METRIC

MIL-STD-376A
21 August 1998
SUPERSEDING
MIL-STD-376
28 June 1993

DEPARTMENT OF DEFENSE
TEST METHOD STANDARD

BALLISTIC PERFORMANCE RANKING OF CERAMIC ARMOR PLATES AGAINST HIGH DENSITY PENETRATORS

AMSC N/A

FSC 9350

FOREWORD

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

2. Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: Director, U.S. Army Research Laboratory, Weapons and Materials Research Directorate, ATTN: AMSRL-WM-M, Aberdeen Proving Ground, MD 21005-5069 by using the Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

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1. SCOPE

1.1 Purpose. The purpose of this standard is to provide a general methodology for the test equipment, procedures, targets, and terminology needed to develop ballistic performance evaluation and ranking of advanced armor materials against high density eroding projectiles.

1.2 Application. This military standard is intended for use in performing ballistic tests on armor materials, selection of materials to employ in armor systems, and as a tool to promote research and development of new armor materials. The method and target assembly technique also provide a means to perform parametric analyses on the effects of material properties, and other factors such as tile size, confinement, and penetrator properties on ballistic performance.

1.3 Materials and test conditions. This ballistic test method is intended for application to armor ceramics and other low ductility materials, for projectiles of heavy alloy, long rod type, and the armor materials to be used with a stiff backing structure. Applications of the test methodology to armor metallic materials are feasible in some instances, but fall outside the scope of this document. Examples of materials for which this test may be appropriately employed are:

a. Single-phase ceramics (such as SiC, TiB_2)
b. Multiple-phase ceramics (aluminas)
c. Glasses
d. Metal-infiltrated ceramic composites
e. Low ductility metal matrix composites

1.4 Limitations. This standard has the following limitations:

a. This standard does not take precedence over nor supersede existing armor specification ballistic test procedures.

b. Specific requirements for the ballistic testing of armor end items are not covered by this standard and must be specified in the appropriate detailed specifications, contracts, or event design plans prepared by the Army's independent evaluator (OPTEC/EAC).

c. Military activities or DoD contractors may use in-house ballistic test facilities and equipment not covered by this standard (see MIL-STD-1161(GL)).

2. APPLICABLE DOCUMENTS

2.1 General. The documents listed in this section are specified in sections 3, 4, and 5 of this standard. This section does not include documents cited in other sections of this standard or recommended for additional information or as examples. While every effort has been made to ensure the completeness of this list, document users are cautioned that they must meet all specified requirements documents cited in sections 3, 4, and 5 of this standard, whether or not they are listed.

2.2 Government documents.

2.2.1 Specifications, standards, and handbooks. The following specifications, standards, and handbooks form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those 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

DEPARTMENT OF DEFENSE

MIL-A-12560 - Armor Plate, Steel, Wrought, Homogeneous (For Use in Combat-Vehicles and for Ammunition Testing)

(Unless otherwise indicated, copies of the above specifications, standards, and handbooks are available from the Defense Automated Printing Service (DAPS), 700 Robbins Avenue, Building 4D, Philadelphia, PA 19111-5094.)

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. DEFINITIONS

3.1 Applique armor. Armor that can be easily installed or removed from a weapon system in kit form without adversely affecting its structural integrity or operation.

3.2 Areal density. A measure of the weight of armor material per unit area, usually expressed in pounds per square foot (lb/ft^2) or kilograms per square meter (kg/m^2) of surface area.

3.3 Armor. A shielding material provided for ballistic defeat of projectiles or fragments when inherent shielding is inadequate.

3.4 Armor system. A combination of various armor materials with properties and geometry chosen to defeat one or more specific threat projectiles.

3.5 Ballistic acceptance test. A test performed on lot representative samples to determine whether or not the lot of armor is ballistically acceptable for use in production armor items.

3.6 Ballistic screening test. A test performed to determine the performance level of an armor material relative to that of known standard materials. Employs a simplified configuration rather than a production armor design for the target.

3.7 Ballistic impact. Those impacts due to hits on the target by projectiles, fragments or other aerodynamically-affected threat mechanisms.

3.8 Ballistic limit, protection criteria (V_{50}BL(P)). The V_{50}BL(P) may be defined as the average of an equal number of highest partial penetration velocities and the lowest complete penetration velocities which occur within a specified velocity spread. The normal up-and-down firing procedure is used. A 0.020 in. (0.51 mm) thick 2024 T3 sheet of aluminum is placed 6 ± 1/2 in. (152 ± 12.7 mm) behind and parallel to the target to witness complete penetrations. Normally, at least two partial and two complete penetration velocities are used to complete the BL(P). Four, six, and ten-round ballistic limits are frequently used. The maximum allowable velocity span is dependent on the armor material and test conditions. Maximum velocity spans of 60, 90, 100 and 125 feet per second (ft/s) (18, 27, 30 and 38 m/s) are frequently used.

