INCH-POUND
MIL-DTL-62474E(AT)
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DETAIL SPECIFICATION

LAMINATE: ARAMID-FABRIC-REINFORCED, PLASTIC

This specification is approved for use by the U.S. Army Tank-automotive and Armaments 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 plastic laminate for use in composite armor systems.

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

Type 1	- Flat.
Type 2	- Molded.
Class A	- Yarn used, nominal 1500 Denier, minimal 1000 filaments.
Class B	- Yarn used, nominal 3000 Denier, minimal 1333 filaments.

Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: U.S. Army Tank-automotive and Armaments Command, ATTN: AMSRD-TAR-E/CM/DM/STND, MS# 268 Warren, MI 48397-5000.

AMSC N/A FSC 9330

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 cited 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 requirement 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.
MIL-STD-810	- Environmental Test Methods and Engineering Guidelines.

(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 or you can get them from their website at http://assist.daps.dla.mil/online/start/)

2.3 Non-Government publications. The following documents form 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 D123	- Textiles, Standard Terminology Relating to (DoD Adopted).
ASTM D2563	- Parts, Glass-Reinforced Plastic Laminate, Classifying Visual Defects in (DoD Adopted).

ASTM D2654	- Textiles, Moisture in (DoD Adopted).
ASTM D3775	- Fabric Count of Woven Fabric (DoD Adopted).
ASTM D3776	- Fabric, Weight Mass per Unit Area (Weight) of (DoD Adopted).

(Application for copies of ASTM publications may be obtained from the American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959 or through their website at http://www.astm.org)

SOCIETY OF AUTOMOTIVE ENGINEERS, INC. (SAE)

AMS 3902	- Cloth, Organic Fiber (Para-Aramid), High Modulus for Structural Composites (DoD Adopted).

(Application for copies may be obtained from the Society of Automotive Engineers, Inc., 400 Commonwealth Drive, Warrendale, PA 15096 or through their website at http://www.sae.org)

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 4.2.

3.2 Materials. Materials used shall be in accordance with the manufacturer's materials specifications for aramid fabrics. The materials shall be capable of meeting all the operational and environmental requirements specified herein (see 4.4).

3.2.1 Aramid fabrics.

3.2.1.1 Class A laminates. The aramid fabric reinforcement used in class A laminates shall be woven from an aramid yarn of nominal 1500 denier, minimal 1000 filaments, 1 percent finish. All yarn shall be of the same production lot as defined in ASTM D123. The fabric construction shall be 42 ±2 ends per inch (in.) by 42 ±2 picks per in. [25.4 millimeters (mm) by 25.4 mm)] in a 7 x 7 basketweave as determined by ASTM D3775. Yarns shall have zero twist (see 4.4).

3.2.1.2 Class B laminates. The aramid fabric reinforcement used in class B laminates shall be woven from an aramid yarn of nominal 3000 denier, minimal 1333 filaments, 1 percent finish. All yarn shall be of the same production lot as defined in ASTM D123. The fabric construction shall be 21 ±1 ends per in. by 21 ±1 picks per in. (25.4 mm by 25.4 mm) in a 4 x 4 or 2 x 2 basketweave as determined by ASTM D3775. Yarns shall have zero twist (see 4.4).

3.2.1.3 Class A and class B. The aramid fabrics described in 3.2.1.1 and 3.2.1.2, shall have a moisture-free weight of 16.25 ±0.75 ounces per square yard (oz/yd^2) [551 ±25 grams per square meter (g/m^2)] 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 scoring 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 (see 4.4).

3.2.2 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. 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 18 to 22 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 ±10 degrees Fahrenheit (°F) [154 ±6 degrees Celsius (°C)] for 60 minutes is considered to be volatile free (see 4.4).

3.2.3 Recycled, recovered, or environmentally preferable materials. Recycled, recovered, or environmentally preferable materials should be used to the maximum extent possible provided that the material meets or exceeds the operational and maintenance requirements, and promotes economically advantageous life cycle costs.

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 (see 4.3.3 and 4.4).

