INCH-POUND

MIL-DTL-32333 (MR)
29 July 2009

DETAIL SPECIFICATION

ARMOR PLATE, MAGNESIUM ALLOY, AZ31B, APPLIQUE

This specification is approved for use by the 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 wrought magnesium alloy armor plate in nominal thicknesses from 0.250 to 3.000 inch, inclusive (see 6.2).

1.2 Classification. The wrought magnesium alloy armor should be of the following class as specified (see 6.2).

1.2.1 Class 1. Wrought magnesium AZ31B alloy armor that has been cold rolled and partially annealed (H24 condition).

2. APPLICABLE DOCUMENTS

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

Comments, suggestions, or questions on this document should be addressed to: Director, U.S. Army Research Laboratory, Weapons and Materials Research Directorate, Materials Application Branch, Specifications and Standards Office, Attn: RDRL-WMM-C, Aberdeen Proving Ground, MD 21005-5069 or emailed to rsquilla@arl.army.mil. Since contact information can change, you may want to verify the currency of this address information using the ASSIST Online database at http://assist.daps.dla.mil/.

AMSC N/A FSC 9535

DISTRIBUTION STATEMENT A. Approved for public release; distribution is unlimited.

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 (see 6.2), the issues of these documents are those cited in the solicitation or contract.

DEPARTMENT OF DEFENSE STANDARDS

MIL-STD-129	-	Military Marking for Shipment and Storage

(Copies of these documents are available online at http://assist.daps.dla.mil/quicksearch/ or http://assist.daps.dla.mil/ or from the Standardization Document Order Desk, 700 Robbins Avenue, Building 4D, Philadelphia, PA 19111-5094.)

2.3 Non-Government publications. The following documents form a part of this specification to the extent specified herein. Unless otherwise indicated (see 6.2), the issue in effect on the date of invitation for bids or request for proposal should apply.

ASTM INTERNATIONAL

ASTM B90/B90M	-	Standard Specification for Magnesium-Alloy Sheet and Plate (DoD Adopted)
ASTM B117	-	Standard Practice for Operating Salt Spray (Fog) Apparatus (DoD Adopted)
ASTM B557	-	Standard Test Method of Tension Testing Wrought and Cast Aluminum- and Magnesium-Alloy Products (DoD Adopted)
ASTM B954	-	Standard Test Method for Analysis of Magnesium and Magnesium Alloys by Atomic Emission Spectrometry
ASTM G97	-	Standard Test Method for Laboratory Evaluation of Magnesium Sacrificial Anode Test Specimens for Underground Applications.

(Copies of these documents are available from www.astm.org or ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959.)

2.4 Order of precedence. Unless otherwise noted herein or in the contract, in the event of a conflict between the text of this document and the references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

3. REQUIREMENTS

3.1 First article. When specified in the contract or purchase order (see 6.2), first article testing shall be required and all test samples required by this specification shall be made available to the contracting officer or his authorized representative for approval in

accordance with 4.3. The contractor shall comply with this requirement at the time of his first order or contract and at any time that the supplier has not furnished the same class of magnesium armor in the applicable thickness range under this specification within a period of 18 months. First article testing shall be completed before production material is submitted for acceptance testing. The approval of the first article samples authorizes commencement of production but does not relieve the supplier of the responsibility to comply with all the applicable provisions of this specification. The first article samples and acceptance test plates shall be manufactured by the process proposed for use on production items.

3.2 Chemical composition. The chemical composition (product analysis) of the plates shall be determined in accordance with ASTM B954 and shall be within the limits specified in Table I. A certification of conformance of the chemical composition of the alloy shall be furnished with the ballistic test plates.

TABLE I. Chemical composition (product analysis), weight percent. 1/

ELEMENTS	AZ31B ALLOY 2/	
	Maximum	Minimum
Aluminum (Al)	3.5	2.5
Zinc (Zn)	1.3	0.7
Manganese (Mn)	1.0	0.20
Silicon (Si)	0.05	---
Copper (Cu)	0.002	---
Calcium (Ca)	0.04	---
Iron (Fe)	0.004	---
Nickel (Ni)	0.002	---
Other, max. Each 3/	0.10	---
Other, max. Total 3/	0.30	---
Magnesium (Mg)	Remainder	

1/ Except for “Magnesium” and “others”, analysis normally is made for elements for which specific limits are shown.

2/ Where single units are shown, these indicate the maximum amounts permitted.

3/ The sum of those “other” metallic elements which are not listed in the Table, but are intentionally added, shall be reported and expressed to the second decimal before determining the sum.

3.3 Corrosion resistance. Magnesium tested as specified in accordance with 4.7.2 shall suffer not more than 7.5 mpy.

3.4 Mechanical properties. Unless otherwise specified in the contract or order (see 6.2), the mechanical properties of the test specimen shall meet the minimum mechanical properties listed in Table II as determined in accordance with ASTM B90/B90M and ASTM B557.

3.4.1 Tensile specimens. Tensile specimens shall be taken parallel to the direction of rolling.

3.5 Compressive properties. If specified in the contract or order (see 6.2), compressive properties shall meet the minimum requirements specified in Table III (see 4.7.4).

TABLE II. Minimum mechanical properties.

Thickness, inches	Ultimate Tensile Strength, Ksi	Total Yield Strength, 0.2% Offset, Ksi	Elongation in 2 Inches or 4D, percent
0.250 to 0.374, incl.	38.0	26.0	8
0.375 to 0.500, incl.	37.0	24.0	8
0.501 to 1.000, incl.	36.0	22.0	8
1.001 to 2.000, incl.	34.0	20.0	8
2.001 to 3.000, incl.	34.0	18.0	8

TABLE III. Minimum compressive properties.

