INCH-POUND

MIL-DTL-32378
27 April 2012

DETAIL SPECIFICATION

LAMINATE: UNIDIRECTIONAL, REINFORCED, CROSS-PLIED, ARAMID FIBER, PLASTIC ARMOR MATERIAL

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

1. SCOPE

1.1 Scope. This specification covers an aramid cross-plied unidirectional fiber-reinforced plastic laminate for use in composite armor systems.

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

1.2.1 Classes.

1.2.1.1 Class A. Homopolymer polypropylene resin.

1.2.1.2 Class B. Aqueous thermoplastic polyurethane.

1.2.2 Types.

1.2.2.1 Type 1. Flat, low pressure (Compression molding) (500 -1000 psi).

1.2.2.2 Type 2. Flat, high pressure (> 1000 psi).

Comments, suggestions, or questions on this document should be addressed to: Director, U.S. Army Research Laboratory, Weapons and Materials Research Directorate, Materials and Manufacturing Technology Branch, Specifications and Standards Office, Attn: RDRL-WMM-D, Aberdeen Proving Ground, MD 21005-5069 or emailed to richard.j.squillacioti.civ@mail.mil. Since contact information can change, you may want to verify the currency of this address information using the ASSIST Online database at https://assist.daps.dla.mil/.

AMSC N/A AREA CMPS

2. APPLICABLE DOCUMENTS

2.1 General. The documents listed in this section are specified in sections 3, 4 or 5 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 requirements of documents cited in sections 3, 4 or 5 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 cited in the solicitation or contract.

DEPARTMENT OF DEFENSE SPECIFICATIONS

MIL-DTL-44050	-	Cloth, Ballistic, Aramid
MIL-DTL-46593	-	Projectile, Calibers .22, .30, .50, and 20mm, Fragment Simulating

DEPARTMENT OF DEFENSE STANDARDS

MIL-STD-662	-	V50 Ballistic Test for Armor.
MIL-STD-810	-	Environmental Engineering Considerations and Laboratory Testing.

(Copies of these documents are available online at https://assist.daps.dla.mil/quicksearch/ or from the Standardization Document Order Desk, 700 Robbins Avenue, Building 4D, Philadelphia, PA 19111-5094.)

2.2.2 Other Government documents, drawings, and publications. The following other Government documents, drawings and publication form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those cited in the solicitation or contract.

CODE OF FEDERAL REGULATIONS (CFR)

21 CFR 177.1520	-	Olefin Polymers

(Copies of these documents are available from www.gpoaccess.gov/cfr/index.html or U.S. Government Printing Office, P.O. Box 979050, St. Louis, MO 63197-9000.)

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 these documents are those cited in the solicitation or contract.

ASTM INTERNATIONAL

ASTM D123	-	Standard Terminology Relating to Textiles
ASTM D790	-	Standard Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials
ASTM D1238	-	Standard Test Method for Melt Flow Rates of Thermoplastics by Extrusion Plastometer
ASTM D1777	-	Standard Test Method for Thickness of Textile
ASTM D1907	-	Standard Test Method for Linear density of Yarn (Yarn Number) by the Skein Method
ASTM D2563	-	Standard Practice for Classifying Visual Defects in Glass-Reinforced Plastic Laminate Parts
ASTM D3776/D3776M	-	Standard Test Method for Mass per Unit Area (Weight) of Fabric
ASTM D7269/D7269M	-	Standard Test Methods for Tensile Test of Aramid Yarns

(Copies of the above documents are available from www.astm.org or ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

2.4 Order of precedence. Unless otherwise noted herein or in the contract, 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 4.3.

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.

3.2.1 Fiber.

3.2.1.1 Class A fiber. The para-aramid yarn used shall be continuous filament, with no air entanglement or texturing and no added twist except for the mild fiber entanglement in the splicing segment of two continuous filament yarns caused by a spool change on a creel, and have the following properties as spun and as specified in Table I.

3.2.1.2 Class B fiber. The para-aramid yarn used shall be continuous filament, with no air entanglement or texturing and no added twist except for the mild fiber entanglement in the splicing segment of two continuous filament yarns caused by a spool change on a creel, and have the following properties as spun and as specified in Table I.

3.2.2 Resin.

3.2.2.1 Class A resin. The raw resin input shall be a nucleated homopolymer polypropylene with a nominal melt mass flow rate of 33-37 g/10 minutes per ASTM D1238 (2.16 kg sample / 230°C). The resin shall be acceptable for food contact per U.S. Food and Drug Administration 21 CFR 177.1520. This requirement is to ensure that the purity of the resin is maintained. The resin content shall be 17±2% by laminate weight. The resin shall be applied to the fibers at or above its melting temperature and below 525°F (274°C). The neat resin flexural modulus in injection molded coupons shall be 200-400 ksi when measured per ASTM D790 at 72°F.

Table I. Fiber properties, as spun.

