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SUPERSEDING
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MILITARY SPECIFICATION

ARMOR: LIGHTWEIGHT, CERAMIC-FACED COMPOSITE, PROCEDURE REQUIREMENTS

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

1. SCOPE

1.1 Scope. This specification covers the procedure requirements for lightweight composite armor composed of high-strength ceramic bonded to nonmetallic backing materials.

1.2 Classification. The armor covered by this specification shall be of the following types and classes (see 6.2):

Type I - For Caliber .30 AP M2 Protection

Class 1 - Aluminum oxide ceramic
Class 2 - Silicon carbide or silicon carbide/silicon ceramic
Class 3 - Boron carbide/silicon carbide/silicon ceramic
Class 4 - Boron carbide ceramic

Type II - For Caliber .50 AP M2 Protection

Class 1 - Aluminum oxide ceramic
Class 2 - Silicon carbide or silicon carbide/silicon ceramic
Class 3 - Boron carbide/silicon carbide/silicon ceramic
Class 4 - Boron carbide ceramic

Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: Director, US Army Materials and Mechanics Research Center, ATTN: DRXMR-LS, Watertown, MA 02172 by using the self-addressed Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

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Type III - For Caliber .30 Ball M2 Protection

Class 1 - Aluminum oxide ceramic
Class 2 - Silicon carbide or silicon carbide/silicon ceramic
Class 3 - Boron carbide/silicon carbide/silicon ceramic
Class 4 - Boron carbide ceramic
Class 5 - Borosilicate glass

2. APPLICABLE DOCUMENTS

2.1 Government documents.

2.1.1 Specifications and standards. Unless otherwise specified (see 6.2), the following specifications and standards of the issue listed in that issue of the Department of Defense Index of Specifications and Standards (DoDISS) specified in the solicitation, form a part of this specification to the extent specified herein.

SPECIFICATIONS

MILITARY
MIL-Q-9858 - Quality Program Requirements
MIL-C-12369 - Cloth, Ballistic, Nylon

STANDARDS

FEDERAL
FED. STD. NO. 406 - Plastics: Methods of Testing

MILITARY
MIL-STD-105 - Sampling Procedures and Tables for Inspection by Attributes.
MIL-STD-109 - Quality Assurance Terms and Definitions.
MIL-STD-129 - Marking for Shipment and Storage.

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

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

AMERICAN SOCIETY FOR TESTING AND MATERIALS STANDARDS

D 635 - Rate of Burning and/or Extent and Time of Burning of Self-Supporting Plastics in a Horizontal Position.
D 792 - Specific Gravity and Density of Plastics by Displacement.
D 2584 - Ignition Loss of Cured Reinforced Resins.

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

(Industry association specifications and standards are generally available for reference from libraries. They are also distributed among technical groups and using Federal agencies.)

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

3. REQUIREMENTS

3.1 Preaward samples, data and certificate.

3.1.1 Preaward samples. The supplier shall furnish to the procuring activity ten complete front armor plates of any size (without spall cover, spall cover edge strip label, integrated carrier and surface coating) of the construction specified in 3.6, and which will conform to the ballistic requirement in 3.7.1. The areal density requirement shall be as specified by the procuring agency (see Table I). Tests for evaluating ballistic requirements shall be conducted from the same samples used for conducting areal density tests. The preaward samples, with spall cover and spall cover edge strip (but without label, integrated carrier and surface coating) shall be evaluated by the government for conformance to ballistic requirements as shown in 3.7.1 and for areal density requirements specified by the procuring agency (see 3.10). Visual, dye penetrant and radiographic examinations shall be performed on the preaward samples by the government and will be used to select the area of impact for ballistic test. Failure of the preaward samples to meet the ballistic, NDT or areal density requirements shall be cause for rejection of the bid.

3.1.2 Preaward data.

3.1.2.1 Thickness of ceramic component. The supplier shall furnish to the contracting officer the data listed below for the preaward samples and a certificate stating that the data and preaward samples supplied are representative of the materials to be delivered under the contract.

(a) Minimum and maximum overall average thickness of the ceramic component to thousandths of an inch determined as specified in 4.3.4.1, that will be furnished in the manufacture of the armor.

3.1.2.2 Ceramic process and formulation. The supplier shall furnish to the contracting officer the data listed below:

(a) Description of specific ceramic process to be used.

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(b) Ceramic formulation:

(1) Chemical composition of each ingredient
(2) Maximum and miminum percent of each major phase composition as it exists in the end item ceramic component.
(3) Hardness 1/
(4) Ceramic thickness to a thousandth of an inch 2/ (see 4.3.4.1).
(5) Areal density in hundredths of a pound per square foot 3/
(6) Modulus of elasticity (by ultrasonic transmission method) 4/ (see 4.3.2).
(7) Specific gravity 4/ (see 4.3.2).
(8) Water absorption 4/ (see 4.3.2).
(9) Porosity or theoretical density 4/ (see 4.3.2).
(10) Surface characteristics (see 4.3.2).
(11) Dimensions and dimensional tolerances (see 6.2).

The physical property values shall include appropriate tolerances and minimum-maximum values. A description of test procedures and apparatus shall also be furnished.

1/ Six tests per piece
2/ Average of five measurements for each ceramic plate.
3/ Value reported for each ceramic plate.
4/ Six tests reported for each production lot.

(c) Minimum and maximum weight of individual ceramic components and the minimum and maximum weight of individual composite armor plate (without spall cover, spall cover edge strip, integrated carrier, surface coating and label) that the offeror proposes to furnish in production.

(d) Fiberglass laminate formulation, consisting of the minimum and maximum resin content, the composition of the resin and the composition and physical properties of the fiberglass fabric as listed below:

(1) Fiber diameter.

(2) Thread count per inch: Warp, Filling

(3) Yarn Size: Warp, Filling

(4) Finish

(5) Weight in ounces per square yard

(6) Weave type

(7) Breaking strength, in pounds per inch of width: Warp, Filling

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(e) Description of specific process to be used for assembling and bonding fiberglass laminate component to ceramic component.

3.1.2.3 Supplier's authorization. The supplier may authorize his supplier of ceramic components or fiberglass laminate components to furnish in his behalf applicable portions of the data and the certificate required by 3.1.2.

3.2 Recorded procedure. Unless otherwise specified in the contract or order, the contractor, prior to manufacture of any composite lightweight armor shall record or have the manufacturer record all armor fabrication procedures to be performed under this specification. This information shall be prepared in duplicate on an approved form (see Appendix A). The cover sheet shall be signed by the manufacturer and the contractor. The recorded fabrication procedure shall be submitted to the procuring activity with the test records specified in 4.6. Any changes in any of these fabrication procedures without prior approval of the contracting officer shall result in rejection of the entire lot, unless it can be shown the lot meets all requirements specified herein.

3.3 First article. When specified, a sample shall be subjected to first article inspection (see 4.2 and 6.10).

3.4 Materials.

3.4.1 Ceramic facing materials. The ceramic component of armor shall be as specified by the contracting officer (see 1.2 and 6.2).

3.4.2 Fiberglass laminate. The fiberglass laminate shall be a minimum of 17 and a maximum of 24 percent of biaxially pressed or a minimum of 27 and a maximum of 32 percent of isostatically pressed by weight of unsaturated polyester type unfilled resin and may contain modifying monomers or polymers and the remainder shall be undyed fiberglass fabric. The resin content shall be determined as specified in 3.4.2.1 and the flame resistance shall be determined as specified in 3.4.2.2.

3.4.2.1 Resin content. Test specimens shall be cut from components and tested for resin content in accordance with ASTM D 2584 as specified in 4.3.2.2.

3.4.2.2 Flammability. Unless otherwise agreed upon between supplier and procuring activity, the fiberglass laminate shall have a maximum burn rate of 3.0 cm/min and the burn length shall not exceed 11 cm when tested in accordance with ASTM D 635 (see 4.3.2.2).

3.4.3 Spall cover and spall cover edge strip. The spall cover for the ceramic component and the spall cover edge strip shall be fabricated from one ply of nylon cloth conforming to MIL-C-12369, color OG-106 unless a change is authorized.

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3.4.4 Adhesives.

3.4.4.1 For bonding ceramic to fiberglass laminate. The adhesive for bonding the ceramic component to the fiberglass laminate component shall be solventless liquid or film epoxy type, two-part polysulfide type, or two-part polyurethane type and capable of passing the requirement in 3.7.2 (see 4.3.2.1).