Thickness, inches	Compressive Yield Strength at 0.2% Offset, Ksi, minimum
0.250 to 0.374, incl.	20.0
0.375 to 0.500, incl.	16.0
0.501 to 1.000, incl.	13.0
1.001 to 2.000, incl.	10.0
2.001 to 3.000, incl.	9.0

3.6 Ballistic limit. The protection ballistic limit, BL(P), shall be as specified in Appendix A.

3.7 Dimensions. Unless otherwise specified in the contract or order (see 6.2), dimensional tolerances shall be as specified by ASTM B90/B90M.

3.7.1 Tolerances. Unless otherwise specified in the contract or order (see 6.2), delivered plates shall meet all the dimensional tolerances as specified by ASTM B90/B90M.

3.8 Marking for identification. Unless otherwise specified in the contract or purchase order (see 6.2), each plate shall be marked in accordance with MIL-STD-129.

3.8.1 Ballistic test plates. In addition to the markings in 3.8, each ballistic test plate shall be marked with the letters PRE for First Article test plates and ACC for Acceptance test plates. This marking shall be impression stamped on the edge in letters 3/8 inch high or greater. Ballistic retest plates shall be marked "R1" and "R2" respectively (see A.5.2).

3.9 Ballistic test plate information. For each lot of magnesium alloy armor a properly completed Magnesium Armor Test Data Form (See Figure 1) shall be submitted with each ballistic test plate that represents that particular processing lot.

REQUEST FOR BALLISTIC TEST OF MAGNESIUM ARMOR												
FIRING RECORD:								**DATE:**				
Plate MANUFACTURER / PRODUCER:								**PRIME CONTRACTOR:**				
Name:								Name:				
Address:								Address:				
POC:								POC:				
Phone No:								Phone No:				
Fax No:								Fax No:				
SPECIFICATION: MIL-DTL-XXXX (MR)								**REVISION:**				**AMENDMENT:**
CONTRACT NO:								TECOM PROJECT NO:				
DCAS REGION:								BALLISTIC TEST CONTRACT NO:				
TEST ITEM IDENTIFICATION:												
Lot No.			Plate No.					Ordered Thickness				Alloy and Temper **AZ31B H24**
PURPOSE: ___ Acceptance ___ First Article ___ Development												
SAMPLE: ___ Primary ___ Retest (Firing Record No. of Failed Sample_____)												
CHEMICAL ANALYSIS:												
Al	Zn	Mn	Si	Cu	Ca	Fe	Ni	**Other Elements**				Mg (Rem)
MECHANICAL PROPERTIES:												
UTS (ksi):			0.2% YS (ksi):					Elongation (%):				
BALLISTIC TEST RESULTS:												
Test	Projectile	Obl. (deg)	Actual Thickness (in)	Required V_{50} (fps)	Actual V_{50} (fps)	Pass/ Fail	Notes					
LOTS REPRESENTED BY:			Reduced Testing			Audit Testing						
Lot [met] [failed to meet] the ballistic requirements of specification MIL-DTL-32333 (MR).												
Government Representative			Date			Supplier Representative						Date

FIGURE 1. Magnesium Armor Test Data Form

3.10 Workmanship. Plate produced under this specification shall be uniform in quality and clean, smooth and sufficiently free from buckles, blisters, hard spots, damaged ends, laminations and other defects which may affect its use.

4. VERIFICATION

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

a. First article inspection (see 4.3).
b. Conformance inspection (see 4.4).

4.2 Lot. A lot shall consist of all plate of the same alloy and ordered thickness which has been processed together by the same mill practice. Unless otherwise specified in the contract or purchase order (see 6.2), the weight of the finished plates in a lot shall not exceed 30,000 pounds and shall be submitted for inspection as a unit.

4.3 First article inspection. First article inspection, except as otherwise indicated in this specification, shall utilize the same requirements and test methods as the production acceptance inspection shown in 4.4.

4.4 Conformance inspection. Conformance inspection or production acceptance inspection shall include the examination of 4.6 and the tests of 4.7.

4.5 Sampling.

4.5.1 First article inspection.

4.5.1.1 Chemical composition. One (1) sample for chemical analysis shall be removed from each plate selected for ballistic testing and shall meet the requirements of 3.2 when tested as specified in 4.7.1.

4.5.1.2 Corrosion. Three (3) test coupons shall be machined to nominal dimensions of 2.0” X 3.0” X 0.25”. All flat surfaces shall be sanded to a uniform 600 grit surface finish.

4.5.1.3 Mechanical properties. One tension test specimen shall be removed from each plate that has been selected for ballistic testing and shall meet the requirements when tested as specified in 4.7.3.

4.5.1.4 Compressive properties. One compressive test specimen shall be removed according to 3.4 from each plate that has been selected for ballistic testing and shall meet the requirements when tested as specified in 4.7.4.

4.5.1.5 Ballistic tests. Two plates, one from the tail and one from the nose, 12 inches by 36 inches of each thickness to be supplied on the contract, shall be submitted for ballistic testing in accordance with Appendix A. The orientation of these plates with respect to the rolling direction shall be noted on the plate.

4.5.2 Conformance inspection.

4.5.2.1 Chemical composition. One (1) sample for chemical analysis shall be removed from each plate selected for ballistic testing and shall meet the requirements of 3.2 when tested as specified in 4.7.1.

4.5.2.2 Mechanical properties. Samples for tension tests shall be selected in accordance with ASTM B90/B90M.

4.5.2.3 Compressive properties. There is no requirement for compressive testing for conformance inspection (production acceptance).

