

INCH-POUND

MIL-PRF-46197A

16 April 1997

SUPERSEDING

MIL-L-46197(MR)

23 December 1987

## PERFORMANCE SPECIFICATION

LAMINATE: HIGH-STRENGTH GLASS, FABRIC-REINFORCED, POLYESTER RESIN  
PREIMPREGNATED

This specification is approved for use by all Departments and Agencies of the Department of Defense.

## 1. SCOPE

1.1 Scope. This specification establishes the requirements for a high strength woven glass roving impregnated with polyester resin for molding thick armored vehicle structures.

1.2 Classification. Laminates to be of the type specified (see 6.2):

Type 1	Flat
Type 2	Curved

## 2. APPLICABLE DOCUMENTS

2.1 General. The documents listed in this section are specified in sections 3 and 4 of this specification. This section does not include documents in other sections of this specification or recommended for additional information or as examples. While every effort has been made to ensure the completeness of this list, document users are cautioned that they must meet all specified requirements documents cited in sections 3 and 4 of this specification, whether or not they are listed.

2.2 Government documents.

2.2.1 Specifications, standards, and handbooks. The following specifications, standards, and handbooks form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those listed in the issue of the Department of Defense Index of Specifications and Standards (DoDISS) and supplement thereto, cited in the solicitation (see 6.2).

## STANDARDS

## DEPARTMENT OF DEFENSE

MIL-STD-662 V50 Ballistic Test for Armor

(Unless otherwise indicated, copies of the above specifications, standards, and handbooks are available from the Standardization Document Order Desk, 700 Robbins Avenue, Building 4D, Philadelphia, PA 19111-5094).

Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: Director, U.S. Army Research Laboratory, Weapons and Materials Research Directorate, ATTN: AMSRL-WM-M, APG, MD 21005-5069 by using the Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

## MIL-PRF-46197A

2.3 Non-Government publications. The following document forms a part of this document to the extent specified herein. Unless otherwise specified, the issues of the documents which are DoD adopted are those listed in the issue of the DoDISS cited in the solicitation. Unless otherwise specified, the issues of documents not listed in the DoDISS are the issues of the documents cited in the solicitation (see 6.2).

## AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

ASTM D638	Standard Test Method for Tensile Properties of Plastics
ASTM D695	Standard Test Method for Compressive Properties of Rigid Plastics
ASTM D790	Standard Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials
ASTM D792	Standard Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement
ASTM D2343	Standard Test Method for Tensile Properties of Glass Fiber Strands, Yarns, and Rovings Used in Reinforced Plastics
ASTM D2344	Standard Test Method for Apparent Interlaminar Shear Strength of Parallel Fiber Composites by Short-Beam Method
ASTM D2584	Standard Test Method for Ignition Loss of Cured Reinforced Resins
ASTM D4065	Standard Practice for Determining and Reporting Dynamic Mechanical Properties of Plastics
ASTM E537	Standard Test Method for Assessing the Thermal Stability of Chemicals by Methods of Differential Thermal Analysis

(Application for copies should be addressed to the American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428).

2.4 Order of precedence. In the event of a conflict between the text of this document and the references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

## 3. REQUIREMENTS

3.1 First article. When specified (see 6.2), a sample shall be subjected to first article inspection in accordance with paragraph 4.2.1.

3.2 Composition. The high strength glass woven roving shall be impregnated with a resin that has been formulated in such a manner as to yield material that meets the requirements of this specification.

## MIL-PRF-46197A

3.3 Roving.

3.3.1 Yield. The nominal roving yield shall be 250 yds/lb (504 m/kg)  $\pm$  8.5%. Rovings with higher yield (750 or 1250 yds/lb) may not be substituted without written approval from the acquisition activity. A semi-compatible sizing shall be used.

3.3.2 Density. The roving shall have a package ball density of not less than 0.035 lb/in<sup>3</sup> nor greater than 0.065 lb/in<sup>3</sup>.

3.3.3 Hardness. The roving shall have a shore "O" package ball durometer hardness of not less than 50 nor greater than 90.

3.3.4 Catenary. The roving shall have a catenary requirement of not greater than 1.0 in/50 ft. Unless otherwise specified, the catenary requirement applies only to rovings having a yield of 700 or more yards per pound.

