wet	dry	wet	dry	wet	dry
B	M	1.5	1.3	0.08	0.07	4.0	2.5	0.13	0.12	1.2	0.5	1.3
	P	1.9	1.7	0.06	0.10	4.6	1.7	0.12	0.06	1.1	1.2	1.3
	R	1.4	1.9	0.09	0.06	2.8	2.3	0.10	0.17	1.1	0.6	1.0
S	M	1.6	2.0	0.07	0.12	2.3	1.4	0.09	0.12	1.0	0.6	0.8
	P	2.9	2.4	0.16	0.17	1.4	3.0	0.16	0.09	1.4	1.0	1.2
	R	1.2	1.7	0.07	0.16	4.0	3.1	0.36	0.12	1.7	0.4	1.1
F	P	2.4	1.5	0.18	0.06	2.4	1.7	0.08	0.15	0.9	1.1	3.0

a. For single measurements.

Table 21. - Unit-to-unit variation in properties of glass fiber reinforced polyester moldings

	Tensile strength		Tensile modulus		Flexural Strength		Flex-ural modu-lus		Compres-sive strength		Impact strength	
	S[a]	B[a]	S	B	S	B	S	B	S	B	S	B
Boxes												
BM	n[b]	n[b]	n	n	n	n	n	n	n	n	n	n
BP	n	s	s	s	n	s	s	s	s	n	s	s
BR	s	s	s	s	n	n	s	s	n	s	s	n
Sheets												
SM		n		s		n		n		n		n
SP		s		s		s		s		n		s
SR		s		s		n		n		n		s
Frames												
FP	n	s	n	s	s	s	s	s	s	s	-	-

a. S indicates sides of boxes and flanges of frames.
B indicates bottom of boxes and frames.

b. s indicates significant variation at the 5 percent level.
n indicates no significant variation at the 5 percent level.

Table 22.- Resin content of unoriented glass fiber reinforced polyester moldings

Test			Resin content, weight percent				
			Unit average		Group average		
Type	Group	Unit	Sides	Bottom	Sides	Bottom	Over-all
B	M	1	64[a]	63[b]			
		2	66	65			
		3	71	66			
		4	66	66	67	65	66
B	P	5	66	58			
		6	70	64			
		7	64	60			
		8	62	50	66	56	63
B	R	9	61	61			
		10	60	56			
		11	58	48			
		12	55	58	58	56	57
S	M	1		62[c]			
		2		62			
		3		60			
		4		67		62	62
S	P	5		57			
		6		58			
		7		60			
		8		50		56	56
S	R	9		54			
		10		47			
		11		52			
		12		58		53	53
F	P	21	75[d]	48[e]			
		22	66	57			
		23	68	66			
		24	53	66	65	59	63
P	G	31-38		35			35

a. Average of eight specimens, two from each side.
b. Average of four specimens, two from each bottom test area.
c. Average of two specimens, one from each test area.
d. Average of four specimens, one from each side.
e. Average of two specimens.

Table 23. - Specific gravity of unoriented glass fiber reinforced polyester moldings

Type	Test Group	Unit	Test areas	Number of measurements per unit[a]	Specific gravity, 23°/23°C Unit average	Specific gravity, 23°/23°C Group average
B	M	1	6	6	1.49	
		2	6	6	1.49	
		3	6	6	1.43	
		4	6	6	1.48	1.47
B	P	5	6	6	1.48	
		6	6	6	1.44	
		7	6	6	1.51	
		8	6	6	1.56	1.50
B	R	9	6	6	1.55	
		10	6	6	1.56	
		11	6	6	1.59	
		12	6	6	1.59	1.57
S	M	1	2	2	1.52	
		2	2	2	1.53	
		3	2	2	1.55	
		4	2	2	1.47	1.52
S	P	5	2	2	1.56	
		6	2	2	1.55	
		7	2	2	1.53	
		8	2	2	1.63	1.58
S	R	9	2	2	1.59	
		10	2	2	1.67	
		11	2	2	1.60	
		12	2	2	1.53	1.60
F	P	21	5	5	1.48	
		22	5	5	1.52	
		23	5	5	1.50	
		24	5	5	1.61	1.53
P	G	31	1	1	1.78	
		32	1	1	1.74	
		33	1	1	1.75	
		34	1	1	1.77	
		35	1	1	1.73	
		36	1	1	1.69	
		37	1	1	1.72	
		38	1	1	1.71	1.74

a. One specimen was tested from each test area.

