

INCH-POUND

MIL-B-44421(GL)  
21 February 1991

## MILITARY SPECIFICATION

## BODY ARMOR, SMALL ARMS PROTECTIVE, AIRCREW, SURVIVAL

This specification is approved for use by the Natick Research, Development, and Engineering Center, Department of the Army, and is available for use by all Departments and Agencies of the Department of Defense.

## 1. SCOPE

1.1 Scope. This specification covers a ceramic body armor insert to be worn by aircrew personnel. The body armor when inserted into the carrier and worn is intended to provide protection from small arms fire. The body armor is part of an aircrew survival system. This is a special purpose Life Support Clothing and Equipment (LSC&E) item. All Government administrative and surveillance procedures applicable to LSC&E items shall be invoked in accordance with the contract or purchase order (see 6.2).

1.2 Classification. The body armor shall be of the following sizes as specified (see 6.2):

Short  
Medium  
Long  
X-Long

## 2. APPLICABLE DOCUMENTS

2.1 Government documents.

2.1.1 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

Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be used in improving this document should be addressed to: U.S. Army Natick Research, Development, and Engineering Center, Natick, MA 01760-5019 by using the Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

AMSC N/A

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are those listed in the issue of the Department of Defense Index of Specifications and Standards (DODISS) and supplement thereto, cited in the solicitation (see 6.2).

## SPECIFICATIONS

## FEDERAL

- DDD-L-20 - Label: For Clothing, Equipage and Tentage, (General Use)
- PPP-B-636 - Boxes, Shipping, Fiberboard

## MILITARY

- MIL-C-12369 - Cloth, Ballistic, Nylon
- MIL-L-35078 - Loads Unit: Preparation of Semiperishable Subsistence Items; Clothing, Personal Equipment and Equipage; General Specification For

## STANDARDS

## MILITARY

- MIL-STD-105 - Sampling Procedures and Tables for Inspection by Attributes
- MIL-STD-129 - Marking for Shipment and Storage
- MIL-STD-147 - Palletized Unit Loads
- MIL-STD-453 - Inspection, Radiographic
- MIL-STD-970 - Standards and Specifications, Order of Precedence For the Selection of

(Unless otherwise indicated, copies of federal and military specifications, standards, and handbooks are available from the Standardization Documents Order Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.)

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

## DRAWINGS

## U.S. ARMY NATICK RESEARCH, DEVELOPMENT, AND ENGINEERING CENTER

- 8-2-893 - Body Armor, Survival, Small Arms Protective, Aircrewman, Short
- 8-2-894 - Body Armor, Survival, Small Arms Protective, Aircrewman, Medium

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- 8-2-895 - Body Armor, Survival, Small Arms Protective, Aircrewman, Long
- 8-2-896 - Body Armor, Survival, Small Arms Protective, Aircrewman, X-Long

(Copies of drawings are available from the U.S. Army Natick Research, Development, and Engineering Center, ATTN: STRNC-UX, Natick, MA 01760-5017.)

2.2 Non-Government publications. The following documents form a part of this document to the extent specified herein. Unless otherwise specified, the issues of the documents which are DOD adopted are those listed in the issue of the DODISS cited in the solicitation. Unless otherwise specified, the issues of documents not listed in the DODISS are the issues of the documents cited in the solicitation (see 6.2).

## AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

- D 792 - Specific Gravity and Density of Plastics by Displacement
- D 2584 - Ignition Loss of Cured Reinforced Resins
- D 2863 - Measuring the Minimum Oxygen Concentration to Support Candle-Like Combustion of Plastics (Oxygen Index)
- D 3951 - Standard Practice for Commercial Packaging

(Application for copies should be addressed to the American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103-1187.)

(Non-Government standards and other publications are normally available from organizations that prepare or distribute the documents. These documents also may be available in or through libraries or other informational services.)

2.3 Order of precedence. In the event of a conflict between the text of this document and the references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

## 3. REQUIREMENTS

3.1 First article. When specified (see 6.2), a sample shall be subjected to first article inspection (see 6.3) in accordance with 4.3.

3.2 Guide samples. Guide samples, when furnished, are solely for guidance and information to the contractor (see 6.11). Variations from this specification may appear in the sample, in which case this specification shall govern.

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3.3 Materials and components. The materials and components shall be as specified herein and on the applicable drawings. Materials and components not specified shall be selected by the contractor in accordance with MIL-STD-970. Materials and components specified in accordance with MIL-STD-970 shall not degrade the operational suitability or effectiveness of the body armor. It is encouraged that recycled material be used when practical as long as it meets the requirements of this specification.

3.3.1 Ceramic. The material for the ceramic plate shall be silicon carbide.

3.3.1.1 Formulation and processing. The ceramic plate shall be homogenous and of one piece (monolithic) construction. All ceramic plates shall be manufactured in distinct production lots (see 4.4.1) and a sequential marking system of individual components shall be provided (see 3.6.1). The contractor shall not change the ceramic formulation or processing technique without approval of the contracting officer (see 4.4.2.1). Information shall also be furnished as to what production lots are affected by the change in ceramic formulation or processing technique. A change in the ceramic formulation or processing technique shall constitute a new lot.

3.3.2 Fiberglass laminate. The fiberglass laminate shall consist of a minimum of 20 percent by weight of unsaturated polyester type, unfilled resin and may contain modifying monomers or polymers and the remainder shall be undyed fiberglass fabric. Resin content shall be determined as specified in 4.4.2.2. The fiberglass laminate shall have an oxygen index value not less than 20 when tested as specified in 4.4.2.2. The fiberglass laminate shall be constructed as specified in the appropriate drawing.

3.3.3 Cloth, nylon. The nylon cloth for the spall cover and spall cover edging shall conform to class 1 of MIL-C-12369. The color shall be natural.

3.3.4 Foam pad. The foam pad shall be vinyl/nitrile, 3/4 inch thick in accordance with Uniroyal Inc., Ensolite, type ALG (see 6.9) or Rubatex, R-310-V, R-338-V (see 6.9) or equal (see 6.10).

3.3.5 Adhesives.

3.3.5.1 For bonding ceramic plate to fiberglass laminate (optional). 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 shall be capable of passing the requirement in 3.5.2 (see 4.4.2.1). Bonding of the ceramic component to the fiberglass laminate component may be performed without adhesive using certain molding techniques.

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3.3.5.2 For bonding spall cover and spall edging to the ceramic plate and fiberglass laminate. The adhesive for bonding the spall cover and edging to the ceramic plate and fiberglass laminate shall be a natural or synthetic rubber base curing type (see 6.4) capable of passing the adhesion requirements specified in 3.5.4 (see 4.4.2.1).

3.3.5.3 For bonding foam pad to fiberglass laminate. The adhesive for bonding the foam pad to the fiberglass laminate shall be a natural or synthetic rubber base curing type (see 6.4) capable of passing the adhesion requirements specified in 3.5.3 (see 4.4.2.1).