3.4.4.2 For bonding spall cover to ceramic component. The adhesive for bonding the spall cover to the ceramic component shall be a natural or synthetic rubber base curing type (see 6.7), capable of passing the adhesion requirements specified in 3.7.3 (see 4.3.2.1).

3.4.4.3 For bonding spall cover edge strip to composite armor plate. The adhesive for bonding the spall cover edge strip shall conform to 3M Company adhesive number EC1357 or equal (see 4.3.2.1).

3.4.4.4 Alternate materials and adhesive systems. Alternate materials and adhesive systems may be used in the fabrication of the armor when approved by the contracting officer and when demonstrated to be equal or better in performance than what is specified above. Complete material analysis and test data which will substantiate the above shall be furnished by the contractor. For alternate adhesive to bond the ceramic and fiberglass components, test data shall include results of ballistic and temperature extremes testing.

3.5 Design. The armor shall consist of a fiberglass laminate component bonded to the back of a ceramic component forming a composite armor plate. The exposed surface of the ceramic component shall be covered with a spall cover. A spall cover edge strip shall extend around the entire periphery of the composite armor plate. The armor plates shall be furnished in the specified class and size and shall be fabricated in accordance with applicable end item drawings listed.

3.6 Construction.

3.6.1 Ceramic component. The ceramic component shall conform to the requirements of 3.4.1 and shall be of one piece (monolithic) construction. There shall be no patching of the ceramic component. The ceramic component shall be uniform in thickness within 5 percent when examined as specified in 4.3.4.1 and the overall average shall be within the thickness range established in 3.1.2.1 (a). All ceramic components shall be manufactured in distinct production lots (see 4.3.1), and a sequential marking system of individual components shall be provided (see 3.8.1). Manufacturing tolerances in the ceramic component shall be considered as defects when determined as specified in 4.3.4.2, 4.3.4.3, 4.3.4.4 and 4.3.5.3.

3.6.2 Fiberglass laminate. The fiberglass laminate shall contain undyed (natural color) fiberglass fabric and a resin used in fabricating the

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fiberglass plies and shall be as specified in 3.4.2. The fiberglass shall be uniform in composition and thickness. It shall be free from blisters, cracks, torn fabrics, dents, crazing, surface roughness and creased plies. Any glass fibers, which were not removed in the fabricating or cutting operation, shall be removed from the edges.

3.6.2.1 Molding. The resin treated fabric shall be molded by vacuum or pressure bag technique (see 6.8) or matched metal molds into the required configuration without breaking or damaging the glass fiber. Such procedures and methods shall be capable of yielding uniform properties in the completed structure. No patching shall be performed after the material has been molded.

3.6.3 Spall cover. The nylon spall cover shall be of such a configuration to cover the entire outer ceramic surface. The spall cover shall finish even or within 0.125 in. (3.1 mm) of the edge of the ceramic surface around its entire periphery.

3.6.4 Spall cover edge strip. The spall cover edge strip shall be cut from the nylon material on a 45 degree bias. The length of the edge strip shall be such as to go around the entire periphery of the composite armor plate with the ends overlapped 0.50-0.75 in. (12.7-19.0 mm). The width of the edge strip shall be such to cover the edge of the composite armor plate and extend beyond the inner and outer edges 0.50-0.75 in. (12.7-19.0 mm). The edges and ends of the edge strip shall be smoothly seared to prevent fraying either in the cutting operation or after cutting and before application to the composite armor plate.

3.6.5 Assembly of components by bonding. All components required to be assembled by bonding shall be thoroughly cleaned of all foreign matter. Surfaces to be bonded shall be properly prepared in a manner which will insure a proper bond capable of meeting the applicable performance requirements specified in 3.7. The required adhesive shall be applied uniformly over the entire contact areas of the components to be joined. When bonding components, uniform pressure shall be applied over the entire surface area in order to obtain intimate contact of all components. There shall be no evidence of unadhered areas and no smearing of the adhesives on the exposed surfaces of the components, except when bonding the spall cover edge strip, the adhesive may extend beyond the edges and ends up to a maximum of 0.18 in.

3.7 Performance.

3.7.1 Ballistic resistance. The armor without spall cover shall have a V_{50} protection ballistic limit of not less than 2850 ft/s (868 m/s) against Caliber .30 AP M2, Caliber .50 AP M2, or Caliber .30 Ball M2 projectiles at 0° obliquity.

3.7.2 Temperature resistance. When tested as specified in 4.4 there shall be no delamination between the fiberglass laminate component and the ceramic component or between the fiberglass plies.

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3.7.3 Adhesion of the spall cover. When tested as specified in 4.4, there shall be no visual peeling of the tab formed on the spall cover for performance of the test.

3.8 Identification marking.

3.8.1 Ceramic component. The serial number shall be marked on the outside face surface within 1 in. (25 mm) of the lower edge of each ceramic component, before it is fired, by inscribing, embossing or with high temperature resistant inorganic ink or after firing with a permanent marking to a maximum depth of 0.010 in. (0.25 mm) so that the serial-number will be legible when the spall cover is stripped by mechanical or solvent action. A list in duplicate of the serial numbers used for each production lot shall be furnished the contracting officer.

3.8.2 Markings. The manufacturer's code number, contract number, lot number, serial number and date of manufacture, as well as the number of this specification, size of armor and designation "Cal .30 AP protective", "Cal .50 AP protective" or "Cal .30 Ball protective", and designation as front or back shall be permanently marked on the face surface of each spall cover or ceramic surface if exposed or on the exposed surface of the fiberglass laminate.

3.9 Production data. The following information determined during production of the armor shall be made a matter of record and shall be furnished to the contracting officer upon request. This data shall be identified with the serial number of the armor plate.

a. The weight of each ceramic component.

b. The weight of each composite armor plate without spall cover, spall cover edge strip, integrated carrier, label and surface coating.

c. All thickness measurements taken for each ceramic component.

3.10 Areal density. The areal density shall be as specified by the contracting officer in accordance with Table I.

TABLE I. Areal density of ceramic armor.

Class	Type I	Type II	Type III
1	9.0	16.0	7.8
2	8.0	13.5	7.6
3	7.5	12.7	6.6
4	6.9	12.4	6.4
5	-	-	8.5

Areal density values are given in units of pounds per square foot (lb/ft^2). Tolerance is ± 0.2 lb/ft^2.

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3.11 Workmanship. The armor shall conform to the quality and grade of product established by this document. The occurrence of defects shall not exceed the applicable acceptable quality levels (AQLs).

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsiblity for inspection. Unless otherwise specified in the contract or purchase order, the contractor is responsible for the performance of all inspection requirements as specified herein in accordance with MIL-Q-9858 Except as otherwise specified in the contract or purchase order, the contractor may use his own or any other facilities suitable for the performance of the inspection requirements specified herein, unless disapproved by the Government. The Government reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to assure supplies and services conform to prescribed requirements.

4.1.1 Certificate of compliance. Where certificates of compliance are submitted, the Government reserves the right to check test such items to determine the validity of the certification.

4.1.2 Radiographic and ballistic laboratory approval. Radiographic examination and ballistic testing shall be performed in certified laboratories. Ballistic testing facilities and procedures shall be in accordance with Appendix B. Radiographic equipment and procedures shall be in accordance with Appendix C.

4.2 First article inspection. When required (see 6.2), the preproduction sample submitted in accordance with 3.3 shall be examined for all the provisions of this specification applicable to end item examination.

4.3 Sampling for inspection. Sampling for inspection shall be performed in accordance with MIL-STD-105, except as otherwise indicated hereinafter.

4.3.1 Inspection lots. Examination of armor plates shall be made in accordance with the classification of defects, inspection levels and acceptable quality levels (AQLs) set forth below. The lot size, for purpose of determining the sample size in accordance with MIL-STD-105, shall be expressed in units of 100 armor plates for examination in 4.3.2.2, 4.3.4, and 4.3.5, and in units of shipping containers in 4.5.5. The lot size shall not exceed 1000 items of one type sequentially produced.

4.3.2 Inspection of materials and components. In accordance with 4.1, the contractor is responsible for insuring that materials and components used, were manufactured, tested, and inspected in accordance with the requirements of referenced subsidiary specifications and standards to the extent specified, or if none, in accordance with this specification. In the event of conflict, this specification shall govern. A contractor's certificate of compliance with 3.2 and 3.1.2.2 shall be furnished.