3.3.5 Tensile strength. The roving shall have a tensile strength of not less than 400,000 psi.

3.3.6 Resistance to fusion. An ignited specimen shall be examined for fusion. The specimen shall not fuse during the specified ignition.

3.3.7 Woven glass roving. The material shall conform to the requirements as specified by the procuring activity. Fabric weight shall be 24 oz/yd<sup>2</sup>  $\pm$  3% (813 g/m<sup>2</sup>  $\pm$  3%). Additional requirements include:

a. A colored tracer yarn shall run down the center of the material to indicate the warp direction.

b. The material shall be free of all knots. Splices between rovings shall allow adequate strength to withstand vertical tower prepregging. Acceptable methods include overwrapping, air splicing, and adhesive splicing. The adhesive used in the latter method shall be limited to the rovings being spliced and shall not be spread to the surrounding fabric.

c. The fabric shall be evenly woven, clean, free of creases, wrinkles and other forms of permanent distortion. The finished fabric shall conform to the quality of product established herein. Any sizings or other fabric treatments shall be compatible with the resin system or shall be formulated to ensure ease of removal during standard fabric cleaning operations.

3.3.8 Resin. The resin shall be in a form (liquid or solid) suitable for impregnating or furnished already impregnated on fabric (pre-impregnated). The resin shall be free from foreign materials.

3.4 Prepreg physical properties.

3.4.1 Characteristics. The impregnated woven glass roving shall be a self-tack material with good drape characteristics. Stiff boardlike material shall not be acceptable. It shall release readily from the polyethylene separator sheet without being deformed or losing resin from the surface.

3.4.2 Volatile content. Volatile content shall be not greater than 3%.

3.4.3 Resin content. Resin content shall be 34  $\pm$  3% by weight.

## MIL-PRF-46197A

3.4.4 Resin flow. Resin flow shall be  $8 \pm 4\%$ .

3.4.5 Gel time. Gel time shall be not less than 50 seconds nor greater than 150 seconds.

3.5 Prepreg reactive properties. A heating rate of  $3^{\circ}\text{C}$  ( $37.4^{\circ}\text{F}$ ) per minute shall be used. The temperature range of the scan shall be room temperature to  $200^{\circ}\text{C}$  ( $392^{\circ}\text{F}$ ). The heat of reaction (cal/gm), onset temperature ( $^{\circ}\text{C}$ ), and peak temperature ( $^{\circ}\text{C}$ ) shall be reported, along with the complete Differential Scanning Calorimetry (DSC) curve.

3.6 Laminate properties.

3.6.1 Test panel. A cured laminate test panel shall be fabricated to conform with the physical and mechanical property requirements in table I.

3.6.2 Flammability. The flame on the laminate shall self-extinguish within 15 seconds following a 10 minute application in order to pass the test specified in 4.6.8.

3.7 Laminate ballistic property test method.

3.7.1 Laminate preparation. The laminate shall have a thickness or aerial density as specified in the contract. The fabric content shall be  $68 \pm 3\%$  by weight.

3.7.2 Ballistic testing. The V50 ballistic limit shall meet or exceed 2380 ft/s ( $725\text{ m/s}$ ).

3.8 Storage and out-time requirements. Material shall comply with the requirements of this specification after the following:

a. 6 months storage in the shipping container at  $39.2^{\circ}\text{F}$  ( $4^{\circ}\text{C}$ ) or less.

b. 240 hours at room temperature ( $80.6^{\circ}\text{F}$  ( $27^{\circ}\text{C}$ ) max) sealed in a polyethylene bag.

After 6 months storage, the material may be recertified to this specification for an additional 3 months shelf life. After 9 months storage the material may be recertified again, for an additional 3 months. The material shall be disposed of after 1 year.

#### 4. VERIFICATION

4.1 Verification alternatives. Alternative test methods, techniques, or equipment, including the application of statistical process control, tool control, or cost effective sampling procedures may be proposed by the contractor. Acceptable alternative verification approaches shall be identified in the contract.

