

INCH-POUND

MIL-L-64154

13 October 1989

## MILITARY SPECIFICATION

## LAMINATE: FIBERGLASS-FABRIC-REINFORCED, PHENOLIC

This specification is approved for use by the U.S. Army Materials Technology Laboratory, Department of the Army, and is available for use by all Departments and Agencies of the Department of Defense.

## 1. SCOPE

1.1 Scope. This specification covers fiberglass-fabric-reinforced phenolic laminate for use in composite armor systems.

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

Type 1 Flat

Type 2 Curved

## 2. APPLICABLE DOCUMENTS

2.1 Government documents.

2.1.1 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).

## SPECIFICATIONS

## MILITARY

MIL-R-60346	- Roving, Glass, Fibrous
MIL-A-46165(MR)	- Armor: Woven Glass Roving Fabrics
MIL-R-9299	- Resin, Phenolic, Laminating
MIL-P-46593	- Projectile, Calibers 0.22, 0.30, 0.50 and 20 mm Fragment-Simulating

## STANDARDS

## MILITARY

MIL-STD-662	- Ballistic Test for Armor
MIL-STD-444	- Nomenclature and Definitions in the Ammunition Area
MIL-STD-810	- Environmental Test Methods and Engineering Guidelines

---

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 Laboratory Command, Materials Technology Laboratory, ATTN: SLCMT-MEE, Watertown, MA 02172-0001 by using the Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

---

AMSC N/A

AREA CMPS

DISTRIBUTION STATEMENT A Approved for public release; distribution unlimited.

MIL-L-64154

## OTHER GOVERNMENT DOCUMENTS

TOP 2-2-710 - U.S. Army Test and Evaluation Center Ballistic  
Tests of Armor Materials

(Unless otherwise indicated, copies of federal and military specifications, standards, and handbooks are available from the Naval Publications and Forms Center, (ATTN: NPODS), 5801 Tabor Avenue, Philadelphia, PA 19120-5099.)

2.2 Non-Government publications. The following documents form a part of this specification 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 D123 - Textiles, Terminology, Relating To  
ASTM D2563 - Classifying Visual Defects in Glass-Reinforced Plastic  
Laminate Parts, Recommended Practice For

(Application for copies of ASTM publications should be addressed to ASTM, 1916 Race Street, Philadelphia, PA 19103)

2.2.1 Industry specifications. The following specification is mentioned in this document for reference purpose only:

## Owens-Corning Specification

CAS RF.47 (28) - Fiberglas 463AA High Tensile Strength Glass, S-2 GLASS

(Application for copies of Owens-Corning Fiberglas Corporation's specification should be addressed to Owens-Corning Fiberglas, S-2 Glass, Fiberglas Tower, Toledo, OH 43659.)

2.3 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. Unless otherwise specified (see 6.2), the contractor shall furnish laminate samples which shall be subjected to first article inspection (see 4.3). First article inspection samples, properly marked with identifying information shall be representative of the unit to be furnished to the procuring activity. All subsequent laminates delivered to the procuring activity shall conform to these samples in all of their pertinent physical and performance attributes. Any change in the place of manufacture, fabric weave, laminating resin, laminate construction, or manufacturing process shall require a first article resubmittal.

## MIL-L-64154

3.2 Materials. Materials shall be as specified herein or as otherwise indicated in specifications, standards, and drawings. Materials shall be free of defects which adversely affect performance of serviceability of the finished product (see 4.4.1).

3.2.1 Fiberglass reinforcement and fabric.

3.2.1.1 Reinforcement. The reinforcement shall be fiberglass, either S-2 Glass Type 463AA-250 or equivalent meeting the requirements of MIL-R-60346, Type IV, Class 1.

3.2.1.2 Fabric. The fabric shall be fiberglass plain weave woven roving (nominal 5 ends warp by 5.2 ends fill) with a nominal weight of 24 ounces/square yard  $\pm 5\%$  ( $814 \text{ g/m}^2 \pm 5\%$ ) or an equivalent meeting the requirements of MIL-A-46165(MR).

3.2.2 Phenolic Resin. The phenolic resin shall be in accordance with MIL-R-9299, Grade B.

3.2.3 Peel ply. Porous, PTFE-coated peel ply, 3 mil thickness.

3.3 Construction (fabrication).

3.3.1 Dimensions and structure. The laminates shall conform to the dimensions stated in the acquisition documents (see 6.2). The laminates shall consist of the specified number of plies of prepreg made with the above fabric and resin. The laminates shall be symmetric about the center line. Laminates of 25 plies or more, shall have no more than 4% of plies containing a splice. Laminates of less than 25 plies shall have no splices.