PROPERTIES	CLASS A	CLASS B
Nominal filament diameter, as measured by photomicrography or calculated from nominal yarn denier, filament count and fiber density	12 ±1 micrometers	12 - 15 micrometers
Denier per Option 1 of ASTM D1907, assuming 4.5% moisture regain	2820 ± 54	3050 ± 150
Tenacity per denier per ASTM D7269/D7269M, tested using 1.1 twist multiplier	24.6 ±2.2 gpd	22.9 ± 2.1 gpd
Modulus per denier per ASTM D7269/D7269M, tested using 1.1 twist multiplier	635 ±100 gpd	555 ± 85 gpd
Elongation to break per ASTM D7269/D7269M, tested using 1.1 twist multiplier	3.6 ±0.5 %	3.7 ± 0.5 %
Finish on yarn by weight, tested using analysis of nuclear magnetic resonance. The finish should be surfactant-containing.	0.8 ±0.3 %	0.9 ± 0.3 %

3.2.2.2 Class B resin. The resin shall be an aqueous thermoplastic resin with a content of 12.5% ± 2.0% by laminate weight. The resin shall be a thermoplastic polyester/polyether copolymer polyurethane with the following physical properties:

Property	Range
100% Modulus	0.5 MPa to 1.0 MPa
300% Modulus	1.5 MPa to 2.5 MPa
500% Modulus	3.0 MPa to 5.0 MPa
Elongation at Break	400% to 600%
Melting Point	125^{o} C to 145^{o} C

3.2.3 Lamina.

3.2.3.1 Class A cross-plied unidirectional lamina. The cross-plied unidirectional lamina shall consist of two (2) unidirectional reinforced plies, at 90 ±3 degrees fiber orientation relative to each other, and one fiber direction substantially parallel to the sheet machine direction. The cross-plied unidirectional lamina shall be made from unidirectional tapes of 10-inch or greater nominal width The unidirectional tape shall have no more than 10 clearly noticeable defects per 100 lin. yds., where defects are defined in Table IIA and the term "clearly noticeable" shall be interpreted to mean visible at normal inspection distance of approximately 3 feet.

Table IIA: Defects in Class A lamina.

DEFECTS	CONDITION
Embedded loose filament bundle	>0.5" width
Gap, fold or overlap	>1/8"x4' length
Plastic Inclusion	>2 square inches in area

3.2.3.1.1 Areal density. The Class A cross-plied unidirectional lamina shall have an areal density of 0.0712- 0.0752 lbf/ft^2 [347.5 – 367.0 g/m^2] as determined by ASTM D3776 /D3776 (option C).

3.2.3.1.2 Thickness of the lamina. The thickness of the Class A lamina shall be 0.013 ± 0.002 inches [0.3302 ± 0.051 mm] as determined by ASTM D1777.

3.2.3.2 Class B cross-plied unidirectional lamina. The cross-plied unidirectional laminate shall consist of four (4) unidirectional reinforced plies, at 0/90/0/90 ±3 degrees fiber orientation relative to each other, and one fiber direction substantially parallel to the sheet machine direction.

3.2.3.2.1 Areal density. The Class B cross-plied unidirectional lamina shall have an areal density of 0.1045 $\pm$ 0.002 lbf/ft^2 [510 $\pm$ 10 g/m^2] as determined by ASTM D3776 /D3776 (option C).

3.2.3.2.2 Thickness of the lamina. The thickness of the Class B lamina shall be 0.0185 ± 0.0015 inches [0.470 ± 0.038 mm] as determined by ASTM D1777.

3.2.3.3 Ballistic resistance of lamina before molding.

3.2.3.3.1 Class A. The ballistic resistance of lots of [0|90]-reinforced Class A lamina shall be tested on a sample from each lot, per section 4.3.2.1. The sample shall consist of two targets, each 10 plies of the [0|90]-reinforced lamina, unmolded, with external dimensions 15-inches x 15-inches, laid up so that the reinforcement is $[0|90]_{10}$. The targets may be taped around the periphery, or tack stitched in the corners, as described in MIL-DTL-44050, paragraph entitled: "Sewing of Ballistic Test Panels (All types)" in section 4, to facilitate handling and maintenance of registry between the layers during testing. No stitching, tape or other materials shall be in the interior of the targets where they are to be impacted. The minimum V50 shall be 1350 ft/s.

3.2.3.3.2 Class B. The ballistic resistance of lots of [0|90|0|90]-reinforced Class B lamina shall be tested on a sample from each lot, per section 4.3.2.1. The sample shall consist of two targets, each 10 plies of the [0|90|0|90]-reinforced lamina, unmolded, with external dimensions 15-inches x 15-inches, laid up so that the reinforcement is [0|90|0|90]. The targets may be taped at the center of each edge or diagonally stitched across the four corners with a 5- inch line of TEX size 50 aramid thread at 5 to 10 stitches per inch to facilitate handling and maintenance of registry between the layers during testing. No stitching, tape or other materials shall be in the interior of the targets where they are to be impacted. The minimum V50 shall be 1580 ft/s.

3.2.4 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) of the laminate.

3.3.1 Dimensions and structure.

3.3.1.1 Classes.

3.3.1.1.1 Class A. The plastic laminates shall be of the dimensions stated in the acquisition documents (see 6.2). The laminates shall meet the specified areal density (see 3.3.1.2 and 3.3.1.3) by bonding together in a single molding step with heat and pressure the necessary number of resin-coated aramid lamina (see 3.2.3.1). The laminates shall be built up from lamina with reinforcement gap no greater than those described in Table IIA and no edge waste in any individual layer. If the lamina is supplied as a rolled good, the nominal core diameter shall be at least six inches, to mitigate buckling.

3.3.1.1.2 Class B. The plastic laminates shall be of the dimensions stated in the acquisition documents (see 6.2). The laminates shall meet the specified areal density (see 3.3.1.2 and 3.3.1.3) by bonding together in a molding step with heat and pressure the necessary number of resin-coated aramid lamina (see 3.2.3.1). Molded panels shall be fabricated from cross ply that is a minimum of 98% defect free, with defects defined in the Table IIB below.

3.3.1.2 Thickness and flatness variation. The thickness at any point more than one inch from an edge shall not vary from the nominal thickness of the panel by more than $\pm$0.015 in. (0.38 mm) for type I and $\pm$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).

Table IIB: Defects in Class B laminate.