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4.3.2.1 Certification. The contractor shall furnish a certificate of compliance certifying the following:

a. That the ceramic formulation and/or production processing have not been changed from that previously submitted to the contracting officer and that the ceramic plates are manufactured in distinct production lots as specified in 3.6.1.

b. Adhesive specified for bonding ceramic component to fiberglass laminate component conform to 3.4.4.1.

c. Adhesive specified for bonding spall cover to ceramic component conforms to 3.4.4.2.

d. Adhesive specified for bonding spall cover edge strip to composite armor plate conforms to 3.4.4.3.

4.3.2.2 Testing of fiberglass laminate component. Testing shall be performed on the fiberglass laminate component for the characteristics listed in Table I. The lot size shall be expressed in terms of front or back fiberglass laminate components. The sample unit shall be one fiberglass laminate component. The requirements shall be applicable to the sample unit. Test specimens of 6 in. x 0.5 in. x thickness (152 mm x 12 mm x thickness) as received shall be cut from each sample unit and conditioned at ambient temperature and relative humidity prior to flammability testing. The inspection level shall be S-1 and the acceptable quality level (AQL) shall be 6.5. When the fiberglass laminate is molded and bonded to the ceramic component in a simultaneous operation the specimens required for testing shall be cut from composite armor plates that have been ballistically tested. Failure of the flame resistance test or failure to keep resin content within limits stipulated in 3.4.2 shall be cause for rejection of the lot.

TABLE II. Testing of fiberglass laminate component.

Characteristic	Requirement paragraph	Test method	No. of det. per sample unit	Results reported as
Resin content (percent)	3.4.2 1/	ASTM D 2584	3	Average of 3 determinations to nearest whole percent.
Flammability	3.4.2 1/	ASTM D 635	10	Pass or fail

1/Unless otherwise specified, a certificate of compliance shall be submitted and will be acceptable for the stated requirement.

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4.3.3 In-process inspection. Inspection shall be made at any point or during any phase of the manufacturing process to determine if requirements have been met which cannot be examined in the intermediate or end item inspection. The areas to be examined shall include the areas listed below. Whenever nonconformance is noted, corrections shall be made to the items affected and lot in process.

Check for	Component or area
Proper preparation, cleanliness and uniformity or application of adhesive	Surfaces of ceramic and fiberglass laminate components prior to bonding together.
Proper preparation, cleanliness and uniformity or application of adhesive	Surfaces of ceramic and fiberglass laminate components where spall cover edge strip is to be bonded.
Size of cut parts	Spall cover (after attachment to armor)

4.3.4 Intermediate examination of armor plate components during process of fabrication.

4.3.4.1 Intermediate examination of ceramic component for thickness. The ceramic component shall be examined for thickness prior to bonding to the fiberglass laminate. One hundred percent inspection shall be performed, and any ceramic component which fails the examination shall be rejected. The ceramic component shall be uniform in thickness as specified in 3.6.1 when examined in the following manner. The thickness shall be measured to 0.001 in. at five locations on the ceramic plate. With the ceramic plate considered as divided into four quadrants (one for each corner area), one reading shall be taken within each quadrant. Each reading shall be taken a minimum of 1.5 in. away from the edge. In addition, one reading shall be taken at the center of the plate. All readings shall be spaced a minimum of 3.0 inches apart. The five readings shall be averaged and reported to the nearest 0.001 in. as the overall average. The difference between the greatest value and the overall average and the smallest value and the overall average shall not be more than 5 percent of the overall average thickness. All determinations shall be reported with the overall average. In addition, the overall average shall be within the thickness range established in 3.1.2.1 (a).

4.3.4.2 Liquid penetrant and visual examination of ceramic component. The ceramic component shall be examined visually and with liquid penetrant on both sides and edges, after furnace firing and prior to application of the adhesive for bonding of the ceramic component to the fiberglass laminate component. Unless otherwise specified, the examination shall be performed at the contractor's plant. The liquid penetrant examination shall be performed in accordance with Appendix D. One hundred percent examination shall be performed on all ceramic components in the lot. A lot of ceramic components

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shall be as stated in 4.3.1. Defects shall be classified in accordance with the applicable defects listed in Table II. For each ceramic component the acceptance number for major defects shall be zero and for minor defects, three. Any ceramic component found with one or more major defects or having four or more minor defects shall be rejected.

4.3.4.3 Radiographic examination of ceramic component. The ceramic component shall be radiographically examined. Unless otherwise specified, the examination shall be performed at the contractor's plant. Industrial radiography shall be carried out in accordance with Appendix C. Radiography shall include the entire ceramic component area and shall contain the same permanent marking (Serial No.) as the ceramic component. Radiographic films shall be made available to the Government upon request.

NOTE: The same ceramic components examined in this examination are required to be examined in accordance with the provisions of 4.3.5.3 (radiographic examination of completed armor plate).

4.3.4.3.1 Initial production lot. One hundred percent radiographic inspection of the initial lot of ceramic components shall be conducted. Defects shall be classified in accordance with the applicable defects listed in Table III. For each ceramic component, the acceptance number for major defects shall be zero and for minor defects three. Any ceramic component found with one or more defects or having four or more minor defects shall be rejected.

4.3.4.3.2 Production lots after initial lot. All production lots after the initial lot shall also be radiographically inspected. The sample unit shall be one armor plate. The inspection level shall be II. The acceptable quality level shall be 0.25 percent defective items. A defective item is a ceramic component containing one or more major defects or four or more minor defects when examined for defects listed in Table II. After radiographic examination, the acceptable samples shall be returned to the production lot and processed in the normal manner with that lot.

4.3.4.4 Visual examination of composite armor plate. Visual examination shall be conducted in accordance with Appendix E on the face side and edge of the ceramic portion of the composite armor plate, and on the exposed surface and edge of the fiberglass laminate component just prior to application of the adhesive for bonding of the spall cover. One hundred percent examination shall be performed on all composite armor plates in the lot. A lot of composite armor plates shall be as stated in 4.3.1. Defects shall be classified in accordance with the applicable defects listed in Table II. For each composite armor plate the acceptance number for major defects shall be zero and for minor defects three. Any composite armor plate found with one or more major defects or having four or more minor defects shall be rejected.

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4.3.4.5 Dimensional examination of composite armor plates prior to application of spall cover, spall cover edge strip, integrated carrier straps and label. The composite armor plate shall be examined prior to application of spall cover, spall cover edge strip, integrated carrier straps, and label for conformance to the dimensional requirements specified on the applicable drawing. Any dimension that is not within the specified tolerance shall be classified as a defect. The lot shall be expressed in terms of armor plates, front or back, without spall cover, spall cover edge strip, integrated carrier straps, and label. The inspection level shall be S-3 and the acceptable quality level (AQL) shall be 4.0 (one class).

4.3.4.6 Visual examination of composite armor using multiple ceramic tile arrays. Examination will be as specified in 4.3.4.2 except that cracks on the interior tile edges (those not on the outside perimeter of the array) shall be treated as gouges for the purposes of the examination specified in 4.3.4.2.

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TABLE III. Classification of characteristics applicable to ceramic plate by visual, liquid penetrant, and radiographic examination; defects applicable to composite armor plate by visual; applicable to completed armor plate by radiographic examination.

Material	Characteristics	Methods of examination: Visual	Liquid Penetrant	Radiographic	Classification: Major	Minor
Ceramic	a. Edge crack (filled or unfilled) greater than 0.5 in. (12 mm) in length and through thickness of plate 2/, 4/, 11/	X	X	X	X	
	b. Edge crack (unfilled) greater than 0.75 in. (19 mm) in length and not through thickness 2/, 4/, 5/, 11/	X	X	X		X
	c. Edge crack (unfilled) greater than 0.75 in. (19 mm) in length and through thickness 2/, 4/, 5/, 11/	X	X	X		X
	d. Any crack (unfilled) over 0.5 in. (12 mm) length other than edge crack 3/, 4/, 11/		X	X	X	
	e. Any crack (filled) over 0.5 in. (12 mm) length other than edge crack 8/, 9/		X	X	X	
	f. Laminar crack along the edge greater than 0.75 in. (19 mm) in length 11/	X	X		X	
	g. Shrinkage, filamentary type, sponge, and silicon rich area indications: 4/					
	(1) Shrinkage, filamentary filled over 0.2 in^2 per 2 in. diameter circle 8/, 9/		X	X	X	X
	(2) Shrinkage, filamentary, unfilled over 0.2 in^2 per 2 in. diameter circle 8/, 9/		X	X	X	X

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TABLE III. Classification of characteristics applicable to ceramic plate by visual, liquid penetrant, and radiographic examination; defects applicable to composite armor plate by visual; defects applicable to completed armor plate by radiographic examination (Cont'd).

