
INCH-POUND

MIL-P-64153(MR)

26 June 1989

MILITARY SPECIFICATION

PLATE: BORON CARBIDE CERAMIC (FOR USE IN ARMOR COMPOSITES)

This specification is approved for use within the U.S. Army Materials Technology Laboratory, 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 the materials and performance requirements for boron carbide plates.

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

SPECIFICATIONS

FEDERAL

PPP-B-621 - Box, Wood, Nailed and Lock Cover
PPP-B-636 - Box, Shipping, Fiberboard

STANDARDS

MILITARY

MIL-STD-105 - Sampling Procedures and Tables for Inspection
by Attributes
MIL-STD-129 - Marking for Shipment and Storage

(Unless otherwise indicated, copies of federal and military specifications, standards, and handbooks are available from the Naval Publications and Forms Center, (ATTN: NPODS), 5801 Tabor Avenue, Philadelphia, PA 19120-5099.)

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 Laboratory Command, Materials Technology Laboratory, ATTN: SLCMT-MEE, Watertown, MA 02172-0001 by using the Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

AMSC N/A

FSC 9350

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2.2 Non-Government publications. The following documents form a part of this specification 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.

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)
AMERICAN SOCIETY OF MECHANICAL ENGINEERS (ASME)

ANSI/ASME B46.1 - Surface Texture (Surface Roughness, Waviness and Lay)

(Application for copies of ANSI/ASME publications should be addressed to The American National Standards Institute, 1430 Broadway, NYC, NY 10018)

ASTM (AMERICAN SOCIETY FOR TESTING AND MATERIALS)

ASTM C499 - Test Method for Facial Dimensions and Thickness of Flat, Rectangular Ceramic Wall and Floor Tile
ASTM E94 - Guides for Radiographic Testing
ASTM E112 - Methods for Determining Average Grain Size
ASTM E142 - Method for Controlling Quality of Radiographic Testing
ASTM E165 - Practice for Liquid Penetrant Inspection Method
ASTM E494 - Recommended Practice for Measuring Ultrasonic Velocity in Materials
ASTM E1001 - Practice for Detection and Evaluation of Discontinuities by the Immersed Pulse-Echo Ultrasonic Method Using Longitudinal Waves.

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

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 (i.e. preproduction). When specified in the contract or purchase order, a sample(s) shall be subjected to first article inspection (see 4.2.1).

3.2 Plate chemical composition. Composition shall be a minimum of ninety-seven (97.0%) weight percent pure boron carbide. Additionally, there shall be a maximum of 1.0 weight percent oxygen present.

3.3 Dimensional tolerances of plates.

3.3.1 Definition. A plate is defined to have two major surfaces and four minor surfaces.

3.3.2 Length and width tolerances. Tolerances for length and width dimensions are either plus or minus two point five percent ($\pm 2.5\%$) of the

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nominal size or plus or minus 1.5 millimeters (0.06 in), whichever is greater. Dimensional measurements between parallel minor surfaces on each individual plate shall not vary by more than 2.0% (see 4.4.2 for specific measurements requirements).

3.3.3 Thickness tolerances. Tolerances for the thickness dimension is either plus or minus three percent ($\pm 3.0\%$) of the nominal size or plus or minus 0.75 millimeters (0.03 in), whichever is greater. Thickness measurements on each individual plate shall not vary by more than 3.0% (see 4.4.2).

3.3.4 Squareness tolerances. All adjacent minor surfaces shall be square to a tolerance of either plus or minus one degree ($\pm 1.0^\circ$) or plus or minus 2.0 mm (0.08 in) from the perpendicular (90 degrees), whichever is greater. All measurements shall be made from corner to corner.

3.3.5 Chamfer. A chamfer of 1 ± 0.25 mm (0.04 ± 0.01 in) shall be made at an angle of 45 degrees ± 10 degrees from the major surface on all corners of plates less than 200 mm x 200 mm (8.0 in x 8.0 in) in size. A chamfer of 1.5 ± 0.5 mm (0.06 ± 0.02 in) shall be made at an angle of 45 degrees ± 15 degrees from the major surface on all corners of plates greater than or equal to 200 mm x 200 mm in size. See 3.3.7 for discretion in this requirement.

3.3.6 Surface finish. Both major surfaces of each individual plate shall have a surface finish of 10 micrometers (395 microinches) RMS maximum. All edge flashing shall be removed by grinding.

3.3.7 Additional requirements. The contracting officer may specify modified dimensional tolerances as the application may require.

3.4 Flaw tolerances of plates.

3.4.1 Internal flaw size. Internal flaws are defined as cracks, inclusions, voids, or measurable collections of porosity. Maximum allowable internal flaw size shall be 1.25 mm (0.05 in) for plates nominally less than 200 mm x 200 mm (8 in x 8 in) and 1.70 mm (0.07 in) for plates nominally greater than or equal to 200 mm x 200 mm (8.0 in x 8.0 in) in size.