4.5.2.4 Ballistic testing. One plate, 12 inches by 36 inches, shall be randomly selected from each lot for ballistic testing. The orientation of the plate with respect to the rolling direction shall be at the option of the producer (see 6.2). The sample shall meet the requirements when tested as specified in 4.7.4.

4.6 Examination.

4.6.1 Visual. Each plate shall be examined for compliance with the identification marking (see 3.7) and workmanship (see 3.9) requirements.

4.6.2 Dimensions. Plates within a lot shall be measured to determine compliance with requirements of paragraph 3.6 in accordance with the sampling procedures approved by the procuring activity (see 6.2).

4.7 Test specimens.

4.7.1 Chemical composition. Samples for chemical analysis shall be prepared and tested in accordance with ASTM B954.

4.7.2 Corrosion testing. Coupons as specified in 4.5.1.2 shall be weighed and exposed to 168 hours of salt fog per ASTM B 117. Coupons shall be cleaned using the solution and procedure contained in ASTM G 97. Coupons shall be reweighed. Mass loss shall be calculated using the formula below and the average of the three coupons shall meet the requirements of 3.3.

$mpy = K*(m_i-m_f)/(A*T*d)$ where

K=constant (546,000 for mpy)
m_i=initial mass (g)
m_f =finial mass (g)
A=area (in^2)
T=time (hours)
d=density (g/cm^2)

4.7.3 Mechanical properties. Tension test specimens shall be prepared and tested in accordance with ASTM B557.

4.7.4 Compressive properties. Compressive test specimens shall be prepared and tested in accordance with the instructions specified in the contract or purchase order (see 6.2). Specimens shall be taken in the short transverse direction (through the thickness) (see 3.5).

4.7.5 Ballistic testing. The ordered thickness specified in the contract shall be used to determine the test projectile in accordance with Table IV. Ballistic testing shall be in accordance with Appendix A. Test plate thickness, as measured by the ballistic testing agency, shall be used in conjunction with Table IV and Appendix A to determine the required V_{50} protection ballistic limit for that plate. For ordered thicknesses between 1.250 inches and 3.000 inches, inclusive, a second ballistic test shall be performed. Thickness shall be determined as the average of at least four thickness measurements read on a deep throat micrometer or by means of an ultrasonic device to the nearest 0.001 of an inch and rounded off to the nearest 0.005 of an inch. Measurements shall be made on the intended impact area. In those cases where the BL(P) is within ±10 fps of the minimum required value for the measured average thickness (to the nearest 0.005-inch), an interpolation of the appropriate ballistic limit table shall be performed. The average plate thickness, computed to the nearest 0.001-inch, shall be used to determine the minimum required BL(P) for that plate.

4.7.5.1 Ballistic testing facility. Unless otherwise specified in the contract or purchase order (see 6.2), the ballistic test plates shall be forwarded to the Commander, USA ATC, ATTN: CSTE-DTC-AT-SL-V, Building 358, 400 Colleran Road, APG, MD 21005-5059 for ballistic testing for first article or lot acceptance.

4.7.5.2 Incomplete penetrations. When a complete penetration can not be obtained, the following rule shall be in effect until a new ballistic acceptance round can be developed and utilized. When the ballistic velocities of four (4) partial penetrations are above the minimum ballistic requirement for the specific thickness, the material shall be certified as acceptable with a V_{50} (which obviously can not be explicitly determined) above the minimum requirement.

TABLE IV. Acceptance ballistic test plates.

Ordered Thickness, Inches	Projectile	Angle of Obliquity in Degrees	TABLE
0.250 – 0.749	Cal. .22 FSP	0	A-I
0.750 – 1.000	Cal. .30 FSP	0	A-II
1.001 – 1.500	Cal. .50 FSP	0	A-III
1.501 – 3.000	20mm FSP	0	A-IV
1.250 – 3.000 , Inclusive 1/	Cal. .30 AP M2	0	A-V

1/ For this thickness range a second ballistic test is required.

4.8 Rejection and retest. Unless otherwise specified in the contract or order (see 6.2) and except as specified in 4.7.3 and 4.7.4, rejection and retest shall be conducted in accordance with 4.8.1, 4.8.1.1, and 4.8.2.

4.8.1 Rejection of first article plates. When one or more first article test specimens fail to meet the requirements of 4.3, the product lot and process, represented by the test plates or specimens shall be subject to rejection except as otherwise provided in a sampling plan approved by the procuring activity and in requirements of 4.8.1.1.

4.8.1.1 Retest of first article samples. Resubmission and retest of first article samples shall not be made until the manufacturer has made necessary corrections in the processing of the material to the satisfaction of the procuring activity. If one of the retest specimens fails the lot shall be permanently rejected with no further testing permitted.

4.8.2 Ballistic. Rejection and retest of ballistic test plates shall be in accordance with A.5.2.

4.9 Reduced testing. At the discretion of the procuring activity (see 6.2), the amount of testing may be reduced provided the results on consecutive lots indicate that a uniform product meeting the testing requirements is being produced and providing the manufacturer agrees to maintain the same manufacturing procedures. Testing for a given plate thickness shall return to standard (non-reduced testing) conditions of one plate per lot, whenever a ballistic test plate fails to meet ballistic requirements.

5. PACKAGING

5.1 Packaging. For acquisition purposes, the packaging requirements shall be as specified in the contract or order (see 6.2). When packaging of materiel components are to be performed by DoD or in-house contractor personnel, these personnel need to contact the responsible packaging activity to ascertain packaging requirements. Packaging requirements are maintained by the Inventory Control Point's packaging activities within the Military Service or Defense Agency, or within the military service's system commands. Packaging data retrieval is available from the managing Military Department's or Defense Agency's automated packaging files, CD-ROM products, or by contacting the responsible packaging activity.