Material	Characteristics	Methods of examination: Visual	Liquid Penetrant	Radiographic	Classification: Major	Minor
	(3) Shrinkage, sponge unfilled over 0.2 in^2 per 2 in. diameter circle 8/, 9/	X	X	X	X	
	(4) Silicon rich area - over 0.2 in^2 per 2 in. diameter circle 8/, 9/			X	X	
	h. Any internal void or unfilled area greater than 0.2 in^2 per 7 in^2 area 4/, 11/			X	X	
	i. Pit greater than:					
	(1) 0.030 in (0.7 mm) in depth and diameter but not more than 0.060 in (1.5 mm) in depth 5/, 6/, 11/	X	X	X		X
	(2) 0.30 in (0.7 mm) in diameter and greater than 0.060 in (1.5 mm) in depth, 11/	X	X	X	X	
	(3) 0.18 in. (4.7 mm) in the longest lateral direction but not more than 0.31 in (7.9 mm) and 0.030 in (0.7 mm) in depth, 5/, 6/, 11/	X	X	X		X
	(4) Greater than 0.31 in. (7.9 mm) in the longest lateral direction and 0.030 in (0.7 mm) or less in depth, 11/					
	j. Rivelet - over 1.5 in. (38 mm) in length, 10/	X		X	X	

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TABLE III. Classification of characteristics applicable to ceramic plate by visual, liquid penetrant, and radiographic examination; defects applicable to composite armor plate by visual; defects applicable to completed armor plate by radiographic examination (Cont'd).

Material	Characteristics	Methods of examination: Visual	Liquid Penetrant	Radiographic	Classification: Major	Minor
	k. Edge chip on either surface:					
	(1) Greater than 0.375 in. (9.5 mm) in any lateral direction, but not more than 0.75 in. (19 mm) and 0.06 in. (1.6 mm) or less in depth, 5/, 11/	X	X			X
	(2) Greater than 0.75 in. (19 mm) any lateral direction and 0.06 in. (1.6 mm) or less in depth, 11/	X	X		X	
	(3) Greater than 0.06 in. (1.6 mm) depth but not more than 0.125 in. 5/, 11/	X	X			X
	(4) Greater than 0.125 in. (3.1 mm) in depth, 11/	X	X		X	
	l. Scratch or gouge:					
	(1) 0.030-0.060 in (0.7-1.5 mm) in depth, 5/, 6/, 11/	X	X			X
	(2) Greater than 0.060 in (1.5 mm) in depth, 5/, 11/	X	X		X	
	m. Any mend or patch, 5/, 11/	X			X	
	n. Markings (Serial No.) omitted, not located or applied as specified, 11/	X				X
Fiber-glass laminate component	a. Any delamination from the ceramic component, 11/	X			X	
	b. Exposed fibers on edge, 11/	X				X
	c. Any blister, crack, torn fabric, crazing, dents or surface roughness, 11/	X				X
	d. Any delamination of fiber-glass plies, 11/	X				X

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TABLE III (Footnotes)

1/ Radiographic examination of the completed armor will be made to ascertain only cracks which may have occurred in the manufacturing process subsequent to the initial radiographic examination.

2/ Edge cracks are defined as those within the 1.5 in. (38 mm) boundary around the periphery of the ceramic component.

3/ Cracks other than edge cracks are defined as those beyond the 1.5 in. (38 mm) edge boundary or those that start within the 1.5 in. edge boundary and extend beyond the 1.5 in. (38 mm) boundary.

4/ For the purposes of radiographic examination and interpretation, the following definitions or descriptions shall apply:

Cracks. Dark, well-defined line or lines having sharp terminal points indicating a break in the ceramic material.

Shrinkage cavities or filamentary unfilled indications. Dark, sharply defined wavy or irregular line or lines usually less than 0.75 inch (19 mm) in length, occurring within the ceramic material and indicating an internal discontinuity.

Internal voids or unfilled areas. Round or elongated, smooth edged dark spots occurring individually or randomly distributed within the ceramic material.

Sponge. Dark localized area or areas occurring within the ceramic and indicating low ceramic density or high porosity.

Silicon Rich Area. A lighter localized area or areas indicating a high concentration of silicon within the ceramic.

5/ All such minor surface defects so identified in the visual and liquid penetrant examination shall be described, located and annotated so that they will not be identified as internal voids or unfilled areas (defect h) when and if the ceramic plate is subjected to radiographic examination.

6/ Any two minor defects on the surfaces of the ceramic, except within the 1.5 in. (38 mm) edge boundary, less than 0.375 in. (9.5 mm) apart shall be classified as a major defect.

7/ Applies to aluminum oxide only.

8/ Applies to silicon carbide only.

9/ Applies to boron carbide silicon carbide silicon only.

10/ Applies to boron carbide only.

11/ Applies to all classes.

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4.3.5 Inspection of the end item.

4.3.5.1 Visual inspection of completed armor plates. The completed armor plates shall be examined for defects in assembly, construction, material and workmanship. Defects shall be scored in accordance with the list below. The sample unit shall be one armor plate. The inspection level and the acceptable quality level (AQL) shall be as specified in 4.3.5.2.

Examine	Defect	Classification Major	Minor
Spall cover	Cut, hole, tear or abraded area:		
	- Up to 0.125 in.(3.1 mm) in length.		X
	- More than 0.125 in.(3.1 mm) in length.	X	
	Any wrinkle or crease		X
	Any mend or patch.		X
	Any area not bonded to ceramic plate:		
	- More than 0.25 in. (6.3 mm) but less than 0.5 in. (12.7 mm) in longest lateral direction.		X
	- 0.5 in. (12.7 mm) or more in longest. lateral direction.	X	
Spall cover edge strip			
	Cut, hole, tear or abraded area:		
	- Up to 0.125 in.(3.1 mm) in length.		X
	- More than 0.125 in.(3.1 mm) in length.	X	
	Any mend or patch.		X
	Not cut on a bias		X
	Edges or ends not fused.		X
	Made with more than two pieces		X
	Any area not bonded to armor plate:		
	- More than 0.25 in.(6.3 mm) but less than 0.5 in.(12.7 mm) in longest lateral direction.		X
	- 0.5 in.(12.7 mm) or more in longest		
	- lateral direction.	X	
	Any wrinkle or crease except where required in forming corners		X
	Ends not overlapped.	X	
Cleanliness	Grease or oil stains clearly noticeable.		X
	Thread ends not trimmed throughout.		X
	Adhesive smeared on webbing, fastener tape, spall cover, or spall cover edge strip.		X
Construction and workmanship	Any component missing or not assembled as specified (unless otherwise classified herein).	X	
	Fiberglass surface not coated with Olive Drab finish.		X

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4.3.5.2 Inspection levels and acceptable quality levels (AQLs) for end item inspection. Inspection levels and acceptable quality levels (AQLs) for each examination shall be as indicated below:

Examination	Inspection level	AQL Major	AQL Total
4.3.5.1	II	1.5	4.0

4.3.5.3 Radiographic examination of completed armor plate. The completed armor plate shall be radiographically examined. The same ceramic components examined in 4.3.4.3, and processed in the normal manner with the production lot, shall be examined in this examination. Industrial radiography shall be carried out in accordance with Appendix C. Radiography shall include the entire ceramic component area and shall contain the same permanent marking as the ceramic component. Radiographic films shall be made available to the Government upon request. The radiographic equipment and procedures shall be in accordance with that specified in Appendix C.

4.3.5.3.1 Initial production lot. One hundred percent radiographic inspection of the initial lot of completed armor plates shall be conducted. Defects shall be classified in accordance with the applicable defects listed in Table III. For each completed armor plate the acceptance number for major defects shall be zero and for minor defects three. Any completed armor plate found with one or more major defects or four or more minor defects shall be rejected.