3.4 Design and construction. The design and construction of the body armor shall be as specified herein and as shown on Drawings 8-2-893, 8-2-894, 8-2-895 and 8-2-896, as applicable.

3.4.1 Ceramic component. The ceramic component shall conform to the requirements of 3.3.1 and 3.3.1.1 and shall be uniform in thickness within 5 percent when examined as specified in 4.4.3.1. Patching of the ceramic component is permitted in the green state only before oven or kiln firing. The ceramic component shall be free from manufacturing anomalies or discontinuities when inspected as specified in 4.4.3.2, 4.4.3.3 and 4.4.5.2.

3.4.2 Fiberglass laminate component. The fiberglass laminate component shall be fabricated from the materials specified in 3.3.2. The finished component shall be free from blisters, cracks, torn fabrics, dents, crazing, areas of non-resin flow, and surface roughness. Glass fibers protruding along the edges shall be removed.

3.4.2.1 Molding. The resin treated fabric shall be molded by vacuum pressure bag (see 6.5) or matched metal molded into the required configuration without breaking or damaging the glass fibers. Such procedures and methods shall be capable of yielding uniform properties in the completed structure. The fiberglass laminate may be molded and attached to the ceramic component in one operation if performance requirements are maintained. No patching shall be performed after the material has been molded.

3.4.3 Spall cover and edging. The nylon spall cover and edging shall be fabricated from one ply of the cloth specified in 3.3.3. The spall cover shall cover the entire front surface and sides of the ceramic component. The spall edging shall cover the ceramic/fiberglass component as shown on Drawings 8-2-893, 8-2-894, 8-2-895 and 8-2-896.

3.4.4 Foam pad construction. The foam pad shall be fabricated from one piece of foam.

3.4.5 Assembly of components by bonding. All components to be assembled 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 3.5.

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The required adhesive shall be applied uniformly over the entire contact areas of the components to be joined. There shall be no evidence of unadhered areas and no smearing of the adhesives on the exposed surfaces of the components.

### 3.5 Performance.

3.5.1 Ballistic resistance. The body armor without spall cover, spall edging, and foam padding shall have a  $V_{50}$  protection ballistic limit of not less than 1800 feet per second with a caliber .50 AP M2 projectile when tested as specified in 4.4.3.5.

3.5.2 Temperature resistance. There shall be no delamination between the fiberglass laminate component and the ceramic component, or between the fiberglass plies when tested as specified in 4.4.3.5.

3.5.3 Adhesion of foam pad. There shall be no visual separation of the foam pad from the armor plate when tested as specified in 4.4.6.

3.5.4 Adhesion of the spall cover and edging. There shall be no visual peeling of the tab formed on the spall cover or edging when tested as specified in 4.4.6.

3.5.5 Areal density. The areal density of the ceramic/fiberglass laminate, without spall cover, edging and foam pad, when tested as specified in 4.4.3.5, shall be  $11.0 \pm .35$  pounds per square foot.

### 3.6 Identification marking.

3.6.1 Ceramic component marking. The serial number shall be marked on the outside face surface within 1 inch 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 inch so that the serial number will be legible when the spall cover is stripped by mechanical or solvent action.

3.6.2 Completed body armor marking. The manufacturer's code number, contract number, lot number, serial number, and date of manufacture, as well as the nomenclature, federal stock number, and size of the body armor shall be permanently and legibly marked on the center of the face surface of each spall cover, at the lower end of the armor plate approximately 1 inch above the edging, in characters 1/4 inch high minimum. The serial number shall be the same as that on the ceramic plate. The letters "U.S." shall be applied approximately 2 inches above the identification markings, centered on the spall cover, in characters 1 inch high minimum. On the upper half of the spall cover, the words "DO NOT DROP" shall be printed in characters 1 inch high minimum. The above marking shall conform to type IV, class 9 of DDD-L-20. The fastness for the class 9 label shall be as specified for

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class 5 labels. A list in duplicate of the serial numbers used for each armor production lot shall be furnished the contracting officer at time of delivery.

3.7 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 body armor.

- a. The weight of each ceramic plate.
- b. The weight of each ceramic/fiberglass laminate without spall cover edging, and foam pad.
- c. All thickness measurements taken for each ceramic plate.

3.8 Workmanship. The end item shall conform to the quality of product established by this specification and the occurrence of defects shall not exceed the applicable acceptable quality levels. Utmost care shall be taken during fabrication to ensure quality workmanship and safety of the service person using the item.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for inspection. Unless otherwise specified in the contract or purchase order, the contractor is responsible for the performance of all inspection requirements (examinations and tests) as specified herein. Except as otherwise specified in the contract or purchase order, the contractor may use his own or any other facilities suitable for the performance of the inspection requirements specified herein, unless disapproved by the Government. The Government reserves the right to perform any of the inspections set forth in this specification where such inspections are deemed necessary to ensure supplies and services conform to prescribed requirements.

4.1.1 Responsibility for compliance. All items shall meet all requirements of sections 3 and 5. The inspection set forth in this specification shall become a part of the contractor's overall inspection system or quality program. The absence of any inspection requirements in the specification shall not relieve the contractor of the responsibility of ensuring that all products or supplies submitted to the Government for acceptance comply with all requirements of the contract. Sampling inspection, as part of manufacturing operations, is an acceptable practice to ascertain conformance to requirements, however, this does not authorize submission of known defective material, either indicated or actual, nor does it commit the Government to accept defective material.

4.1.2 Responsibility for dimensional requirements. Unless otherwise specified in the contract or purchase order, the contractor is responsible for ensuring that all specified dimensions have been met. When dimensions

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cannot be examined on the end item, inspection shall be made at any point, or at all points in the manufacturing process necessary to ensure compliance with all dimensional requirements.

4.1.3 Certificate of compliance. When certificates of compliance are submitted, the Government reserves the right to inspect such items to determine the validity of the certification.

4.1.4 Ballistic and radiographic laboratory approval. Ballistic testing and radiographic examination shall be performed in certified laboratories (see 6.8). Ballistic testing equipment and procedures shall be in accordance with Appendix A. The radiographic equipment and procedures shall be in accordance with Appendix B.

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

- a. First article inspection (see 4.3).
- b. Quality conformance inspection (see 4.4).

4.3 First article inspection. When a first article is required (see 3.1 and 6.2), it shall be examined for the defects specified in 4.4.4 and 4.4.5 and shall be tested as specified in 4.4.6. Any nonconformance shall be cause for the rejection of the first article.

4.4 Quality conformance inspection. Unless otherwise specified, sampling for inspection shall be performed in accordance with MIL-STD-105.