3.9 Ballistic limit. The minimum velocity at which a particular projectile is expected to consistently, completely penetrate armor of given thickness and physical properties at a specified angle of obliquity. The ballistic limit may also be defined as the maximum velocity at which a particular projectile is expected to consistently fail to penetrate armor of given thickness and physical properties at a specified angle of obliquity. Because of the expense of firing tests and the impossibility of controlling striking velocity precisely, plus the existence of a zone of mixed results in which a projectile may completely penetrate or only partially penetrate under apparently identical conditions, statistical approaches are necessary, based upon limited firings. Certain approaches lead to approximation of the V_{50} Point, that is, the velocity at which complete penetration and incomplete penetration are equally likely to occur. Other methods attempt to approximate the V_{0} Point, that is, the maximum velocity at which no complete penetration will occur. Other methods attempt to approximate the V_{100} Point, that is, the minimum velocity at which all projectiles will completely penetrate.

3.10 Ballistic resistance. A measure of the capability of a material or component to stop or reduce the impact velocity and mass of an impacting projectile or fragment.

3.11 Break screens. A screen with a conductive pattern printed on the surface which is broken (opened) by a projectile impacting the screen. Used to activate or deactivate a chronograph upon passage of a projectile.

3.12 Cell size. The lateral dimensions of an armor tile used in an armor array.

3.13 Ceramic armor. Any ceramic material which is employed as a component of an armor array for protection against projectiles. In this sense, includes glasses as well as polycrystalline materials.

3.14 Ceramic percentage. The fraction of ceramic present in an armor system as determined from dividing the areal density of its ceramic components by the total areal density of the system.

3.15 Chronograph. An electronic instrument used to determine the time interval of projectile flight between two fixed measuring stations.

3.16 Comminution. Fracture or fragmentation of ceramic material into fine particulates as a result of projectile impact.

3.17 Composite armor. An armor system consisting of two or more different armor materials bonded together to form a protective unit.

3.18 Confinement frame. A steel frame or other structural support surrounding a ceramic tile which serves to retain it in place after it is damaged by impact of a projectile.

3.19 Depth of residual penetration (DOP). In the context of this test standard, the length or depth of the penetration cavity of the projectile in the steel backing plate after passing through the ceramic.

3.20 Fair test. In the context of this standard, a test shot should be considered fair when a test projectile having total yaw under 3 degrees strikes the target within a radius equal to two penetrator diameters of the exact tile center.

3.21 Integral armor. Armor material used as part of a structure to perform a load-carrying or other operational function, in addition to ballistic protection. Also known as structural armor.

3.22 Long rod penetrator. Any projectile having a length to diameter (aspect) ratio greater than five.

3.23 Lumiline screens. Photoelectric device used to activate or deactivate a chronograph upon passage of a projectile.

3.24 Muzzle velocity. The velocity of the projectile with respect to the muzzle at the instant the projectile leaves the weapon. This velocity is a function of projectile weight, firing charge of the projectile, and barrel characteristics.

3.25 Obliquity. A measure, normally in degrees, of the extent to which the impact of a projectile on an armor material deviates from a line normal to the target. Thus, a projectile fired perpendicular to the armor surface has 0 degrees obliquity.

3.26 Obturator. A component of the sabot package which serves as a bore seal.

3.27 Overmatching. As used herein, a condition in which the penetration capability of the projectile is much greater than the stopping capability of the armor or armor material. Also used in association with steel armor, where it indicates that the diameter of the impacting projectile is larger than the thickness of the armor plate.

3.28 Penetration, complete (CP). A complete penetration occurs when a projectile or fragment has penetrated the armor sufficiently to permit the passage of light through a hole or crack developed in the armor, or when the projectile lodged in the armor can be seen from the rear of the armor sample.

3.29 Penetration, reference (PO). The depth to which the standard test projectile penetrates when fired at the standard striking velocity into a semi-infinite RHA steel block.

3.30 Penetration, residual (PR). In general, the length or depth of the penetration cavity of a projectile into a witness pack or plate. As applied herein, the penetration in the steel backup block behind the ceramic target assembly. (See also DOP)

3.31 Performance map, ballistic. A plot of residual penetration as a function of areal density of armor ceramic.

3.32 Propellant. A rapidly burning substance or mixture whose combustion or release produces the gas pressure that propels the projectile through the gun bore.

3.33 Pusher. A metallic disk used to transmit launch loads to the base of a projectile when a traction-launch system is not employed.

3.34 Rolled homogeneous armor (RHA). Armor steel produced as per the requirements of MIL-A-12560.

3.35 Sabot. Lightweight carrier in which a specified caliber projectile is centered to permit firing the projectile in the larger caliber weapon. The sabot diameter fills the bore of the weapon from which the projectile is fired. The sabot is usually discarded in flight a short distance from the muzzle, and only the subcaliber projectile continues downrange.

3.36 Semi-infinite. As related to penetration of a thick target, implies that the rear surface of the plate receives only elastic loading, with no permanent deformation being discernible.

3.37 Small arms. All gas-propelled, tube-type weapons firing a ballistic projectile with a diameter up to and including 20 millimeters (0.787 inches).

3.38 Small arms ammunition. All ammunition up to and including 20 millimeters (0.787 inches). A round of ammunition includes a ballistic projectile, propellant charge, charge igniter (primer), and a charge case.

3.39 Spaced armor. Armor systems having spaces between armor elements.

3.40 Spalling. The detachment or delamination of a layer of material in the area surrounding the location of impact, which may occur on either the front or rear surfaces of the armor. Spalling may be a threat mechanism even when penetration of the armor itself is not complete.

3.41 Striking velocity. The velocity of a projectile or missile at the instant of impact (also known as impact velocity).

