INCH-POUND

MIL-DTL-32549
21 July 2016

DETAIL SPECIFICATION

LAMINATE: MULTI-LAYER POLYPROPYLENE THERMOPLASTIC COMPOSITE ARMOR

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

1. SCOPE

1.1 Scope. This specification covers a multi-layer woven polypropylene tape thermoplastic 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. Coextruded polypropylene film, slit and stretched to form a white tape, woven and laminated with nonwoven surface for bonding.

1.2.2 Types

1.2.2.1 Type 1. Flat, high density (see 3.4.2), compression molded.

1.2.2.2 Type 2. Flat, low density (see 3.4.2), compression molded.

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.dla.mil/.

AMSC N/A AREA CMPS

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 requirements of 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 cited in the solicitation or contract.

FEDERAL STANDARDS

21 CFR 177.1520	-	Olefin Polymers

(Copies of these documents are available online from www.gpoaccess.gov/cfr/index.html.)

DEPARTMENT OF DEFENSE SPECIFICATIONS

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 http://quicksearch.dla.mil/.)

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 D638	-	Standard Test Method of Tensile Properties of Plastics
ASTM D1777	-	Standard Test Method for Thickness of Textile Materials
ASTM D1907/D1907M	-	Standard Test Method for Linear Density of Yarn (Yarn Number) by the Skein Method

ASTM D3776/D3776M	-	Standard Test Method for Mass per Unit Area (Weight) of Fabric
ASTM D5034	-	Standard Test Method for Breaking Strength and Elongation of Textile Fabrics (Grab Test)

(Copies of these documents are available online at http://www.astm.org.)

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. First article testing shall be completed before production material is submitted for acceptance testing. The approval of the first article samples authorizes commencement of production but does not relieve the supplier of the responsibility to comply with all the applicable provisions of this specification. The first article samples and acceptance test plates shall be manufactured by the process proposed for use on production items.

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

3.2.1 Tape.

3.2.1.1 Tape Description. The tape is manufactured by the co-extrusion of polypropylene and a lower melting polypropylene co-polymer, slit and highly stretched to form white 2.2 mm wide tapes. The tape used shall be continuous with no delamination between coextruded layers, and have average lot properties as specified in Table I.

3.2.1.2 Tape Signature. Tape with a Fourier Transform Infrared spectroscopy - Attenuated Total Reflectance (FTIR-ATR) signature with dominant absorbance at 2950, 2920, 2865, 2838, 1454, and 1377 cm^{-1} and little to no absorbance at 765 cm-1.

Table I. Tape Properties

PROPERTIES	REQUIREMENT	Test Method
Color	white	Visual
Tape Denier	900-1100	ASTM D1907
Tape Width	2.0-2.4 mm	ASTM D638
Tensile Modulus*	13.0-16.5 GPa	ASTM D638
Sealing Temperature	120-135C	3.2.1.3

*Tensile modulus measured at least 5 days after manufacture of tape.

3.2.1.3 Sealing Temperature. The sealing temperature measurement requires the use of two heated plates capable of being controlled to +/- 3C and placed in direct contact with one another. Two tapes are aligned/overlapped for at least 2 cm and pressed between the heated plates with a pressure of at least 1 psi but no more than 50 psi for 30 sec. The sealing temperature is determined as the lowest temperature at which the resistance to separation is measurable and fibrils are observed at the peeled interface.

3.2.2 Fabric.

3.2.2.1 Single ply woven fabric. Woven fabric properties values are listed in Table II. The woven fabric consists entirely of tape as defined in 3.2.1 in a 2x2 left-hand twill weave construction with minimal crimp and no applied twist to the warp flat tapes. The filling/weft direction will have some twist due to the nature of the insertion process but shall not exceed on average 2 twists per foot per tape. The woven fabric shall have no more than 5 clearly noticeable defects per 100 lyds, 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 II. Woven Fabric Properties