4.4.1 Inspection lots. The maximum lot size for all tests and examinations shall not exceed 1000 items of ceramic plates or ceramic/fiberglass laminates, as applicable, sequentially produced. Lots shall be composed of ceramic components or ceramic/fiberglass laminates only.

4.4.1.1 Initial production lot. The minimum lot size for the initial production lot shall be as specified in the contract or purchase order (see 6.2).

4.4.2 Component and material inspection. In accordance with 4.1, components and materials shall be inspected in accordance with all the requirements of referenced documents unless otherwise excluded, amended, modified, or qualified in this specification or applicable purchase document.

4.4.2.1 Component and material certification. A certificate of compliance may be acceptable as evidence that the characteristics listed below conform to the specified requirements when tested by the specified methods.

- 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 homogeneous, one piece monolithic construction and manufactured in distinct production lots as specified in 3.3.1.1.



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b. Adhesive for bonding ceramic plate to fiberglass laminate component conforms to 3.3.5.1.

c. Adhesive for bonding spall cover and edging to ceramic plate and fiberglass laminate conforms to 3.3.5.2

d. Adhesive for bonding the foam pad to fiberglass laminate conforms to 3.3.5.3.

4.4.2.2 Fiberglass laminate testing. Testing shall be performed on the fiberglass laminate component for the characteristics listed in table I. The lot size shall be expressed in units of fiberglass laminate components. The sample unit shall be one fiberglass laminate component. The inspection level shall be S-1 and the acceptable quality level (AQL), expressed in terms of defects per hundred units, shall be 6.5. When the fiberglass laminate is molded and bonded to the ceramic plate in a simultaneous operation, the specimens required for testing shall be cut from ceramic/fiberglass laminates that have been ballistically tested.

TABLE I. Fiberglass laminate component tests

<u>Characteristic</u>	<u>Requirement paragraph</u>	<u>Test method</u>	<u>No. of det. per sample unit</u>	<u>Results reported as</u>
Resin content (percent)	3.3.2 1/	ASTM D 2584	3	Avg. of 3 det. to nearest 1 percent
Oxygen index value	3.3.2 1/	ASTM D 2863	1	Nearest 1

1/ A certificate of compliance will be acceptable for the stated requirement after the first acceptable production lot.

4.4.3 In-process inspection. Inspection of subassemblies shall be made to ascertain that construction details which cannot be examined in the finished product are in accordance with specified requirements. The Government reserves the right to exclude from consideration for acceptance, any material or service for which in-process inspection has indicated non-conformance.

Check for

Proper preparation, cleanliness, and uniformity of application of adhesive

Component or requirement

Surfaces of ceramic and fiberglass laminate components prior to bonding  
Surfaces of ceramic and fiberglass laminate components where spall cover and edging is to be bonded  
Surface of fiberglass laminate component where foam pad is to be bonded

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Size of cut or molded parts	Spall cover and edging (after attachment to armor)
	Foam position after attachment to fiberglass laminate
	Ceramic/fiberglass laminate after molding and bonding

4.4.3.1 Examination of ceramic plate for thickness. Prior to bonding to the fiberglass laminate, every ceramic plate shall be examined as follows for conformance to the uniformity of thickness requirement in 3.4.1. Any ceramic plate which fails this examination shall be rejected. The thickness shall be measured to 0.001 inch 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 1-1/2 inches away from the edge. In addition, one reading shall be taken at the center of the ceramic plate. All readings shall be spaced a minimum of 3 inches apart. The five readings shall be averaged and reported to the nearest 0.001 inch 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. A deep throat type depth gage conforming to Federal Products Corp. Model KP 125 or KP 129 or equal (see 6.10) with standard measuring tips, shall be used for taking the measurements.

4.4.3.2 Liquid penetrant examination of ceramic plates. Every ceramic plate, after furnace firing and prior to application of the adhesive for bonding to the fiberglass laminate, shall be liquid penetrant examined in accordance with Appendixes C and D. Unless otherwise specified, the examination shall be performed at the contractor's plant (see 6.2). The ceramic plates shall be examined for the liquid penetrant "L" defects listed in table II. Any ceramic plate found to contain one or more major defects, or four or more minor defects shall be rejected.

4.4.3.3 Visual examination of fiberglass/ceramic plates. Every ceramic plate bonded to the fiberglass laminate, but prior to application of the adhesive for bonding the spall cover and edging, shall be examined in accordance with Appendix D for the visual "V" defects listed in table II. Any fiberglass/ceramic plate found to contain one or more major defects, or four or more minor defects shall be rejected.

TABLE II. Visual, liquid penetrant, and radiographic defects

Examine component	Defect	Defects applicable to examination by:		Classification	
		V-Visual	L - Liquid penetrant	R-Radiographic I/	Major Minor
Ceramic component	Edge crack (filled or unfilled) greater than 1-1/2 inches in length and through thickness of plate $2/3$	V	L	R	X
	Edge crack (unfilled) greater than $3/4$ inch in length and not through thickness $2/3$ $4/$	V	L	R	X
	Edge crack (unfilled) less than $3/4$ inch in length and through thickness $2/3$ $4/$	V	L	R	X
	Any crack (unfilled) over 1/2 inch in length other than edge crack $3/5$	V	L	R	X
	Any crack (filled) other than edge crack and over 1/2 inch in length	V	L	R	X
	Laminar crack along edge greater than $3/4$ inch in length	V	L	---	X

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TABLE II. Visual, liquid penetrant, and radiographic defects (cont'd)

Examine component (cont'd)	Defect	Defects applicable to examination by:			Classification	
		V-Visual	L - Liquid penetrant	R-Radiographic 1/	Major	Minor
Ceramic	Shrinkage, filamentary type, (filled or unfilled) indications: 3/	---	---	R		X
	a. Three or less such defects in any 2 inch diameter circle anywhere on the plate whose combined length, when measured from end to end in a straight line, is greater than 1 linear inch	---	---			
Ceramic	b. Four or more such defects regardless of length in any 2 inch diameter circle anywhere on the plate	---	---	R		X
	Sponge area, (unfilled) over 0.2 inch <sup>2</sup> (1/2 inch diameter circle) per any 2 inch diameter circle 3/				V	
Ceramic	Silicon rich area over 0.2 inch <sup>2</sup> (1/2 inch diameter circle) per any 2 inch diameter circle 3/				L	
						X

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TABLE II. Visual, liquid penetrant, and radiographic defects (cont'd)

