

MIL-L-62474B(AT)

25 June 1984

SUPERSEDING

MIL-L-62474A(AT)

30 March 1984

## MILITARY SPECIFICATION

### LAMINATE: ARAMID-FABRIC-REINFORCED, PLASTIC

This specification is approved for use by US Army Tank-Automotive Command, 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 an aramid fabric-reinforced laminate for use in composite armor systems.

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

Type 1	Flat.
Type 2	Molded.

Class A	Yarn used, nominal 1500 Denier, 1000 filaments.
Class B	Yarn used, nominal 3000 Denier, 1333 filaments.

Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: US Army Tank-Automotive Command, ATTN: DRSTA-GSS, Warren, MI 48090, by using the self-addressed Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document, or by letter.

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## 2. APPLICABLE DOCUMENTS

2.1 Government documents.

2.1.1 Specifications, standards, and handbooks. Unless otherwise specified, the following specifications, standards, and handbooks of the issue listed in that issue of the Department of Defense Index of Specifications and Standards (DoDISS) specified in the solicitation form a part of this specification to the extent specified herein.

SPECIFICATIONS  
MILITARY

MIL-R-9300	- Resin, Epoxy, Low Pressure Laminating.
MIL-P-46593	- Projectile, Calibers .22, .30, .50 and 20mm, Fragment Simulating.

STANDARDS  
MILITARY

MIL-STD-662	- Ballistic Acceptance Test Method for Personnel Armor Material.
MIL-STD-810	- Environmental Test Methods and Engineering Guidelines.

(Copies of specifications, standards, handbooks, drawings, and publications required by manufacturers in connection with specific acquisition functions should be obtained from the contracting activity or as directed by the contracting officer.)

2.2 Other publications. The following document(s) form a part of this specification to the extent specified herein. The issues of the documents which are indicated as DoD adopted shall be the issue listed in the current DoDISS and the supplement thereto, if applicable.

## SOCIETY OF AUTOMOTIVE ENGINEERS (SAE)

AMS 3902	- Cloth, Organic Fiber, High Modulus for Structural Composites.
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(Applications for copies of SAE publications should be addressed to the Society of Automotive Engineers, 400 Commonwealth Drive, Warrendale, Pennsylvania, 15096.)

## AMERICAN SOCIETY FOR TESTING AND MATERIAL (ASTM)

ASTM D123	- Textiles, Terminology Relating To.
ASTM D2563	- Classifying Visual Defects in Glass-Reinforced Plastic Laminate Parts, Recommended Practice for.

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|------------|---|
| ASTM D2654 | - Moisture Content and Moisture Regain of Textiles, Test Methods for. |
| ASTM D3775 | - Fabric Count of Woven Fabric, Test Method for.                      |
| ASTM D3776 | - Weight (Mass Per Unit Area) of Woven Fabric, Test Method for.       |

(Applications for copies of ASTM publications should be addressed to the American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA, 19103.)

2.2.1 Industry specifications. The following specifications are mentioned in this document for reference purposes only:

**DuPont Material Specifications:**

- |                 |  |
|-----------------|--|
| DPMS-2/1500-964 | - Kevlar, 29 Aramid Yarn - 1500 Denier, 1.0% Finish. |
| DPMS-2/3000-963 | - Kevlar, 29 Aramid Yarn - 3000 Denier, 1.0% Finish. |

(Applications for copies of DuPont specifications should be addressed to E.I. DuPont DeNemours and Company, Kevlar Special Products, Centre Road Building, Wilmington, DE 19898.)

2.3 Order of precedence. In the event of a conflict between the text of this specification and the references cited herein, the text of this specification shall take precedence.

### 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 Government. All subsequent laminates delivered to the Government shall conform to these samples in all of their pertinent physical and performance attributes. Any change in the place of manufacture, method of fabric weave, laminating resin or laminate construction shall require a first article resubmittal.

3.2 Materials. Materials shall be as specified herein and in referenced specifications, standards and drawings. Materials shall be free of defects which adversely affect performance or serviceability of the finished product (see 4.1.1).

3.2.1 Qualified products. The contractor shall be responsible for using materials from Qualified Products Lists (QPLs) when applicable. Contractor's inspection records shall specifically list all QPL items by number and date of the QPL, name of supplier and part or drawing number(s). When materials are approved as qualified products, but not yet listed on the QPL, the contractor shall list the products by number and date of the approved document and name of supplier(s) (see 4.1.1).