PROPERTIES	VALUE	TEST METHOD
Fabric Weight	2.75-3.05 osy	ASTM D3776
Tape Density (warp end count)	10.5-11.2 tapes/in	3.2.2.1.3
Tape Density (fill pick count)	10.7-11.2 tapes/in	3.2.2.1.3
Warp Tensile Strength	140-220 lbf	3.2.2.1.2
Fill Tensile Strength	130-200 lbf	3.2.2.1.2

Table IIA: Defects in Class A woven fabric

EFECTS	CONDITION
Visible gap between tapes	>0.25” width
Broken/missing tapes	>36” long
Hard Crease >2” wide	>12” long

3.2.2.1.2 Tensile Strength of woven fabric. The tensile strength of the woven fabric shall be determined by ASTM D5034. At least ten continuous tapes must be gripped by the upper and lower grips. Care must be taken to prevent slippage of the fabric in the grips during testing. Thin rubber pads have been found to be beneficial in preventing this slippage.

3.2.2.1.3 Tape density of woven fabric. The density of the tapes in both warp and fill directions is determined by counting 50 tapes along the warp and fill directions of the fabric at least 2 inches away from the selvedge and measuring the distance in inches accurate to at least 0.05

inches in each direction. The density is calculated by dividing 50 tapes by the measured distance. Care must be taken to prevent the distortion of the fabric before or during this measurement.

3.2.2.2 Surface bond layer material. Class A laminates require the incorporation of this surface nonwoven bond layer to allow ready adhesion to other materials. This surface bond layer is comprised of a polyester nonwoven spun bond fabric (2.9 osy) mechanically stitched with a 2/150 textured polyester yarn to a layer of woven fabric described in 3.2.2.1. The 3.2.2.1 fabric may be woven from a different colored tape provided the tape and fabric properties comply with Tables I and II. The surface bond layer material further comprises a 2 mil (0.05 mm) polyethylene copolymer bonding film with peak melting temperature of 246° F (119° C) to securely bind the stitched nonwoven to the woven laminate plies.

3.2.2.2.1 Areal density. The surface bond layer material shall have an areal weight of 7.15 ± 0.7 oz/yd^2 [241 ± 24 g/m^2] as determined by ASTM D3776/D3776M (option C).

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) of the laminate.

3.3.1 Dimensions and structure. The laminates shall be of the dimensions stated in the acquisition documents (see 6.2). The laminates shall consist of the specified areal density (see 3.3.1.1 and 3.3.1.2) of woven fabric and the surface bond layer material (for Class A) bonded together in a single molding step with heat and pressure. The laminates shall be built up from plies of woven fabric with no reinforcement gap or edge waste in any individual layer (see 4.3.3 and 4.4).

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 3.3.2.1 and 3.3.2.2) by bonding together in a single molding step with heat and pressure the necessary number of woven fabric layers (see 3.2.2.1) with surface bond layer material (see 3.2.2.2) on one or both of the outer surfaces. The surface bond layer material must be oriented with the polyester nonwoven layer facing outward such that the final laminate surface is comprised of the readily bondable polyester surface. The laminates shall be built up from fabric plies with gap no greater than those described in Table IIA and no edge waste in any individual layer.

3.3.1.2 Thickness and flatness variation. The thickness at any point more than one inch from a usable or cut edge shall not vary from the average thickness of the panel by more than ±0.015 in. (0.37 mm). Variation from flatness for each finished panel shall not exceed 0.06 inch per foot (in/ft.) (5.00 millimeters per meter (mm/m)). The thickness variation within the outermost one inch at the edge of a finished/cut laminate must be less than 0.05 inches of the average thickness of the panel.

3.3.1.3 Weights and thicknesses. The unit weight or areal density of the finished Class A laminates shall fall within the ranges established by Figure 1 (Type 1) and Figure 2 (Type 2), (see 4.3.2.2.2). Type 2 Laminated plates should be within ±5% of the specified nominal areal density, as determined by Section 4.3.2.2.3 where 't' is the thickness of the laminate in inches and AD is the measured areal density in pounds per square foot (psf). The maximum and minimum boundaries establish a range of +/- 5% for Type 1 and +/- 10% for Type 2 allowable for the thickness variation from the standard equation.