Examine	Defect	Defects applicable to examination by:			Classification	
		V-Visual	L - Liquid penetrant	R-Radiographic	Major	Minor
Ceramic component (cont'd)	Any internal void or unfilled area greater than 0.2 inch <sup>2</sup> per any 2 inch diameter circle $\frac{3}{4}$ inch	---	---	R		X
	pit greater than:					
	a. 0.030 inch in depth and diameter but not more than 0.060 inch in depth $\frac{4}{5}$ inch	V	L	R		X
	b. 0.030 inch in diameter and greater than 0.060 inch in depth	V	L	R	X	
	c. $\frac{3}{16}$ inch in the longest lateral direction but not more than $\frac{5}{16}$ inch and 0.030 inch or less in depth $\frac{4}{5}$ inch	V	L	R		X
	d. $\frac{5}{16}$ inch in the longest lateral direction and 0.030 inch or less in depth	V	L	R		X

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TABLE II. Visual, liquid penetrant, and radiographic defects (cont'd)

Examine	Defect	Defects applicable to examination by:			Classification	
		V-Visual	L - Liquid penetrant	R-Radiographic I/	Major	Minor
Ceramic component (cont'd)	Edge chip on either surface beyond 1/8 inch outer boundary:					
	a. Greater than 3/8 inch in any lateral direction but not more than 3/4 inch and 1/16 inch or less in depth 4/	V	L	R		X
	b. Greater than 3/4 inch in any lateral direction and 1/16 inch or less in depth	V	L	---	X	
	c. Greater than 1/16 inch in depth but not more than 1/8 inch 4/	V	L	---		X
	d. Greater than 1/8 inch in depth	V	L	---		X
	Edge chip on either surface within the 1/8 inch outer boundary greater than 3/16 inch in depth	V	L	---		X

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TABLE II. Visual, liquid penetrant, and radiographic defects (cont'd)

Examine	Defect	Defects applicable to examination by:			Classification	
		V-Visual	L - Liquid penetrant	R-Radiographic 1/	Major	Minor
Ceramic component (cont'd)	Scratch or gouge:					
	a. 0.030 to 0.060 inch in depth 4/ 5/	V	L	---		X
	b. Greater than 0.060 inch in depth	V	L	---	X	
	Any mend or patch	V	---	---	X	
Fiberglass laminate component	Markings (serial number) omitted, not located or applied as specified	V	---	---		X
	Any delamination from the ceramic component	V	---	---	X	
	Exposed fibers on edge	V	---	---		X
	Any blister, crack, torn fabric, crazing, dent, area of non-resin flow or surface roughness	V	---	---		X
	Any delamination of fiberglass plies	V	---	---		X

1/ Radiographic examination shall be performed on the end item (see 4.4.5).

2/ Edge cracks are defined as those within the 1-1/2 inches boundary around the periphery of the ceramic component.

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- 3/ For the purposes of radiographic examination and interpretation, the following definitions or descriptions shall apply (see 6.7):

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

Shrinkage filamentary type indications. Sharply defined wavy or irregular line or lines usually less than 3/4 inch 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.

- 4/ All such surface defects so identified in the visual and liquid penetrant examinations shall be described, located, and annotated so that they will not be identified as internal voids or unfilled areas when and if the ceramic component is subjected to radiographic examination.
- 5/ Cracks other than edge cracks are defined as those beyond the 1-1/2 inch edge boundary or those that start within the 1-1/2 inch edge boundary and extend beyond the 1-1/2 inch boundary.
- 6/ Any defect on the surfaces of the ceramic component, except within the 1-1/2 inch edge boundary, less than 3/8 inch apart shall be classified as a defect.

4.4.3.4 Dimensional examination of fiberglass/ceramic plates. The fiberglass/ceramic plates, prior to application of the spall cover and edging, shall be examined for conformance to the dimensional requirements specified on the applicable drawing. Any dimension not within the specified tolerance shall be classified as a defect. The lot size shall be expressed in units of fiberglass/ceramic plates (see 4.4.1). The sample unit shall be one fiberglass/ceramic plate. The inspection level shall be S-3 and the AQL, expressed in terms of defects per hundred units, shall be 4.0.

4.4.3.5 Testing of fiberglass/ceramic plates. The fiberglass/ceramic plates, prior to application of the spall cover and edging, shall be tested for the characteristics listed in table III. The lot size shall be expressed in units of fiberglass/ceramic plates (see 4.4.1). The sample unit for ballistic and areal density tests shall consist of 10 randomly selected fiberglass/ceramic plates and for the temperature resistance test the sample unit shall be one composite fiberglass/ceramic plate. When more than one size is in the lot, the sample unit used in the ballistic test shall contain at least



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two of each size. All areal density and ballistic tests shall be witnessed by a Government inspector. The sample size shall be in accordance with the following:

<u>Lot size</u>	<u>Sample size</u>
1200 or less	2
1201 to 35,000 inclusive	3
35,001 and over	5

TABLE III. Fiberglass/ceramic plate tests

<u>Characteristic</u>	<u>Requirement paragraph</u>	<u>Test method</u>	<u>No. deter. per sample unit</u>	<u>Results reported as</u>	
				<u>Pass or fail</u>	<u>Numerically to the nearest</u>
Ballistic resistance 2/	3.5.1	4.5.1	10 1/	---	Ft./sec.
Temperature resistance	3.5.2	4.5.2	10	X	---
Areal density 2/	3.5.5	4.5.5	10	---	0.1 lb./sq.ft.

1/ The fiberglass/ceramic plate having the lowest area 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 specimens.

4.4.4 End item visual examination. The body armor inserts shall be examined for the defects listed below. The lot size shall be expressed in units of body armor inserts (see 4.4.1). The sample unit shall be one body armor insert. The inspection level shall be S-1 and the AQL, expressed in terms of defects per hundred units, shall be 4.0.

<u>Examine</u>	<u>Defect</u>
Spall cover	Cut, hole, tear, or abraded area Any wrinkle or crease Any mend or patch Any areas not bonded to ceramic component exceeding 1/4 inch in longest lateral direction

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<u>Examine</u>	<u>Defect</u>
Spall cover edging	Not one continuous piece Abraided, torn, or cut except where permitted Any area of non-adhesive in excess of 1/4 inch Does not overlap peripheral edge of armor as specified
Foam padding	Not one piece Torn, cut, or abraided except where permitted Any area of non-adherence exceeding 1/2 inch Any wrinkle or crease
Cleanliness	Grease or oil stains clearly noticeable Adhesive smeared on spall cover or foam pad (except where allowable)
Construction and workmanship	Any component missing or not assembled as specified (unless otherwise classified herein) 1/
Identification markings	Not as specified, missing, of improper size, or illegible

1/ Presence of this defect in one or more of the samples shall be cause for rejection of the lot.

4.4.5 End item radiographic examination. The completed body armor inserts shall be radiographically examined. Industrial radiography shall be performed in accordance with Appendix B. 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 MIL-SID-453, except where noted in Appendix B.

4.4.5.1 Initial production lot. Every body armor insert in the initial lot of end items shall be subjected to the radiographic procedure and examined for the radiographic "R" defects listed in table II. Any end item found to contain one or more major defects, or four or more minor defects shall be rejected.