3.42 Target base line. The distance from a point midway between the two velocity measuring, triggering devices to the test sample.

3.43 Terminal ballistics. A branch of ballistics which is concerned with the effects of weapons on targets including penetration, fragmentation, detonation, shaped charge, blast, combustion and incendiary effects.

3.44 Test sample. An armor plate or fabricated armor section or component which is to be ballistically tested for evaluation of ballistic protection properties.

3.45 Tungsten heavy alloy. A high density composite material consisting of a large (usually >90%) weight fraction of tungsten particles bound in a matrix material, which is usually a Ni-Fe alloy. Commonly used to make long rod penetrators.

3.46 Undermatch. As used herein, a condition in which the penetration capability of the projectile is much lower than the stopping capability of the armor or armor material. Also used in association with steel armor, where it indicates that the diameter of the impacting projectile is less than the thickness of the armor plate.

3.47 V_{50} ballistic limit. In general, the velocity at which the probability of penetration of an armor material is 50 percent.

3.48 Witness plate. A thin sheet located behind and parallel to the ballistic test sample which is used to detect penetrating projectiles or spall.

3.49 Yaw. Projectile yaw is the angular deviation of the longitudinal axis of the projectile from the line of flight at a point as close to the impact point on the target as is practical to measure.

4. GENERAL REQUIREMENTS

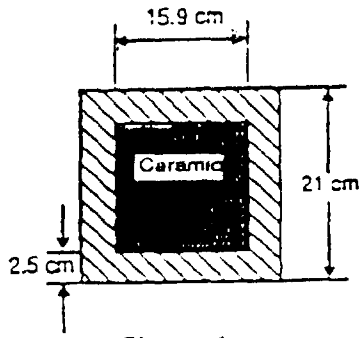
4.1 Target configuration and setup.

4.1.1 Ceramic tile and confinement frame. The standard target configuration to be employed in these tests is shown in figures 1 and 2. The target consists of a 15 cm by 15 cm square ceramic tile of a chosen thickness (t), which is laterally confined in a steel frame with a 2.5 cm web and a depth equal to or greater than the tile thickness. No cover plate is employed. A polymeric adhesive is used to retain the tile in the frame, in addition to being spread in a thin layer (approximately 0.5 mm) behind the tile to accommodate any slight surface irregularities, thus preventing nonuniform contact between the ceramic and the backing plate. The use of a 5 kg load uniformly distributed on the ceramic plate during the adhesive curing cycle is recommended. Two fabrication options are permissible:

a) a 0.5 mm aluminum sheet may used behind the tile to contain the epoxy within the frame.

b) the confinement frame and ceramic may be attached directly to the surface of the backing plate (4.1.2) by the adhesive.

4.1.2 Thickness of the ceramic plates. Thickness of the ceramic plates should vary no more than ± 3% for any given series of targets.



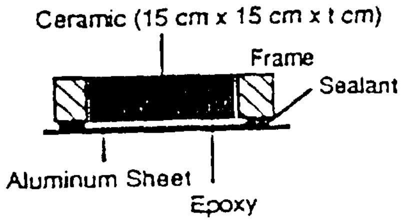


FIGURE 1. & FIGURE 2. Standard target configuration.

4.1.3 Backing plate. The backing plate employed shall be RHA steel (MIL-A-12560, class 1 or class 3) of a thickness sufficient to be effectively semi-infinite or with respect to the residual penetration of the tested projectile/material combination. The hardness level of the steel plate shall be in the range of 26 ± 1.5 on the Rockwell "C" scale. Commonly employed plate thickness is 10 cm and 12.5 cm. Specification requirements for this steel mandate approximately this hardness range for this thickness. The plates shall have a surface finish of 13.2 m. If RHA steel is not readily available, 4340 steel at the specified hardness level may be substituted.

4.1.4 Target fixturing. If 4.1.1 (a) is followed, ceramic target assemblies will be mechanically clamped against the steel backup block for testing, and removed after firing. Clamping shall be performed so as to produce uniform contact between the ceramic target assembly and the steel block. Visual inspection should show no gap between the target assembly and the block. In either case, the target system shall be supported on a test table or other fixture such that it is properly restrained and that the target face is normal to the projectile line-of-flight. Figure 3 presents a general schematic.

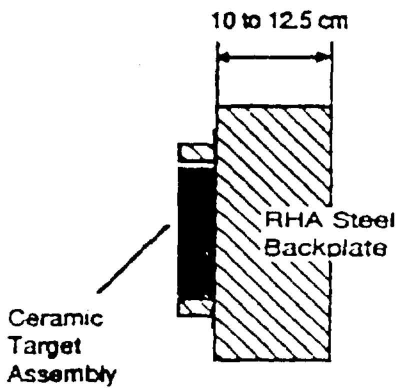


FIGURE 3. General schematic.

4.2 Projectile specifications. The standard projectile employed shall be a long rod penetrator with a mass of 65 ± 0.25 g and an aspect ratio of 10:1. It should have an hemispherical nose and preferably shall not be threaded or grooved for traction launch. The alloy used should be either a 91% or 93%

tungsten heavy alloy composition, with a minimum ultimate tensile strength (UTS) of 1000 MPa and elongation of 5%. Exact projectile dimensions will vary with the alloy density. By way of example, a penetrator fabricated from a 91% tungsten heavy alloy, with a density of 17.45 g/cc, will have a diameter of 7.87 mm.