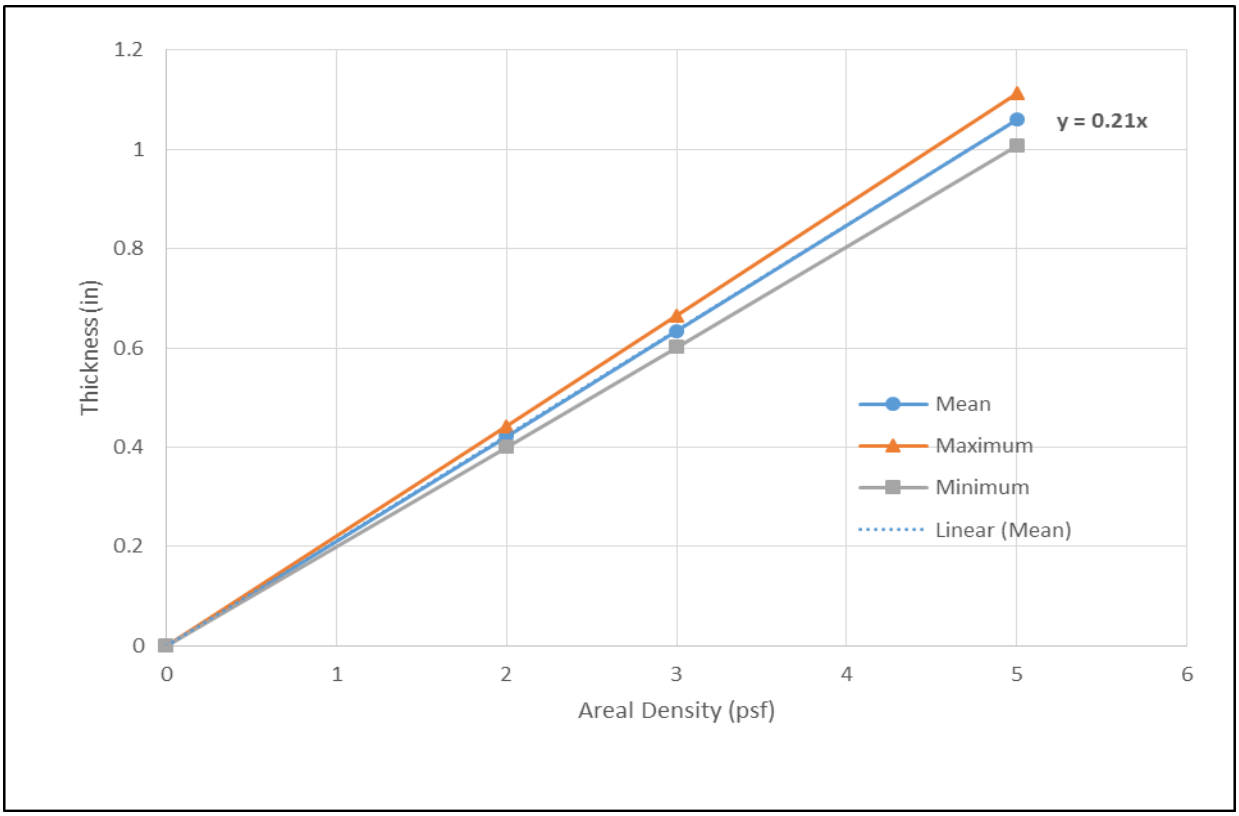

Figure 1. Type 1 - Weight and Thickness Variations of the Finished Laminate for Class A with Surface Bond Layers on Both Sides.

3.3.2 Molding conditions

3.3.2.1 Class A, Type 1 laminates. The laminated panel should be laid up so that every woven ply is substantially parallel to each woven layer in contact with each other. The surface bond layers must be properly oriented with the polyester nonwoven surface being the outermost layer of the lay-up. The laminates shall be press-molded using a temperature-pressure-dwell time sufficient to achieve the targeted thickness defined in Figure 1. Furthermore, the density of the polypropylene core material can be confirmed after removing the surface bond layer as outlined in 4.3.2.2.4.