Table 24. - Barcol hardness of unoriented glass fiber reinforced polyester moldings

Type	Test Group	Unit	Test areas	Number of measurements per unit[a]	Barcol hardness Unit average	Barcol hardness Group average
B	M	1	6	24	54	
		2	6	24	54	
		3	6	24	51	
		4	6	24	52	53
B	P	5	6	24	54	
		6	6	24	55	
		7	6	24	54	
		8	6	24	58	55
B	R	9	6	24	57	
		10	6	24	59	
		11	6	24	54	
		12	6	24	57	57
S	M	1	2	8	53	
		2	2	8	52	
		3	2	8	51	
		4	2	8	47	51
S	P	5	2	8	51	
		6	2	8	48	
		7	2	8	48	
		8	2	8	52	50
S	R	9	2	8	53	
		10	2	8	54	
		11	2	8	52	
		12	2	8	45	51
F	P	21	5	20	45	
		22	5	20	48	
		23	5	20	46	
		24	5	20	51	48
P	G	31	1	4	48	
		32	1	4	48	
		33	1	4	46	
		34	1	4	46	
		35	1	4	48	
		36	1	4	45	
		37	1	4	47	
		38	1	4	41	46

a. One specimen was tested from each test area. Four measurements were made on each specimen.

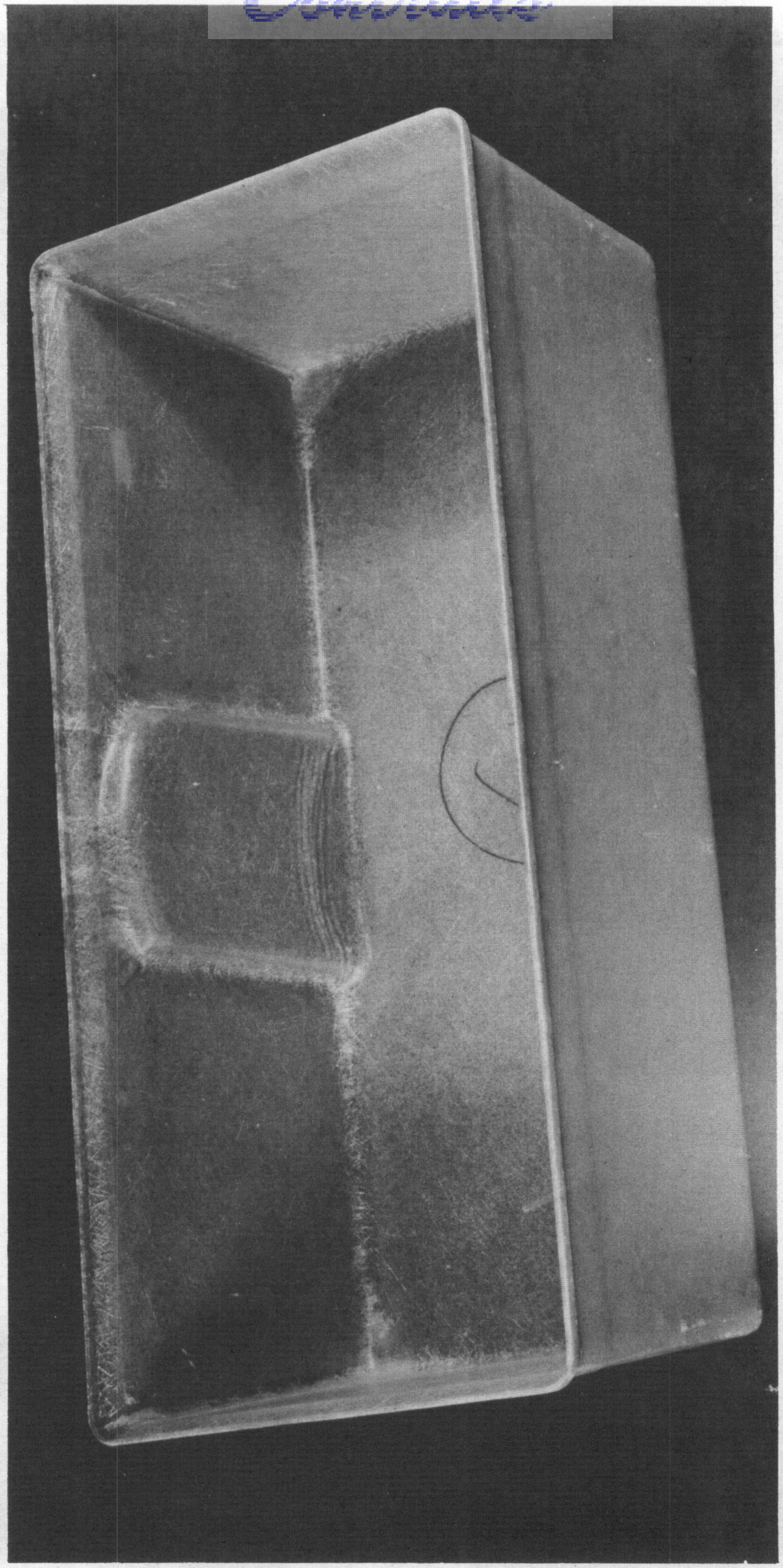

FIGURE I. TOTE BOX

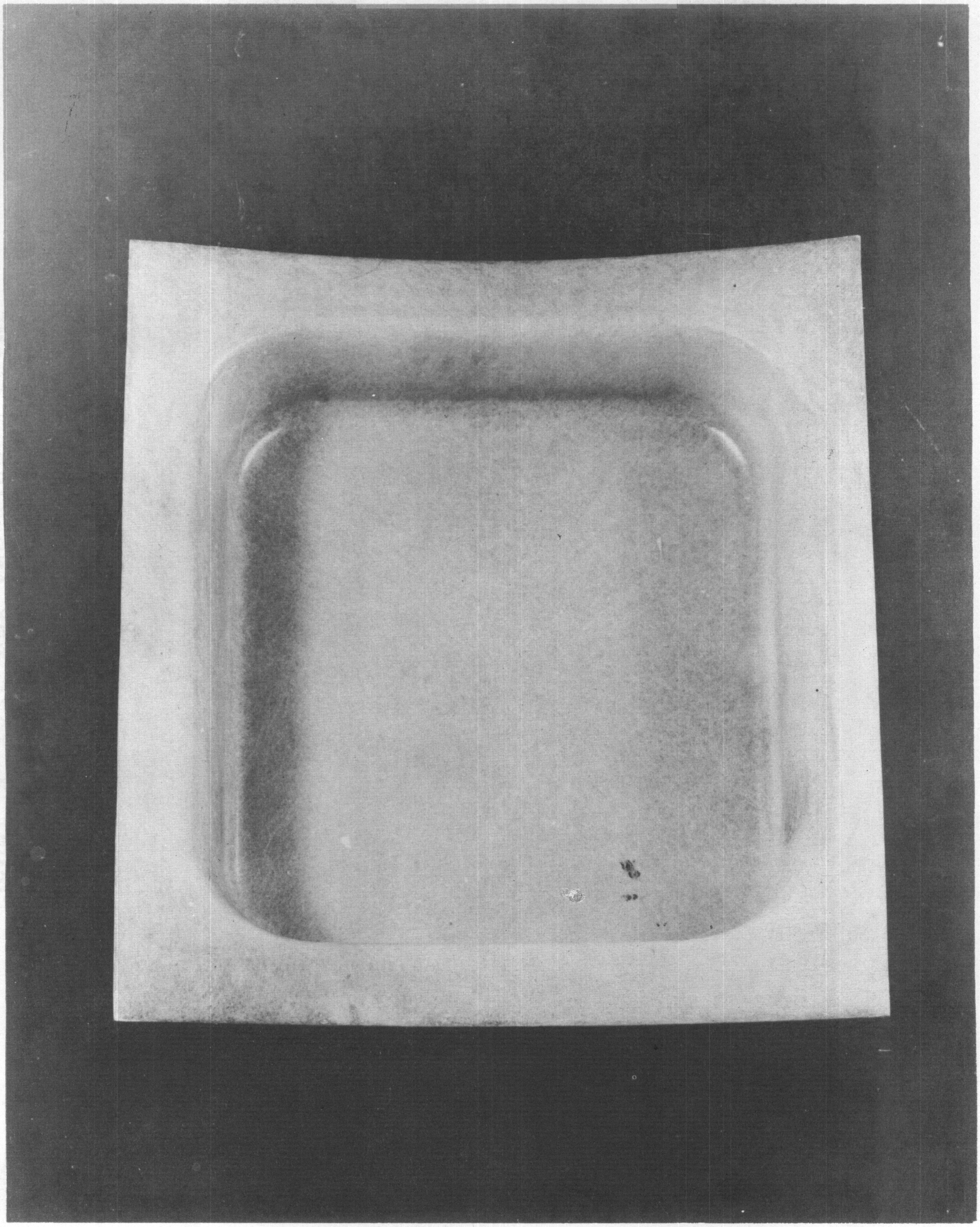

FIGURE 2. WINDOW FRAME

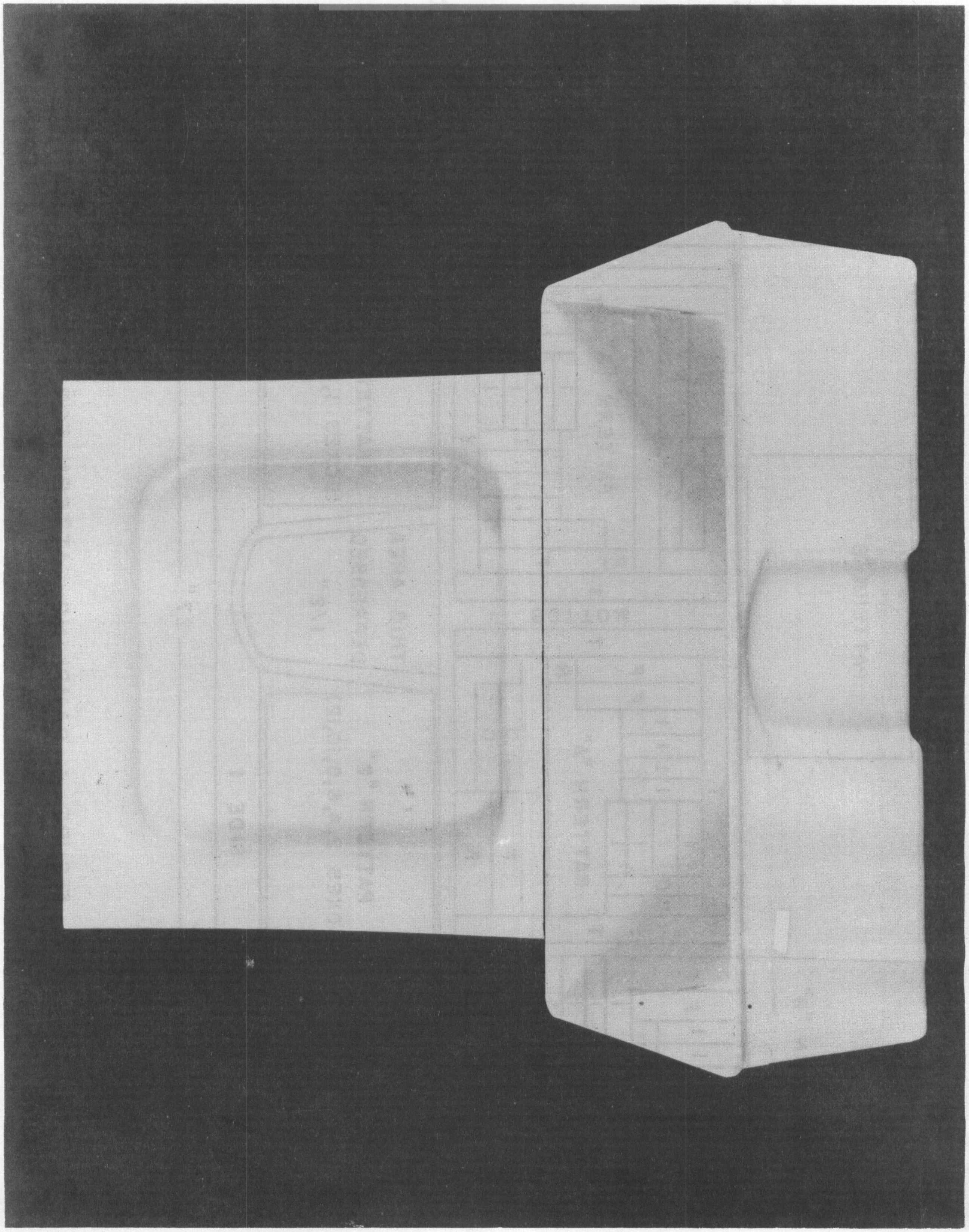