4.3 Test conditions.

4.3.1 Launch system. The penetrator may be launched by any normal ballistic test practice which will consistently achieve the desired launch velocity and yaw control parameters.

4.3.1.1 Gun system and launch package. The suggested configuration is to employ a pusher-type sabot package, fired from a smooth-bore test barrel of at least 20 mm bore diameter.

4.3.1.2 Propellant. Any propellant which is either standard or suitable for the weapon shall be used. A projectile velocity-propellant charge curve for the weapon shall be determined before any testing is performed. This curve is required to provide a basis for selecting a powder charge to achieve the desired velocity. It is recommended that the propellant storage and weighing area be maintained at 23 ± 2°C and 50 ± 5% relative humidity.

4.3.2 Launch parameters. The nominal test velocity employed for ceramic testing is 1500 m/s. All baseline performance data cited in Section 5 of this specification were obtained at this test velocity. In some instances, variations from this reference velocity may be desired, but this introduces the need to perform additional baseline material performance tests at the selected velocity. To ensure a fair test, total projectile yaw must be under 3 degrees.

4.4 Velocity measuring equipment.

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

4.4.2 Detectors. Either high-velocity lumiline screens, or electrical contact screens which either open or close an electrical circuit by passage of the projectile through the detector shall be used. 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. This system may be employed in order to provide a starting time for operation of the flash x-ray system, and will also provide a check velocity in the event of timer failures in the x-ray system.

4.4.3 Flash radiography system. Measurement of the projectile yaw and velocity shall be accomplished by a flash radiography system. Exact setup and nature of the system shall be in accordance with established range procedures and the operational requirements of the specific equipment being employed. Total yaw and velocity of the projectile will be measured from two sets of orthogonal radiographs in accordance with appropriate practices for the system setup being employed. Striking velocity shall be recorded to within 1 m/s, and yaw shall be determined in increments of no greater than 0.25 degrees.

5. DETAILED REQUIREMENTS

5.1 Test conditions. All ballistic tests shall be performed in a standard atmosphere of 23 ± 2°C and 50 ± 5% relative humidity. These conditions are recommended in order to provide for optimal control of projectile velocities.

5.2 Ballistic test procedure. The procedure listed below is a general description of the method for obtaining residual penetration data on a ceramic or other type of target material. One should note that the actual method to be used may vary depending on target composition, specification or contract requirement.

5.2.1 Firing practices. All ballistic tests shall be conducted in accordance with commonly accepted procedures for the particular gun setup being employed, in a manner which complies with the requirements of Section 4. All appropriate general safety procedures applicable to the performance of ballistic tests shall be followed, including any accepted local regulations as implemented at particular installations.

5.2.2 Measurement of residual penetration. When using this method all residual penetration measurements will be made directly from sections of the RHA steel block. A saw or other appropriate cutting tool (such as a wire EDM unit) shall be used to section all penetration cavities. Measurements should be made with vernier calipers on both sides of the cavity sections as indicated in figure 4, choosing the lower of the resultant values for "a". Measurement of the "a" value in this way avoids error which will be caused by deformation of the steel block around the entrance cavity. When the cavity is non-uniform, the portion which shows the deepest penetration (that is the lowest "a" value) shall be chosen. An alternative to sectioning the block to measure residual penetration may be industrial x-ray techniques. These techniques can be used to measure the distance from the bottom of the cavity (or tip of the penetrator slug if it is lodged in the end of the cavity) to the rear surface of the RHA plate.

$$DOP = T_b - a$$

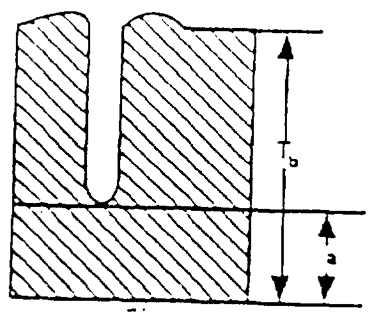


FIGURE 4. Vernier measurements.

5.2.3 Baseline penetrator calibration. In order to provide a suitable set of baseline data for residual penetration into the RHA steel backup, a minimum of 8 tests evenly spaced over a velocity range from 1000 m/s to 1700 m/s shall be performed. This procedure need only be performed once to cover any individual lot of penetrators obtained at one time from a single manufacturer. If the penetrator is a 91% W to 93% W long rod with the specified 10:1 aspect ratio and 65 g mass, the following equation may be employed to determine reference penetration as a function of velocity over a range from 800 to 1750 m/s. A graphical representation of this plot is shown in figure 5.

$$DOP\ (mm) = -55.734 + (0.08342 \times V_s) \qquad \text{(Equation 1)}$$

with V_s being the striking velocity in units of m/s.

5.2.4 Quantity of test specimens. Test targets shall be prepared in keeping with the parameters given in section 4.1. For each ceramic material which is to be tested, a minimum of three (3) fair impacts shall be obtained. A fair impact is a shot which has a total yaw of under 3 degrees, and a striking velocity within ± 25 m/s of the chosen nominal test velocity (see 4.3.2). In addition, the shot must impact the target within a distance of two penetrator diameters from the geometrical center of the ceramic plate, and there must not be any visible deformation or bulging of the rear surface of the RHA steel block. Sufficient targets shall be tested to obtain the required three fair impacts.