For all laminates, the material shall be heated such that the platen temperatures are >315° F (157° C), all parts of the panel exceed a temperature of 20° F less than the platen temperature under pressure, and the panel is cooled to a platen temperature of less than 100° 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 (Contracting Officer) shall have the final decision to accept or reject the proposed molding process. Heating and cooling dwell times must be sufficient to ensure heating and cooling through the thickness of the panel while maintaining a constant pressure.

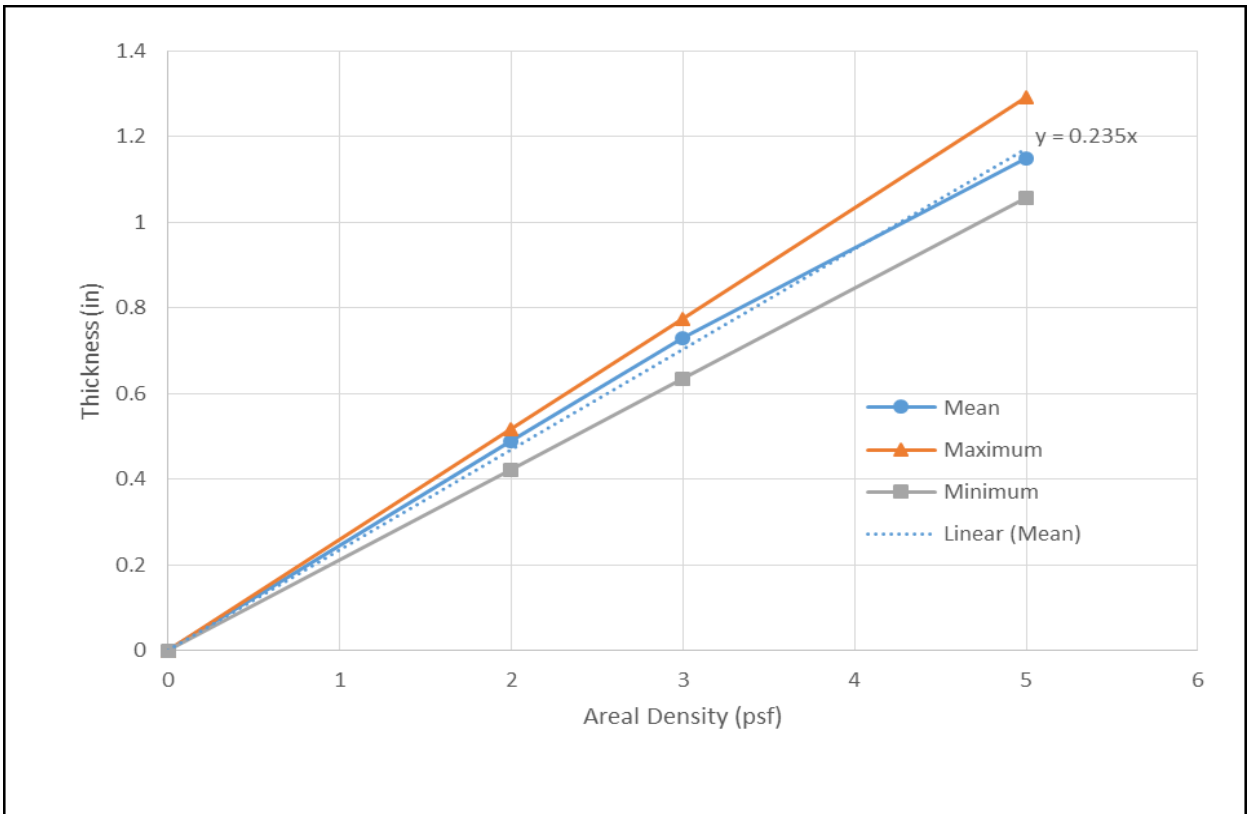

Figure 2. Type 2 - Weight and Thickness Variations of the Finished Laminate for Class A with Surface Bond Layers on Both Sides.