FIGURE 3. TOTE BOX AND WINDOW FRAME

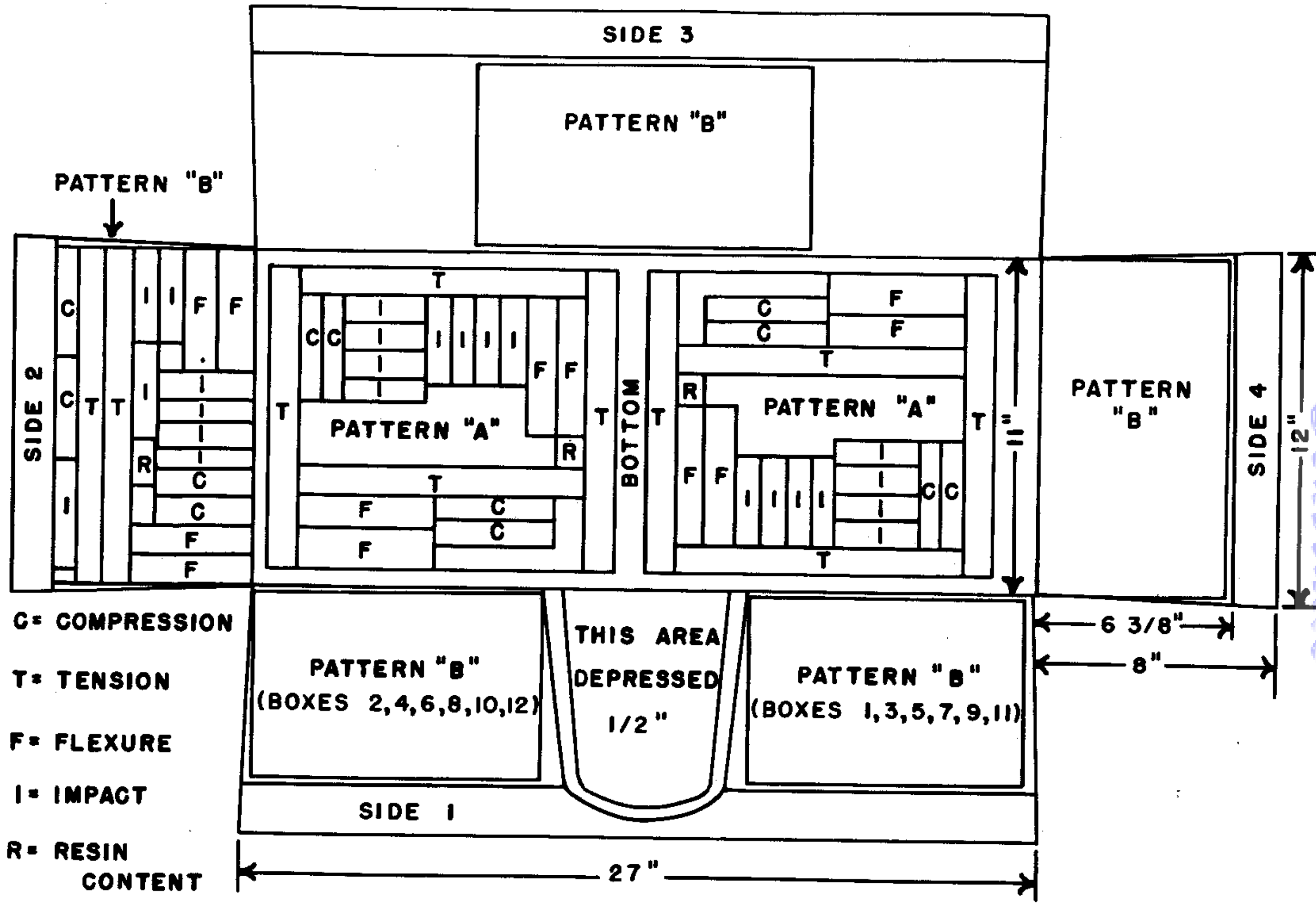

FIGURE 4. SAMPLING PATTERN FOR TOTE BOXES

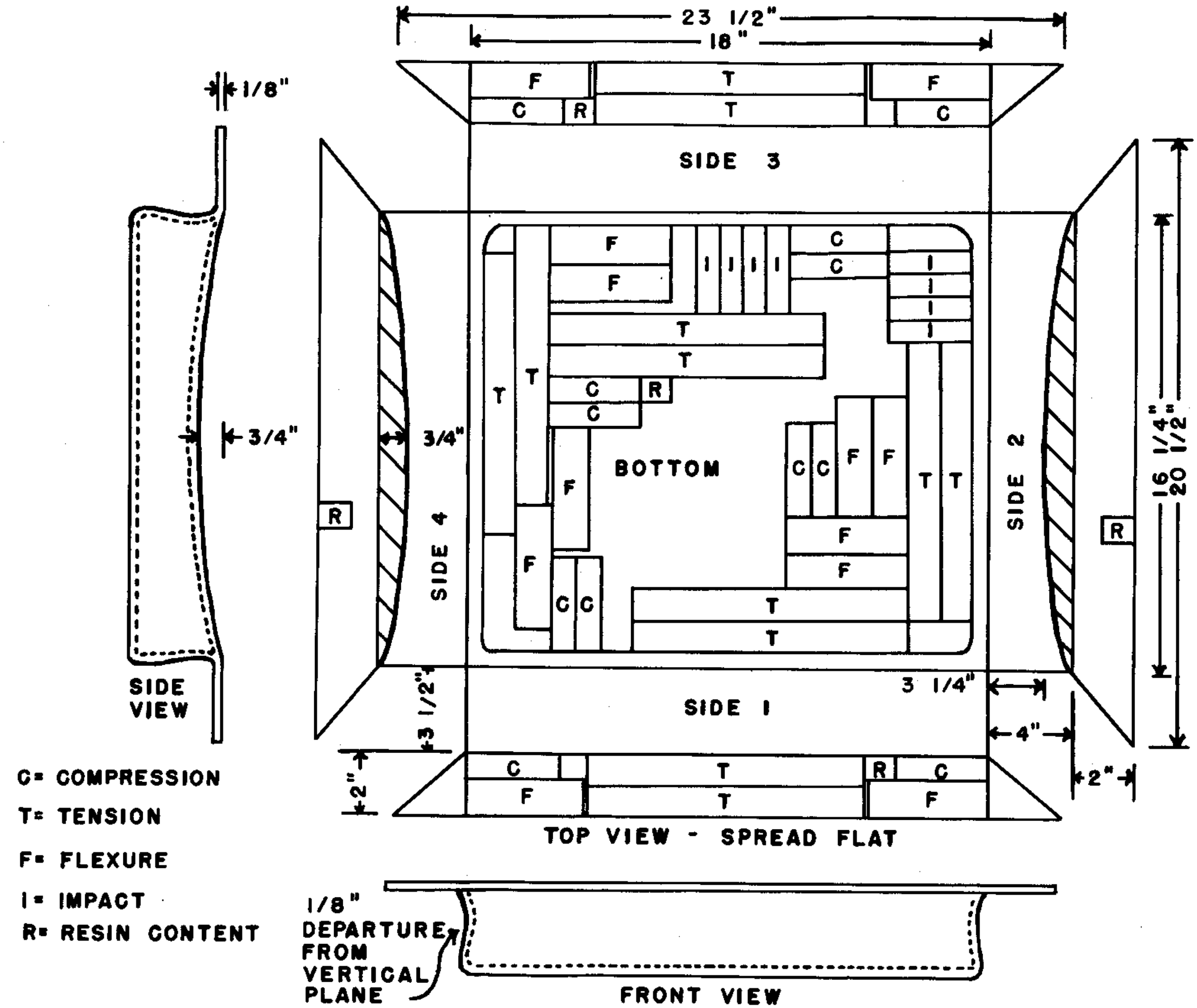

FIGURE 5. SAMPLING PATTERN FOR WINDOW FRAMES