5.2.5 Corrections for striking velocity variations. In order to normalize all penetration values to the nominal striking velocity, measured DOP values should be corrected by applying the following equation:

$$DOP_{corrected}\ (mm) = DOP_{measured}\ (mm) + (0.08342 \times (1500 - V_s)) \qquad \text{(Equation 2)}$$

where $DOP_{corrected}$ is the corrected residual penetration, $DOP_{measured}$ is the measured residual penetration, and V_s is the striking velocity in m/s.

5.3 Ballistic test report. It is recommended that ballistic test reports have the following information:

For each test series:

a. Contractor identification.
b. Contract number.
c. Material producer test facility.
d. Date test conducted.
e. Personnel conducting test and any witnesses.
f. Projectile used.
g. Armor material description.

For each test target:

a. Identification number for each material sample (including lot numbers).
b. Projectile mass (g).
c. Striking velocity (as determined from flash radiographs).
d. Total projectile yaw (as determined from flash radiographs).
e. Measured block thickness (Tb)

f. Cavity-rear surface thickness (a).
g. Calculated DOP.
h. Other remarks pertinent to the conduct of the test, or behavior of the material.

Additional data may be required by a contracting activity. When testing is done at a place other than a Government facility, results should be reported on forms either furnished or approved by the Government. One copy of each complete report shall be forwarded to the agency designated by the Government.

5.4 Ceramic performance evaluation.

5.4.1 Reference ceramics. Reference maps for the performance of four armor ceramics are available for comparison with test materials. These reference materials are:

a. Aluminum oxide (composition shall be a minimum of 90.0 weight percent pure aluminum oxide).

b. Boron carbide (composition shall be a minimum of 97.0 weight percent pure boron carbide; additionally, there shall be a maximum of 1.0 weight percent oxygen present).

c. Silicon carbide (composition shall be a minimum of 99.0 weight percent pure silicon carbide).

d. Titanium diboride (composition shall be a minimum of 98.0 weight percent pure titanium diboride; additionally, there shall be a maximum of 0.50 weight percent oxygen present, and a maximum of 0.65 weight percent tungsten present).

Test materials should be related to reference materials on the basis of bulk density. For example the appropriate reference material to use for comparisons of titanium carbide (TiC) at 4.9 g/cc would be item d, titanium diboride.

5.4.1.1 Aluminum oxide baseline. The baseline performance map is shown in figure 6. For this material, the residual penetration may be obtained from the following equation:

$$\text{DOP (mm)} = 63.98 - (0.1907 \times \text{AD}) \qquad \text{(Equation 3)}$$

with AD being the areal density in units of kg/m^2. This is valid over the range of areal densities from 50 to 270 kg/m^2.

5.4.1.2 Boron carbide baseline. The baseline performance map is shown in figure 7. For this material, the residual penetration may be obtained from the following equation:

$$\text{DOP (mm)} = 54.08 - (0.2357 \times \text{AD}) \qquad \text{(Equation 4)}$$

with AD being the areal density in units of kg/m^2. This is valid over the range of areal densities from 60 to 130 kg/m^2.

5.4.1.3 Silicon carbide baseline. The baseline performance map is shown in figure 8. For this material, the residual penetration must be obtained from the following equation:

DOP (mm) = 3508 * AD expo (-1.126) (Equation 5)

with AD being the areal density in units of kg/m^2. Valid comparisons may be made over the range of areal densities from 60 to 220 kg/m^2.

5.4.1.4 Titanium diboride baseline. The baseline performance map is shown in figure 9. No equation of fit is available for this material. The residual penetration should be obtained either directly from the curve, or by reference to the data given in table I, which contains expected DOP values for a range of areal densities between 30 and 180 kg/m^2 (that is, over the complete extent of the curve). Valid comparisons may be made over the range of areal densities from 70 to 150 kg/m^2.

5.4.2 Performance ranking of tested materials. The performance of the tested ceramic or other material may be related to the reference ceramic by determining the residual penetration (DOP) for the appropriate reference material (as indicated in 5.4.1 above), and comparing this to the average value of DOP obtained from the requisite three fair impacts on the tested ceramic. Comparison of DOP values are made at equal areal density of reference and trial materials. The resultant difference provides the basis for comparison. A qualitative result can be determined based upon the position of the tested material relative to the baseline material. A tested material which exhibits an increased residual penetration has a lower performance, and one which exhibits a reduced residual penetration from the reference material has an improved performance. Quantitative comparisons may be made in terms of percentage differences between DOP values obtained for the tested and reference materials.

5.4.3 Applications to variant test configurations. If it is desired to perform residual penetration screening tests employing a penetrator or a test condition not explicitly set out or incorporated in this standard, the methods and approach employed should parallel the ones set forth herein as much as is possible. It should be recognized that significant variation from the test conditions described by this standard may require extensive work to provide suitable baseline data sets for both penetrator calibration and reference material performance maps. This fact should be kept in mind when determining whether a variant test configuration is desirable.

5.5 Acceptance and rejection. If this test method is employed as a purchasing guidance tool, the selected material samples must meet the minimum ballistic requirements specified in the order for the represented lot to be acceptable. Failure of any averaged series of test samples to meet the minimum specified ballistic performance level shall constitute rejection of the entire lot which they represent. Unless otherwise specified, the ballistic tests shall be conducted and the test results considered prior to accepting shipment of the lot of material represented by the test samples.