DEFECTS	CONDITION	
	English Units	**SI Units**
Fill Gap	> 0.23”	> 6 mm
Warp Gap (Space between parallel fibers in the warp direction)	> 0.05” and > 63”	> 1.3 mm and > 160 cm
Consolidation Failure (Single area where both plies do not adhere)	> 0.75” x 0.75”	> 20 mm x 20 mm
Contamination (Single area containing foreign material not typical to product)	> 0.25” x 0.25”	> 6.4 mm x 6.4 mm
Resin Rich Area (Single area containing an increase amount of resin)	> 2.0” x 2.0”	>50 mm x 50 mm

3.3.1.3 Weights and thicknesses. The unit weight or areal density of the finished laminates (Class A or Class B) shall fall within the ranges established by Figure 1A (Class A) or Figure 1B (Class B) (see 4.3.2.3.2). Laminated plates should be within ±5% of the specified nominal areal density, as determined by Section 4.3.2.3.2.

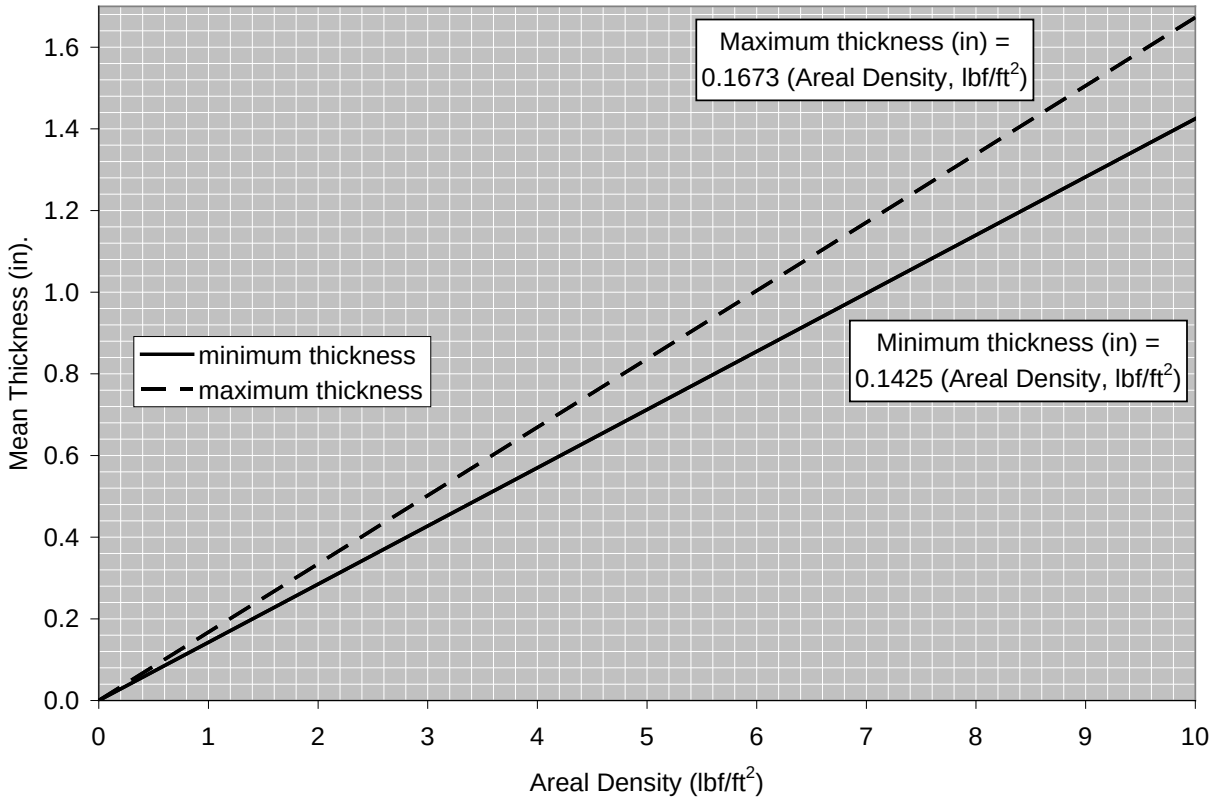

Figure 1A. Weight and Thickness Variations of the Finished Laminate for Class A.