4.4.5.2 Production lots after initial lot. All production lots after the initial lot shall be subjected to the radiographic procedure and examined for the radiographic "R" defects listed in table II. Any end item found to contain one or more major defects, or four or more minor defects shall be

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Considered defective. The lot size shall be expressed in units of body armor inserts (see 4.4.1). The sample unit shall be one body armor insert. The inspection level shall be II and the AQL, expressed in terms of percent defective, shall be 0.25.

4.4.6 End item testing. The body armor inserts shall be tested for the characteristics listed in table IV. The lot size shall be expressed in units of body armor inserts (see 4.4.1). The sample unit shall be one body armor insert. The inspection level shall be S-1 and the AQL, expressed in terms of defects per hundred units, shall be 4.0.

TABLE IV. End item tests

Characteristic	Requirement	Test method	No. deter. per sample unit	Results reported as pass or fail
Adhesion of foam pad	3.5.3	4.5.3	1	X
Adhesion of spall cover and edging	3.5.4	4.5.4 and 4.5.4.1	1	X

4.4.7 Packaging examination. The fully packaged end items shall be examined for the defects listed below. The lot size shall be expressed in units of shipping containers. The sample unit shall be one shipping container fully packaged. The inspection level shall be S-2 and the AQL, expressed in terms of defects per hundred units, shall be 2.5.

<u>Examine</u>	<u>Defect</u>
Marking	Omitted; incorrect; illegible; of improper size, location, sequence, or method of application
Materials	Any component missing, damaged, or not as specified
Workmanship	Inadequate application of components, such as: incomplete sealing or closure of flap, improper taping, loose strapping, or inadequate stapling Bulged or distorted container
Contents	Number per container is more or less than required

4.4.8 Palletization examination. The fully packaged and palletized end items shall be examined for the defects listed below. The lot size shall be expressed in units of palletized unit loads. The sample unit shall be one palletized unit load, fully packaged. The inspection level shall be S-1 and the AQL, expressed in terms of defects per hundred units, shall be 6.5.

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<u>Examine</u>	<u>Defect</u>
Finished dimensions	Length, width, or height exceeds specified maximum requirement
Palletization	Pallet pattern not as specified Load not bonded as specified
Weight	Exceeds maximum load limits
Marking	Omitted; incorrect; illegible; of improper size, location, sequence, or method of application

4.5 Methods of inspection.

4.5.1 Ballistic test. The ballistic test shall be conducted in accordance with Appendix A unless otherwise specified. The areal density shall be reported for each ceramic/fiberglass laminate.

4.5.2 Temperature extremes test. The ceramic/fiberglass laminate, less the spall cover, edging and foam pad shall be heated in an oven operating at  $160^{\circ} \pm 5^{\circ}\text{F}$  for  $6 \pm 1/4$  hours. The test specimen shall then be allowed to cool to room temperature followed by cold exposure at  $-65^{\circ} \pm 5^{\circ}\text{F}$  for  $6 \pm 1/4$  hours. The specimen shall be allowed to warm to room temperature ( $70^{\circ}$  to  $90^{\circ}\text{F}$ ) and shall then be examined at edges for evidence of delamination of the fiberglass laminate component from the ceramic plate or any delamination of the fiberglass plies. Specimens that have passed the test may be returned to the production lot.

4.5.3 Adhesion test for foam pad. The foam pad shall not be capable of being pulled in four separate areas (away from the armor plate insert) by hand without tearing the foam.

4.5.4 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 covering 4 inches long and 1 inch apart along the weave. At one end of the cut, make a cut at a right angle so that a 1 inch wide by 2 inch long tab can be peeled from the armor plate. Attach a 2 pound 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 hang for 4 hours minimum at room temperature ( $70^{\circ}$  to  $90^{\circ}\text{F}$ ). Any visual peeling of the tab exceeding 1/16 inch constitutes failure of the test.

4.5.4.1 Adhesion test for spall cover edging. The sample for this test will be the same as specified in 4.5.4, however the test will be performed on the edge of the plate parallel to the long axis. Make parallel cuts through

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the spall cover edging edge covering 4 inches long and 3/4 inch apart along the weave. At one end of the cut, make a cut at a right angle so that a 3/4 inch wide by 2 inch long tab can be peeled from the plate. Attach a 2-pound weight to this tab so the resultant peel force is normal to the plane of the edge 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 hang for 4 hours minimum at room temperature (70° to 90°F). Any visual peeling of the tab exceeding 1/16 inch constitutes failure of the test.

4.5.5 Areal density. The areal density in pounds per square foot of the ceramic/fiberglass laminate, without spall cover and edging, shall be calculated from measurements on the ceramic/fiberglass laminate. The ceramic/fiberglass laminate shall be weighed to the nearest 0.01 pound. The thickness shall be measured to 0.001 inch at four corner locations on the laminate. Six measurements shall be made at each corner with the first measurement taken approximately 1 inch 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 at 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 KP 125 or KP 129, or equal (see 6.10), with standard tips, shall be used for taking measurements. The average of the 24 readings shall be used in the calculation of the areal density. All thickness determinations shall be reported. The edges of the glass fiber laminate shall be painted with a slow drying lacquer or resin to seal the edges. The lacquer shall be allowed to dry (at least 1/2 hour) before proceeding with the determination of density. The average density of the armor plate shall be determined by Method A of ASIM D 792, except that the immersed weight shall be determined to 0.01 pound 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 armor plate without spall cover and edging shall be calculated to the nearest 0.1/lb/sq. ft. as follows:

$$\text{Areal density (lb/sq. ft.)} = 5.202 \times \text{Density (g/cc)} \times \text{Thickness (in.)}$$

## 5. PACKAGING

### 5.1 Preservation. Preservation shall be level A.

5.1.1 Level A preservation. Each body armor insert shall be completely wrapped in cushioning to prevent damage.

### 5.2 Packing. Packing shall be level A, B or Commercial, as specified (see 6.2).

5.2.1 Level A packing. Two inserts of one size only, preserved as specified in 5.1, shall be packed in a shipping container conforming to style RSC-L, grade V2s of PPP-B-636. Inside dimensions of the shipping container

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for sizes short and medium shall approximate 14-1/2 inches in length, 12-1/2 inches in width, and 8 inches in depth. Inside dimensions of the shipping container for sizes long and X-long shall be approximate 15-1/4 inches in length, 14-1/2 inches in width, and 8-1/2 inches in depth. Each shipping container shall be closed, waterproofed, and reinforced in accordance with the appendix of PPP-B-636. Shipping containers shall be arranged in unit loads in accordance with MIL-L-35078 for the type and class of load specified (see 6.2). Strapping shall be limited to nonmetallic strapping, except for type II, class F loads.