5.6 Test samples ownership. Ballistic test samples that comply with ballistic requirements are considered as part of the lot of material they represent, and ownership of them passes to the Government upon acceptance. The Government inspector shall dispose of these test samples unless instructed otherwise by the procuring activity. Test samples that fail to comply with the ballistic requirements are considered as part of the lot they represent and remain the property of the supplier just as does the rejected lot they represent.

5.7 Retests. Reference shall be made to the appropriate specification or applicable test directive for guidance on the number of retest samples required, if such are allowed. If the retest samples do not pass the ballistic test, the lot from which they came, or the process by which they were made is permanently rejected. Otherwise, if all retest samples pass, the lot or process is accepted.

5.8 Security classification of armor. Terminal ballistics performance data on armor materials shall be classified in accordance with ARL PROGRAM No. 0183009, "Security Classification Guide for Armor Materials" dated 30 July 1993.

6. NOTES

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

6.1 Intended use. This test method standard is military unique because it is intended for use in the ballistic evaluation of ceramic armor plates against high density eroding projectiles and as a tool to promote research and development of new armor materials.

6.2 Issue of DoDISS. When this standard is used in acquisition, the applicable issue of the DoDISS must be cited in the solicitation (see 2.2.1).

6.3 Subject term (key word) listing.

Aluminum oxide
Boron carbide
Chronograph
Flash radiography
Metal matrix composites
Silicon carbide
Titanium diboride

6.4 Changes from previous issue. Marginal notations are not used in this revision to identify changes with respect to the previous issue due to the extent of the changes.

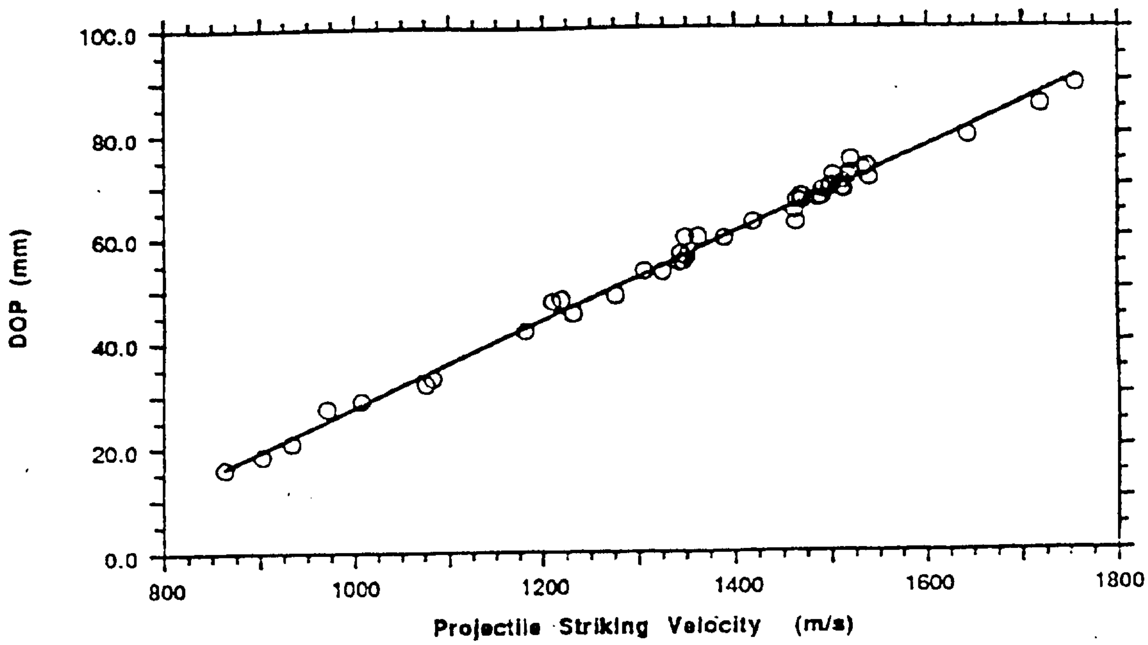


FIGURE 5. Penetration depth in RHA steel as a function of projectile velocity for 91% W rod.