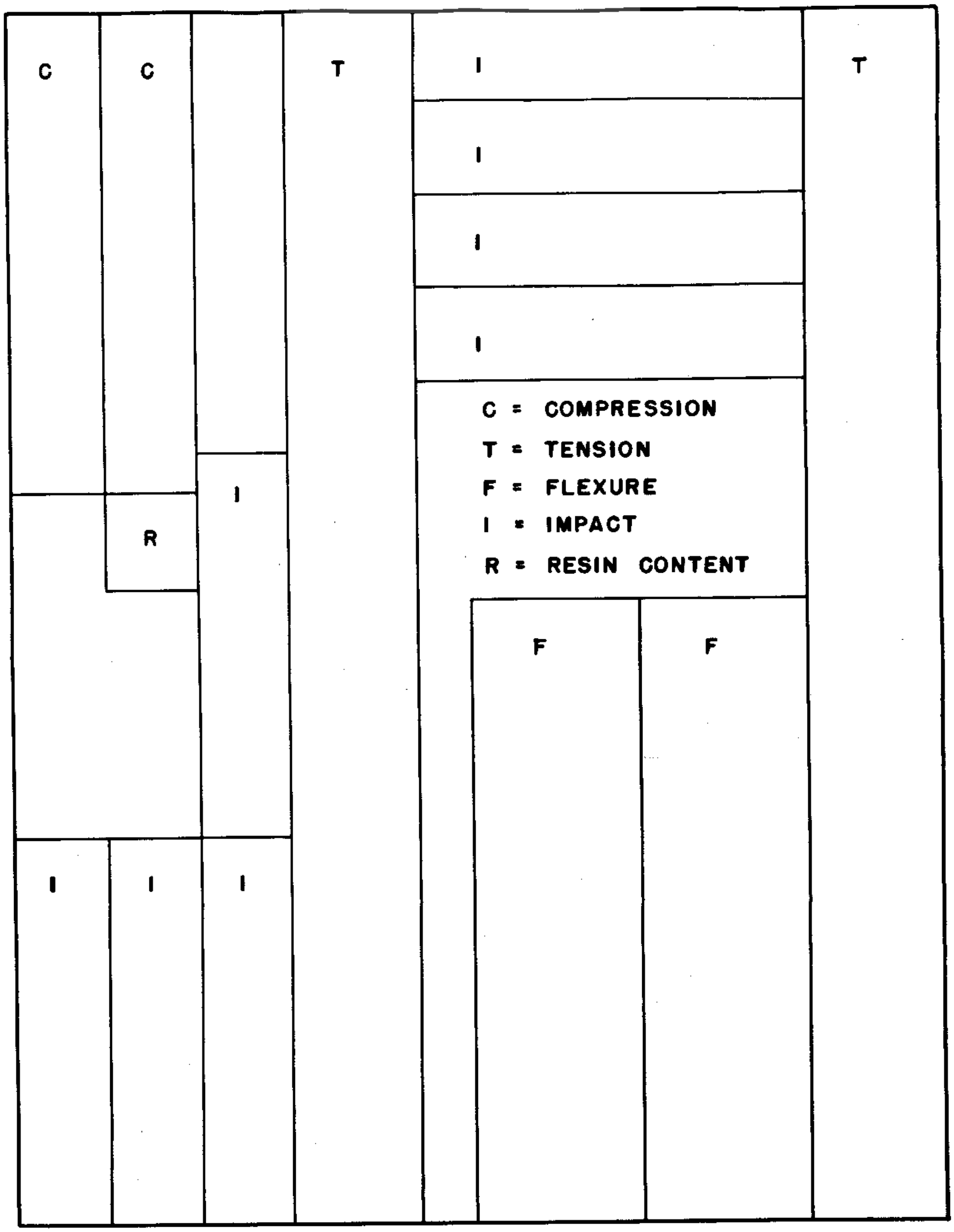

FIGURE 6. SAMPLING PATTERN FOR SMALL PANELS

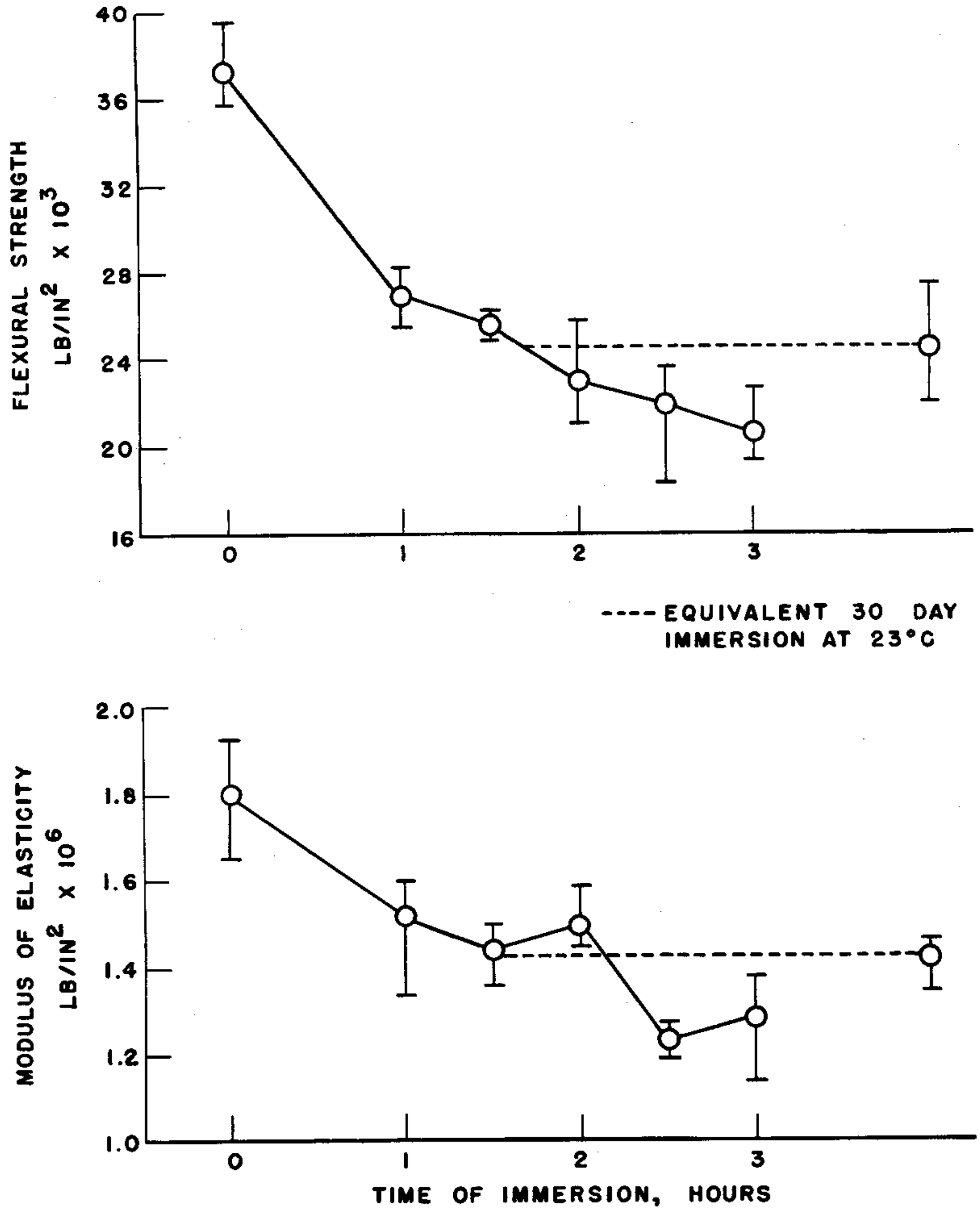

FIGURE 7. FLEXURAL PROPERTIES OF GLASS FIBER REINFORCED POLYESTER MOLDING FROM SHEET SMI AFTER IMMERSION IN BOILING WATER