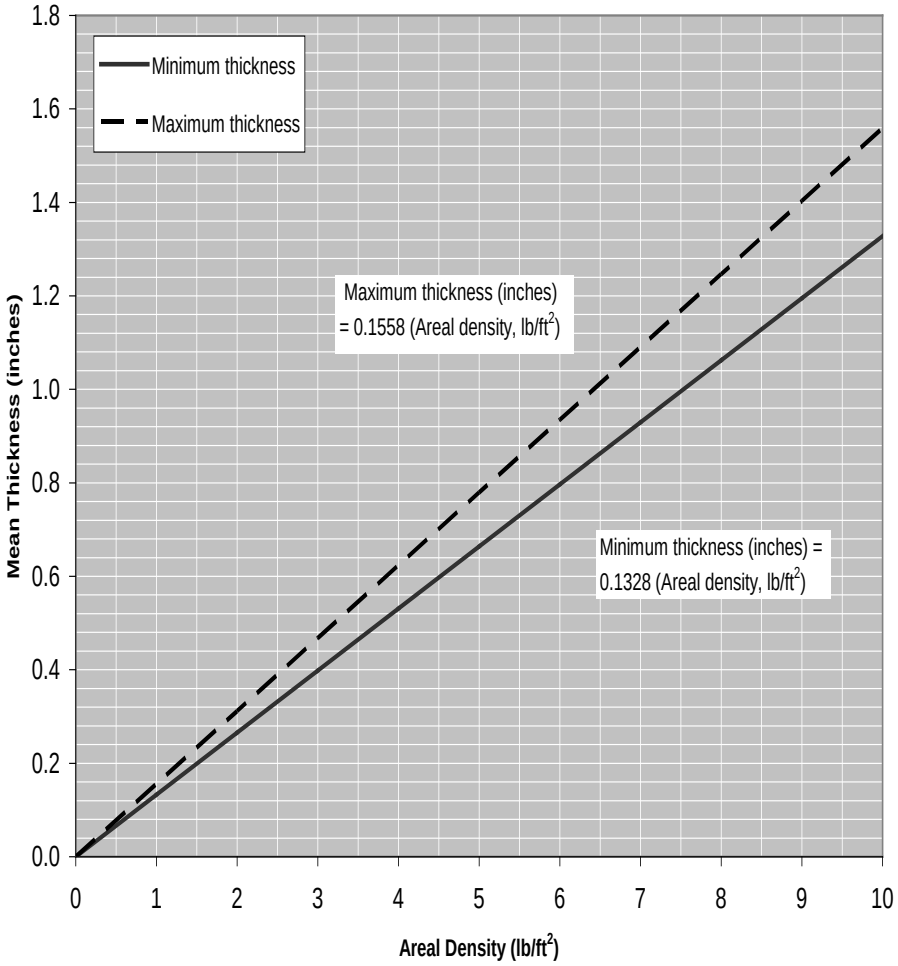

Figure 1B. Weight and Thickness Variations of the Finished Laminate for Class B

3.3.2 Molding conditions - lamination pressures and temperatures.

3.3.2.1 Class A laminates. The laminated panel should be laid up so that every unidirectional layer is substantially perpendicular to lamina in contact with it (e.g. for three lamina, the lamination schedule should be [0|90|0|90|0|90] and not [0|90|90|0|0|90]). The following conditions shall prevail during lamination processes:

a. Type I and II.
    1. Type I (flat, low pressure) laminates shall be press-molded at 500 ±20 pounds per square inch (psi).
    2. Type II (flat, high pressure) laminates shall be press-molded at 3000±100 pounds per square inch (psi).

For all laminates, the material shall be heated such that the platen temperatures are 350±10°F, all parts of the panel exceed 340°F for at least 10 minutes under pressure, and the panel is cooled to a platen temperature of less than 180°F before releasing pressure. An acceptable molding process meeting these requirements can be proposed by the panel manufacturer to the government quality representative for a given combination of press and panel areal density, using thermocouple data on sample panels. The government may choose to accept the proposed molding process. Otherwise, pressures indicated above shall be maintained until the following stages have been completed.

b. Type I and II.
   1. Press platen temperature increased to 350 ±10°F.
   2. Dwell in accordance with schedule of Table III with platens at 350 ±10°F.
   3. Press platen temperature reduced to a maximum of 180°F before laminate removal.

TABLE III. Laminating dwell times for Class A.

Laminate AD (psf)	Dwell time (minutes)
< 1.5	30
1.5 – 3.0	45
> 3.0	75

3.3.2.2 Class B laminates. The laminated panel should be laid up so that every unidirectional layer is substantially perpendicular to lamina in contact with it (e.g. for two lamina, the lamination schedule should be [0|90| 0| 90| 0| 90| 0| 90]. The following molding process should be followed:

a. Type I and II.
   1. Type I (flat, low pressure) laminates shall be press-molded at 600 ±100 pounds per square inch (psi).
   2. Type II (flat, high pressure) laminates shall be press-molded at 2500±100 pounds per square inch (psi).

For all laminates, the material shall be heated such the platen temperatures are 290±10°F, and all parts of the panel exceed 280°F for a minimum of 15 minutes under a contact pressure of less than 200 psi. before the molding pressure is applied. Apply molding pressure according to the laminate Type classification and hold for a minimum of 15 minutes, then cool until all parts of the panel are less than 125°F before releasing pressure.

b. Compression molding process for Type I and II.
   1. Insert material stack and preheat until centerline of panel is 280°F using a panel contact pressure of less than 200 psi.
   2. Hold centerline at 280°F for a minimum of 15 minutes using a panel contact pressure of less than 200 psi.

3. Increase part pressure according to laminate Type classification, such that all parts of the panel exceed 280°F under pressure for a minimum of 15 minutes.
4. Initiate cooling cycle.
5. Cool panel until centerline is less than 125°F.
6. Release applied pressure.

An acceptable molding process meeting these requirements can be proposed by the panel manufacturer to the government quality representative for a given combination of press and panel areal density, using thermocouple data on sample panels. The government may choose to accept the proposed molding process.

3.3.3 Finished laminate. The finished laminates shall consist of the specified number of plies or areal density sandwiched between single peel-plies which can be incorporated in the lamination process unless otherwise specified in the contract or purchase order (see 6.2). 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. 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 adhesive sealed surface on all cut, trimmed or drilled hole edges which is applied after any required drying process. The sealing adhesive 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, assuming the contract or purchase order does not specify that peel-plies are not required (see 6.2).

3.4 Performance of the finished laminate.

3.4.1 Peel-ply removal. The peel-plies, assuming the contract or purchase order does not specify that peel-plies are not required (see 6.2), 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 4.3.2.3.3).

3.4.2 Thermal shock resistance. The plastic laminates shall not show evidence of delamination (as describe below) following a two cycle exposure to a temperature range of -65°F to 250°F (-54°C to 121°C) (See 4.3.2.3.1). Evidence of delamination is when the average thickness change calculated from the procedure outlined in Appendix A is greater than the absolute value of 0.008 inches for Class A material and greater than the absolute value of 0.025 inches for Class B material. It shall be specified in the contract or purchase order (see 6.2) that this test shall not be needed if the application of these materials does not require delamination resistance.