3.3.2.2 Class A, Type 2 laminates. The laminated panel should be laid up so that every woven ply is substantially parallel to each woven layer in contact with each other. The surface bond layers must be properly oriented with the polyester nonwoven surface being the outermost layer of the lay-up. The laminates shall be press-molded using a temperature-pressure-dwell time sufficient to achieve the targeted thickness defined in Figure 2. Furthermore, the density of the polypropylene core material can be confirmed after removing the surface bond layer as outlined in 4.3.2.2.4.

For all laminates, the material shall be heated such that the platen temperatures are <315° F (157° C), all parts of the panel exceed a temperature of 20° F less than the platen temperature under pressure, and the panel is cooled to a platen temperature of less than 100° 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 (Contracting Officer) shall have the final decision to accept or reject the proposed molding process. Heating and cooling dwell times must be sufficient to ensure heating and cooling through the thickness of the panel while maintaining a constant pressure.

3.3.3 Finished laminate. The finished laminates shall consist of the specified number of plies or areal density. Wet cutting and machining procedures shall be followed by a drying process. Any resulting moisture film remaining on cut surface shall be removed by local heat application (heater/blower) or by using clean, dry toweling.

3.4 Performance of the finished laminate.

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

3.4.1.1 Class A; Type 1 laminates. The V_{50} protection ballistic limit as defined in MIL-STD-662 caliber 0.30 shall be determined for test panels of nominal areal density of 2.0 psf. Test panels shall be provided within the range of 2.0 +/- 0.1 psf; and the V_{50} protection ballistic limit shall be calculated by the following equation: V50 = 496.3 x (AD) + 350.6, units of ft./s for V50 and lbs./ft^2 for AD (areal density). All submitted panels must have the measured V50 greater than the V50 calculated by the equation above, for the actual areal density delivered.

3.4.2 Stripped polypropylene laminate density. The bulk density of the Class A, Type 1 laminate after stripping away the outermost surface bond layers shall be 0.900 g/cm^3 +/- 0.010 (see 1.2.2.1) as measured following 4.3.2.2.4 for laminates of nominal areal density greater than 1.5 psf. The bulk density of the Class A, Type 2 laminate after stripping away the outermost surface bond layers shall be 0.83 g/cm^3 +/- 0.02 (see 1.2.2.2) as measured following 4.3.2.2.4 for laminates of nominal areal density greater than 1.5 psf.

3.4.3 Thermal shock resistance. The plastic laminates shall not show evidence of delamination (as described below) following a two cycle exposure to a temperature range of -65° F to 250° F (-54° C to 121° C) (See 4.3.2.2.1). Evidence of delamination is when the average thickness change calculated from the procedure outlined in Appendix A is greater than 3.0 % for Class A 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.

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

a. Blister
b. Burned

c. Cracked
d. Crack, surface
e. Crazing
f. Delamination, edge
g. Delamination, internal
h. Wrinkles.

Reinforcement layers shall not have pleats, wrinkles, or creases. Reinforcement layers shall be free of tears, reasonably straight, and reasonably aligned layer-to-layer. 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 4.3).
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 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 fabric 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 laminate ballistic testing. Supply two test samples at an areal density specified in 3.4.1 for Class A: Type 1. 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, however a minimum of 21 in. x 21 in. (534mm x 534mm) shall be required. 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.

4.3.1.2 For all other required tests (control tests). Supply 3 test samples at an areal density specified in the contract. These test samples shall be used to verify the requirements of workmanship (3.5), temperature resistance test (3.4.2), and dimensions and structure (3.3.1).

4.3.2 Tests for first article.

4.3.2.1 Tensile Strength of woven fabric. The tensile strength of the woven fabric shall be determined by ASTM D5034. At least ten continuous tapes must be gripped by the upper and lower grips. Care must be taken to prevent slippage of the fabric in the grips during testing. A minimum of 6 specimens shall be measured in each direction (warp and fill) and the average shall meet the requirements of 3.2.2.

4.3.2.2 Control tests for first article laminate.

4.3.2.2.1 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) 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.

4.3.2.2.2 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 weigh in the standard atmosphere for testing textiles as defined in ASTM D123. Calculate the unit weight to three significant figures as follows:

$$\text{Unit Weight} = \frac{100000 \times M}{LW} \quad \text{Kg/m}^2$$

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.