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3.2.2 Aramid fabrics.

3.2.2.1 Class A laminates. The aramid fabric reinforcement used in class A laminates shall be woven from an aramid yarn of nominal 1500 denier, 1000 filaments, 1 percent finish, satisfying DuPont Material Specification DPMS-2/1500-964. All yarn shall be of the same production lot as defined in ASTM D123. The fabric construction shall be  $42 \pm 2$  ends per inch [25.4 millimeters (mm)] by  $42 \pm 2$  picks per inch (25.4 mm) in a 7 x 7 basketweave as determined by ASTM D3775. Yarns shall have zero twist.

3.2.2.2 Class B laminates. The aramid fabric reinforcement used in class B laminates shall be woven from an aramid yarn of nominal 3000 denier, 1333 filaments, 1 percent finish, satisfying DuPont Material Specification DPMS-2/3000-963. All yarn shall be of the same production lot as defined in ASTM D123. The fabric construction shall be  $21 \pm 1$  ends per inch (25.4 mm) by  $21 \pm 1$  picks per inch (25.4 mm) in a 4 x 4 basketweave as as determined by ASTM D3775. Yarns shall have zero twist.

3.2.2.3 Class A and Class B. The aramid fabrics described in 3.2.2.1 and 3.2.2.2, shall have a moisture-free weight of  $16.25 \pm .75$  ounces per square yard (oz/yd<sup>2</sup>) [ $551 \pm 25$  grams per square meter (g/m<sup>2</sup>)] as determined by ASTM D3776 (option C) after drying in accordance with Procedure 2 of ASTM D2654. If sizing is used in the weaving process, it shall be a water soluble polyvinyl alcohol. If sizing is used, the fabric shall be cleaned (scoured) to a maximum content of 0.5 weight percent of the moisture-free fabric weight. The maximum moisture content of the aramid fabric after weaving or weaving and scouring shall be five (5) percent by weight as determined by ASTM D2654, Procedure 2. Fabric quality shall conform to paragraph 3.3 of AMS 3902. Selvages shall be woven or three-end leno. Tension in warp and fill shall be adequate to assure uniform fabric construction after resin coating/impregnation.

3.2.3 Laminating resin. The resin for coating and laminating the aramid fabric laminate shall be a catalyzed system composed of a mixture of phenol formaldehyde and polyvinyl butyral resins (see 6.3). Resin coating of the fabric shall be uniform and accomplished by continuous preimpregnation of the fabric. Moisture content of the aramid fabric as determined by ASTM D2654, Procedure 1 shall be reduced to less than two (2) percent prior to resin coating. Resin content of the aramid fabric after coating shall be 16 to 20 weight percent solids (volatile free) based on the weight of aramid fabric as determined by ASTM D3776 (option C) with moisture content reduced to less than 2 percent. Note: A sample of resin coated fabric that has been placed in a forced air circulating oven at  $330 \pm 10$  degrees Fahrenheit (°F) [ $154 \pm 6$  degrees Celsius (°C)] for 60 minutes is considered to be volatile free.

3.3 Construction (fabrication).

3.3.1 Dimensions and structure. The plastic laminates shall be of the dimensions stated in the acquisition documents (see 6.2). The laminates shall consist of the specified number of plies of resin-coated aramid fabric reinforcement bonded together in a single molding step with heat and pressure. The laminates shall be built up from individual plies of fabric with no fabric gap or selvage in any individual ply.

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3.3.1.1 Thickness and flatness variation. The thickness at any point more than one inch from an edge shall not vary from the average thickness of the panel by more than  $\pm 0.015$  inch (0.38 mm) for type I and  $\pm 0.030$  inch (0.76 mm) for type II. Variation from flatness for each finished panel shall not exceed 0.06 inch per foot (5.00 mm/m).

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

TABLE I. Finished laminate unit weights.  
[pounds per square foot (lb/ft<sup>2</sup>)]