3.3.1.1 Thickness and flatness variation. The thickness at any point more than one in. from an edge shall not vary from the nominal thickness of the panel by more than ±0.015 in.

(0.38 mm) for type I and ±0.030 in. (0.76 mm) for type II. Variation from flatness for each finished panel shall not exceed 0.06 inch per foot (in/ft) (5.00 millimeters per meter (mm/m) (See 4.3.3 and 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 I (see 4.3.4.1).

TABLE I. Finished laminate unit weights. 1/

Plies	wt (lb/ft^2)	Plies	wt (lb/ft^2)	Plies	wt (lb/ft^2)	Plies	wt (lb/ft^2)
1	0.127-0.152	11	1.40-1.67	21	2.67-3.18	31	3.95-4.69
2	0.255-0.303	12	1.53-1.82	22	2.80-3.33	32	4.08-4.85
3	0.382-0.454	13	1.65-1.97	23	2.93-3.48	33	4.20-5.00
4	0.510-0.606	14	1.78-2.12	24	3.06-3.64	34	4.33-5.15
5	0.637-0.757	15	1.91-2.27	25	3.18-3.79	35	4.46-5.30
6	0.765-0.908	16	2.04-2.42	26	3.31-3.94	36	4.59-5.45
7	0.892-1.06	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	1.27-1.57	20	2.55-3.03	30	3.82-4.54	40	5.10-6.06

1/ pounds per square foot (lb/ft^2)

TABLE Ia. Finished laminate unit weights. 1/

Plies	wt (kg/m^2)	Plies	wt (kg/m^2)	Plies	wt (kg/m^2)	Plies	wt (kg/m^2)
1	0.62-0.74	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	28	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

1/ kilograms per square meter (kg/m^2)

3.3.2 Lamination pressures and temperatures. The following conditions shall prevail during lamination processes (see 4.3.3):

a. Type I and II.
   1. Type I (flat) laminates shall be press-molded at 250 ±10 pounds per square inch (psi) [1725 ±69 kilopascals (kPa)].
   2. Type II (molded) laminates shall be press-molded at 200 ±10 psi (1380 ±69 kPa) or may be autoclaved at 50 psi (345 kPa) minimum.

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 ±10°F (166 ±6°C).
   2. Dwell in accordance with schedule of table II with platens at 330 ±10°F (166 ±6°C).
   3. Press platen temperature reduced to a maximum of 180°F (82°C) before laminate removal.

c. Type II (autoclave)
   1. Autoclave temperature increased to 330 ±10°F (166 ±6°C).
   2. Dwell in accordance with table II with autoclave at 330 ±10°F (166 ±6°C).
   3. Autoclave temperature reduced to a maximum of 180°F (82°C) before laminate removal.

TABLE II. Laminating dwell times.

Laminate plies (number)	Dwell time (minutes)
1-10	30
11-20	45
21-30	75
31-40	75

3.3.3 Finished laminate. The finished laminates shall consist of the specified number of plies sandwiched between single peel-plies which can be incorporated in the lamination process. Peel-plies 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-plies 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 ±10°F (93 ±6°C) for a period of not less than four hours. NOTE: This drying requirement shall be waived if an abrasive water-jet cutter is used. Any resulting moisture film remaining on cut surface shall be removed by local heat application (heater/blower) or by using clean, dry toweling. 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 epoxy resin used shall have a service temperature of not less than 250°F (121°C) and meet the requirement of 3.4.2. Application of the resin shall not interfere with the peel-ply removal (see 4.3.3 and 4.3.4.1).

3.4 Performance.

3.4.1 Peel-ply removal. The peel-plies 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 4.3.4).

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 4.3.4 and 4.3.4.3).

3.4.3 Ballistic resistance. The V_{50} protection ballistic limit as defined in MIL-STD-662 shall not be less than that indicated in table III for the number of plies indicated when tested as specified in 4.3.5.

TABLE III. Ballistic requirements.