6. NOTES

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

6.1 Intended use. The armor specified herein is intended for use on vehicle and personal armor systems. It is highly favorable because of its lightweight, high stiffness, and high damping properties. The creation of this specification is the result of an Army Research Laboratory (ARL) Research & Development (R&D) Program. The information related to this study was published in a Technical Report, ARL-TR-4077, dated April 2007, entitled "Ballistic Evaluation of Magnesium Alloy AZ31B" [1/]. The R&D study illustrated that

magnesium alloys can be used for applications in lightweight armor. Application for this armor is in the development for body armor, helmets, and LTAS vehicle armor systems. Future applications will be in the development of a lightweight tactical hull. Corrosion resistance has been evaluated and tests have shown that with a suitable coating this alloy can be used in the above mentioned applications.

1/ Copies of this report are published as ADA466839 and are available from the Defense Technical Information Center (DTIC), Suite 0944, 8725 John J. Kingman Road, Fort Belvoir, VA 22060-6218 (Toll Free No.: 1-800-225-3842).

6.2 Ordering data. Procurement documents should specify the following:

(a) Title, number and date of this specification.
(b) Specify choice of alloy, and ordered thickness (see 1.1)
(c) Specify classification (see 1.2).
(d) If issues of documents are different (see 2.2.1 and A.2.1.1).
(e) If a different issue is to be used (see 2.3)
(f) When first article is required (see 3.1).
(g) If a different set of mechanical properties are required (see 3.4).
(h) If a different set of compressive properties are required (see 3.5).
(i) If a different document is used to specify dimensional tolerances (see 3.7).
(j) If a different document is used to specify delivered plates dimensional tolerances (see 3.7.1).
(k) If a different document is used to specify markings (see 3.8).
(l) If the weight of the finished plates in a lot can exceed 30,000 pounds (see 4.2).
(m) The orientation of the ballistic plate is different (see 4.5.2.4).
(n) Dimensional sampling procedure approved by the procuring activity (see 4.6.2).
(o) Specify standard test methods for compression testing of Magnesium materials (see 4.7.4)
(p) If approval was requested and received for a different ballistic testing facility (see 4.7.5.1)
(q) Rejection and retest requirement, if other than that as specified (see 4.8, A.5.2.1 and A.5.2.3).
(r) If reduced testing is allowed (see 4.9).
(s) Packaging requirements (see 5.1).

6.3 Machining. Magnesium alloys can be machined more aggressively than aluminum alloys; however, magnesium fines, turnings and chips can be ignited by sparks or open flame. Care should be taken to eliminate any source of sparks or flame and to ensure a maximum chip mass. Water-based emulsion machining lubricants are not recommended because the reaction between water and magnesium causes the evolution of flammable hydrogen gas. Magnesium is typically machined dry, although oil based lubricants are acceptable. Dry or oily magnesium fines, turnings and chips should be segregated and stored in dry, air-tight containers. Wet magnesium fines, turnings and chips must be stored in ventilated area and not stored sealed containers due to the explosive hazard caused by hydrogen gas evolution. It is strongly recommended that the machining operation is monitored continuously by a

machinist equipped with a magnesium fire arresting kit (e.g., Class D extinguishers and/or G-1 powder or dry sand) be part of the procedure.

6.4 Definitions.

6.4.1 Nose. Extreme leading edge of the as-rolled strip. A "Nose" sample is a sample representing acceptable material extracted from the extreme leading edge of the as-rolled plate.

6.4.2 Tail. Extreme trailing edge of the as-rolled strip. A "Tail" sample is a sample representing acceptable material extracted from the extreme trailing edge of the as-rolled plate.

6.5 Metric units. When metric divisions are required, units for inch, foot, foot-pounds, feet per second, and pounds per square inch may be converted to the metric equivalent by multiplying them by the following conversion factors:

English	Multiply by	Equals	Metric SI unit
inch	0.0254	=	meter (m)
foot	0.3048	=	meter (m)
pound	0.4536	=	kilogram (kg)
foot-lb	1.3558	=	joule (j)
feet/s	0.3048	=	meter per second (m/s)
pounds/sq. inch	0.00689	=	mega Pascal (MPa)

6.6 Alternate ballistic testing facility. Request for approval for an alternate ballistic testing facility should be forwarded by the procuring activity to the Director, U.S. Army Research Laboratory, Weapons and Materials Research Directorate, Specifications and Standards Office, Attn: RDRL-WMM-C, Aberdeen Proving Ground, MD 21005-5069 and should be obtained prior to the contract award. Please note that alternate ballistic testing facilities are being considered but at the present time, the requirements needed for approving an alternate facility are not fully known.

6.7 Subject term (key word) listing.

Ballistic testing
Caliber .22 FSP
Caliber .30 AP M2
Caliber .30 FSP
Caliber .50 FSP
Military vehicles
M1114 HMMWV
Stress corrosion
20-mm FSP

APPENDIX A

BALLISTIC TESTING OF MAGNESIUM ALLOY AZ31B ARMOR PLATE

A.1 SCOPE

A.1.1 Scope. This appendix covers the minimum ballistic limits for acceptable requirements of magnesium alloy AZ31B armor plate, when tested in accordance with the provisions of this specification. When there is mutual agreement between contractor and procuring activity, this appendix becomes a mandatory part of this specification and the information contained herein is intended for compliance.

A.2 APPLICABLE DOCUMENTS

A.2.1 Government documents.

A.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 (see 6.2), the issues of these documents are those cited in the solicitation or contract.

STANDARDS

DEPARTMENT OF DEFENSE

MIL-STD-662 - V50 Ballistic Test for Armor

(Copies of this document are available online at http://assist.daps.dla.mil/quicksearch/ or from the Standardization Document Order Desk, 700 Robbins Avenue, Building 4D, Philadelphia, PA 19111-5094.)