5.2.2 Level B packing. Two inserts of one size only, preserved as specified in 5.1, shall be packed in a shipping container conforming to style RSC-L, type CF (variety SW) or SF, class domestic, grade 275 of PPP-B-636. Inside dimensions of the shipping container for short and medium shall approximate 14-1/2 inches in length, 12-1/2 inches in width, and 8 inches in depth. Inside dimensions of the shipping container for sizes long and X-long shall approximate 15-1/4 inches in length, 14-1/2 inches in width, and 8-1/2 inches in depth. Each shipping container shall be closed in accordance with method II as specified in the appendix of PPP-B-636.

5.2.2.1 Weather-resistant shipping container. When specified (see 6.2), the shipping container shall be a grade V3c, V3s, or V4s fiberboard box fabricated in accordance with PPP-B-636 and closed in accordance with the appendix of PPP-B-636.

5.2.3 Commercial packing. Inserts, preserved as specified in 5.1, shall be packed in accordance with ASTM D 3951.

5.3 Palletization. When specified (see 6.2), inserts packed as specified in 5.2.2 or 5.2.3 shall be palletized on a 4-way entry pallet in accordance with load type Ia of MIL-STD-147. Pallet types shall be type I (4-way entry), type IV, or type V in accordance with MIL-STD-147. Each prepared load shall be bonded with primary and secondary straps in accordance with bonding means C and D or film bonding means F or G. Pallet pattern shall be number 95 in accordance with the appendix of MIL-STD-147.

5.4 Marking. In addition to any special marking required by the contract or purchase order, unit packs, shipping containers and palletized unit loads shall be marked in accordance with MIL-STD-129 or ASTM D 3951, as applicable.

## 6. NOTES

(This section contains information of a general or explanatory nature that may be helpful, but is not mandatory.)

6.1 Intended use. The body armor is intended for use by aircrew personnel to provide protection against small arms fire.

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6.2 Acquisition requirements. Acquisition documents must specify the following:

- a. Title, number, and date of this specification.
- b. Special provisions for verification inspection of Life Support Clothing and Equipment (see 1.1).
- c. Size required (see 1.2).
- d. Issue of DODISS to be cited in the solicitation, and if required, the specific issue of individual documents (see 2.1.1 and 2.2).
- e. When a first article is required (see 3.1, 4.3, and 6.3).
- f. Minimum size of initial production lot (see 4.4.1.1).
- g. Location for liquid penetrant examination, when required to be at other than the contractors plant (see 4.4.3.2).
- h. Level of packing (see 5.2).
- i. Type and class of unit load required (see 5.2.1).
- j. When weather-resistant grade fiberboard shipping containers are required for level B packing (see 5.2.2.1).
- k. When palletization is required (see 5.3).

6.3 First article. When a first article is required, it shall be inspected and approved under the appropriate provisions of Federal Acquisition Regulation (FAR) 52.209. The first article should be a preproduction sample. The contracting officer should specify the appropriate type of first article and the number of units to be furnished. The contracting officer should include specific instructions in acquisition documents regarding arrangements for selection, inspection, and approval of the first article.

6.4 Adhesive for bonding spall cover and edging. Minnesota Mining and Manufacturing Company adhesive EC 1300 has been used in the manufacture of prototype items to adhere the spall cover and edging (see 3.3.5.2).

6.5 Fabrication of fiberglass laminate. Fabrication of the fiberglass laminate has been made successfully by the following technique. One piece pressed ceramic components 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 (PVA) vacuum bag and the assembly placed in an autoclave. The evacuated assembly was pressurized at 100 pounds per square inch at room temperature for 2 hours and then subjected to a temperature of 200°F for 3 hours 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 (see 3.4.2.1).

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 even in small residual amounts.

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6.7 Definition photographs. Photographs showing examples of the definitions defined in footnote 3 of table II may be obtained from the procuring activity issuing the invitation for bids.

6.8 Certification activity. Unless otherwise designated, the Army Materials Technology Laboratory, Watertown, MA, is responsible for the certification of radiographic examination facilities and procedures and for the certification of the ballistic testing facility and equipment.

6.9 Sources of supply for foam pad. The foam pad specified in 3.3.4 is available from Uniroyal Elastomeric Products Division, Mishawaka, IN 46544, or Rubatex Corporation, 906 Adams Street, P.O. Box 340-T, Bedford, VA 24523.

6.10 Equal item. Prior to the use of an "or equal" item, the contractor shall submit the item with supporting data to the contracting officer for subsequent approval or disapproval by the responsible military agency.

6.11 Samples. For access to samples, address the contracting activity issuing the invitation for bids or request for proposal.

6.12 Subject term (key word) listing.

Carrier  
Ceramic  
Insert  
Life Support Clothing & Equipment  
LSC&E  
Protection  
SARVIP system

Custodian:

Army - GL

Review activities:

Army - MD  
DLA - CT

Preparing activity:

Army - GL

(Project 8470-0141)



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APPENDIX A

BALLISTIC TEST

10. SCOPE

10.1 Scope. This appendix details the procedure to be used in determining the ballistics resistance of ceramic faced armor materials with caliber .50 AP M2 projectiles. This appendix is a mandatory part of the specification. The information contained herein is for compliance.

20. APPLICABLE DOCUMENTS

20.1 Government documents.

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

DRAWINGS

C6138195 - Bullet

(Copies of drawing are available from Commander, Armament Research, Development and Engineering Center, ATTN: SMCAR-BAC-C, Picatinny Arsenal, NJ 07807-5000.)

30. REQUIREMENTS

30.1 Equipment. Equipment for ballistic testing shall consist of the following items:

a. Gun Mount - The gun mount shall be suitable for firing the caliber .50 gun to muzzle velocity of at least 2400 ft/sec.

b. Test Sample Mounting - The armor test sample shall be mounted in a frame which is suspended from overhead by means of steel cables, wires, or chains. The armor test sample shall be secured in the vertical position, perpendicular to line-of-flight 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 .50 AP M2 projectile (kinetic energy approximately 3500 ft.-lbs.) on the test sample. The test sample mounting shall 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.

c. Weapon - A caliber .50 weapon shall be used.

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d. Projectile - The projectile to be used is the caliber .50 AP M2 standard service projectile (bullet) conforming to Frankford Arsenal Drawing C6138195.

e. Witness Plate - The witness plate shall be a 2024-T3 or 2024-T4 aluminum alloy sheet, 0.020 inch thick and shall be a minimum of 11 inches by 14 inches in size.

f. Velocity measuring equipment.

1. Chronograph - An electronic counter type chronograph measuring to the nearest microsecond or as a minimum to the nearest 10 microseconds.