3.4.3 Ballistic resistance. The test projectile for this ballistic acceptance test shall be the caliber 0.30 (44 grain) fragment simulating projectile at 0° obliquity.

3.4.3.1 Class A laminates. The V_{50} protection ballistic limit as defined in MIL-STD-662 shall not be less than 1900 ft/s for a laminate composed of 26 lamina with an areal density of 1.96 +/- 0.1 psf.

3.4.3.2 Class B laminates. The V_{50} protection ballistic limit as defined in MIL-STD-662 shall not be less than 1820 ft/s for a laminate composed of 19 lamina with an areal density of 1.98 +/- 0.1 psf.

3.5 Workmanship. The plastic laminates shall satisfy visual acceptance Level I of ASTM D2563 for the following defects as defined in ASTM D2563 (see 4.3.3):

a. Burned
b. Crack
c. Crazing
d. Delamination, internal

Level II of ASTM D2563 for the following defects as defined in ASTM D2563 (see 4.3.3):

a. Crack, surface

Reinforcement layers shall not have pleats, wrinkles, or creases. Reinforcement layers shall be free of tears, reasonably straight, and reasonably perpendicular layer-to-layer. The laminated panel should be laid up so that every unidirectional layer is substantially perpendicular to layers in contact with it (e.g. for a laminate of *N*-lamina, the lamination schedule should be $[0|90]_N$ for Class A and $[0|90|0|90]_N$ for Class B. It should not be $[0|90|90|0]_{N/2}$] or $[0|90|0|90|90|0|90|0|]_{N/2}$). Edges of the finished laminate shall be free of excessively frayed edges (see 4.3.2.3.5).

4. VERIFICATION

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

a. First article inspection (see 4.3).
b. Production acceptance inspection (see 4.4).

4.2 Lot. 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. Unless otherwise specified in the contract or purchase order (see 6.2), the default definition of a lot shall be 30 days of production of the product or 1/12 of the average yearly production of the product, whichever is larger. Any changes in materials, composition, reinforcement architecture, the reinforcement material, the laminating resin, the laminate construction (see 3.2) or the manufacturing process including changes in the place or location of manufacture shall constitute another lot and therefore require a separate set of testing requirements.

4.3 First article inspection. When required (see 3.1), the first article sample shall be examined for compliance with the requirements and verifications in section 3 and section 4. Fiber and resin certification (see 3.2.1 and 3.2.2) shall be provided to the procuring activity. 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. 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, unless otherwise specified in the contract or purchase order (see 6.2).

4.3.1 Sampling for first article.

4.3.1.1 For lamina ballistic testing. Supply 2 targets as specified in 3.2.3.3.1 (Class A) or 3.2.3.3.2 (Class B).

4.3.1.2 For laminate ballistic testing. Supply two test samples at an areal density specified in 3.4.3 for either Class A or Class B. The size of the test sample shall coincide with the width of the product that would allow minimizing waste of material in preparation of the samples for testing. For example, for a 63 inch product, a size of 21 in. x 21 in. (534mm x 534mm) would be appropriate and for a 70 inch product, a size of 23 in. x 23 in. (584mm x 584mm) would be appropriate. Therefore, the size of the test sample shall be accordance with the following Table IV.

Table IV. Sample Size.

PRODUCT WIDTH	TEST SAMPLE SIZE
Under 63 inch	24 in. x 24 in
63 inch	21 in. x 21 in
64 inch	21 in. x 21 in
65 inch	21 in. x 21 in
66 inch	22 in. x 22 in
67 inch	22 in. x 22 in
68 inch	22 in. x 22 in
69 inch	23 in. x 23 in
70 inch	23 in. x 23 in
71 inch	23 in. x 23 in
72 inch and above	24 in. x 24 in

4.3.1.3 For all other required tests (control tests). Supply 3 test samples at an areal density specified in the contract. The test sample size shall be in accordance with Table IV. These test samples shall be used to verify the requirements of workmanship (3.5), temperature resistance test (3.4.2), peel-ply test (3.4.1), assuming the contract or purchase order does not specify that peel-plies are not required (see 6.2), and dimensions and structure (3.3.1).

4.3.2 Tests for first article.

4.3.2.1 Ballistic test – un-molded panel (lamina). The ballistic resistance test shall be conducted in accordance with MIL-STD-662. Test projectile shall be the caliber 0.22 (17 grain) MIL-DTL-46593, Type 1, un-saboted fragment simulating projectile at 0° obliquity. The V_{50}

protection ballistic limit reported shall be the average of two determinations made on separate assemblies of unmolded lamina. Each determination shall be a six round V_{50} ballistic limit with a maximum velocity spread of 125 ft/sec. If a panel has at least five partial penetrations at impact velocities above the required minimum V50, and no complete penetrations at impact velocities below the required minimum V50, then that panel test result shall be considered compliant with the ballistic test requirement, even if the range of results is greater 125 ft/s and the V50 cannot be determined. In such a case where a panel is determined to meet the ballistic test requirement but its V50 cannot be determined, the highest partial penetration velocity or the lowest complete penetration velocity, whichever is lower, shall be used to represent the panel V50 when averaging the result with the other panel to determine compliance of the first articles or production lot.