3.3.1.1 Thickness. The average thickness of the finished laminates shall fall within the ranges established by table I (see 4.4.4).

3.3.1.2 Weights. The unit weight or areal density of the finished laminates shall fall within the ranges established by table II (see 4.4.4).

3.3.2 Finished laminate. The finished laminates shall consist of the specified number of plies with exterior peel-ply incorporated in the lamination process. All cutting and machining of laminate panels shall be done with the peel-ply intact.

3.4 Performance.

3.4.1 Peel-ply removal. The peel-ply are intended to keep panel surfaces clean and shall be easily removable by hand, without requiring heat or solvents. Laborious or difficult removal shall be unacceptable (see 4.4.4).

3.4.2 Temperature resistance. The composite armor laminate shall not show evidence of delamination following a two-cycle exposure to a temperature range of  $-65^{\circ}\text{F}$  to  $250^{\circ}\text{F}$  ( $-54^{\circ}\text{C}$  to  $121^{\circ}\text{C}$ ) (see 4.4.4.4).

3.4.3 Ballistic resistance. The  $V_{50}$  protection ballistic limit as defined by MIL-STD-662 and tested per TOP 2-2-710 shall not be less than 2400 ft/sec (731m/sec) for a laminate of twenty-five (25) plies when tested as specified in 4.4.5.

TABLE I. Finished laminate thickness range (inches).

Plies	Thickness Range (inches)	Plies	Thickness Range (inches)	Plies	Thickness Range (inches)	Plies	Thickness Range (inches)
1	0.019 - 0.021	11	0.207 - 0.233	21	0.395 - 0.445	31	0.583 - 0.657
2	0.038 - 0.042	12	0.226 - 0.254	22	0.414 - 0.466	32	0.602 - 0.678
3	0.056 - 0.064	13	0.244 - 0.276	23	0.432 - 0.488	33	0.620 - 0.700
4	0.075 - 0.085	14	0.263 - 0.297	24	0.451 - 0.509	34	0.639 - 0.721
5	0.094 - 0.106	15	0.282 - 0.318	25	0.470 - 0.530	35	0.658 - 0.742
6	0.113 - 0.127	16	0.301 - 0.339	26	0.489 - 0.551	36	0.677 - 0.763
7	0.132 - 0.148	17	0.320 - 0.360	27	0.508 - 0.572	37	0.696 - 0.784
8	0.150 - 0.170	18	0.338 - 0.382	28	0.526 - 0.594	38	0.714 - 0.806
9	0.169 - 0.191	19	0.357 - 0.403	29	0.545 - 0.615	39	0.733 - 0.827
10	0.188 - 0.212	20	0.376 - 0.424	30	0.564 - 0.636	40	0.752 - 0.848

Laminates greater than 40 plies will use the thickness range  $0.0188n - 0.0212n$  (inches), where  $n$  is the number of plies.

TABLE Ia. Finished laminate thickness range (millimeters).

Plies	Thickness Range (millimeters)	Plies	Thickness Range (millimeters)	Plies	Thickness Range (millimeters)	Plies	Thickness Range (millimeters)
1	0.478 - 0.538	11	5.25 - 5.92	21	10.0 - 11.3	31	14.8 - 16.7
2	0.955 - 1.08	12	5.73 - 6.46	22	10.5 - 11.8	32	15.3 - 17.2
3	1.43 - 1.62	13	6.21 - 7.00	23	11.0 - 12.4	33	15.8 - 17.8
4	1.91 - 2.15	14	6.69 - 7.54	24	11.5 - 12.9	34	16.2 - 18.3
5	2.39 - 2.69	15	7.16 - 8.08	25	11.9 - 13.5	35	16.7 - 18.8
6	2.87 - 3.23	16	7.64 - 8.62	26	12.4 - 14.0	36	17.2 - 19.4
7	3.34 - 3.77	17	8.12 - 9.15	27	12.9 - 14.5	37	17.7 - 19.9
8	3.82 - 4.31	18	8.60 - 9.69	28	13.4 - 15.1	38	18.1 - 20.5
9	4.30 - 4.85	19	9.07 - 10.2	29	13.8 - 15.6	39	18.6 - 21.0
10	4.78 - 5.38	20	9.55 - 10.8	30	14.3 - 16.2	40	19.1 - 21.5

Laminates greater than 40 plies will use the thickness range  $0.4775n - 0.5385n$  (millimeters), where  $n$  is the number of plies.