A.3 DEFINITIONS

A.3.1 Complete penetration, (CP). A complete penetration occurs when the impacting projectile, or any fragment thereof, or any fragment of the test specimen perforates the witness plate, resulting in a crack or hole which permits light passage when a 60-watt, 110-volt bulb is placed proximate to the witness plate.

A.3.2 Fair impact. An impact may be considered fair when an un-yawed fragment simulator or test projectile strikes an unsupported area of the target material at a specified obliquity at a distance of at least two projectile diameters from any previous impact or disturbed area resulting from an impact, or from any crack, or from any edge of the test specimen.

A.3.3 Gap. A gap is the difference in fps between the high partial penetration velocity and the low complete penetration velocity used to compute the ballistic limit when the high partial penetration velocity is lower than the low complete penetration velocity.

A.3.4 Partial penetration, (PP). Any impact which is not a complete penetration may be considered a partial penetration.

A.3.5 Witness plate. A thin sheet located behind and parallel to the ballistic test sample which is used to detect penetrating projectiles or spall.

A.4 REQUIREMENTS

A.4.1 Resistance to penetration. The minimum required V50 ballistic limit shall be in accordance with the values shown in tables A-I through A-V.

A.5 TESTS

A.5.1 Ballistic tests. Testing shall be in accordance with MIL-STD-662, V50 Ballistic Test for Armor, except that nothing in this procedure shall be construed to supersede or invalidate the requirements of this specification.

A.5.1.1 Temperature Conditioning. Prior to the test, the test item(s) shall be temperature conditioned at least eight hours. Thermostatic control shall be such that the average temperature of the item during the test shall be 72 ± 15°F (22 ± 8°C).

A.5.1.2 Protection ballistic limit, BL(P).

A.5.1.2.1 Normal circumstances. The BL(P) shall consist of an equal number of fair impact complete and partial penetration velocities attained by the up-and-down firing method. All BL(P)'s shall be computed using the highest partial penetration velocities and the lowest complete penetration velocities. Firing shall continue until either a 4-round BL(P) having a maximum velocity spread of 60 fps or a 6-round BL(P) having a maximum velocity spread of 90 fps has been attained, whichever comes first in the normal sequence of firing. If both occur simultaneously, the 6-round BL(P) shall be reported.

A.5.1.2.2 Large zone of mixed results. In the event that the zone of mixed results (difference between the high partial penetration velocity and the low complete penetration velocity, the PP[P] velocity being higher than the low CP[P] velocity) exceeds 90 fps, the firing data shall be compared with the specification minimum ballistic requirements. If the lowest complete penetration velocity is equal to or above the minimum specified ballistic limit velocity for the plate thickness, the ballistic limit shall be computed on the basis of 4- or 6-rounds using the smallest possible velocity spread. If the lowest complete penetration velocity is below the minimum allowable ballistic limit velocity, then testing shall continue until a 10-round ballistic limit has been attained using the smallest possible velocity spread. Ten-round ballistic limits shall be reported as agreed upon between the contractor and procuring activity.

A.5.1.2.3 Reduction of large velocity gap in borderline cases. If the ballistic limit, which has been determined, is within ± 10 fps from the minimum allowable ballistic limit and a

gap exists which is greater than 25 fps, then another round, or rounds, shall be fired to reduce the gap to 25 fps or less. The ballistic limit shall then be recomputed using the above criteria. The recomputed BL(P) shall be reported as the BL(P) of the plate (in borderline cases, a reduction of the gap between the high partial penetration velocity and the low complete velocity should result in a better evaluation of the BL(P)).

A.5.2 Rejection and retest of ballistic plates.

A.5.2.1 First article tests (rejection). Unless otherwise specified in the contract or order (see 6.2), failure of any of the first article test plates to meet the minimum ballistic requirements shown in the appendix of this specification indicates failure of the product and process.

A.5.2.2 First article (retests). Resubmission of ballistic retest plates shall not be made until the manufacturer has made the necessary corrections in the processing of the material to the satisfaction of the procuring activity. Two retest plates shall be submitted for first article testing, and both tests shall pass; otherwise, the armor material shall be rejected.

A.5.2.3 Acceptance tests (rejection). Unless otherwise specified in the contract or order (see 6.2), failure of a test plate to meet the ballistic requirements indicates failure of the lot; however, the final decision shall depend on the outcome of retests, if submitted.

A.5.2.4 Acceptance tests (retests). If a test plate representing a lot fails to meet the ballistic requirement, the manufacturer, upon notification of the failure may submit at his own expense two additional test plates from the same lot for ballistic retest. If either of these plates fail the ballistic test, the lot shall be rejected. The manufacturer may elect to resubmit the lot after retreatment of the entire lot by submitting two additional test plates. If either of these plates fail, the lot shall be permanently rejected.

A.5.3 Disposal of ballistic test plates.

A.5.3.1 First article test plates. Upon request of the applicant within 15 days after ballistic testing, first article plates shall be returned "as is" to the applicant, at his expense, unless the plates were destroyed in testing.

A.5.3.2 Acceptance test plates. Acceptance test plates that comply with the requirements of this specification are considered part of the lot they represent, and ownership of the test plates passes to the Government with the acceptance of that lot. Acceptance test plates that fail to comply with the requirements of this specification are considered part of the lot they represent and remain the property of the producer. The now rejected lot also remains the property of the producer. The failed plates shall be returned, upon request, as in A.5.3.1.

APPENDIX A

TABLE A-I. Minimum required ballistic limits - caliber .22 fragment simulating projectiles at 0° obliquity.