4.3.2.2 Ballistic test – molded panel (laminate). The ballistic resistance test shall be conducted in accordance with MIL-STD-662. Test projectile shall be the caliber 0.30 (44 grain) MIL-DTL-46593, Type 1, un-saboted 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. (38 m/s). If a panel has at least five partial penetrations at impact velocities above the required minimum V50, and no complete penetrations at impact velocities below the required minimum V50, then that panel test result shall be considered compliant with the ballistic test requirement, even if the range of results is greater 125 ft/s and the V50 cannot be determined. In such a case where a panel is determined to meet the ballistic test requirement but its V50 cannot be determined, the highest partial penetration velocity or the lowest complete penetration velocity, whichever is lower, shall be used to represent the panel V50 when averaging the result with the other panel to determine compliance of the first articles or production lot.

4.3.2.3 Control tests for first article.

4.3.2.3.1 Thermal shock resistance test. The thermal shock resistance test shall be performed in accordance with APPENDIX A.

4.3.2.3.2 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 in. by 20 in. (508 mm x 508 mm) and remove peel-plies (see 3.3.3) assuming the contract or purchase order does not specify that peel-plies are not required (see 6.2). Dry the panel in a forced draft or convection type oven in a stream of ambient air heated to 200 $\pm$10°F (93 $\pm$ 6°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:

$$\text{Unit Weight} = \frac{1000000\ M}{LW}\ \text{Kg/m}^2$$

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.

4.3.2.3.3 Peel-ply test. The peel-ply test, assuming the contract or purchase order does not specify that peel-plies are not required (see 6.2), shall consist of removing the peel-plies by hand (see 3.4.1).

4.3.2.3.4 Determination of laminate thickness. The thickness of a finished laminate is determined as follows: Choose a square laminate of nominal size at least 24 in. by 24 in. (610 mm by 610 mm), and remove peel-plies, assuming the contract or purchase order does not specify that peel-plies are not required (see 6.2). Measure thickness to the nearest 0.001 in. (0.0254 mm) at least 1.0 in. (25.4 mm) in from each of four (4) corners. Average the four (4) readings.

4.3.3 Workmanship. The plastic laminates shall satisfy visual acceptance Level I of ASTM D2563 for the defects listed in 3.5, as defined in ASTM D2563.

4.3.4 Failure. Failure of the samples to meet the test requirements (ballistic and control) shall be cause for the Government to refuse acceptance of first article samples until the cause of failure(s) is identified, corrective action is taken by the contractor, and approved by the Government.

4.4 Production acceptance inspection.

4.4.1 Sampling for production acceptance.

4.4.1.1 Ballistic testing. The contractor shall supply two test samples at the areal density specified in 3.4.3.1 for Class A or in 3.4.3.2 for Class B for each lot of test laminate fabrication for ballistic testing at the facility specified in 6.3 unless otherwise specified in the contract or purchase order (see 6.2) to show conformance to 3.4.3. The test sample size shall be in accordance with Table IV. The test panels shall be adequately identified as to contractor, contract number, manufacturer, and date.

4.4.2 Tests for production acceptance.

4.4.2.1 Ballistic test – molded panel (laminate). 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. If a panel has at least five partial penetrations at impact velocities above the required minimum V50, and no complete penetrations at impact velocities below the required minimum V50, then that panel test result shall be considered compliant with the ballistic test requirement, even if the range of results is greater 125 ft/s and the V50 cannot be determined. In such a case where a panel is determined to meet the ballistic test requirement but its V50 cannot be determined, the highest partial penetration velocity or the lowest complete penetration velocity, whichever is lower, shall be used to represent the panel V50 when averaging the result with the other panel to determine compliance of the first articles or production lot.

4.4.3 Workmanship. The plastic laminates shall satisfy visual acceptance Level I of ASTM D2563 for the defects listed in 3.5, as defined in ASTM D2563.

4.4.4 Failure. Failure of the samples to meet the test requirements (ballistic) shall be cause for the Government to stop acceptance of production samples until the cause of failure(s) is identified, corrective action is taken by the contractor, and approved by the Government.

4.5 Materials, design and construction. To determine conformance to first article and production, 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 packaging of materiel is to be performed by DoD or in-house contractor personnel, these personnel need to contact the responsible packaging activity to ascertain packaging requirements. Packaging requirements are maintained by the Inventory Control Point's packaging activities within the Military Service or Defense Agency, or within the military service's system commands. 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, the product from this specification will typically be used in military applications (military unique). However, this does not exclude the product of this specification from being used for non military applications.

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. When first article is required (see 3.1 and 6.4).
d. Production component dimensions and areal density (see 3.3.1.1.1 and 3.3.1.1.2).
e. Specify if peel-plies are not required (see 3.3.3, 3.4.1, 4.3.1.3, 4.3.2.3.2, 4.3.2.3.3, and 4.3.2.3.4).

f. If the temperature resistance test is not required (see 3.4.2).
g. If the default definition of a lot is different (see 4.2).
h. If inspection is carried out under Government surveillance (see 4.3).
i. Specify the ballistic test facility if different then 6.3 (see 4.4.1.1).
j. Packaging requirements (see 5.1).

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 4.4.1.1).

6.4 First article. It is suggested that first article testing be required for every new contract especially if the possible vendor is new (has not produced this product before) or has not produced this product within the last six (6) months.

6.5 Definitions.

6.5.1 Lamina. Two (2) layers for class A or four (4) layers for class B of essentially unidirectional fibers, where each layer of fibers is cross-plied essentially 90° relative to the adjacent layer(s). The 2 or 4 layers have been bonded to form a single article.

6.5.2 Fair impact. An impact is considered fair when an un-yawed fragment simulator strikes an unsupported area of the target material at a specified obliquity at a distance of at least two inches from any previous impact or disturbed area resulting from an impact, or from any crack, or from any edge of the specimen.