Minimum Required Ballistic Limits CAL 0.30 (44 Grains) Fragment Simulating Projectile (FSP) at 0° Obliquity			
Aramid (plies)	V_{50} protection ballistic limit 1/	Aramid (plies)	V_{50} protection ballistic limit 1/
17	1581	31	2336
18	1626	32	2401
19	1672	33	2468
20	1720	34	2537
21	1769	35	2607
22	1819	36	2679
23	1871	37	2754
24	1924	38	2830
25	1978	39	2908
26	2034	40	2988
27	2091	41	3071
28	2150	42	3155
29	2210	43	3242
30	2272	44	3331
31	2336	45	3423

1/ Average of two ballistic limits, each made on a separate specimen.

3.5 Workmanship. The plastic laminates shall satisfy visual acceptance Level I of ASTM D2563 for the following defects:

a. Blister
b. Burned
c. Cracked
d. Crack, surface
e. Crazing
f. Delamination, edge
g. Delamination, internal
h. Dry spot
i. Lack of fillout
j. 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. Edges of the finished laminate shall be free of frayed edges (see 4.3.4).

4. VERIFICATION

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

a. First article inspection (see 4.2).
b. Conformance inspections (see 4.3).
    1. Conformance examination (see 4.3.2).
    2. In-process examination (see 4.3.3).
    3. Control test (see 4.3.4).

4.2 First article inspection. The contractor shall supply two samples for first article inspection. Two samples shall measure 20 in. by 20 in. (508 mm by 508 mm) by contract designated plies. 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 and control tests. Upon successful completion of the quality conformance and control test, the samples shall be forwarded to the test site identified by the procuring activity (see 6.2). The test samples shall be adequately identified as to the contractor, contract number, manufacturer, and date. The ballistic test samples will be tested by the Government for the requirements of 3.4.3 in accordance with 4.3.5.1, except that for each ballistic sample must meet the V_{50} protection ballistic limit. Any changes or deviations of production units from the first article sample shall be subject to the approval of the contracting officer.

4.3 Conformance inspection. Conformance inspection shall include the examination of 4.3.2 and the control tests of 4.3.4 thru 4.3.4.3 and 4.3.5 (see table IV).

TABLE IV. Classification of inspections.

Title	Require-ment	Inspec-tion	First article	Conformance		
				Conform-ance exam	In- process exams	Control tests
Materials and design construction	3.2 thru 3.3.1.1	4.4.1	X			
Dimension and structure	3.3.1	4.3.3	X		X	
Thickness and flatness variation	3.3.1.1	4.3.3	X		X	
Weights	3.3.1.2	4.3.4.1	X		X	X
Lamination pressures and temperatures	3.3.2	4.3.3	X		X	
Finished laminate	3.3.3	4.3.3.1	X		X	
Peel-ply removal	3.4.1	4.3.4.2				X
Ballistic resistance	3.4.3	4.3.5.1	X			X
Workmanship	3.5	4.3.5	X	X		X

4.3.1 Sampling.

4.3.1.1 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.

4.3.1.2 Sampling for examination. All laminates shall be examined.

4.3.2 Conformance examination. All laminates shall meet the visual criteria as specified in 3.5.

4.3.3 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.

4.3.4 Control tests. The contractor shall supply two test samples, 20 in. x 20 in. (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.

4.3.4.1 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 in. by 20 in. (508 mm x 508 mm) and remove peel-plies (see 3.3.3). Dry the panel in a forced draft or convection type oven in a stream of ambient air heated to 200 ±10°F (93 ±5°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:

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

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.)

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

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

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

4.3.5 Ballistic control test. The contractor shall supply two test samples 20 in. by 20 in. (508 mm by 508 mm) by contract designated plies for each three months of test laminate fabrication for ballistic control testing at the facility identified by the procuring activity to show conformance to 3.4.3 (see 6.2). The test panels shall be adequately identified as to contractor, contract number, manufacturer, and date.

4.3.5.1 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 at 0° obliquity. The V_{50} protection ballistic limit reported shall be the average of two determinations made on separate laminates. Each determination shall be a six round V_{50} ballistic limit with a maximum velocity spread of 125 ft/sec.