PLIES WT (lb/ft <sup>2</sup> )		PLIES WT (lb/ft <sup>2</sup> )		PLIES WT (lb/ft <sup>2</sup> )		PLIES WT (lb/ft <sup>2</sup> )	
1	.127-.152	11	1.40-1.67	21	2.67-3.18	31	3.95-4.69
2	.255-.303	12	1.53-1.82	22	2.80-3.33	32	4.08-4.85
3	.382-.454	13	1.65-1.97	23	2.93-3.48	33	4.20-5.00
4	.510-.606	14	1.78-2.12	24	3.06-3.64	34	4.33-5.15
5	.637-.757	15	1.91-2.27	25	3.18-3.79	35	4.46-5.30
6	.765-.908	16	2.04-2.42	26	3.31-3.94	36	4.59-5.45
7	.892-1.06	17	2.16-2.58	27	3.44-4.09	37	4.71-5.60
8	1.02-1.21	18	2.29-2.73	28	3.57-4.24	38	4.84-5.75
9	1.14-1.37	19	2.42-2.88	29	3.69-4.39	39	4.97-5.91
10	1.27-1.52	20	2.55-3.03	30	3.82-4.54	40	5.10-6.06

TABLE Ia. Finished laminate unit weights.  
[kilograms per square meter (kg/m<sup>2</sup>)]

PLIES WT (kg/m <sup>2</sup> )		PLIES WT (kg/m <sup>2</sup> )		PLIES WT (kg/m <sup>2</sup> )		PLIES WT (kg/m <sup>2</sup> )	
1	.62-.74	11	6.84-8.15	21	13.04-15.53	31	19.29-22.90
2	1.25-1.48	12	7.47-8.89	22	13.67-16.26	32	19.92-23.68
3	1.87-2.22	13	8.06-9.62	23	14.31-16.99	33	20.51-24.41
4	2.49-2.96	14	8.69-10.35	24	14.94-17.77	34	21.14-25.15
5	3.11-3.70	15	9.33-11.08	25	15.53-18.51	35	21.78-25.88
6	3.74-4.43	16	9.96-11.82	26	16.16-19.24	36	22.41-26.61
7	4.36-5.18	17	10.55-12.60	27	16.80-19.97	37	23.00-27.34
8	4.98-5.91	18	11.18-13.33	28	17.43-20.70	38	23.63-28.08
9	5.57-6.69	19	11.82-14.06	29	18.02-21.44	39	24.27-28.86
10	6.20-7.42	20	12.45-14.80	30	18.65-22.17	40	24.90-29.59

3.3.2 Lamination pressures and temperatures. The following conditions shall prevail during lamination processes:

- a. 1. Type I (flat) laminates shall be press-molded at  $200 \pm 10$  pounds per square inch (psi) [ $1380 \pm 70$  kilopascals (kPa)].
2. Type II (molded) laminates shall be press-molded at  $200 \pm 10$  psi ( $1380 \pm 70$  kPa) or may be autoclaved at 50 psi (345 kPa) minimum.

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Pressures indicated above shall be maintained until the following stages have been completed:

- b. Type I and II (except autoclave).
  1. Press platen temperature increased to  $330 \pm 10^{\circ}\text{F}$  ( $166 \pm 6^{\circ}\text{C}$ ).
  2. Dwell in accordance with schedule of table II with platens at  $330^{\circ}\text{F} \pm 10^{\circ}\text{F}$  ( $166 \pm 6^{\circ}\text{C}$ ).
  3. Press platen temperature reduced to a maximum of  $180^{\circ}\text{F}$  ( $82^{\circ}\text{C}$ ) before laminate removal.
- c. Type II (autoclave)
  1. Autoclave temperature increased to  $330^{\circ}\text{F} \pm 10^{\circ}\text{F}$  ( $166 \pm 6^{\circ}\text{C}$ ).
  2. Dwell in accordance with table II with autoclave at  $330^{\circ}\text{F} \pm 10^{\circ}\text{F}$  ( $166 \pm 6^{\circ}\text{C}$ ).
  3. Autoclave temperature reduced to a maximum of  $150^{\circ}\text{F}$  ( $66^{\circ}\text{C}$ ) before laminate removal.

TABLE II. Laminating dwell times.

LAMINATE PLIES (Number)	DWELL TIME (Minutes)
1-10	30
11-20	45
21-30	60

3.3.3 Finished laminate. The finished laminates shall consist of the specified number of plies sandwiched between single peel-ply which can be incorporated in the lamination process. Peel-ply coated with a release agent shall not transfer to the laminate surfaces. All cutting and machining of laminate panels shall be done with the peel-ply intact. Wet cutting and machining procedures shall be followed by a drying process. The drying process shall consist of drying the panel in a forced draft or convection type oven in a stream of ambient air heated to  $200 \pm 10^{\circ}\text{F}$  ( $93 \pm 6^{\circ}\text{C}$ ) for a period of not less than four hours. The finished laminate shall have an epoxy resin sealed surface on all cut, trimmed or drilled hole edges which is applied after any required drying process. The resin shall conform to MIL-R-9300. The epoxy resin used shall have a service temperature of not less than  $250^{\circ}\text{F}$  ( $121^{\circ}\text{C}$ ) and meet the requirement of 3.4.2. Application of the resin shall not interfere with the peel-ply removal.