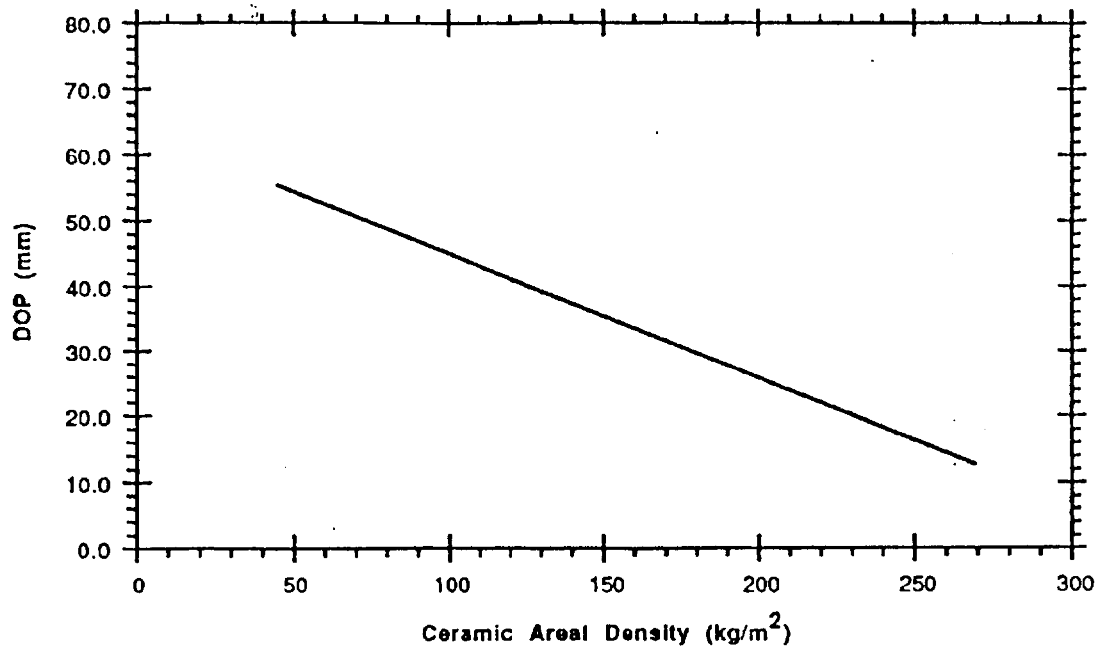


FIGURE 6. Aluminum oxide reference map.

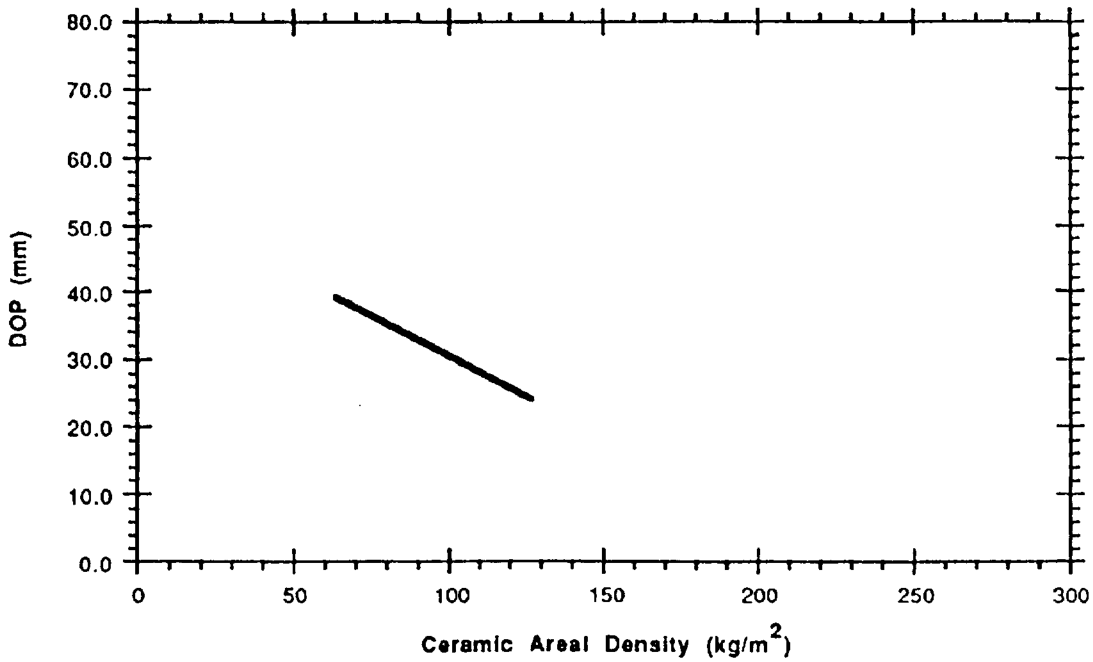


FIGURE 7. Boron carbide reference map.