3.4.2 Length of chips. The total length of chips on any side surface edge shall not exceed 20.0% of the edge length. The maximum chip depth on plate major surfaces shall not exceed 5.0% of the plate thickness.

3.4.3 Pits. Maximum surface pit diameter shall not exceed 5.0% of the plate length. Maximum surface pit depth shall not exceed 2.5% of the plate thickness. The maximum concentration for pits on the major surfaces are: 1) One per surface for pits with diameters between 2.5% to 5.0% of the plate length and depths between 1.0% to 2.5% of the plate thickness and 2) Ten per surface for pits with diameters between 2.0% to 4.0% of the plate thickness, and depths up to 1.5% of the plate thickness..

3.4.4 Surface crack tolerances. No plate shall have any cracks with a length of more than 5% of the plate length, or a depth exceeding 5% of the plate thickness. There shall be no more than one crack per linear inch (2.5 cm) as measured from corner to corner along any minor face.

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3.5 Density.

3.5.1 Bulk density of plates. The bulk density shall be a minimum of 97.5% of the appropriate theoretical density (see 3.5.2).

3.5.2 Theoretical density. The appropriate theoretical density shall be calculated for each plate lot by assuming a simple mixed composition of theoretically dense boron carbide (alpha or beta) and theoretically dense "additional elements", other than oxygen and nitrogen. "Additional elements" to be used in the determination are those detected through chemical analysis of the fully densified plate and present in concentrations of 0.4 weight percent or more:

Appropriate Theor. Density = $100 / (\text{volume SiC} + \text{vol. of Addl. elements})$.

where,

Volume of SiC = $\text{Wt\% of SiC} / \text{Density of pure SiC}$.

and

Volume of Addl. elements = $(\text{Wt\% A} / \text{Density A}) + (\text{Wt\% B} / \text{Density B}) + \dots + (\text{Wt\% Z} / \text{Density Z})$.

Here, "A, B, ..., and Z" are various metallic oxides.

3.5.2.1 Density of pure boron carbide. The density of pure boron carbide shall be taken as 2.5/gm/cc.

3.5.2.2 Elemental weight percents. The element weight percents to be used in the calculations shall be those measured from a powder of the crushed plate as described in 4.4.1 and any added oxides which remain during processing.

3.6 Young's Modulus. Young's Modulus based upon the bulk density of each plate shall not vary locally more than five percent (5%) from minimum to maximum value in a given direction of measurement, e.g. (Minimum Modulus/Maximum Modulus) X 100% \geq 95.0%. In addition, Young's Modulus shall not exceed 492 gigapascals (GPa) (71×10^6 psi) nor fall below 430 GPa (62.5×10^6 psi) within any plates in any direction.

3.7 Final microstructure. The final microstructure shall be uniform with an average grain size based on ASTM E122 of less than fifteen (15) micrometers and no grain shall exhibit an aspect of more than fifty (50) micrometers in any direction.

3.8 Identification marking. Plates of a given size shall be legibly numbered consecutively with adhesive labels or wear-resistant paint (e.g. white bin) directly on each plate for each delivery order. The contractor shall provide data sheets for each plate prepared at the time of processing using the numbering system mentioned below. Plate data sheets shall contain the following information:

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- a) Plate Identification Numbers. To be assigned immediately prior to shipping. Additional vendor identification may be included as necessary.
- b) Date of Fabrication: Month/Day/Year
- c) Nominal plate size.

3.9 Ballistic resistance. [The ballistic resistance of the boron carbide ceramic plate shall be specified at a later date, when appropriate.]

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 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.

4.1.3 Data sheet distribution. At least seven (7) calendar days prior to delivery of each shipping lot, copies of both plate shipping data and plate sampling data (see 3.8) shall be distributed as follows:

- a) One (1) copy with the appropriate plates
- b) Two (2) copies to the contracting officer.
- c) The original shall be retained by the contractor (see 4.1.1).

4.1.4 Contractor's calibration system. The contractor shall maintain a calibration system to control the accuracy of measurement and test equipment used in the fulfillment of 4.2. The system shall include as a minimum the source of calibration (traceable to the National Bureau of Standards) and a semi-annual calibration schedule. Documentation in support of this requirement shall be readily available to the contracting officer or his/her technical representative.