4.3.5.2 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.

4.4 Materials, design and construction. To determine conformance to 3.2 thru 3.2.2 and 3.3 thru 3.3.1.1, inspection and material certification records shall be maintained by the contractor. Records shall be subject to review by the Government and shall be determined by inspection of contractor records providing proof or certification that materials conform to requirements. Applicable records shall include drawings, specifications, design data, receiving inspection records, processing and quality control standards, vendor catalogs and certifications, industry standards, test reports, and rating data.

5. PACKAGING

5.1 Packaging. For acquisition purposes, the packaging requirements shall be as specified in the contract or order (see 6.2). When actual packaging of materiel is to be performed by DoD personnel, these personnel need to contact the responsible packaging activity to ascertain requisite packaging requirements. Packaging requirements are maintained by the Inventory Control Point's packaging activity within the Military Department or Defense Agency, or within the Military Department's System Command. 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 which may be helpful, but is not mandatory.)

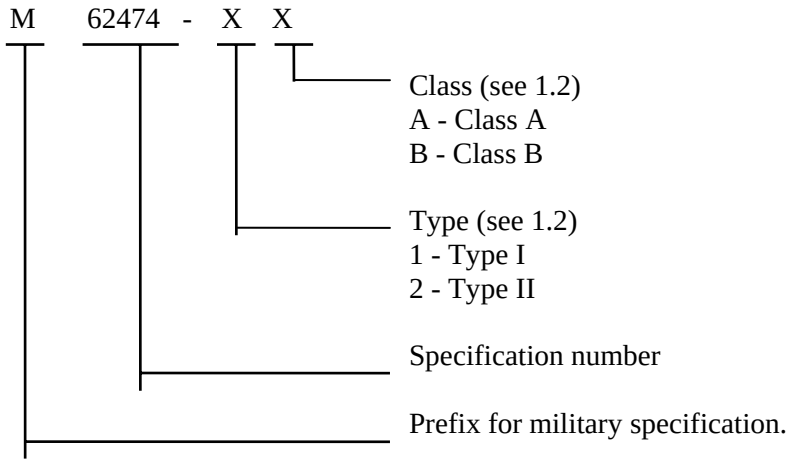
6.1 Intended use. The laminates furnished under this specification are intended for use as a component of composite armor. Since these laminates must maintain a ballistic resistance sufficient to survive under extreme battlefield conditions, under which commercial alternatives characteristically fail, this item is military unique.

6.2 Acquisition requirements. Acquisition documents must specify the following:

a. Title, number, and date of this specification.
b. Type and class (see 1.2).
c. Issue of DoDISS to be cited in the solicitation, and if required, the specific issue of individual documents referenced (see 2.2.1 and 2.3).
d. When first article is required (see 3.1).
e. Production component dimensions and ply count (see 3.3.1).
f. If ballistic control test is required (see 4.3.5).
g. Packaging requirements (see 5.1).
h. Part or identifying number (PIN) (see 6.4).

6.3 Test samples. Ballistic test samples should be sent to: Commander, U.S. Army Aberdeen Test Center, 400 Colleran Road. Bldg. 358, ATTN: CSTE-DTC-AT-SL-V (D. Gessleman), Armor Acceptance – B690, Aberdeen Proving Ground, MD 21005-5059 (see 4.3.5).

6.4 Part or identifying number (PIN). The PIN to be used for laminate acquired to this document is created as follows:



6.5 Subject term (key word) listing.

Ballistic resistance
Laminating resin
Lamination pressures and temperatures
Peel-ply
Polyvinyl butryal
Temperature resistance

6.6 Changes from previous issue. The margins of this specification are marked with vertical lines to indicate where changes from the previous issue were made. This was done as a convenience only and the Government assumes no liability whatsoever for any inaccuracies in these notations. Bidders and contractors are cautioned to evaluate the requirements of this document based on the entire content irrespective of the marginal notations and relationship to the last previous issue.

Custodian:
Army - AT

Preparing Activity:
Army - AT

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