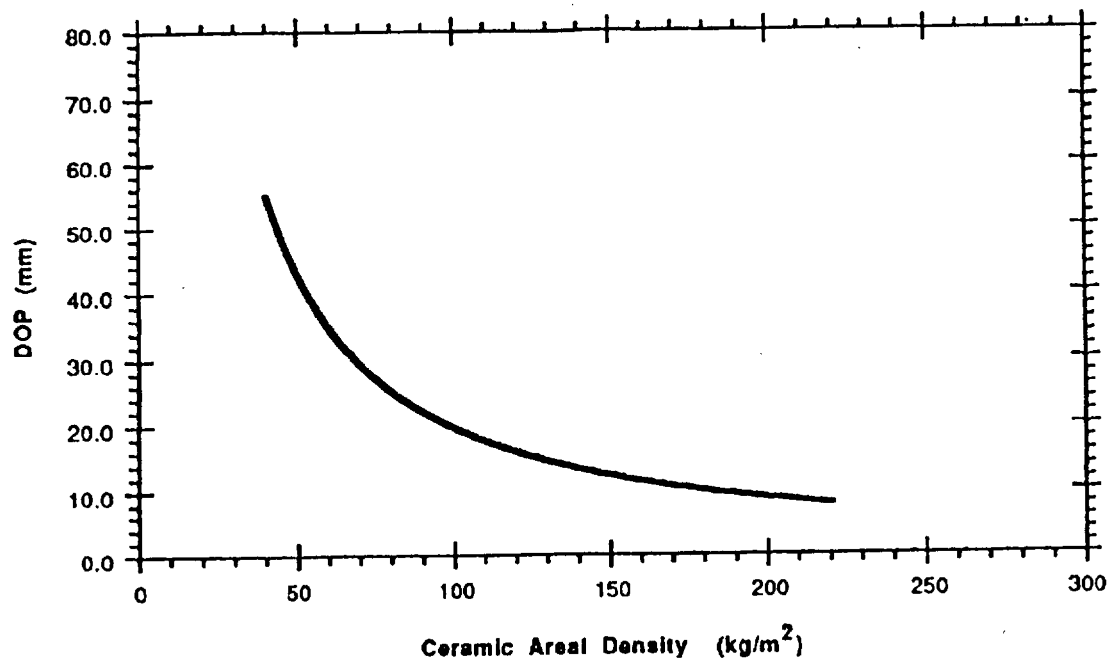


FIGURE 8. Silicon carbide reference map.

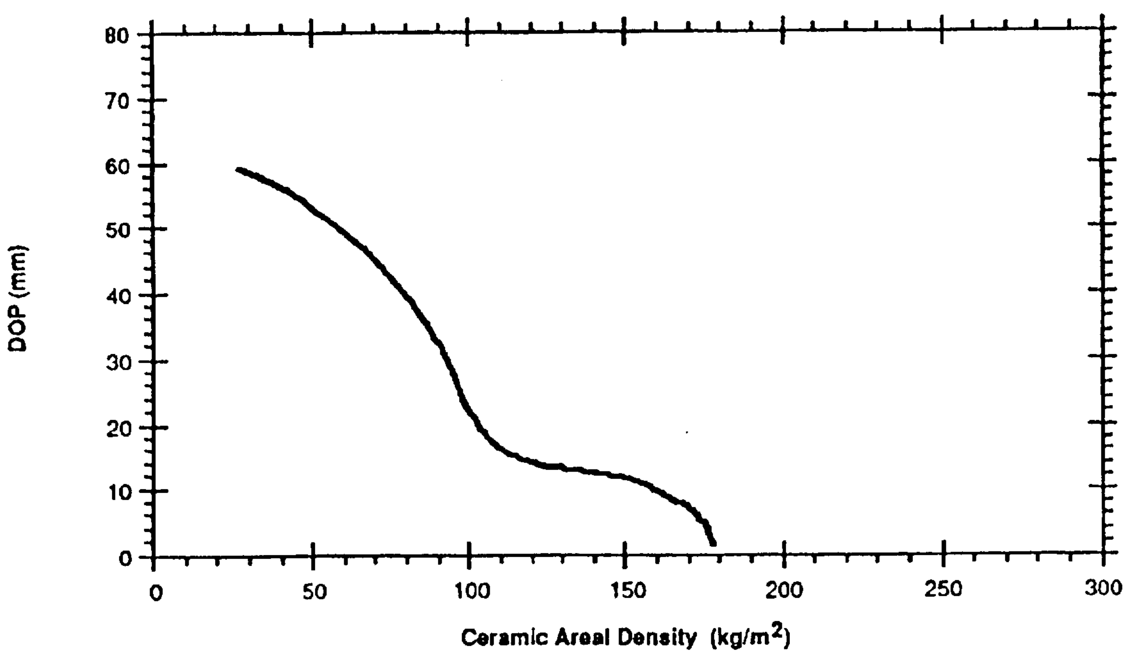


FIGURE 9. Titanium diboride reference map.

TABLE I. Expected DOP values for titanium diboride for 30-180 kg/m^2 areal densities.

AD (kg/m^2)	DOP (mm)	AD (kg/m^2)	DOP (mm)
29.5	58.5	112.5	15.5
32.5	58.0	115.5	14.5
35.5	57.4	119.0	14.0
38.5	56.5	121.5	13.5
41.5	55.5	124.5	13.0
44.5	55.0	127.5	13.0
47.5	54.0	130.5	13.0
50.5	53.0	133.5	12.5
53.5	51.5	136.5	12.5
56.5	50.5	139.0	12.0
59.0	49.5	142.5	11.5
62.5	48.5	145.5	11.5
65.0	47.0	148.0	11.5
68.0	46.0	151.0	11.0
71.0	44.5	154.0	10.5
74.0	43.0	157.0	10.5
77.0	41.5	160.0	9.0
80.0	40.0	163.0	8.5
83.0	37.5	166.0	7.5
85.0	35.5	169.0	7.0
89.0	33.5	172.0	6.0
92.0	31.5	175.0	5.0
95.0	28.5	178.0	2.0
98.0	25.0	181.0	0.0
101.0	21.5		
104.0	20.0		
107.0	17.5		
110.0	16.5		

CONCLUDING MATERIAL

Custodians:
Army - MR
Navy - SH
Air Force - 99

Review activities:
Army - AT, TE
Navy - AS, CG
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DLA - GS

Preparing activity:
Army - MR

(Project 9350-0012)

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DOCUMENT TITLE BALLISTIC PERFORMANCE RANKING OF CERAMIC ARMOR PLATES AGAINST HIGH DENSITY PENETRATORS

4. NATURE OF CHANGE *(Identify paragraph number and include proposed rewrite, if possible. Attach extra sheets as needed.)*

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