2. Detectors - Either high-velocity luminine screens, or electrical contact screens which either open or close an electric 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.

g. Propellant - Any propellant which is standard for the weapon may be used, however, when other than a standard propellant is used, extreme care must be exercised in selecting the charge weight. 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  $72^{\circ} \pm 5^{\circ}\text{F}$  and  $50 \pm 5$  percent relative humidity.

30.2 Set-up. The required set-up for the ballistic equipment is shown in figure 1.

30.3 Data sheet. Data sheets shall be provided and shall contain the following information:

- a. Item document number.
- b. Material description (including physical characteristics if required).
- c. Material identification number for each test sample.
- d. The areal density of 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.

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- 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 remarks pertinent to the conduct of the test, or behavior of the material.

30.4 Procedure.

30.4.1 Marking, samples. Areal density must have been previously determined on the test samples before they are tested ballistically. Each test sample will be marked in the following manner (see figure 2):

- 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 nearest edge (the narrowest) portion of the test sample (see figure 2).
- d. The upper area is marked A, the lower right area B, and the lower left area C, respectively.
- e. The first test sample will be impacted in area A, the second test sample in area B, and the third test sample in area C. Each successive test sample will be fired in the same order, i.e. area 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.

30.4.2 Velocity, projectile. A test round will be fired through a witness plate to determine the exact position of impact. Three additional rounds shall be fired using the appropriate projectile velocity - propellant charge curve for the weapon being used, and selecting propellant weights to achieve a velocity of approximately 1800 ft/sec. The last three of these rounds shall be within the range of 1800 to 1850 ft/sec (hereinafter designated the "reference velocity"). If it is not, additional rounds shall be fired and the projectile velocity - propellant charge curve corrected until reference velocity is achieved. The propellant charge for the last warm-up round shall be considered the reference charge for the test. From the curve, the increments to and decrements from the reference propellant charge to yield approximate velocity changes at the reference velocity of 100 ft/sec and of 50 ft/sec shall be determined and recorded. These shall be the only

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increments used during the test. The reference charge and propellant increments and decrements 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 propellant charges, and increments and decrements of propellant weights developed for a test or utilized from a previous test shall be recorded 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.

30.4.3 Mounting, sample. The sample will be mounted as specified in 30.1.b, Test Sample Mounting. The point of impact will be located on the test sample as specified in 30.4.1 and will be positioned to line up with the previously determined line of flight. The point of impact is now checked for obliquity. The obliquity shall be  $0 \pm 5$  degrees. The angle of obliquity is determined by the angle formed by a perpendicular to a plane 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. Once the point of impact has been determined on the test sample, and the obliquity fixed, the gun and velocity screen distances must not be changed until the test has been completed.

30.5 Testing.

30.5.1 Test, ballistic. The first round shall be loaded with the reference propellant charge and fired into the sample, and the reading on the chronograph recorded. The velocity shall be computed and recorded. The witness plate shall then be 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. 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 of 50 or 100 ft/sec in an attempt to obtain a partial penetration. If the first round yields a partial penetration, use a propellant charge for the second equal to that of the first plus a propellant increment for 50 or 100 ft/sec in an attempt to obtain a complete penetration. A propellant increment or decrement, as applicable, for at least 50 ft/sec should be used until one partial and one complete penetration are obtained. After obtaining a partial and complete penetration, the propellant increment or decrement for 50 ft/sec 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/sec is obtained (see 30.5.2). This up-and-down method of firing must be followed in order to achieve an acceptable ballistic limit ( $V_{50}$ ). No further testing shall be conducted on the sample unit as soon as this

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condition has been achieved. A  $V_{50}$  protection ballistic limit shall be determined from single round fair impacts on each of at least 6 complete armor inserts of the ballistic sample unit. A fair impact results when an unyawed projectile strikes an unsupported area of the ballistic test plate at least 1-1/2 inches from the outside edge of the ceramic component. (The impacted area shall contain no belts, buckles, webbing, etc.)

30.5.2 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/sec. 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 penetration within a spread of 125 ft/sec, 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/sec; and second, if the first alternative cannot be applied, the 2 lowest velocities for complete penetration and the 2 highest velocities for partial penetration with a 150 ft/sec spread. 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 1800 ft/sec and that there are no complete penetration velocities lower than 1800 ft/sec. If these conditions are satisfied, the sample unit will be considered to have met the ballistic limit ( $V_{50}$ ) requirement. If none of the acceptable calculation procedures 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 1800 ft/sec and no complete penetration velocities lower than 1800 ft/sec, then the sample unit shall be considered to have failed the ballistic limit ( $V_{50}$ ) requirement. The ballistic limit ( $V_{50}$ ) must be at least 1800 ft/sec in order to pass the ballistic test requirement.

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APPENDIX 2

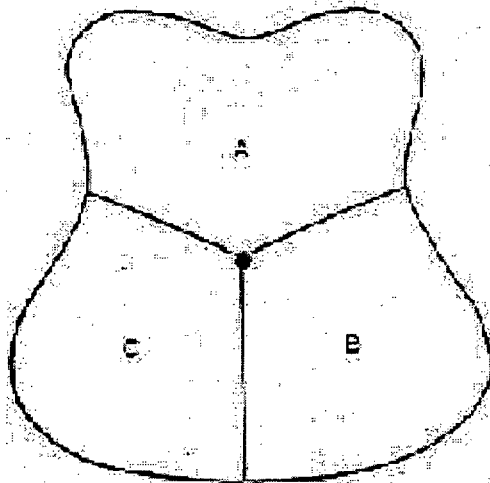
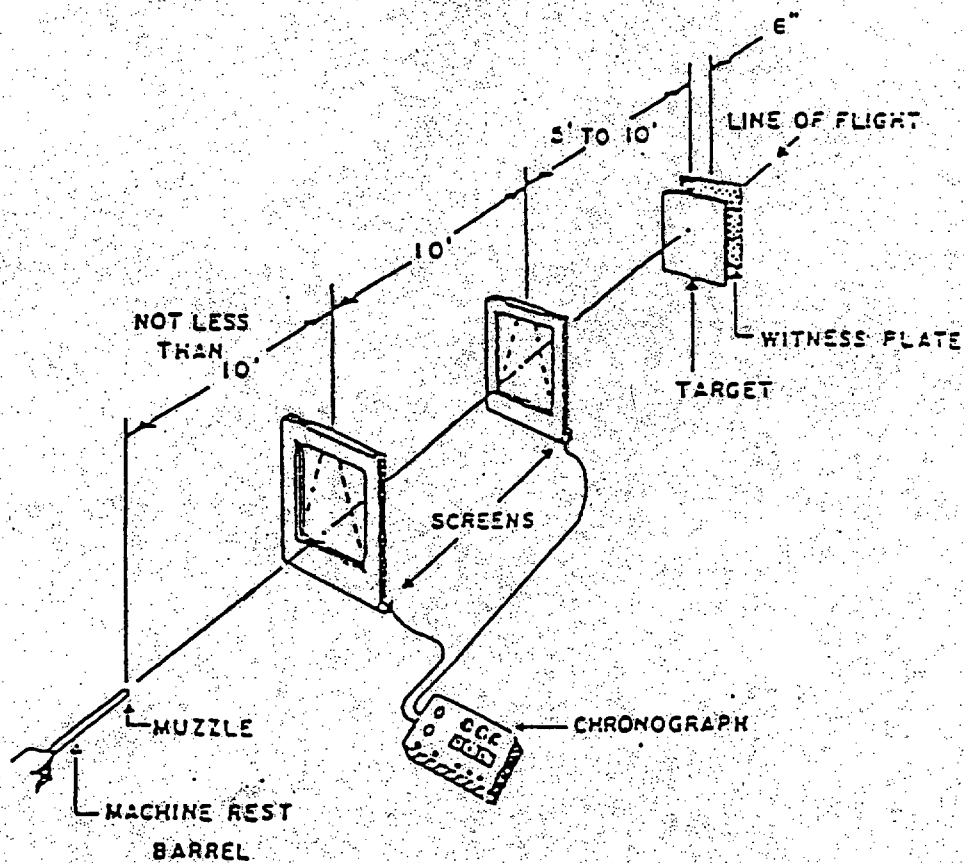