4.2 Classification of inspections. The inspection requirements specified herein are classified as follows:

a. First article inspection (see 4.2.1)

b. Conformance inspection (see 4.2.2)

## MIL-PRF-46197A

4.2.1 First article inspection. First article inspection shall be performed on the first production-representative sample(s) of an order when a first article sample is required (see 3.1). The first article sample(s) shall be examined for all the provisions specified by the procuring activity, the contract or the purchase order (see 6.2).

This inspection shall consist of the tests specified in 4.3 through 4.8. The supplier has the option to perform either the Package (Ball) density or the Shore "O" Package hardness test. Only one of these two tests is required.

4.2.2 Conformance inspection. Conformance inspection for acceptance of high strength woven glass roving impregnated with polyester resin shall meet all the provisions specified by the procuring activity, the contract or the purchase order (see 6.2).

#### 4.3 Roving.

4.3.1 Yield. Compute the roving yield by dividing the weight of the specimen into the measured length of the specimen resulting in units such as yards/pound.

4.3.2 Density. Test the Package (Ball) density using the standard test methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement, ASTM D792.

4.3.3 Hardness. Use a shore "O" durometer or equivalent to test the outermost layer of the roving ball. Make three readings randomly spaced around the circumference and along the length of the ball.

4.3.4 Catenary. Measure the distance between the furthestmost separated strands perpendicular to the lengthwise direction.

4.3.5 Tensile strength. Test five specimens per roving ball using the standard test method for Tensile Properties of Glass Fiber Strands, Yarns, and Rovings Used in Reinforced Plastics, ASTM D2343.

4.3.6 Resistance to fusion. Ignite at a temperature of  $1494 \pm 45$  °F ( $812 \pm 25$  °C) a specimen of accurately measured length weighing 10 grams.

4.3.7 Woven glass roving. Examine the material for compliance with the requirements specified in 3.3.7.

#### 4.4 Prepreg physical properties.

4.4.1 Characteristics. Examine the impregnated woven glass roving for the characteristics specified in 3.4.1.

4.4.2 Volatiles content. The specimen shall be three (3) 4 inch (10 cm) square pieces of material. One piece to be cut from each side, within 6 inches (15 cm) of the edge, and a third piece cut from the center. The specimen shall be weighed, dried by suspending for 10 minutes  $\pm$  1 minute in a circulating air oven at the materials postcure temperature  $250 \pm 10$  °F ( $121 \pm 6$  °C), cooled in a desiccator, and re-weighed.

$$\text{Volatile Content \%} = \frac{(\text{Initial wt} - \text{Dry wt})}{\text{Initial wt}} \times 100$$

## MIL-PRF-46197A

4.4.3 Resin content. The specimen shall be three (3) 4 inch (10 cm) square pieces of material. One piece to be cut from each side, within 6 inches (15 cm) of the edge, and a third piece cut from the center. The specimen shall be placed in a tared dry dish (or equivalent), weighed, and ignited in a muffle furnace at  $1051 \pm 50$  °F ( $566 \pm 28$  °C) for 30 minutes or until the specimen has the color of the glass reinforcement. The crucible and contents shall be cooled in a desiccator and re-weighed.

$$\text{Resin Content \%} = \frac{(\text{Initial wt} - \text{Ignited wt})}{\text{Initial wt}} \times 100$$

For reference, the fiber areal weight (oz/sq yd) shall also be reported based on the ignited wt/area of the specimen.

4.4.4 Resin flow. Four (4) 4 inch (10 cm) square pieces of material, taken from across the width of the material, shall be cut, stacked, and weighed. The stack shall be covered with 6 inch (15 cm) squares of non-porous polytetrafluoroethylene (PTFE) release fabric or equivalent, and placed in a press at 15 psi (103 kPa) pressure and a platen temperature of 250 °F (121 °C) for 10 minutes. After removing the specimen from the press, the release fabric shall be removed and edge flash shall be trimmed. The edge flash shall be trimmed such that the remaining matrix is flush with the edge of the fiberglass reinforcement. Care shall be exercised during edge flash removal to ensure that fiberglass reinforcement is not removed during the edge flash trimming process. After trimming, the specimen shall be re-weighed.

$$\text{Resin flow \%} = \frac{(\text{Initial wt} - \text{Final wt})}{\text{Initial wt}} \times 100$$

4.4.5 Gel time. Approximately twenty (20) 2 inch (5 cm) square pieces of material, taken across the width of the material, shall be cut, stacked, wrapped in foil, and placed in a press with the platens heated to the materials' postcure temperature. A hole shall be pierced in the edge of the foil, and then pressure shall be applied to squeeze resin onto the lower platen. The extruded resin shall be stirred with a wooden spatula, and the time for gelation to occur shall be noted. Gelation shall be indicated by a rubbery, but not stringy, condition.