Thickness inches	Required BL(P), ft/s	Thickness inches	Required BL(P), ft/s	Thickness inches	Required BL(P), ft/s
0.200	752	0.375	1563	0.550	2375
0.205	775	0.380	1587	0.555	2398
0.210	798	0.385	1610	0.560	2421
0.215	822	0.390	1633	0.565	2444
0.220	845	0.395	1656	0.570	2467
0.225	868	0.400	1679	0.575	2491
0.230	891	0.405	1702	0.580	2514
0.235	914	0.410	1726	0.585	2537
0.240	938	0.415	1749	0.590	2560
0.245	961	0.420	1772	0.595	2583
0.250 [1/]	984	0.425	1795	0.600	2607
0.255	1007	0.430	1818	0.605	2630
0.260	1030	0.435	1842	0.610	2653
0.265	1053	0.440	1865	0.615	2676
0.270	1077	0.445	1888	0.620	2699
0.275	1100	0.450	1911	0.625	2722
0.280	1123	0.455	1934	0.630	2746
0.285	1146	0.460	1957	0.635	2769
0.290	1169	0.465	1981	0.640	2792
0.295	1192	0.470	2004	0.645	2815
0.300	1216	0.475	2027	0.650	2838
0.305	1239	0.480	2050	0.655	2861
0.310	1262	0.485	2073	0.660	2885
0.315	1285	0.490	2097	0.665	2908
0.320	1308	0.495	2120	0.670	2931
0.325	1332	0.500	2143	0.675	2954
0.330	1355	0.505	2166	0.680	2977
0.335	1378	0.510	2189	0.685	3001
0.340	1401	0.515	2212	0.690	3024
0.345	1424	0.520	2236	0.695	3047
0.350	1447	0.525	2259	0.700	3070
0.355	1471	0.530	2282	0.705	3093
0.360	1494	0.535	2305	0.710	3116
0.365	1517	0.540	2328	0.715	3140
0.370	1540	0.545	2352	0.720	3163

[1/] Specification requirements begin for this ordered thickness.

Note: Tabulated values on either side of the ordered thicknesses are for interpolation of BL(P) requirements on undersize or oversize plates.

APPENDIX A

TABLE A-I. Minimum required ballistic limits - caliber .22 fragment simulating projectiles at 0° obliquity - Continued.

Thickness inches	Required BL(P), ft/s	Thickness inches	Required BL(P), ft/s	Thickness inches	Required BL(P), ft/s
0.725	3186	0.755	3325	0.785	3464
0.730	3209	0.760	3348	0.790	3487
0.735	3232	0.765	3371	0.795	3511
0.740	3256	0.770	3395	0.800	3534
0.745	3279	0.775	3418	0.805	3557
0.749 [2/]	3297	0.780	3441	0.810	3580

[2/] Specification requirements end for this ordered thickness.

Note: Tabulated values on either side of the ordered thicknesses are for interpolation of BL(P) requirements on undersize or oversize plates.

APPENDIX A

TABLE A-II. Minimum required ballistic limits - caliber .30 fragment simulating projectiles at 0° obliquity.

Thickness inches	Required BL(P), ft/s	Thickness inches	Required BL(P), ft/s	Thickness inches	Required BL(P), ft/s
0.700	1990	0.830	2312	0.960	2634
0.705	2002	0.835	2324	0.965	2646
0.710	2015	0.840	2337	0.970	2659
0.715	2027	0.845	2349	0.975	2671
0.720	2039	0.850	2362	0.980	2684
0.725	2052	0.855	2374	0.985	2696
0.730	2064	0.860	2386	0.990	2708
0.735	2077	0.865	2399	0.995	2721
0.740	2089	0.870	2411	1.000 [2/]	2733
0.745	2101	0.875	2423	1.005	2746
0.750 [1/]	2114	0.880	2436	1.010	2758
0.755	2126	0.885	2448	1.015	2770
0.760	2138	0.890	2461	1.020	2783
0.765	2151	0.895	2473	1.025	2795
0.770	2163	0.900	2485	1.030	2808
0.775	2176	0.905	2498	1.035	2820
0.780	2188	0.910	2510	1.040	2832
0.785	2200	0.915	2523	1.045	2845
0.790	2213	0.920	2535	1.050	2857
0.795	2225	0.925	2547	1.055	2870
0.800	2238	0.930	2560	1.060	2882
0.805	2250	0.935	2572	1.065	2894
0.810	2262	0.940	2585	1.070	2907
0.815	2275	0.945	2597	1.075	2919
0.820	2287	0.950	2609	1.080	2931
0.825	2300	0.955	2622	1.085	2944

[1/] Specification requirements begin for this ordered thickness.
[2/] Specification requirements end for this ordered thickness.

Note: Tabulated values on either side of the ordered thicknesses are for interpolation of BL(P) requirements on undersize or oversize plates.

APPENDIX A

TABLE A-III. Minimum required ballistic limits - caliber .50 fragment simulating projectiles at 0° obliquity.