FIGURE 2

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NOTE: MEASUREMENTS TO BE TAKEN TO THE NEAREST 0.01 FOOT

FIGURE 1. BALLISTICS FACILITY LAYOUT

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APPENDIX B

RADIOGRAPHIC REQUIREMENTS FOR EXAMINATION OF CERAMIC BODY ARMOR INSERTS

10. SCOPE

10.1 Scope. This appendix details radiographic inspection process to be used for the examination of ceramic body armor materials. This appendix is a mandatory part of the specification. The information contained herein is intended for compliance.

20. APPLICABLE DOCUMENTS

20.1 Government documents.

20.1.1 Specifications, standards, and handbooks. The following specifications, standards and handbooks form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those listed in the issue of the Department of Defense Index of Specifications and Standards (DODISS) and supplement thereto, cited in the solicitation (see 6.2).

SPECIFICATIONS

MILITARY

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

STANDARDS

MILITARY

MIL-STD-453 - Inspection, Radiographic

(Unless otherwise indicated, copies of federal and military specifications, standards, and handbooks are available from the Standardization Documents Order Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.)

30. REQUIREMENTS

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

30.2 Equipment. Equipment for radiographic inspection shall consist of the following items:

- a. 150 kv X-Ray Equipment.



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- 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 1/8 inch thick to conform to ceramic armor insert.
- g. High intensity radiographic viewer.
- h. 10X magnifier and film processing facilities.

30.3 Test method. Unless otherwise specified, all radiographic test equipment and procedures shall conform to the requirements of MIL-R-11470 and MIL-STD-453. 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. 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.

30.4 Radiograph identification. 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. 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 \_\_\_\_\_ Ma \_\_\_\_\_ Exp. time \_\_\_\_\_  
 Film type \_\_\_\_\_ Screens \_\_\_\_\_  
 FF distance \_\_\_\_\_ Equipment \_\_\_\_\_  
 H&D density \_\_\_\_\_ No. of exp. \_\_\_\_\_  
 Remarks \_\_\_\_\_

30.5 Procedures.

30.5.1 Radiographic coverage. Two radiographs, each representing at least half of each ceramic plate, shall be made to effect 100 percent 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 normal as possible to the X-ray beam.

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30.5.2 Radiographic technique. A standard X-ray technique for the ceramic material shall be established subject to the approval of the procuring agency. The radiograph shall be in the H&D density range of 1.5 -2.2, +0.20. The radiographic quality level shall be 2-2T. Radiographic equivalence systems shall be permitted using stopwedges and penetrameters exhibiting the same radiographic attenuation properties as ceramic armor materials. The suggested X-ray techniques for silicon carbide ceramic armor composites shall be as follows:

Complete Composite - 80 kv, 10 Ma, 40"FFD, 1'30", Kodak M, NS

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

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APPENDIX C

LIQUID PENETRANT REQUIREMENTS FOR THE EXAMINATION OF  
CERAMIC BODY ARMOR INSERTS

10. SCOPE

10.1 Scope. This appendix details the liquid penetrant inspection process to be used for the examination of ceramic body armor materials. This appendix is a mandatory part of the specification. The information contained herein is intended for compliance.

20. APPLICABLE DOCUMENTS

20.1 Government documents.

20.1.1 Specification, standards, and handbooks. The following specifications, standards, and handbooks form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those listed in the issue of the Department of Defense Index of Specifications and Standards (DODISS) and supplement thereto, cited in the solicitation (see 6.2).

SPECIFICATIONS

MILITARY

MIL-I-25135 - Inspection Materials, Penetrants

20.2 Non-Government publications. The following documents form a part of this document to the extent specified herein. Unless otherwise specified, the issues of the documents which are DOD adopted are those listed in the issue of the DODISS cited in the solicitation. Unless otherwise specified, the issues of documents not listed in the DODISS are the issues of the documents cited in the solicitation (see 6.2).

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

ASTM E. 165 - Liquid Penetrant Inspection

(Application for copies should be addressed to the American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103-1187.)

(Non-Government standards and other publications are normally available from organizations that prepare or distribute the documents. These documents also may be available in or through libraries or other informational services.)

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APPENDIX C

30. REQUIREMENTS

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

30.2 Equipment. The equipment required shall be capable of performing uniform controlled operation using ASTM test procedures A1 per ASTM E 165.

30.3 Penetrant materials. For procedure A1 per ASTM E 165, Magnaflux ZL-17B penetrant shall be used. Equivalent materials complying with MIL-I-25135 may be used.

30.4 Test method. The test procedures as outlined in ASTM E 165 (procedure A1 for silicon carbide, high purity and modified boron carbide) shall be used. All discontinuities detected shall be marked for further evaluation or disposition. A ten power magnifying lens with or without illumination shall be used as necessary to assure accurate detection of indications.

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APPENDIX D

VISUAL INSPECTION REQUIREMENTS FOR THE EXAMINATION  
OF CERAMIC BODY ARMOR INSERTS

10. SCOPE

10.1 Scope. This appendix details the visual inspection process to be used for the examination of ceramic body armor materials. This appendix is a mandatory part of the specification. The information contained herein is intended for compliance.

20. APPLICABLE DOCUMENTS

This section is not applicable to this appendix.

30. REQUIREMENTS

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

30.2 Equipment. The equipment for visual inspection shall consist of the following items:

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

30.3 Test method. Each ceramic insert shall be carefully examined visually using ten power magnification where necessary. Flaw type indications shall be identified and measured. All discontinuities detected shall be marked for further evaluation or disposition.