4.5 Prepreg reactive properties. A sample of resin which has been mechanically removed (by scraping) from the edge of the prepreg material shall be analyzed by Differential Scanning Calorimetry (DSC) according to the method established in the standard test method for Assessing the Thermal Stability of Chemicals by Methods of Differential Thermal Analysis, ASTM E537.

#### 4.6 Laminate properties

4.6.1 Resin content. The standard test method for Ignition Loss of Cured Reinforced Resins, ASTM D2584, shall be used.

4.6.2 Density. The standard test methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement, ASTM D792, shall be used.

4.6.3 Tensile. The standard test method for Tensile Properties of Plastics, ASTM D638, Specimen Type I, shall be used. Speed of testing shall be 0.2 inch/min (5.1 mm/min). The axis of the specimen shall be in the 0 ° direction.

## MIL-PRF-46197A

4.6.4 Flexural. The standard test methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials, ASTM D790. The axis of the specimen shall be in the 0° direction.

4.6.5 Compressive strength. The standard test method for Compressive Properties of Rigid Plastics, ASTM D695, shall be used. The axis of the specimen shall be in the 0° direction.

4.6.6 Short beam shear strength. The standard test method for Apparent Interlaminar Shear Strength of Parallel Fiber Composites by Short-Beam Method, ASTM D2344 shall be used. The axis of the specimen shall be in the 0° direction.

4.6.7 Glass transition temperature. The glass transition temperature "T<sub>g</sub>" shall be determined according to ASTM D4065 using the following parameters:

Heating rate	3 °C/minute
Temperature range	RT-225 °C (437 °F)
Oscillatory amplitude	0.2 mm
Grip length	2.54 cm (1 inch)
Atmosphere	Dry, nitrogen purge

The temperature of the damping peak maximum shall be assigned as the "T<sub>g</sub>" value.

4.6.8 Flammability. A weighed specimen layed up and cured according to the manufacturers' specifications shall be supported in a vertical position on a standard laboratory jack with a 0.25 inch (6.35 mm) layer of rigid thermal insulating material between the jack and specimen. A 14 oz (414 ml) propane gas cylinder fitted with a "Turbo Torch" head, model STK-9 (Wingearsheek Co., Danvers, MA) or equivalent shall be adjusted to produce a 4-5 inch (10.2-12.7 cm) long flame jet. With the entire set up placed in a fume hood, the torch shall be positioned such that the tip of the flame jet impinges on the sample surface. The samples shall then be subjected to the flame for 10 minutes, unless catastrophic failure, excessive smoke, or any other event dictates termination of the test. During the 10 minute interval, significant events shall be recorded with respect to elapsed time: flame breakthrough, sustained combustion, time to flame, etc. At the 10 minute mark, the flame source shall be removed and the time for any sustained flame to extinguish shall be noted and the specimen shall be allowed to cool. The specimen shall then be weighed, the weight loss determined, and the specimen shall be sealed in a watertight bag for future reference.

4.7 Laminate ballistic property test method.

4.7.1 Laminate preparation. Four cured ballistic test laminates measuring 1 x 1 ft (30.5 x 30.5 cm) shall be layed up and cured according to the manufacturers' specifications.

4.7.2 Ballistic testing. The V50 ballistic limit shall be determined as defined in MIL-STD-662 using a 20 mm fragment simulating projectile.

4.8 Storage and out-time requirements. Examine the material for compliance with the storage and out-time requirements specified in 3.8.

## 5. PACKAGING

MIL-PRF-46197A

5.1 Packaging. For acquisition purposes, the contract or order should specify packaging requirements (see 6.2). When DoD personnel perform material packaging, those personnel need to contact the responsible packaging activity to ascertain requisite packaging requirements. The Inventory Control Point packaging activity within the Military Department of Defense Agency, or within the Military Department's System Command, maintains packaging requirements. Packaging data retrieval is available from the managing Military Department's or Defense Agency's automated packaging files, CD-ROM products, or by contacting the responsible packaging activity.