TABLE II. Finished laminate unit weights - pounds/square foot (lb/ft<sup>2</sup>)

Plies	Weight Range (lbs/sq. ft.)	Plies	Weight Range (lbs/sq. ft.)	Plies	Weight Range (lbs/sq. ft.)	Plies	Weight Range (lbs/sq. ft.)
1	0.184 - 0.216	11	2.02 - 2.38	21	3.86 - 4.54	31	5.70 - 6.70
2	0.368 - 0.432	12	2.21 - 2.59	22	4.05 - 4.75	32	5.89 - 6.91
3	0.552 - 0.648	13	2.39 - 2.81	23	4.23 - 4.97	33	6.07 - 7.13
4	0.736 - 0.864	14	2.58 - 3.02	24	4.42 - 5.18	34	6.26 - 7.34
5	0.920 - 1.08	15	2.76 - 3.24	25	4.60 - 5.40	35	6.44 - 7.56
6	1.10 - 1.30	16	2.94 - 3.46	26	4.78 - 5.62	36	6.62 - 7.78
7	1.29 - 1.51	17	3.13 - 3.67	27	4.97 - 5.83	37	6.81 - 7.99
8	1.47 - 1.73	18	3.31 - 3.89	28	5.15 - 6.05	38	6.99 - 8.21
9	1.66 - 1.94	19	3.50 - 4.10	29	5.34 - 6.26	39	7.18 - 8.42
10	1.84 - 2.16	20	3.68 - 4.32	30	5.52 - 6.48	40	7.36 - 8.64

Laminates greater than 40 plies will use the unit weight range  $0.184n - 0.216n$  (pounds/square foot), where  $n$  is the number of plies.

TABLE IIa. Finished laminate unit weight - kilograms/square meter (Kg/m<sup>2</sup>)

Plies	Weight Range (Kg/sq. meter)	Plies	Weight Range (Kg/sq. meter)	Plies	Weight Range (Kg/sq. meter)	Plies	Weight Range (Kg/sq. meter)
1	0.900 - 1.06	11	9.90 - 11.6	21	18.9 - 22.2	31	27.9 - 32.8
2	1.80 - 2.11	12	10.8 - 12.7	22	19.8 - 23.3	32	28.8 - 33.8
3	2.70 - 3.17	13	11.7 - 13.7	23	20.7 - 24.3	33	29.7 - 34.9
4	3.60 - 4.23	14	12.6 - 14.8	24	21.6 - 25.4	34	30.6 - 35.9
5	4.50 - 5.28	15	13.5 - 15.9	25	22.5 - 26.4	35	31.5 - 37.0
6	5.40 - 6.34	16	14.4 - 16.9	26	23.4 - 27.5	36	32.4 - 38.0
7	6.30 - 7.40	17	15.3 - 18.0	27	24.3 - 28.5	37	33.3 - 39.1
8	7.20 - 8.46	18	16.2 - 19.0	28	25.2 - 29.6	38	34.2 - 40.2
9	8.10 - 9.51	19	17.1 - 20.1	29	26.1 - 30.6	39	35.1 - 41.2
10	9.00 - 10.6	20	18.0 - 21.1	30	27.0 - 31.7	40	36.0 - 42.3

Laminates greater than 40 plies will use the unit weight range  $0.900n - 1.058n$  (kilograms/square meter), where  $n$  is the number of plies.

MIL-L-64154

3.5 Workmanship. The laminates shall satisfy visual acceptance Level 1 of ASTM D2563 for the following defects: (1) blister, (2) burned, (3) crack, (4) crack, surface, (5) crazing, (6) edge delamination, (7) internal delamination, (8) dry spot, (9) lack of fillout, and (10) wrinkles. Fabric reinforcement layers shall not have pleats, wrinkles, or creases. Fabric layers shall be free of tears, reasonably straight, and perpendicular warp-to-fill (see 4.4.4).