4.3.2.2.3 Determination of laminate thickness. The thickness of a finished laminate is determined as follows: Choose a square laminate of nominal size at least 21 in. by 21 in. (533 mm by 533 mm). 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.

4.3.2.2.4 Determination of stripped polypropylene laminate density. The density of a finished laminate is determined as follows: Using an end mill, cut four (4) 3 in. by 3 in. (7.6 cm by 7.6 cm) blocks from the corner portions of a laminate sample of at least 21 in. by 21 in. (53 cm by 53 cm). Machine off the outer 0.125" to completely remove the bond layer and any external non-olefin materials with as smooth of a finish as possible. For each block, measure the weight to the nearest 0.01 g and measure thickness to the nearest 0.001 in. (0.0254 mm) at least 0.25 in from each of the four (4) edges of each block. Average the four (4) readings. Measure the length and the width of each block to the nearest 0.001 in. (0.0025 cm). Calculate the polypropylene laminate density to three significant figures as follows:

$$\text{Laminate Density} = (m / l\ w\ t)$$

Where m is the block weight in grams and l is the length, w is the width, and t is the thickness of the block in centimeters.

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

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 3.4.1.1 for Class A, Type 1 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 3.4.1. 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 ballistic 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), such as external supplemental plating, tactical and light armored vehicle appliques, modular upgrade armor kits, etc. 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. Specify dimensions of the laminates as listed (see 3.3.1).
e. Production component dimensions and areal density (see 3.3.1.1.1 and 3.3.1.1.2).
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 (K. Beavers), Armor Acceptance – B690, Aberdeen Proving Ground, MD 21005-5059 (see 4.4.1.1 and 6.2)).

6.4 First article. It is suggested that first article testing be required for every new contract (see 3.1 and 6.2) 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.

6.4.1 Potential suppliers. Throughout the development of this specification products from the following list of suppliers have shown that they can meet the requirements and tests specified by this specification. However, past performance does not intend to constitute an order or commitment by or for the Department of the Army or the Government that this company(s) should be the only acceptable supplier, nor does it constitute a waiver of established specification requirements for acceptance, inspection, testing, scheduling or any other provision that may be specified in the contract for this product. The purpose of this paragraph is to assist Government or commercial buyers who are unfamiliar with the end items from this specification with potential suppliers. When other products are found to be acceptable and can meet the requirements and tests specified in the latest effective issue of this specification, they will be added to this list.

CLASS A	**CLASS (tbd)[1/]**	**TYPE 1**	**TYPE 2**
MILLIKEN & CO.		Tegris P4600	Tegris P1400

[1/] To Be Determined

6.5 Definitions.

6.5.1 Lamina. Woven ply of fabric as defined in 3.2.2.

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.

6.5.3. Void defects. Void defects or “visible trapped air” is not intended to describe the actual void structure inherent to the product originally tested.

6.6 Subject term (key word) listing.

Areal density (AD)
Ballistic resistance
Tape
Lamination pressures and temperatures
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.

NOTE: 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.