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

- a. First article (i.e. preproduction) inspection (see 4.2.1)
- b. Quality conformance inspection (see 4.2.2)

4.2.1 First article inspection. First article inspection shall consist of all the tests in table I.

4.2.2 Quality conformance inspection. Quality conformance inspection shall consist of all the tests in table II.

4.3 Sampling procedure. The supplier shall furnish the acquisition activity a lot of complete plates of the requested size and class. 100% visual inspection of plates for external flaws shall be carried out (see 4.4.2, 4.4.3 and 4.4.4) and defective plates shall be rejected. Only those plates meeting this requirement of this specification shall be retained. General Inspection Level II, AQL 1.5 of MIL-STD-105 shall be used in plates for all other tests. Failure of the sample to pass these inspection criteria shall be cause for rejection of the lot.

4.4 Test methods. Testing of boron carbide ceramic plate for compliance with the requirements of this specification shall be performed in accordance with the applicable test methods described in this specification to the maximum extent practicable or as otherwise specified by the acquisition activity.

4.4.1 Plate chemical composition. Composition of boron carbide plate shall be determined as follows: At least 10 gram samples of boron carbide representative of the process shall be provided for analysis. Sample shall be powderized using a non-contaminating crusher to minimize impurities in the sample. The particle size shall be no greater than 200 mesh (0.0029 in) (0.074 mm) (square opening). Inductively-coupled or direct-coupled (IC or DC) plasma emission spectrometry are suggested analytical methods. X-ray fluorescence spectrometry is also suggested. Classical wet chemical analysis and atomic absorption spectrometry are also acceptable.

The analysis shall detect constituents present in amounts over 0.010 weight percent. The measurement accuracy shall be ± 1.5 percent or better with respect to the actual amount of major constituents. The accuracy shall be ± 10.0 percent or better with respect to all impurities.

The analytical report shall contain the following information:

- (1) Date sample was received
- (2) Sample identification number or powder lot number
- (3) Test methods used, elements identified, and date of each test
- (4) Measured weight percents to a precision of at least 0.02 weight percent

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4.4.2 Dimensional measurements. Dimensional measurements of boron carbide plates shall be determined in accordance with ASTM C499, Test Method for Facial Dimensions and Thickness of Flat, Rectangular Ceramic Wall and Floor Tile. Surface finish shall be determined in accordance with ANSI/ASME B46.1, Surface Texture (Surface Roughness, Waviness and Lay), using a profilometer or similar device capable of measuring surface finishes under 10 micrometers RMS.

4.4.3 Flaw tolerances. External flaws (such as cracks) of boron carbide plates shall be detected in accordance with ASTM E165, procedure A-1, Practice for Liquid Penetrant Inspection Method. Internal flaws may be detected in accordance with ASTM E94, Guides for Radiographic Testing, and ASTM E142, Method for Controlling Quality of Radiographic Testing. A preferred method for detection of internal flaws is ultrasonic defect scanning in accordance with ASTM E1001, Practice for Detection and Evaluation of Discontinuities by the Immersed Pulse-Echo Ultrasonic Method Using Longitudinal Waves. Surface crack depth may be determined via ultrasonic testing using an A-scan. Inspection parameters such as transducer type, frequency, transmission mode, etc., depend upon the specific inspection technique used, i.e. contact angle, immersion testing and longitudinal beam. Depending upon the location of the cracks, it may be necessary to scan both from the top and bottom surface. The technique established to measure the crack depth shall be fully documented and shall demonstrate sufficient sensitivity and precision on a standard plate to achieve crack measurement accuracy required in this paragraph.

4.4.4 Bulk density. The bulk density of boron carbide plates shall be determined as follows: Weigh the dry plate in air to an accuracy of 0.05% for all plates. Suspend the plate in a tank of temperature-controlled pure water after taring the suspending equipment and weigh again to within the precision of the dry plate weighing. When determining the weight in water, completely submerge the plate with at least 2.5 cm (1-inch) of water above its top surface. The tank shall have minimum dimensions at least twice those of the plate in length and width. In addition, the tank shall contain a minimum depth of 20.0 cm (8-in) of water or as much more as is required to submerge satisfactorily the entire plate. The water temperature shall not vary by more than $\pm 0.5^{\circ}\text{C}$ ($\pm 1^{\circ}\text{F}$) during the measurement. The average temperature shall be recorded. The bulk density shall be calculated using the following formula:

$$\text{Bulk density} = \frac{(\text{Dry Weight} \times \text{Density of Water at Temperature})}{\text{Dry Weight} - \text{Submerged Weight}}$$

Data for the density of pure water as a function of temperature may be obtained from standard handbooks. Units of grams per cubic centimeter shall be used to report the bulk density.

4.4.5 Young's Modulus. Young's Modulus of boron carbide plates shall be determined in accordance with ASTM E494, Recommended Practice for Measuring Ultrasonic Velocity in Materials. Young's Modulus shall be determined at five (5) points, the corners and center of each plate.

4.4.6 Final microstructure. Final microstructure of boron carbide plates shall be determined in accordance with ASTM E112, Methods for Determining Average Grain Size.