## 6. NOTES

(This section contains information of a general or explanatory nature that may be helpful, but is not mandatory).

6.1 Intended use. Material procured in accordance with this specification is intended for use as armor in military ground vehicles. Due to its lightness, strength-to-weight ratio, and capacity to withstand impact from projectiles, this material can replace metal alloy skins and improve the fuel economy and maneuverability of military vehicles.

6.2 Ordering data. Acquisition documents should specify the following:

- a. Title, number, and date of this specification.
- b. Type of laminate, flat, curved, or both (see 1.2).
- c. Issue of DoDISS to be cited in the solicitation, and if required, the specific issue of individual documents referenced (see 2.2 and 2.3).
- d. When first article is required (see 3.1).
- e. Packaging requirements (see 5.1).
- f. Dimensions in SI and English units.

6.3 Subject term (key word) listing.

Advanced composites  
Armor material  
Polyester composites  
Prepreg

### Custodians:

Army - MR  
Navy - AS  
Air Force - 11

### Preparing activity

Army - MR

Project No. CMPS-0134

### Review activities:

Army - AT, AV, IE  
Navy - SH  
Air Force - 13  
DLA - DH



MIL-PRF-46197A

TABLE I. Laminate physical and mechanical properties .

Property Paragraph	Requirement	Test Method
Resin content, % by wt	32 ± 3	4.6.1
Density, g/cc	1.84 - 1.98	4.6.2
Tensile modulus, (min avg)	2.3 Msi (15859 Mpa)	4.6.3
Tensile strength, (min avg)	43 Ksi (296 Mpa)	4.6.3
Flexural modulus, (min avg)	2.5 Msi (17238 Mpa)	4.6.4
Flexural strength, (min avg)	32 Ksi (221 Mpa)	4.6.4
Compressive strength, (min avg)	20 Ksi (138 Mpa)	4.6.5
Short beam shear strength, (min avg)	2.5 Ksi (17.2 Mpa)	4.6.6
Glass transition temp, °F (°C) min	295°F (146°C)	4.6.7
Flammability	Pass	4.6.8

# STANDARDIZATION DOCUMENT IMPROVEMENT PROPOSAL

## INSTRUCTIONS

1. The preparing activity must complete blocks 1, 2, 3, and 8. In block 1, both the document number and revision letter should be given.
2. The submitter of this form must complete blocks 4, 5, 6, and 7.
3. The preparing activity must provide a reply within 30 days from receipt of the form.

NOTE: This form may not be used to request copies of documents, nor to request waivers, or clarification of requirements on current contracts. Comments submitted on this form do not constitute or imply authorization to waive any portion of the referenced document(s) or to amend contractual requirements.

### I RECOMMEND A CHANGE:

1. DOCUMENT NUMBER  
MIL-PRF-46197A

2. DOCUMENT DATE (YYMMDD)  
970416

3. DOCUMENT TITLE LAMINATE: HIGH-STRENGTH GLASS, FABRIC-REINFORCED, POLYESTER RESIN PREIMPREGNATED

4. NATURE OF CHANGE *(Identify paragraph number and include proposed rewrite, if possible. Attach extra sheets as needed.)*

5. REASON FOR RECOMMENDATION

### 6. SUBMITTER

a. NAME *(Last, First, Middle Initial)*

b. ORGANIZATION

c. ADDRESS *(Include Zip Code)*

d. TELEPHONE *(Include Area Code)*  
(1) Commercial  
(2) AUTOVON  
*(if applicable)*

7. DATE SUBMITTED  
(YYMMDD)

### 8. PREPARING ACTIVITY

a. NAME

US Army Research Laboratory

b. TELEPHONE *Include Area Code)*

(1) Commercial  
302-892-6558 (2) AUTOVON

c. ADDRESS *(Include Zip Code)*

Weapons & Materials Research Directorate  
ATTN: AMSRL-WM-M  
Aberdeen Proving Ground, MD 21005-5069

**IF YOU DO NOT RECEIVE A REPLY WITHIN 45 DAYS, CONTACT:**

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