4.3.5.3.2 Production lots after initial lot. All production lots after the initial lot shall also be radiographically inspected. The sample unit shall be one armor plate. The inspection level shall be II. The acceptable quality levels shall be 0.25 percent defective items. A defective item is a ceramic component containing one or more major defects or four or more minor defects when examined for defects listed in Table III.

4.4 Testing. The armor shall be tested for the characteristics listed in Table IV. The sample unit for ballistic and areal density tests shall consist of 10 randomly selected armor plates and for all other tests, the sample unit shall be one armor plate. When more than one size is in the lot, the sample unit used in the ballistic test shall contain at least two of each size. The inspection level shall be S-1 and the AQL shall be 4.0 expressed in defects per hundred units. There shall be no evidence of failure to meet the requirements specified. All ballistic test results obtained on preaward and production testing shall be classified confidential.

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Table IV. Instructions for testing.

Characteristics	Specs Reference Requirement	Test Method	Requirements Applicable To Sample Unit	Lot Avg	No. Deter. per Unit	Results Reported As Pass or Fail	Numerically to nearest
Ballistic resistance 2/	3.7.1	4.5.1	X		1 1/	X	ft/s
Temperature resistance 4/	3.7.2	4.5.2	X		1	X	
Adhesion of spall cover	3.7.3	4.5.3	X		1	X	
Areal density 2/, 3/	6/	4.5.4	5/	3/			0.1 lb/ft^2

1/The plate having the lowest areal density shall be tested first. Each succeeding plate tested shall be the next plate having the lowest areal density.

2/Areal density test and ballistic test shall be conducted on the same sample.

3/Areal density to be performed on each armor plate of the sample unit.

4/Tested prior to the application of the spall cover, spall edge strip, surface coating.

5/Requirements applicable to individual plates. All thickness determinations shall be reported.

6/Areal density shall be as specified by the contracting officer.

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4.5 Test procedures.

4.5.1 Ballistic test for armor. The ballistic test shall be conducted in accordance with Appendix B unless otherwise specified by the contracting officer. The areal density shall be reported for each test plate.

4.5.2 Temperature extremes test. The armor plate, less the spall cover and spall cover edge strip, shall be heated in an oven operating at 160° ± 5°F (71° ± 2° C) for 6 ± 0.25 h. The test specimen shall then be allowed to cool to room temperature followed by cold exposure at -65° ± 5° F for 6 ± 0.25 h. The specimen shall be allowed to warm to room temperature and shall then be examined at edges for evidence of delamination of the fiberglass plies.

4.5.3 Adhesion test for spall cover. The sample for this test may be made from an armor plate which has been tested ballistically using an undamaged area, or a small test specimen made identically to the armor plate with respect to surface preparation, adhesive, application and bonding. Make parallel cuts through the spall cover 4 in. (102 mm) long and 1 in. (25 mm) apart along weave. At one end of the cut, make a cut at a right angle so that a 1 in. x 2 in. (25 mm x 51 mm) tab can be peeled from the armor plate. Attach a 2 lb (0.9 kg) weight to this tab so that the resultant peel force is normal to the plane of the armor plate. Make gage marks on the specimen for the measurement of the amount of peeling during the test. Allow the weight to stand for four hours minimum at room temperature. Any visual peeling of the tab constitutes failure of the test.

4.5.4 Areal density. The areal density in pounds per square foot (lb/ft^2) of the composite armor plate, without spall cover, spall cover edge strip, surface coating, label and integrated carrier, shall be calculated from measurements on the composite armor plate. The composite armor plate shall be weighed to the nearest 0.01 lb. The thickness shall be measured to 0.001 in. at four corner locations on the composite armor plate. Six measurements shall be made at each corner with the first measurement taken approximately 1.0 in. from the edge of the corner and the remaining five taken on a straight line toward the center of the armor with the measurements spaced in approximately 1 inch increments. Three measurements shall be taken at the low points of the fabric weave and three at the high points. A deep throat type depth gage conforming to Federal Products Corp. Model KP125 or KP129, or equal, shall be used for taking measurements. The average of the 24 readings shall be used in the calculation of the areal density. The edges of the glass fiber laminate shall be painted with a slow drying lacquer to seal the edges. The lacquer shall be allowed to dry (at least 0.5 h) before proceeding with the determination of density. The average density of the composite armor plate shall be determined by Method A-3 of ASTM D 792, except the immersed weight shall be determined to 0.01 lb and the liquid used shall be clean tap water, containing a wetting agent if necessary, which shall be changed just prior to examination of each lot. The areal density of the composite armor plate, without spall cover and spall cover edge strip, shall be calculated to the nearest 0.1 lb/ft^2 as follows:

$$\text{Areal density } (lb/ft^2) = 5.202 \times \text{Density } (g/cm^3) \times \text{Thickness (in)}.$$

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5 PACKAGING

5.1 Preservation and packaging. Preservation and packaging shall be as specified in the contract or end item specification.

6. NOTES

6.1 Intended use. The lightweight ceramic armor covered by this specification is intended for use in applications when resistance to armor piercing projectiles and limited multi-hit capability are required.

Type I - Type I materials are intended primarily for use in applications requiring ballistic protection against Caliber .30 AP M2 and small arms projectiles.

Type II - Type II materials are intended primarily for use in applications requiring ballistic protection against Caliber .50 AP M2 and small arms projectiles.

Type III - Type III materials are intended primarily for use in applications requiring ballistic protection against Caliber .30 Ball M2 and small arms projectiles.

6.2 Ordering data. Procurement documents should specify the following:

a. Title, number and date of this specification.

b. Type, class and size required (see 1.2, 3.10)

c. Special physical properties when desired (see 3.4, 3.1.2.2).

d. Ballistic test facility (see Appendix B).

e. Requirements for ballistic samples when other than in 3.7.1.

f. Requirements for multiple tile or monolithic ceramic construction.

g. Requirements for ballistic resistance of multiple tile ceramic arrays if other than that stated in 3.7.1.

6.3 Certification testing. The certification test is intended to ascertain that fabrication procedures are capable of producing satisfactory armor. This test need not be repeated so long as the design and materials of the parts being produced remain unchanged, except as may be required in 4.1.

6.4 Definitions.

6.4.1 Contractor. The term "contractor" is defined as the organization having a direct contract with the procuring activity.

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6.4.2 Manufacturer. The term "manufacturer" is defined as the organization actually performing the operations covered by this specification.

6.4.3 V_{50} protection ballistic limit, BL(P). The protection V_{50} ballistic limit is defined as the average of 6 fair impact velocities comprising the 3 lowest velocities resulting in complete penetration and the 3 highest velocities resulting in partial penetration. A maximum spread of 125 ft/s shall be permitted between the lowest and highest velocities employed in determination of ballistic limits.

6.4.4 Protection complete penetration, CP(P). A protection complete penetration will have been obtained when the projectile of a fragment or the projectile or a fragment of the ballistic test plate is thrown beyond the rear face of the plate with sufficient energy to perforate an approximately 0.020 in. thick sheet of 2024-T3 aluminum alloy placed parallel and 6 ± 0.5 in. (152 ± 12 mm) behind the plate.

6.4.5 Partial penetration PP(P). Any fair impact that is not a complete penetration shall be considered a partial penetration.

6.4.6 Fair impact. A fair impact results when a projectile of less than 3° yaw strikes an unsupported area of the ballistic test plate at least 1.5 in. from the outside edge of the ceramic component. (The imported area shall contain no belts, buckles, webbing, etc.)

6.5 Disposition of ballistic test plates.

6.5.1 First article test plates. At the time of shipment of the test plates, the government agency should be informed by the manufacturer, in writing, as to the disposition of acceptance plates that fail the test. If instructions for disposal of the tested plates are not received after 15 days, the government agency will exercise the prerogative of disposing of the material.

6.5.2 Acceptance test plates. Acceptance test plates that comply with the requirements of this specification are considered as part of the lot they represent. Ownership of the test plates passes to the government with acceptance of that lot. Acceptance test plates that fail to comply with the requirements of this specification are considered as part of the lot, and remain the property of the producer. The rejected plates will be returned, upon request, as in 6.5.1.

6.6 Mold release agents. Manufacturers are advised not to use mold release agents that are difficult to wash off or which are known to interfere with adhesive bonding.

6.7 Adhesive for spall cover. Minnesota Mining and Manufacturing Company adhesive EC 1300 has been used in the manufacture of prototype items to adhere the spall cover.