#### 4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for inspection. Unless otherwise specified in the contract or purchase order, the contractor is responsible for the performance of all inspection requirements (examinations and tests) as specified herein. Except as otherwise specified in the contract or purchase order, the contractor may use his own or any other facilities suitable for the performance of the inspection requirements specified herein, unless disapproved by the Government. The Government reserves the right to perform any of the inspections set forth in this specification where such inspections are deemed necessary to ensure supplies and services conform to prescribed requirements.

4.1.1 Responsibility for compliance. All items shall meet all requirements of sections 3 and 5. The inspection set forth in this specification shall become a part of the contractor's overall inspection system or quality program. The absence of any inspection requirements in the specification shall not relieve the contractor of the responsibility of ensuring that all products or supplies submitted to the Government for acceptance comply with all requirements of the contract. Sampling inspection, as part of manufacturing operations, is an acceptable practice to ascertain conformance to requirements, however, this does not authorize submission of known defective material, either indicated or actual, nor does it commit the Government to accept defective material.

4.1.2 Materials. To determine conformance to 3.2 through 3.2.3, inspection and material certification records shall be maintained by the contractor. Records shall be subject to review by the Government and shall include date, part, inspection results, and disposition of lot (accepted or rejected). Corrective action taken on noted defects shall be subject to approval by the Government.

4.1.3 Parts and components. Components and assemblies shall be inspected for conformance to specified requirements of drawings and in accordance with pertinent specifications and standards.

#### 4.2 Classification of inspection.

- a. First article inspection (see 4.3).
- b. Quality conformance inspection (see 4.4).
  - 1. Quality conformance examination (see 4.4.2).
  - 2. In-process examination (see 4.4.3).
  - 3. Control test (see 4.4.4).

## MIL-L-64154

4.3 First article inspection. The contractor shall supply four samples for first article inspection. Two samples shall measure 20 inches by 20 inches (508 mm by 508 mm) by contract designated plies. Two samples shall measure 20 inches by 20 inches (508 mm by 508 mm) by 25 plies for ballistic test. All samples shall be produced with materials and processes proposed for use on production laminates. Inspection shall be carried out by the contractor under Government surveillance. Inspection shall consist of all quality conformance examinations and control tests. Upon successful completion of the quality conformance and control tests, the two ballistic samples shall be forwarded to the test site identified by the procuring activity. The test samples shall be adequately identified as to contractor, contract number, manufacturer, and date.

4.3.1 First article inspection failure. Failure of any first article sample to pass specified examinations or tests shall be cause for refusal to grant first article approval and to reject product until corrective action by the contractor has been approved by the procuring agency.

4.4 Quality conformance inspection.

4.4.1 Sampling.

4.4.1.1 Lot formation. An inspection lot shall consist of all the laminated assemblies of one type and part number, from an identifiable production period, from one manufacturer, submitted at one time for acceptance.

4.4.1.2 Sampling for examination. All laminates shall be examined.

4.4.2 Quality conformance examination. All laminates shall meet the visual criteria as specified in 3.5.

4.4.3 In-process examination. To determine conformance to 3.3.1 through 3.3.2, the contractor shall initiate, perform, and document on an essentially continuous basis, an in-process procedure consisting of process controls and examination criteria satisfactory to the Government.

4.4.4 Control test. The contractor shall supply two test samples, 20 inches by 20 inches (508 mm by 508 mm), for each month laminate fabrication, for control testing. The samples shall have the contract designated plies and shall be produced with materials and processes used for production laminates. Testing shall be carried out by the contractor under Government surveillance and shall consist of tests to show conformance to 3.3.1.1, 3.3.1.2, 3.4.1, 3.4.2, and 3.5.

4.4.4.1 Determination of laminate thickness. The thickness of a finished laminate is determined as follows: Choose a square laminate of nominal size as least 20 inches by 20 inches (508 mm by 508 mm), and remove peel plies. Measure thickness to nearest 0.001 inch at least one (1) inch (2.5 cm) in from each of four (4) corners. Average the four (4) readings (see table I).