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4.4.7 Ballistic resistance. [A procedure for determining the ballistic resistance of boron carbide armor plate shall be provided at a later date, when appropriate.]

5. PACKAGING

5.1 Preservation, packaging and marking. Preservation and packaging shall be accomplished by placing the boron carbide plates into containers conforming to PP-B-636; class, weather resistant. The containers shall be overpacked into wood boxes as per PPP-B-621, or packaged as specified in the contract. All containers shall be marked in accordance with MIL-STD-129 including bar coding and special marking instructions of 3.8.

6. NOTES

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

6.1 Intended use. Boron carbide ceramic plate is to be used for components of various armor systems.

6.2 Ordering data.

6.2.1 Acquisition requirements. Acquisition documents shall specify the following:

- a. Title, number and date of this specification
- b. Requirements for ballistic samples, if applicable
- c. Requirements for first article inspection, if applicable
- d. Requirements for quality conformance inspection
- e. Preservation and packaging if other than specified in 5.1

6.2.2 Consideration of data requirements. The following data requirements should be considered when this specification is applied on a contract. The applicable Data Item Descriptions (DID's) should be reviewed in conjunction with the specific acquisition to ensure that only essential data are requested/provided and that the DID's are tailored to reflect the requirements of the specific acquisition. To ensure correct contractual application of the data requirements, a Contract Data Requirements List (DD Form 1423) must be prepared to obtain the data, except where DOD FAR Supplement 27.475-1 exempts the requirement for a DD Form 1423.

<u>Reference Paragraph</u>	<u>DID Number</u>	<u>DID Title</u>	<u>Suggested Tailoring</u>
3.8	UDI-S-21270	Report, Materials and	Use contractor
4.4.1	UDI-S-21270	Processes Development and Evaluation	format

The above DID's were those cleared as of the date of this specification. The current issue of DOD 5010.12-L, Acquisition Management Systems and Data

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Requirements Control List (AMSDL), must be researched to ensure that only current, cleared DID's are cited on the DD Form 1423.

6.3 Keywords. The following terms are provided to facilitate retrieval searches:

Silicon carbide
Ceramic armor

Custodians:

Army - MR

Preparing activity

Army - MR

Review activities:

Army - AT, AV

DLA - GS

(Project 9350-A102)

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TABLE I. First article inspection of boron carbide ceramic plate.

<u>Characteristic</u>	<u>Requirement</u>	<u>Test Method</u>
Plate chemical composition	3.2	4.4.1
Dimensional tolerances	3.3	ASTM C499, ANSI B46.1
Flaw tolerances, External	3.4	4.4.3
Internal		4.4.3
Density, Bulk,	3.5.1	4.4.4
Young's Modulus	3.6	ASTM E494
Final microstructure	3.7	ASTM E112
Ballistic resistance	3.9	4.4.7

TABLE II. Quality conformance inspection.

<u>Characteristic</u>	<u>Requirement</u>	<u>Test Method</u>
Dimensional tolerances	3.3	ASTM C499, ANSI B46.1
Flaw tolerances, External	3.4	4.4.3
Internal		4.4.3
Density, Bulk	3.5.1	4.4.4
Young's Modulus	3.6	ASTM E494
Ballistic resistance	3.9	4.4.7

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NOTE: This form may not be used to request copies of documents, nor to request waivers, deviations, or clarification of specification requirements on current contracts. Comments submitted on this form do not constitute or imply authorization to waive any portion of the referenced document(s) or to amend contractual requirements.

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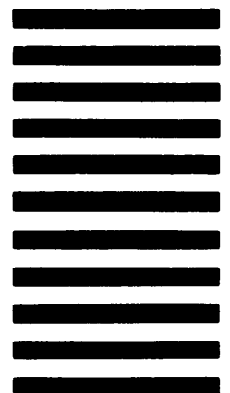
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STANDARDIZATION DOCUMENT IMPROVEMENT PROPOSAL

1. DOCUMENT NUMBER

MIL-P-64153(MR)

2. DOCUMENT TITLE

PLATE: BORON CARBIDE CERAMIC (FOR USE IN ARMOR COMPOSITES)

3a. NAME OF SUBMITTING ORGANIZATION**4. TYPE OF ORGANIZATION (Mark one)**☐

VENDOR

☐

USER

☐

MANUFACTURER

☐

OTHER (Specify): _____

b. ADDRESS (Street, City, State, ZIP Code)**5. PROBLEM AREAS****a. Paragraph Number and Wording:****b. Recommended Wording:****c. Reason/Rationale for Recommendation:****6. REMARKS****7a. NAME OF SUBMITTER (Last, First, MI) – Optional****b. WORK TELEPHONE NUMBER (Include Area Code) – Optional****c. MAILING ADDRESS (Street, City, State, ZIP Code) – Optional****8. DATE OF SUBMISSION (YYMMDD)**