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6.8 Fabrication of fiberglass laminate. Fabrication of the fiberglass laminate has been made by the following technique: One piece pressed ceramic plates were used as molds. The fabrication technique consisted of hand laying the polyester impregnated glass cloth into the ceramic cavity. The mold was fitted with a polyvinyl alcohol (PVOH) vacuum bag and the assembly placed in an autoclave. The evacuated assembly was pressurized at 100 psi (689 kPa) at room temperature for two hours and then subjected to a temperature of 200°F (93°C) for 3 h without removing the pressure. The assembly was removed from the autoclave and allowed to cool to room temperature. The ceramic was removed and the front of the fiberglass laminate backing abraded to provide good adhesion when cemented to the ceramic piece.

6.9 Certification activity. Unless otherwise designated, the Army Materials & Mechanics Research Center (AMMRC), Watertown, MA, is responsible for the certification of radiographic examination facilities and procedures, and for the certification of ballistic testing facilities and equipment.

6.10 First article instructions. The item covered by this specification requires first article inspection and approval under the appropriate provisions of paragraph 7-104.55 of the Armed Services Procurement Regulations. The first article should be a preproduction sample. The first article should consist of one completed armor plate. The contracting officer should include specific instructions in all procurement instruments, regarding arrangements for examination, test and approval of the first article.

6.11 Flammability. ASTM D 635 should be used to measure and describe the properties of materials, products, or systems in response to heat and flame under controlled laboratory conditions and should not be used for the description or appraisal of the fire hazards of materials, products, or systems under actual fire conditions.

6.12 Changes from previous issue. Asterisks are not used in this revision to identify changes with respect to the previous issue due to the extensiveness of the changes.

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

Preparing activity:
Army - MR

Project No. 9390-0068

Review activities:

Army - AV, GL, AL, AT, TE
Navy - SH

User activities:
Army - ME
Navy - OS, MC
Air Force - 18

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APPENDIX A

RECORDED FABRICATION PROCEDURES

10. SCOPE

10.1 Scope. This appendix contains a suggested format for the submittal of the recorded fabrication procedures.

20. INSTRUCTIONS

20.1 Recorded procedure. The recorded procedure consists of pertinent information on an approved form.

20.1.1 Sheet one, title sheet.

a. Record number. Number selected by the contractor or manufacturer to designate a particular procedure.

b. Manufacturer. Name of company fabricating the lightweight composite armor.

c. Location. Full address of manufacturer including street and zip code.

d. Approval of manufacturer. Signature of responsible employee of the company holding the Government contract.

e. Approval of contractor. Signature of responsible employee of the company holding the Government contract.

20.1.2 Sheet two, drawing showing composite construction. This sheet should contain an isometric or perspective drawing or sketch showing the assembly. Additional sheets may be used if additional views are required. Dimensions are not required, but the drawing or sketch should indicate the relationship of components.

20.1.3 Sheet three, summary sheet.

a. Procedure record number. Reference number from sheet 1 and carried on each additional sheet for identification.

b. Summary of fabrication procedure. Description of materials, preparation, assembly and conditioning or curing procedures.

c. Material references. Designation of materials compositional limit(s) for ceramic plates, backing adhesive bonding and spall shields.

d. Cleaning and preparation. Statement of treatments given materials for cleaning and preparation prior to assembly.

e. Dimensions. Dimensions and tolerances.

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APPENDIX B

BALLISTIC TEST

10. SCOPE

10.1 Scope. This appendix delineates the level of ballistic resistance required for lightweight composite armor composed of ceramic bonded to non-metallic backing materials.

20. EQUIPMENT

20.1 Gun mount. The gun mount must be capable of firing the Caliber gun necessary to achieve the velocity required for the conduct of the test.

20.2 Test sample mounting. The armor test sample shall be secured in the vertical position, perpendicular to line-of-flight of projectile, using quick release clamps. The frame supports and clamps must be capable of retaining the sample and withstanding shock resulting from ballistic impact by Caliber .30 AP M2, Caliber .30 Ball M2 or Caliber .50 AP M2 projectiles. The test sample mounting must be capable of adjustment for moving the sample in the vertical or horizontal directions so that the point of impact can be located anywhere on the sample, and rotation on the vertical axis so that zero degree obliquity impacts can be achieved anywhere on the sample. Mounting the test sample in a frame suspended from overhead by means of steel cables, wires or chains has been found to be an acceptable method of test sample mounting.

20.3 Weapon. As specified.

20.4 Projectile. As specified.

20.5 Witness plate. The witness plate shall be a 2024-T3 or 2024-T4 aluminum alloy sheet, 0.014-0.020 in. thick (0.3-0.5 mm) and shall be a minimum of 11 in. x 14 in. (279 mm x 355 mm) in size, located 6 $\pm$ 0.5 in. (152 $\pm$ 12 mm) behind and parallel to the target. (Not shown in Figure 1.)

20.6 Velocity measuring equipment.

20.6.1 Chronograph. An electronic counter type chronograph measuring to at least the nearest microsecond (10^{-6} s).

20.6.2 Detectors. Either high-velocity luminline screens, or electrical contact screens which either open or close an electrical circuit by passage of the projectile through the detector. Contact screens may consist of metallic foils separated by a thin insulating layer, or may consist of a circuit printed on paper with the circuit spacing such that the projectile passing through the screen will "break" the circuit. Three velocity screens and three time interval counters are to be used as shown in Figure 1. This system provides an average bullet velocity, V_a between the screens. It is a self checking system that gives V_a over the base line and a V_a over two intervals of the base line. The recorded average velocities must check, e.g., they should be in descending order over the base line.

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20.7 Propellant. Any propellant which is standard for the weapon may be used. A projectile velocity - propellant charge curve for the weapon shall be determined before any testing is performed. This curve is required to provide a basis for selecting a powder charge to achieve a desired velocity. It is recommended that the propellant storage and weighing area be maintained at 72° ± 1.8° F (22 ± 1° C) and 50 ± 5% relative humidity.

20.8 Ballistic resistance. The V_{50} ballistic limit of the preceding types and classes of composite armor shall meet or exceed values specified in 3.7.1.

20.9 Multiple tile armor. If armor consists of an array of multiple tiles, the impacts will be within ± 2 projectile diameters from joint intersections. A reduction of 5% in the ballistic levels indicated in 3.7.1 will be permitted unless the contract specified that the ballistic resistance of joints be as specified in 3.7.1.

20.10 Spall shield. If armor is tested with a spall shield consisting of one layer of MIL-C-12369 ballistic nylon fabric bonded to the front ceramic surface, a reduction of 2% in the ballistic level indicated in 3.7.1 will be permitted.

30. SETUP:

30.1 Equipment setup. The required setup for the ballistic equipment is shown in Figure 1.

40. DATA SHEETS

40.1 Data sheet information. Data sheets will contain the following information:

a. Item specification number.
b. Material description (including physical characteristics if required).
c. Material identification number for each test sample.
e. Temperature and humidity of the test facility.
f. Date.
g. Personnel conducting test and any witnesses.
h. Weapon used.
i. Projectile used.
j. Projectile weight, grains.
k. Type of propellant.
l. Weight of propellant for each shot, grains.
m. Impact velocities used in computing V_{50}'s with highest partial penetration, lowest complete penetration, range (spread), and velocities of rounds all being listed.
n. Witness plate characteristic, partial or complete.
o. Calculated ballistic limit (V_{50}).
p. Any reports pertinent to the conduct of the test, or behavior of the material.

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50. PROCEDURE

50.1 Marking procedure. Areal density must have been previously determined on the test samples before they are tested ballistically. Test sample configurations will vary according to end item application. For body armor plates, the marking procedure will be as indicated in (a) through (e) and Figure 2. For other configurations the marking of the ceramic armor plates shall be as agreed upon between the manufacturer and the procuring activity.

a. The approximate center of the test sample will be located.

b. From the center of the test sample, a line is drawn to the center of the bottom of the test sample.

c. From the center of the test sample, lines are drawn on both sides of the test sample to the sample to the nearest edge (the narrowest portion of the test sample). See Figure 2.

d. The upper area is marked A, the lower right area B, the lower left area C, respectively.

e. The first test sample will be impacted in Area A, the second in Area B, the third in Area C. Each successive test sample will be fired in the same order, i.e., Areas A, B, and C. Only one shot will be fired in each test sample. All shots shall be fired at the approximate center of the area to be impacted.