## MIL-L-64154

4.4.4.2 Determination of laminate unit weight. The unit weight or areal density of a finished laminate is determined as follows:

Choose a square laminate of nominal size at least 20 inches by 20 inches (508 mm by 508 mm), and remove peel-ply. Dry the panel in a forced draft or convection type oven in a stream of ambient air heated to  $200 \pm 10^{\circ}\text{F}$  ( $93 \pm 5^{\circ}\text{C}$ ) until no further change of mass occurs when the panel is weighed with an error of less than 0.1 percent after cooling to room temperature in the standard atmosphere for testing textiles as defined in ASTM D123. Calculate the unit weight to three significant figures as follows:

$$\text{Unit weight} = \frac{144M}{LW} \text{ lb/ft}^2$$

Where M is the dry panel weight in pounds measured with an error of less than 0.1 percent, L is the length of the panel in inches measured to the nearest 1/16 inch, and W is the width of the panel in inches measured to the nearest 1/16 inches (see table II).

$$\text{Unit weight} = \frac{1 \times 10^6 M}{LW} \text{ kg/m}^2$$

Where M is the dry panel weight in kilograms measured with an error of less than 0.1 percent, L is the length of the panel in millimeters measured to the nearest 1.5 mm, and W is the width of the panel in millimeters measured to the nearest 1.5 mm (see table IIa).

4.4.4.3 Peel-ply test. The peel-ply test shall consist of removing the peel-ply by hand.

4.4.4.4 Temperature resistance test. The temperature resistance test shall be performed in accordance with method 503.2 of MIL-STD-810, except the temperature extremes and number of cycles shall be as specified in 3.4.2.

4.4.5 Ballistic control test. The contractor shall supply two test samples 20 inches by 20 inches (508 mm by 508 mm) by 25 plies for each three months of laminate fabrication for ballistic control testing at a Government approved facility to show conformance to 3.4.3. The test panels shall be adequately identified as to contractor, contract number, manufacturer, and date.

4.4.5.1 Ballistic test. The ballistic resistance test shall be conducted in accordance with MIL-STD-662. Test projectile shall be the caliber 0.30 (44 grain) fragment-simulating projectile conforming to MIL-P-46593 at  $0^{\circ}$  obliquity. The  $V_{50}$  protection ballistic limit reported shall be the average of two determinations made on separate 25 plies laminates. Each determination shall be a six-round  $V_{50}$  ballistic limit with a maximum velocity spread of 125 feet/second (38 m/sec).



MIL-L-64154

4.4.6 Failure. Failure of the samples to meet any of the test requirements shall be cause for the procuring activity to stop acceptance of quality conformance samples until the cause of failure(s) is identified, corrective action is taken by the contractor, and approved by the procuring activity.

## 5. PACKAGING

5.1 Preservation, packaging, packing, and marking. Preservation, packaging, packing, and marking shall be in accordance with applicable packaging standard or packaging data sheet specified by the procuring activity (see 6.2).

## 6. NOTES

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

6.1 Intended use. The laminates furnished under this specification are intended for use as a component of composite armor.

6.2 Ordering data. Acquisition documents should specify the following:

- a. Title, number, and date of this specification.
- b. Classification type (see 1.2).
- c. If first article is not required (see 3.1).
- d. Production component dimensions and ply count (see 3.3.1).
- e. Selection of applicable levels of preservation, packaging, packing, and marking (see 5.1).

### 6.4 Key Words.

Armor Woven Glass Roving  
S-2 Glass  
Composite Armor Laminate

Custodians:  
Army - MR  
Air Force - 11

Preparing activity:  
Army - MR

(Project CMPS-0056)

(WP# ID-0848B/DISC-0165B. FOR MTL USE ONLY.)

## STANDARDIZATION DOCUMENT IMPROVEMENT PROPOSAL

## 1. DOCUMENT NUMBER

MIL-L-64154

## 2. DOCUMENT TITLE

LAMINATE: FIBERGLASS-FABRIC-REINFORCED, PHENOLIC

## 3a. NAME OF SUBMITTING ORGANIZATION

## 4. TYPE OF ORGANIZATION (Mark one)

☐

VENDOR

☐

USER

☐

MANUFACTURER

☐

OTHER (Specify): \_\_\_\_\_

## b. ADDRESS (Street, City, State, ZIP Code)

## 5. PROBLEM AREAS

## a. Paragraph Number and Wording:

## b. Recommended Wording:

## c. Reason/Rationale for Recommendation:

## 6. REMARKS

## 7a. NAME OF SUBMITTER (Last, First, MI) - Optional

## b. WORK TELEPHONE NUMBER (Include Area Code) - Optional

## 8. MAILING ADDRESS (Street, City, State, ZIP Code) - Optional

## 9. DATE OF SUBMISSION (YYMMDD)