6.6 Subject term (key word) listing.

Areal density (AD)
Ballistic resistance
Laminating resin
Lamination pressures and temperatures
Peel-ply
Temperature resistance

APPENDIX A

THERMAL SHOCK TEST PROCEDURE

A.1 SCOPE

A 1.1 Scope. This appendix covers a procedure used to measure the dimensional changes of materials which are exposed to extreme rapid temperature changes. This appendix is a mandatory part of this specification. The information contained herein is intended for compliance.

A1.2 Applicability. The requirements specified in this appendix are required. The content of this appendix was taken for the most part from MIL-STD 810G, Method 503.5 Temperature Shock.

A.2 APPLICABLE DOCUMENTS (Not Applicable)

A.3 REQUIREMENTS

A.3.1 Equipment. The equipment listed below or its equivalent shall be required to perform the thermal shock test.

1. Hot Chamber @ 275°F, Ex: Russells Technical Products, Model GD-64-5-5-AC
2. Cold Chamber @ -90°F, Ex: Russells Technical Products, Model GD-64-5-5-AC
3. Temperature Recorder w/ multiple channels, Ex: Yokogawa Mobilecorder, Model MV200
4. Thermocouple wire, Ex: Type J, 100ft
5. Micrometer, Ex: Mitutoyo, IP65, No. 389-351, Res = 0.00005
6. Transfer board, Ex: ½" Teflon sheet or ¾" plywood board, 24" x 24"
7. PPE: Safety glasses, Face shield, and insulated gloves
8. Misc: Steel Ruler 24", Marker (Sharpie), High Temp adhesive tape, Timer, binder clips

A 3.2 Test panel. The test panel shall be manufactured as specified herein and shall be of the size specified in 4.3.1.2 and have a weight of 3.0 psf.

A 3.3 Procedure.

A 3.3.1 Chamber preparation. Both chambers (Hot and Cold) shall be turned on and set at the following set points.

a. Hot chamber set point = 275°F/135°C
b. Cold chamber set point = -90°F/-68°C

APPENDIX A

The installation of shelving racks shall be used as needed. Note: Use of shelf racks are optional and may increase or decrease cycle times. Allow up to 1 hour for preheat/precool.

A 3.3.2 Test panel preparation and pretest measurement. Identify and place a mark on the test panel at the eight measurement locations. Each location is to be 1 ¼" from the edge and 6" from the side as shown in FIGURE A-1. Measure thickness at each location using a micrometer. Ensure the micrometer is flat and level relative to the panel and that the panel is clean and free of debris. Record to the nearest 0.001". Measure and record the weight of the test panel. Place and center the test panel on the transfer board. Construct a five wire thermocouple harness and connect to a recorder. Use enough wire length to reach both hot and cold chambers. Attach each of five thermocouple wires to the thermocouple locations shown in FIGURE A-2. Use high temperature tape to secure the thermocouple to the panel. Additional binder clips can be used to hold the lead wires to the transfer board.

*** Safety: Always use appropriate Personal Protective Equipment while working at elevated or sub-ambient conditions. Several steps in the following sections of the procedure shall be designated in bold red font, which require the use of safety glasses, face shield, and insulated gloves.