50.2 Warm-up procedure for constant velocity. A test round will be fired through a witness plate to determine the exact position of impact. At least three additional rounds shall be fired using the appropriate projectile striking velocity - propellant charge curve for the weapon being used, and selecting propellant weights to achieve the specified velocity. The last of these rounds shall be within the range of ± 25 ft/s (7.6 m/s). If it is not, additional rounds shall be fired and the projectile velocity - propellant charge curve corrected until constant velocity is achieved. The propellent charge for the last warm-up round shall be considered the reference charge for the test. The reference charge may be redetermined between tests whenever difficulty is experienced in completing the last test. The entire procedure must then be repeated. All reference velocities, and propellent charges developed for a test or utilized from a previous test shall be recorded for the procedure with the test that immediately follows. This procedure must be repeated for succeeding tests if the weapon has not been fired within two hours previous to the test.

50.3 Point of impact and obliquity. The sample will be mounted as described in 20.2. The point of impact will be located on the test sample as described in the Procedure, Item a, and will be positioned to line up with the previously determined line of flight. The point of impact is not checked for obliquity. The obliquity shall be 0 ± 5 degrees. The angle of obliquity is determined by the angle formed by a perpendicular to a plate tangent to the point of impact and line of flight of the projectile. The obliquity can be determined by any suitable method, however, it is important that the obliquity is determined with respect to the line of flight, and not any other reference.

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A single sheet of processed photographic paper positioned 6-12 inches (152-305 mm) in front of target, perpendicular to line of fire, will be used to measure yaw. The sheet can be taped to the rear of the last velocity screen. Once the point of impact has been determined on the test sample, and the obliquity fixed, the gun and velocity screen distance must not be changed until the test has been completed.

50.4 First firing. The first round is loaded with the reference propellent charge and fired into the sample, and the reading on the chronographs recorded. The velocity is computed and recorded.

50.5 Penetration of witness plate. The witness plate is examined for penetration. A complete penetration is recorded when the witness plate is held up to a light and any penetration is noted, regardless of what has penetrated the witness plate. If no light is visible through the witness plate, a partial penetration is recorded.

50.6 Subsequent firings. If the first round fired yields a complete penetration, for the second round use a propellant charge equal to that of the first minus the propellant decrement for 50 or 100 ft/s (15 or 30 m/s) in an attempt to obtain a partial penetration. If the first round yields a partial penetration, use a propellant charge for the second round equal to that of the first round plus a propellant increment for 50 ft/s (15 m/s) in an attempt to obtain a complete penetration. A propellant increment or decrement, as applicable, for at least 50 ft/s (15 m/s) should be used until one partial and one complete penetration is obtained. After obtaining a partial and complete penetration, the propellant increment or decrement for 50 ft/s (15 m/s) should be used. Continue firing using this up (on a partial penetration) and down (on a complete penetration) method until at least 3 complete and 3 partial penetrations having a velocity spread not greater than 125 ft/s (38 m/s) is obtained (see 50.8). The V_{50} BL(P) will be computed by averaging the three high PP(P) velocities and the three low CP(P) velocities within 125 ft/s (38 m/s) allowable velocity spread.

50.7 Calculation of ballistic limit. The ballistic limit (V_{50}) is calculated by taking the arithmetic mean of the 3 lowest velocities producing complete penetration and the 3 highest velocities producing partial penetration, provided the velocity spread for the 6 rounds is not greater than 125 ft/s (38 m/s). If, after all samples in the sample unit have been tested and it was not possible to obtain the 3 lowest velocities for complete penetrations and the 3 highest velocities for partial penetrations within a spread of 125 ft/s (38 m/s), then the ballistic limit (V_{50}) calculation shall be based on one of the following two alternatives. First, the 3 lowest velocities for complete penetration and the 3 highest velocities for partial penetration within a spread of 150 ft/s (45 m/s). If none of the preceding ballistic limit (V_{50}) calculation stipulations regarding test velocity spreads apply, then all the valid test velocity values shall be examined to determine whether there are at least 3 partial penetration velocities above 2850 ft/s (868 m/s), and that there are no complete penetration velocities lower than 2850 ft/s (868 m/s).

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If these conditions are satisfied, the sample unit will be considered to have met the ballistic limit (V_{50}) requirement in 3.7.1. If none of the acceptable calculation prodedures can be applied, and if the analysis of the individual test velocities show that they do not meet the requirement for partial penetration velocities higher than 2850 ft/s (868 m/s), and no complete penetration velocities lower than 2850 ft/s (868 m/s), then the sample unit shall be considered to have failed the ballistic limit (V_{50}) requirement.

50.8 Ballistic limit (V50) requirement. The ballistic limit (V_{50}) must be equal to or greater than 2850 ft/s (868 m/s) in order to pass the ballistic test requirement.

50.9 Minimum number of plates to be tested. A V_{50} protection ballistic limit shall be determined from single round fair impacts on each of at least six composite armor plates of the ballistic sample unit.

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C_1, C_2, C_3 - TIME INTERVAL COUNTERS

S_1, S_2, S_3 - VELOCITY SCREENS

NOTE: Measurements to be taken to the nearest 0.01 ft (0.3 m).

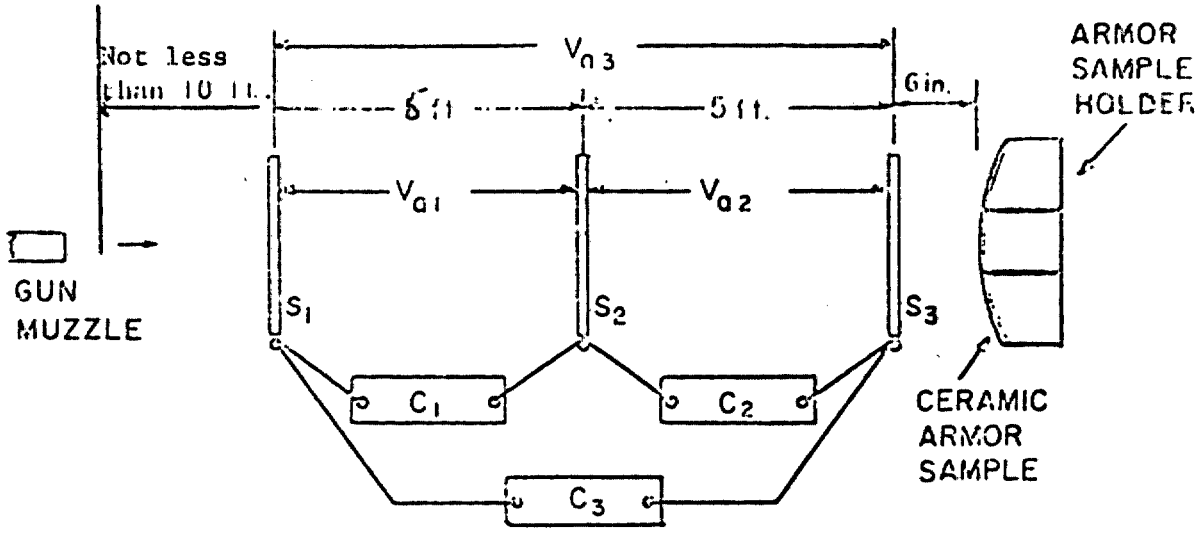

FIGURE 1. Instrumentation setup for ballistic testing of ceramic armor sample

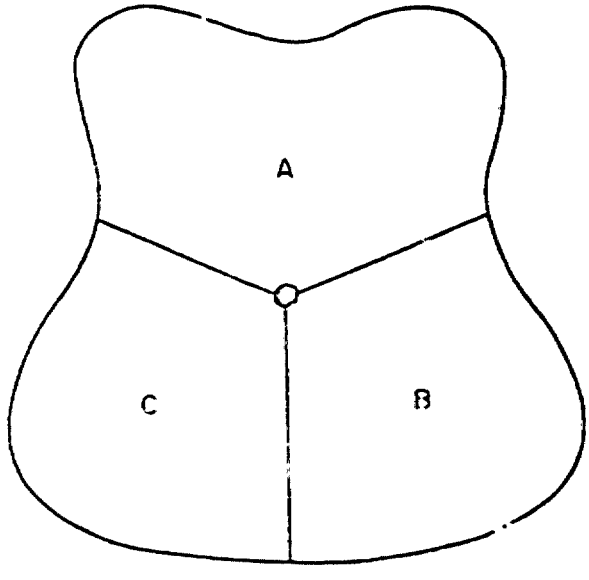

FIGURE 2. Marking of test sample (body armor plate)

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APPENDIX C

RADIOGRAPHIC REQUIREMENTS FOR THE EXAMINATION OF CERAMIC ARMOR PLATES

10. SCOPE

10.1 Scope. These instructions establish suggested radiographic inspection processes to be used for the examination of ceramic armor materials.