Thickness inches	Required BL(P), ft/s	Thickness inches	Required BL(P), ft/s	Thickness inches	Required BL(P), ft/s
0.910	1480	1.085	1728	1.260	1976
0.915	1487	1.090	1735	1.265	1983
0.920	1494	1.095	1742	1.270	1990
0.925	1501	1.100	1749	1.275	1998
0.930	1508	1.105	1756	1.280	2005
0.935	1515	1.110	1764	1.285	2012
0.940	1522	1.115	1771	1.290	2019
0.945	1529	1.120	1778	1.295	2026
0.950	1537	1.125	1785	1.300	2033
0.955	1544	1.130	1792	1.305	2040
0.960	1551	1.135	1799	1.310	2047
0.965	1558	1.140	1806	1.315	2054
0.970	1565	1.145	1813	1.320	2061
0.975	1572	1.150	1820	1.325	2069
0.980	1579	1.155	1827	1.330	2076
0.985	1586	1.160	1834	1.335	2083
0.990	1593	1.165	1842	1.340	2090
0.995	1600	1.170	1849	1.345	2097
1.001 [1/]	1609	1.175	1856	1.350	2104
1.005	1615	1.180	1863	1.355	2111
1.010	1622	1.185	1870	1.360	2118
1.015	1629	1.190	1877	1.365	2125
1.020	1636	1.195	1884	1.370	2132
1.025	1643	1.200	1891	1.375	2139
1.030	1650	1.205	1898	1.380	2147
1.035	1657	1.210	1905	1.385	2154
1.040	1664	1.215	1912	1.390	2161
1.045	1671	1.220	1920	1.395	2168
1.050	1678	1.225	1927	1.400	2175
1.055	1685	1.230	1934	1.405	2182
1.060	1693	1.235	1941	1.410	2189
1.065	1700	1.240	1948	1.415	2196
1.070	1707	1.245	1955	1.420	2203
1.075	1714	1.250	1962	1.425	2210
1.080	1721	1.255	1969	1.430	2217

[1/] Specification requirements begin for this ordered thickness.

Note: Tabulated values on either side of the ordered thicknesses are for interpolation of BL(P) requirements on undersize or oversize plates.

APPENDIX A

TABLE A-III. Minimum required ballistic limits - caliber .50 fragment simulating projectiles at 0° obliquity - Continued.

Thickness inches	Required BL(P), ft/s	Thickness inches	Required BL(P), ft/s	Thickness inches	Required BL(P), ft/s
1.435	2225	1.495	2310	1.555	2395
1.440	2232	1.500 [2/]	2317	1.560	2402
1.445	2239	1.505	2324	1.565	2409
1.450	2246	1.510	2331	1.570	2416
1.455	2253	1.515	2338	1.575	2423
1.460	2260	1.520	2345	1.580	2430
1.465	2267	1.525	2352	1.585	2437
1.470	2274	1.530	2359	1.590	2444
1.475	2281	1.535	2366	1.595	2452
1.480	2288	1.540	2374	1.600	2459
1.485	2295	1.545	2381	1.605	2466
1.490	2303	1.550	2388	1.610	2473

[2/] Specification requirements end for this ordered thickness.

Note: Tabulated values on either side of the ordered thicknesses are for interpolation of BL(P) requirements on undersize or oversize plates.

APPENDIX A

TABLE A-IV. Minimum required ballistic limits – 20 mm fragment simulating projectile at 0° obliquity

Thickness inches	Required BL(P), ft/s	Thickness inches	Required BL(P), ft/s	Thickness inches	Required BL(P), ft/s
1.400	1358	1.750	1690	2.100	2022
1.410	1368	1.760	1699	2.110	2031
1.420	1377	1.770	1709	2.120	2040
1.430	1387	1.780	1718	2.130	2050
1.440	1396	1.790	1728	2.140	2059
1.450	1406	1.800	1737	2.150	2069
1.460	1415	1.810	1747	2.160	2078
1.470	1425	1.820	1756	2.170	2088
1.480	1434	1.830	1766	2.180	2097
1.490	1444	1.840	1775	2.190	2107
1.501 [1/]	1454	1.850	1785	2.200	2116
1.510	1463	1.860	1794	2.210	2126
1.520	1472	1.870	1804	2.220	2135
1.530	1482	1.880	1813	2.230	2145
1.540	1491	1.890	1823	2.240	2154
1.550	1501	1.900	1832	2.250	2164
1.560	1510	1.910	1842	2.260	2173
1.570	1519	1.920	1851	2.270	2183
1.580	1529	1.930	1860	2.280	2192
1.590	1538	1.940	1870	2.290	2201
1.600	1548	1.950	1879	2.300	2211
1.610	1557	1.960	1889	2.310	2220
1.620	1567	1.970	1898	2.320	2230
1.630	1576	1.980	1908	2.330	2239
1.640	1586	1.990	1917	2.340	2249
1.650	1595	2.000	1927	2.350	2258
1.660	1605	2.010	1936	2.360	2268
1.670	1614	2.020	1946	2.370	2277
1.680	1624	2.030	1955	2.380	2287
1.690	1633	2.040	1965	2.390	2296
1.700	1643	2.050	1974	2.400	2306
1.710	1652	2.060	1984	2.410	2315
1.720	1662	2.070	1993	2.420	2325
1.730	1671	2.080	2003	2.430	2334
1.740	1680	2.090	2012	2.440	2344

[1/] Specification requirements begin for this ordered thickness.

Note: Tabulated values on either side of the ordered thicknesses are for interpolation of BL(P) requirements on undersize or oversize plates.

TABLE A-IV. Minimum required ballistic limits – 20 mm fragment simulating projectile at 0° obliquity - Continued.

Thickness inches	Required BL(P), ft/s	Thickness inches	Required BL(P), ft/s	Thickness inches	Required BL(P), ft/s
2.450	2353	2.680	2571	2.910	2789
2.460	2363	2.690	2580	2.920	2798
2.470	2372	2.700	2590	2.930	2808
2.480	2381	2.710	2599	2.940	2817
2.490	2391	2.720	2609	2.950	2827
2.500	2400	2.730	2618	2.960	2836
2.510	2410	2.740	2628	2.970	2846
2.520	2419	2.750	2637	2.980	2855
2.530	2429	2.760	2647	2.990	2865
2.540	2438	2.770	2656	3.000 [2/]	2874
2.550	2448	2.780	2666	3.010	2883
2.560	2457	2.790	2675	3.020	2893
2.570	2467	2.800	2685	3.030	2902
2.580	2476	2.810	2694	3.040	2912
2.590	2486	2.820	2704	3.050	2921
2.600	2495	2.830	2713	3.060	2931
2.610	2505	2.840	2722	3.070	2940
2.620	2514	2.850	2732	3.080	2950
2.630	2524	2.860	2741	3.090	2959
2.640	2533	2.870	2751	3.100	2969
2.650	2542	2.880	2760	3.110	2978
2.660	2552	2.890	2770	3.120	2988
2.670	2561	2.900	2779	3.130	2997

[2/] Specification requirements end for this ordered thickness.