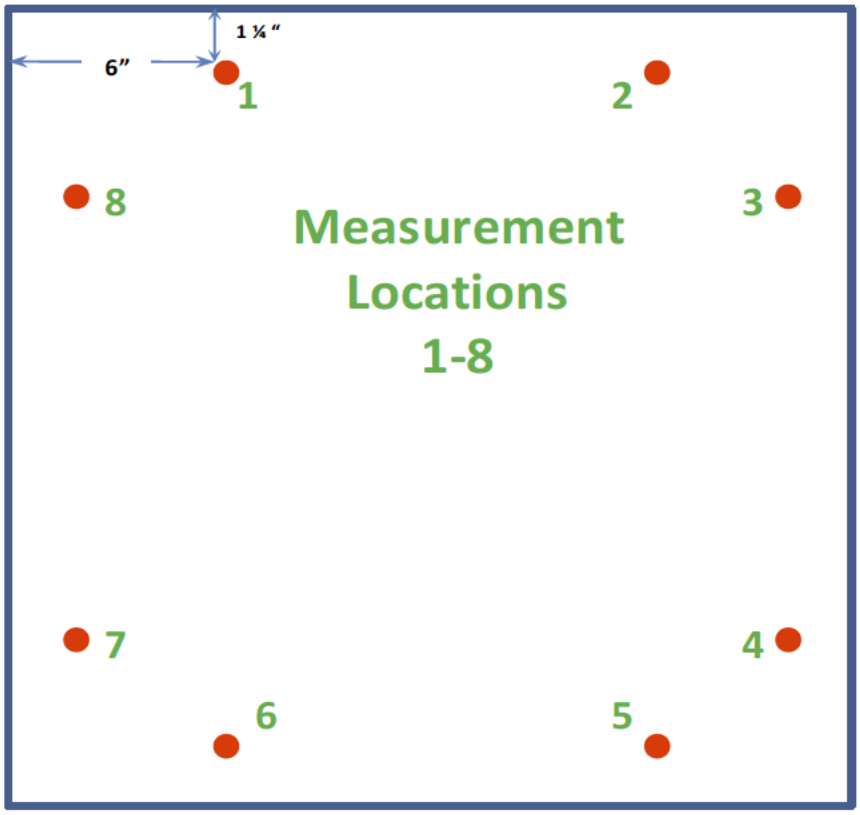

FIGURE A-1. Measurement Locations

APPENDIX A

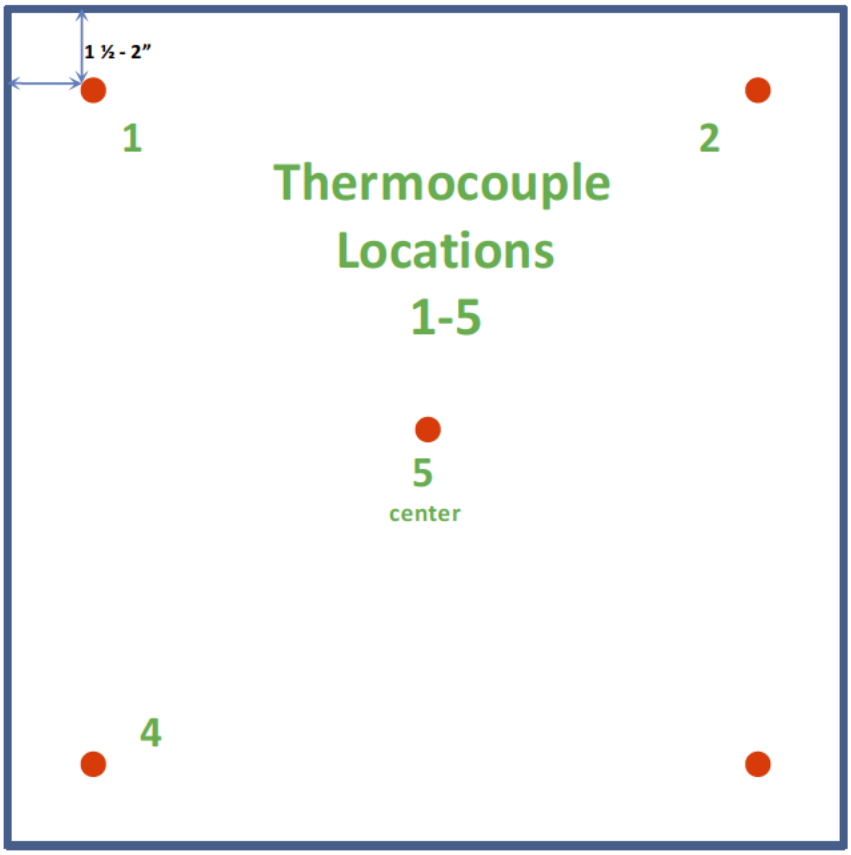

FIGURE A-2. Thermocouple Locations

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.

APPENDIX A

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

Preparing Activity:
Army - MR

(Project CMPS-2010-006)

Review Activities:
Army – AT, AV, MI
Navy – SH
DLA – DH

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.dla.mil/.