10.2 Application. Radiographic inspection is applicable for the detection of internal discontinuities in ceramic armor plates and concurrently providing a permanent and ready future reference of internal conditions.

20. APPLICABLE DOCUMENTS

20.1 Government documents.

20.1.1 Specifications and Standards.

SPECIFICATIONS

MILITARY

MIL-R-11470 - Radiographic Inspection, Qualification of Equipment, Operators and Procedures

STANDARDS

MILITARY

MIL-STD-453 - Inspection, Radiographic

30. EQUIPMENT

30.1 Equipment.

a. 150 kv X-ray equipment
b. Transmission densitometer
c. Penetrameters and stepwedges
d. Fine grain film and film envelope
e. Lead letters and numerals for X-ray film/part identification
f. Sheet lead 0.125 in. (3.1 mm) thick to conform to ceramic armor plate
g. High intensity radiographic viewer
h. 10X magnifier and film processing facilities

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40. TEST METHOD

40.1 Equipment requirements. Unless otherwise specified, all radiographic test equipment and procedures shall conform to the requirements of paragraph 20, Applicable Documents.

40.2 Other methods. When other inspection methods are used in addition to X-ray, the X-ray inspection shall be performed prior to more expensive methods and subsequent to less expensive methods.

40.2.1 Condition of parts. Parts or material showing evidence of inadequate visual or penetrant inspection or parts not in a suitable condition for radiographic inspection shall not be inspected unless properly prepared and recycled.

40.3 Radiographic identification.

40.3.1 Marking of radiographs. Each radiograph shall be permanently marked with the name of the test laboratory, X-ray control or test number, part serial number, if any, and view number. All identification markings shall be outside the area being inspected whenever practical.

40.3.2 Radiographic envelopes. Each radiograph envelope shall contain no more than 12 radiographs and shall list plate serial numbers of the radiographs contained therein. Each envelope shall also bear a rubber stamp image outlining exposure factors and technique employed.

RADIOGRAPHIC TEST RECORD

Date_____ Material_____ Thickness_____

Kilo Voltage _____ M.A._____ Exp. Time _____

Film Type_____ Screens_____

FF Distance_____ Equipment_____

H&D Equipment_____ No. of Exposures_____

Remarks_____

40.4 Radiographic coverage. Two radiographs, each representing at least half of each ceramic plate, shall be made to effect 100% radiographic coverage. In order to avoid image distortion, each exposure shall be made with the ceramic plate angulated or propped so as to be as close as possible to the X-ray beam.

40.5 Radiographic technique. A standard X-ray technique for each ceramic material and type or design shall be established subject to the approval of the procuring agency.

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40.5.1 Density range. All radiographs shall be in the H&D density range of 1.5-2.2±0.20.

40.5.2 Quality level. The radiographic quality level shall be 2-2T. Radiographic equivalence systems shall be permitted using stepwedges and penetrameters exhibiting the same radiographic attenuation properties as ceramic armor materials.

40.5.3 X-ray techniques (boron carbide). The suggested X-ray techniques for high purity boron carbide ceramic armor materials and composites shall be as follows:

Ceramic plate only.
Ground Troop - 50 kv, 15 Ma, 40"FFD, 2'0", Kodak M, NS.
Aircrewman - Same.

Complete Composite.
Ground Troop - 70 kv, 5 Ma, 40"FFD, 1'45", Kodak M, NS.
Aircrewman - Same.

40.5.4 X-ray techniques (modified boron carbide). The suggested X-ray techniques for modified boron carbide ceramic armor materials and composites shall be as follows:

Ceramic plate only.
Ground Troop - 60 kv, 18 Ma, 40"FFD, 1'50", Kodak M, NS.
Aircrewman - Same.

Complete Composite.
Ground Troop - 70 kv, 10 Ma, 40"FFD, 1'20", Kodak M, NS.
Aircrewman - Same.

40.5.5 X-ray techniques (silicon carbide). The suggested X-ray techniques for silicon carbide ceramic armor materials and composites shall be as follows:

Ceramic plate only.
Ground Troop - 70 kv, 10 Ma, 40"FFD, 1'15", Kodak M, NS.
Aircrewman - Same.

Complete Composite.
Ground Troop - 70 kv, 15 Ma, 40'0"FFD, 1'20", Kodak M, NS.
Aircrewman - 80 kv, 10 Ma, 40"FFD, 1'30", Kodak M, NS.

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40.5.6 X-ray techniques (aluminum oxide). The suggested X-ray techniques for aluminum oxide ceramic armor materials and composites shall be as follows:

Ceramic plate only.
Ground Troop - 80 kv, 5 Ma, 40"FFD, 1'30", Kodak M, NS.
Aircrewman - Same.

Complete Composite.
Ground Troop - 80 kv, 10 Ma, 40"FFD, 1'30", Kodak M, NS.
Aircrewman - Same.

40.5.7 Penetrameters. Penetrameters shall be placed so as not to obscure X-ray images. Penetrameters holes and outline shall be as specified in MIL-STD-453.

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APPENDIX D

LIQUID PENETRANT REQUIREMENTS FOR THE EXAMINATION OF CERAMIC ARMOR PLATES

10. SCOPE

10.1 Scope. These instructions establish the suggested liquid penetrant inspection process to be used for the examination of ceramic armor materials.

10.2 Application. Liquid penetrant inspection is applicable for the detection of surface discontinuities and shall be applied prior to radiography.

20. APPLICABLE DOCUMENTS

20.1 Government documents.

20.1.1 Specifications and Standards.

SPECIFICATIONS

MILITARY

MIL-I-6866 - Liquid Penetrant Inspection Method
MIL-I-6870 - Inspection Program Requirements, Nondestructive Testing for Aircraft and Missile Materials and Parts
MIL-I-25135 - Inspection Materials, Penetrant

STANDARDS

MILITARY

MIL-STD-410 - Nondestructive Testing Personnel Qualification and Certification

20.2 Other publications.

AMERICAN SOCIETY FOR TESTING AND MATERIALS

E165 - Liquid Penetrant Inspection Method

30. EQUIPMENT

30.1 Requirements. The equipment required shall be capable of performing uniform controlled operation using ASTM Test Procedures A1 and B3.

30.2 Penetrant materials. For procedure A1, Magnaflux 2L-17B penetrant shall be used. For procedure B3, Magnaflux SKL-HF penetrant shall be used.

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40. TEST METHOD

40.1 Procedures. The test procedures as outlined in ASTM E 165 (procedure A1 for high purity and modified boron carbide and procedure B3 for aluminum oxide) shall be used.

40.2 Markings. All discontinuities detected shall be marked for further evaluation or disposition.

40.3 Use of magnifying lens. A ten power magnifying lens with or without illumination shall be used as necessary to assure accurate detection or indications.

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APPENDIX E

VISUAL INSPECTION REQUIREMENTS FOR THE EXAMINATION OF CERAMIC ARMOR PLATES

10. SCOPE

10.1 Scope. These instructions establish suggested visual inspection process to be used for the examination of ceramic armor materials.

10.2 Application. Visual inspection is applicable for the detection of surface discontinuities and shall be applied prior to any other nondestructive test.

20. EQUIPMENT

20.1 Equipment.

a. Suitable work bench.
b. Ten power magnifier.
c. Suitable lighting (can be part of magnifier).
d. Scales or graduated magnifiers for recording diameter of flaw.
e. Suitable gage for measuring depth of flaw.

30. TEST METHOD

30.1 Visual examination. Each ceramic plate shall be carefully examined visually using ten power magnification where necessary. Flaw type indications shall be identified and measured.

30.2 Marking. All discontinuities detected shall be marked for further evaluation or disposition.

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MIL-A-46103C, ARMOR: LIGHTWEIGHT, CERAMIC-FACED COMPOSITE, PROCEDURE REQUIREMENTS (FSC 9390)

NAME OF ORGANIZATION AND ADDRESS OF SUBMITTER

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