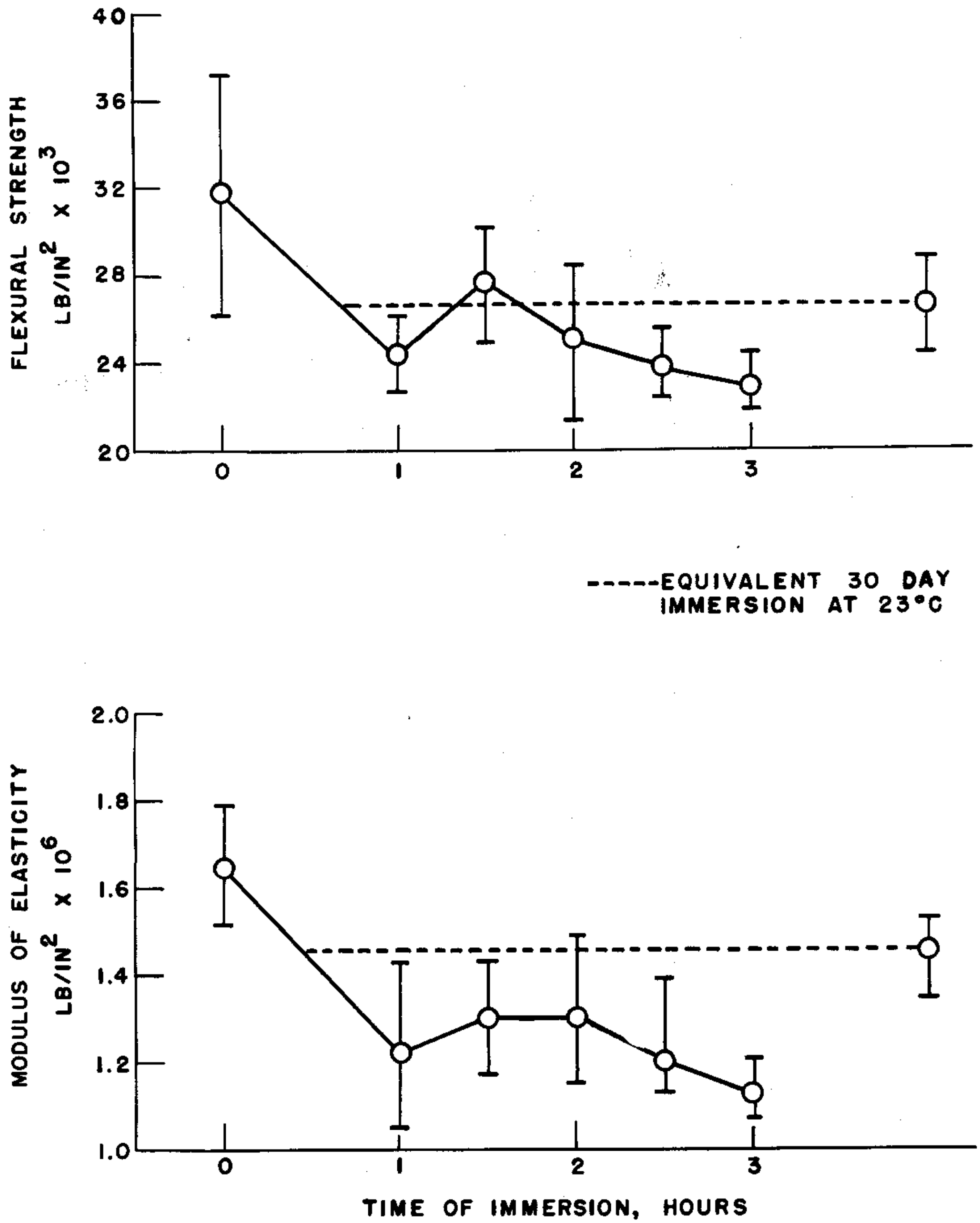

FIGURE 8. FLEXURAL PROPERTIES OF GLASS FIBER REINFORCED POLYESTER MOLDING FROM SHEET SP5 AFTER IMMERSION IN BOILING WATER