#### 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).

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3.4.2 Temperature resistance. The plastic laminates shall not show evidence of delamination following a two cycle exposure to a temperature range of -65°F to 250°F (-54°C to 121°C) (see 4.4.4.3).

3.4.3 Ballistic resistance. The V<sub>50</sub> protection ballistic limit as defined in MIL-STD-662 shall not be less than 2250 ft/sec for a laminate of twenty-six (26) plies when tested as specified in 4.4.4.

3.5 Workmanship. The plastic laminates shall satisfy visual acceptance Level I of ASTM D2563 for the following defects: (1) Blister, (2) Burned, (3) Crack, (4) Crack, surface, (5) Craze, (6) Delamination, edge, (7) Delamination, internal, (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 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 or witness any of the inspections set forth in the specification where such inspections are deemed necessary to assure supplies and services conform to prescribed requirements. Ballistic tests shall be performed only by a Government approved test facility.

4.1.1 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, or characteristic identification, inspection results, and disposition of lot (accepted or rejected). Corrective action taken on noted defects shall be subject to approval by the Government.

4.1.2 Parts and components. Components and assemblies shall be inspected for conformance to requirements of drawings on which laminate is specified and applicable specifications and standards. When applicable, inspection shall also be in accordance with Quality Assurance Provisions (QAPs).

#### 4.2 Classification of inspection:

- a. First article inspections (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).

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4.3 First article inspection. The contractor shall supply four samples for first article inspection. Two samples shall measure 20 inch by 20 inch (508mm by 508mm) by contract designated plies. Two samples shall measure 20 inch by 20 inch (508mm by 508mm) by 26 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 accept product until corrective action by the contractor has been approved by the Government.

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 3.3.3, 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 inch x 20 inch (508 mm x 508 mm), for each month of 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 3.3.1.2, 3.4.1, 3.4.2 and 3.5.

4.4.4.1 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 inch by 20 inch (508 mm x 508 mm) and remove peel-ply (see 3.3.3). 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% 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:

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

Where M is the dry panel weight in pounds measured with an error of less than 0.1%, 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 inch (see table I).

$$\text{Unit Weight (metric)} = \frac{10^6 M}{LW} \text{ kg/m}^2$$

Where M is the dry panel weight in kilograms measured with an error of less than 0.1%, L is the length of the panel in millimeters measured to the nearest 2 millimeters and W is the width of the panel in millimeters measured to the nearest 2 millimeters (see table Ia).

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

4.4.4.3 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.

4.4.4.4 Failure. Failure of the samples to meet the control test requirements shall be cause for the Government 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 Government.

4.4.5 Ballistic control test. The contractor shall supply two test samples 20 inch by 20 inch (508mm by 508mm) by 26 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 .30 (44 grain) fragment simulating projectile conforming to MIL-P-46593 at 0° obliquity. The  $V_{50}$  protection ballistic limit reported shall be the average of two determinations made on separate 26 plies laminates. Each determination shall be a six round  $V_{50}$  ballistic limit with a maximum velocity spread of 125 ft/sec.

4.4.5.2 Failure. Failure of the samples to meet the control test requirements shall be cause for the Government 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 Government.

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## 5. PACKAGING

5.1 Preservation, packaging, packing, and marking. Preservation, packaging, packing, and marking for the desired level shall be in accordance with the applicable packaging standard or packaging data sheet specified by the contracting authority (see 6.2).

## 6. NOTES

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. Selection of type and class (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).

6.3 Laminating resin formulation (see 3.2.3). The following resin system formulation is offered as a guide only. Any contractor electing to use this formulation, in part or in total, does so with the knowledge that the Government is not liable for any expense or adverse results arising from its use.

<u>Components</u>	<u>Parts by weight</u>	<u>Percent of total solids</u>
Polyvinyl Butyral (18-20% Hydroxyl)	868 (25% Solids in Ethanol)	47.2
Phenol Formaldehyde	100 (57% Solids in Ethanol)	12.4
Trimethylol Phenol	267 (60% Solids in Ethanol)	34.8
Phthalic Anhydride	25.6	5.6
Methanol	51.2	
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