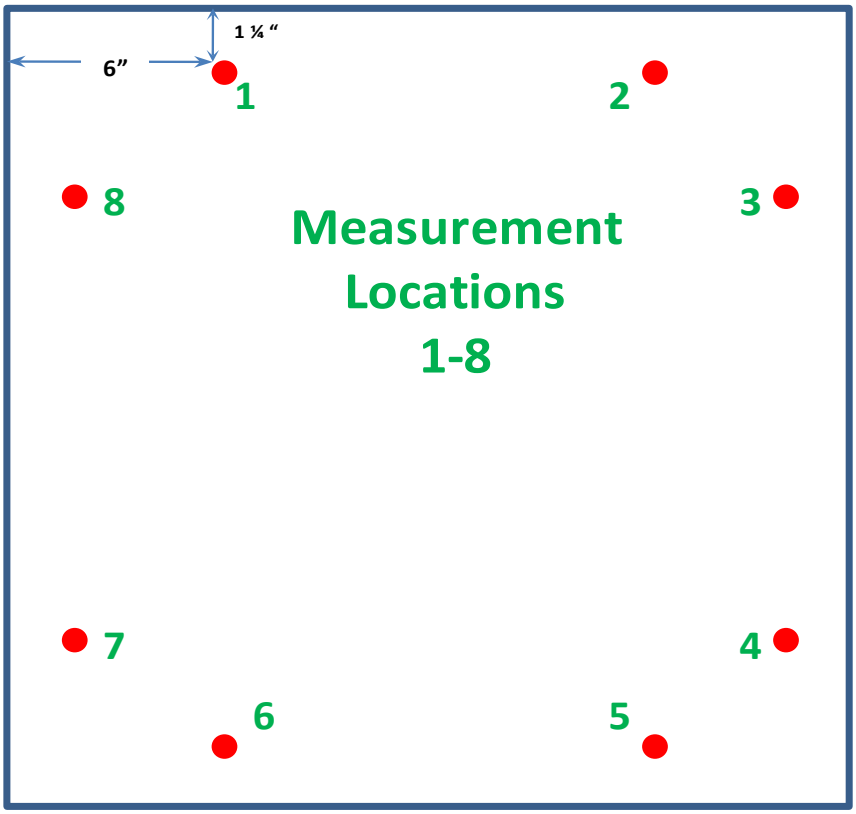

FIGURE A-1. Measurement Locations

APPENDIX A

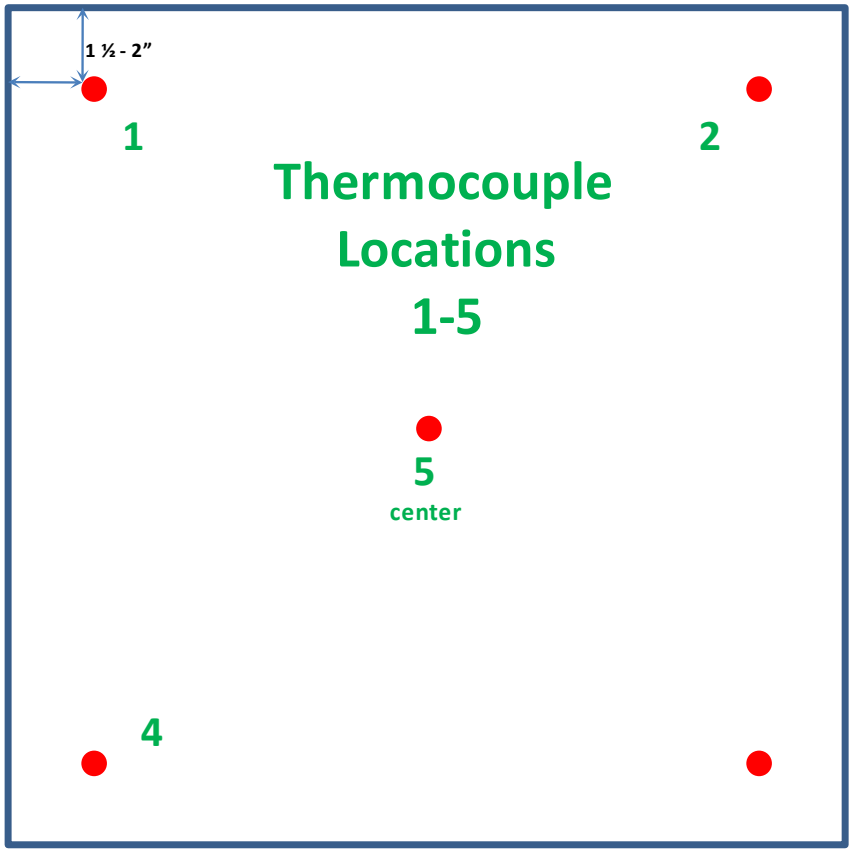

FIGURE A-2. Thermocouple Locations

A 3.3.3 Thermal cycling. Record initial temperatures of each thermocouple and inspect recorder for proper functioning**. Place test panel/transfer board into center of cold chamber and begin timer.** Record time and temperature of each thermocouple location at intervals of: 1 min, 2 min, 5 min, 10 min, etc. Recording interval may be adjusted based on relative ramp rate of test panel. Continue recording the temperature of each thermocouple location until one of the thermocouples reach set point = -65°F. See note 1. **Transfer the test panel/transfer board to the hot chamber and record time. Transfer should be completed in 5 minutes or less. Inspect the thermocouple wires to confirm secure attachment and proper location.** Record time and temperature of each thermocouple location at intervals of: 1 min, 2 min, 5 min, 10 min, etc. Recording interval may be adjusted based on relative ramp rate of test panel. Continue recording the temperature of each thermocouple location until one of the thermocouples reach set point = 250°F. **Transfer the test panel/transfer board to the cold chamber and record time. Transfer should be completed in 5 minutes or less. Inspect the thermocouple wires to confirm secure**

attachment and proper location. Record time and temperature of each thermocouple location at intervals of: 1 min, 2 min, 5 min, 10 min, etc. Recording interval may be adjusted based on relative ramp rate of test panel. Continue recording the temperature of each thermocouple location until one of the thermocouples reach set point = -65°F. **Transfer the test panel/transfer board to the hot chamber and record time. Transfer should be completed in 5 minutes or less. Inspect the thermocouple wires to confirm secure attachment and proper location.** Record time and temperature of each thermocouple location at intervals: 1 min, 2 min, 5 min, 10 min, etc. Recording interval may be adjusted based on relative ramp rate of test panel. Continue recording the temperature of each thermocouple location until one of the thermocouples reach set point = 250°F. **Remove the test panel/transfer board from the hot chamber to a flat countertop and allow it to cool and equilibrate for a minimum of 8 hours in normal ambient conditions (70°F +/- 5°F, 50% +/- 20% RH).**

Note 1: Thermal chambers can have uneven and irregular air flow patterns. It is the intent of the test to expose the panel to a maximum temperature of 250°F and a minimum of -65°F. Hence, when the first of the five measurements reaches the designated 250°F or -65°F, the panel should be transferred to the other environment to achieve the temperature shock and to avoid thermal soak.

A 3.3.4 Post-test measurement. Carefully remove the thermocouple wires and harness so as not to distort or damage the surface at or near the measurement locations. Measure thickness at each location using micrometer. Ensure the micrometer is flat and level relative to the panel and that the panel is clean and free of debris. Record to 0.001". Measure and record the weight of the test panel. Calculate the thickness change for each location and the average thickness change of the panel.

CONCLUDING MATERIAL

Custodian:
Army - MR
Navy - AS
Air Force - 11

Review Activities:
Army – AT, AV, MI
Navy – SH
Air Force - 13
DLA – DH, IS

Preparing Activity:
Army - MR

(Project CMPS -2010-004)

NOTE: The activities listed above were interested in this document as of the date of this document. Since organizations and responsibilities can change, you should verify the currency of the information above using the ASSIST Online database at https://assist.daps.dla.mil.