Note: Tabulated values on either side of the ordered thicknesses are for interpolation of BL(P) requirements on undersize or oversize plates.

APPENDIX A

TABLE A-V. Minimum required ballistic limits - caliber .30 AP M2 projectiles at 0° obliquity.

Thickness inches	Required BL(P), ft/s	Thickness inches	Required BL(P), ft/s	Thickness inches	Required BL(P), ft/s
1.150	1594	1.500	1823	1.850	2051
1.160	1601	1.510	1829	1.860	2058
1.170	1607	1.520	1836	1.870	2065
1.180	1614	1.530	1842	1.880	2071
1.190	1620	1.540	1849	1.890	2078
1.200	1627	1.550	1855	1.900	2084
1.210	1633	1.560	1862	1.910	2091
1.220	1640	1.570	1869	1.920	2097
1.230	1646	1.580	1875	1.930	2104
1.240	1653	1.590	1882	1.940	2110
1.250 [1/]	1659	1.600	1888	1.950	2117
1.260	1666	1.610	1895	1.960	2123
1.270	1673	1.620	1901	1.970	2130
1.280	1679	1.630	1908	1.980	2136
1.290	1686	1.640	1914	1.990	2143
1.300	1692	1.650	1921	2.000	2149
1.310	1699	1.660	1927	2.010	2156
1.320	1705	1.670	1934	2.020	2163
1.330	1712	1.680	1940	2.030	2169
1.340	1718	1.690	1947	2.040	2176
1.350	1725	1.700	1953	2.050	2182
1.360	1731	1.710	1960	2.060	2189
1.370	1738	1.720	1967	2.070	2195
1.380	1744	1.730	1973	2.080	2202
1.390	1751	1.740	1980	2.090	2208
1.400	1757	1.750	1986	2.100	2215
1.410	1764	1.760	1993	2.110	2221
1.420	1771	1.770	1999	2.120	2228
1.430	1777	1.780	2006	2.130	2234
1.440	1784	1.790	2012	2.140	2241
1.450	1790	1.800	2019	2.150	2247
1.460	1797	1.810	2025	2.160	2254
1.470	1803	1.820	2032	2.170	2261
1.480	1810	1.830	2038	2.180	2267
1.490	1816	1.840	2045	2.190	2274

[1/] Specification requirements begin for this ordered thickness.

Note: Tabulated values on either side of the ordered thicknesses are for interpolation of BL(P) requirements on undersize or oversize plates.

TABLE A-V. Minimum required ballistic limits - caliber .30 AP M2 projectiles at 0° obliquity. - Continued.

Thickness inches	Required BL(P), ft/s	Thickness inches	Required BL(P), ft/s	Thickness inches	Required BL(P), ft/s
2.200	2280	2.530	2496	2.860	2711
2.210	2287	2.540	2502	2.870	2718
2.220	2293	2.550	2509	2.880	2724
2.230	2300	2.560	2515	2.890	2731
2.240	2306	2.570	2522	2.900	2737
2.250	2313	2.580	2528	2.910	2744
2.260	2319	2.590	2535	2.920	2751
2.270	2326	2.600	2541	2.930	2757
2.280	2332	2.610	2548	2.940	2764
2.290	2339	2.620	2555	2.950	2770
2.300	2345	2.630	2561	2.960	2777
2.310	2352	2.640	2568	2.970	2783
2.320	2359	2.650	2574	2.980	2790
2.330	2365	2.660	2581	2.990	2796
2.340	2372	2.670	2587	3.000 [2/]	2803
2.350	2378	2.680	2594	3.010	2809
2.360	2385	2.690	2600	3.020	2816
2.370	2391	2.700	2607	3.030	2822
2.380	2398	2.710	2613	3.040	2829
2.390	2404	2.720	2620	3.050	2835
2.400	2411	2.730	2626	3.060	2842
2.410	2417	2.740	2633	3.070	2849
2.420	2424	2.750	2639	3.080	2855
2.430	2430	2.760	2646	3.090	2862
2.440	2437	2.770	2653	3.100	2868
2.450	2443	2.780	2659	3.110	2875
2.460	2450	2.790	2666	3.120	2881
2.470	2457	2.800	2672	3.130	2888
2.480	2463	2.810	2679	3.140	2894
2.490	2470	2.820	2685	3.150	2901
2.500	2476	2.830	2692	3.160	2907
2.510	2483	2.840	2698	3.170	2914
2.520	2489	2.850	2705	3.180	2920

[2/] Specification requirements end for this ordered thickness.

Note: Tabulated values on either side of the ordered thicknesses are for interpolation of BL(P) requirements on undersize or oversize plates.

CONCLUDING MATERIAL

Custodians:
Army – MR

Preparing activity:
ARMY – MR
(Project 9535-2008-002)

Review activities:
Army – AR, AT, AV, TE
DLA – IS

NOTE: The activities listed above were interested in this document as of the date of this document. Since organizations and responsibilities can change, you should verify the currency of the information above using the ASSIST Online database at http://assist.daps.dla.mil/.