

INCH-POUND

MIL-DTL-46193A(MR)  
9 October 1998  
SUPERSEDING  
MIL-A-46193(MR)  
31 August 1988

## DETAIL SPECIFICATION

ARMOR PLATE, CONTROL ROLLED, STEEL, WROUGHT,  
HIGH STRENGTH, HIGH QUALITY

This specification is approved for use by the U.S. Army Research 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 materials requirements for control rolled, quenched and tempered high strength wrought steel armor plate for lightweight armor applications up to and including 1/2 inches in thickness (see 6.2).

## 2. APPLICABLE DOCUMENTS

2.1 General. The documents listed in this section are specified in sections 3 and 4 of this specification. This section does not include documents 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 documents cited in sections 3 and 4 of this specification, 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).

## STANDARDS

## DEPARTMENT OF DEFENSE

MIL-STD-662 V<sub>50</sub> Ballistic Test for Armor

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

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

## AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

- ASTM A751 Standard Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products (DoD adopted)
- ASTM E10 Brinell Hardness of Metallic Materials (DoD adopted)
- ASTM E18 Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials (DoD adopted)
- ASTM E23 Notched Bar Impact Testing of Metallic Materials (DoD adopted)

(Application for copies should be addressed to the American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.)

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

## 3. REQUIREMENTS

3.1 First article. When specified in the contract or purchase order (see 6.2) and before production has commenced, samples of the specified item shall be made available to the contracting officer or his authorized representative for approval in accordance with 4.2.1.1. The approval of the first article samples authorizes the commencement of production but does not relieve the supplier of responsibility for compliance with all applicable provisions of this specification. The first article samples shall be manufactured by the process proposed for use on production.

3.1.1 Potential suppliers. Potential suppliers wishing to qualify to this specification should follow the instructions in 6.4.

3.1.2 Change in mill processing. After an armor material has successfully complied with the requirements of this specification, any deliberate change in the mill processing by the manufacturer shall be drawn to the attention of the procuring activity and the contractor. If the material processing is changed, the first article tests of this specification may be again called upon to assure compliance with the requirements of this specification.

3.2. Acceptance requirements.

3.2.1 General material requirements. Material shall be produced by open hearth, basic oxygen furnace, or electric furnace.

3.2.1.1 Condition. Plates shall be in the as tempered condition. Flame cutting or pickling of the surfaces is not permitted, however abrasive wheel cutting is permitted (see 6.2).

3.2.1.2 Formulation.

3.2.1.2.1 Chemical composition. The chemical composition shall conform to table I. In addition, those additives which are hardening agents intentionally added shall be declared and must meet with the approval of the procuring activity. Also, some methods of sulfide shape control shall be used.

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TABLE I. Chemical composition (ladle analysis).

<u>ELEMENT</u>	<u>RANGE PERCENT</u>
Carbon	.37 to .40
Manganese	.50 to .70
Phosphorous	.014 max
Sulfur	.007 max
Silicon	1.15 to 1.45
Nickel	5.30 to 5.60
Copper	.85 to 1.10
Molybdenum	.40 to .60
Aluminum	.02 to .08
Residual Elements *	
Boron	.0025 max
Nitrogen	.012 max

\* Elements not intentionally added.

3.2.1.2.2 Rolling criteria. Hot shearing of slabs followed by slow cooling is recommended. All starting slab material shall be heated to 1700°F ± 25°F. For all final gages the slab thickness must allow for a minimum of 85 percent reduction. A slab to plate finishing rolling temperature shall not be lower than 1350°F. A slab to plate reduction of 10 to 20 percent per pass is recommended along with air cooling and/or spray quenching of top and bottom of oscillating material.

3.2.2 Heat treatment. All plates in each lot, including samples, shall receive the same tempering. Local or general heating shall not be performed after final tempering operation (see 6.2). All plates shall be tempered at a temperature of at least 325°F + 25°F for a total of 30 minutes after the center line of the plate reaches 325°F. Since material made to this specification may develop stress cracks it is recommended that all plates be tempered immediately after quenching.

### 3.2.3 Mechanical properties.

3.2.3.1 Hardness. The Brinell hardness of each plate including first article samples shall not be below 496 HB. The diameters of Brinell hardness impressions on any individual plate shall not vary by more than 0.15 mm and in accordance with ASTM E10. For plates less than 3/16 inches in thickness a Rockwell C hardness test shall be substituted for HB tests. Tests shall be conducted in accordance with ASTM E18 and the readings shall be converted to HB. Hardness readings shall be taken on opposite corners (or opposite ends) of an individual plate (see 4.4.2.2 and 4.6.2.1.2).

3.2.3.2 Impact resistance. The minimum Charpy V-notch impact energy of the plate, as determined by the average of two or more specimens in accordance with ASTM E23, shall be as shown in table II. The Charpy V-notch impact specimens shall be obtained in both the TL orientation, which is transverse to the major direction of rolling, with the notch perpendicular to the plate surface so that the crack will propagate in the longitudinal direction and the LT orientation, which is parallel to the major direction of rolling.

TABLE II. Minimum Charpy V-notch impact energy in ft-lb  
at -40°F ± 2°F for standard or sub-size specimens.

<u>Specimen orientation</u>	<u>Impact energy for standard depth specimens</u> <u>but with the following width</u> <u>(Average of two or more tests), ft-lb</u>			
	<u>Standard width</u>	<u>3/4 width</u>	<u>1/2 width</u>	<u>1/4 width</u>
	Transverse (T-L)	10.0	7.5	5.0
Longitudinal (L-T)	12.0	9.0	6.0	3.0

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3.2.4 Ballistic requirements. Ballistic requirements shall be in accordance with the appendix of this specification.

3.2.5 Dimensions and tolerances.

3.2.5.1 Dimensions. Plates shall comply with the dimensions specified in the applicable drawings or in the contract or order (see 6.2).

3.2.5.2 Thickness. The thickness tolerance of each plate, after final treatment, shall be in accordance with table III for the thickness specified.

3.2.5.3 Flatness. Unless otherwise specified in the contract or order (see 6.2), the flatness tolerance of each plate shall be within the requirements specified in table IV. Tighter tolerance requirements may be specified in the contract or order and shall be as agreed upon between the contractor and the procuring activity.

3.2.5.4 Waviness. Unless otherwise specified in the contract or order (see 6.2), the waviness tolerance of each plate shall be within the requirements of table V.

TABLE III. Thickness tolerances for ordered thickness, inches (over and under). <sup>1/</sup>

Specified Thickness (Inches)	Up to 72"	Tolerance (inch) for width of plate					
		72" to 84" excl.	84" to 96" excl.	96" to 108" excl.	108" to 120" excl.	120" to 132" excl.	132" to 144" excl.
1/8	.016	.016	.019	.019	.023	--	--
3/16	.016	.016	.019	.019	.023	--	--
1/4	.016	.016	.019	.019	.023	--	--
5/16	.016	.019	.019	.019	.023	.026	--
3/8	.016	.019	.019	.023	.023	.026	--
7/16	.016	.019	.019	.023	.026	.026	.031
1/2	.016	.019	.019	.023	.026	.026	.031

<sup>1/</sup> For intermediate thickness, the tolerance of the closer specified gage shall apply.

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TABLE IV. Permissible variations from flatness.

Variations from a flat surface for specified widths, in.									
Specified Thickness (Inches)	Over 8 to 36 excl.	36 to 48 excl.	48 to 60 excl.	60 to 72 excl.	72 to 84 excl.	84 to 96 excl.	96 to 108 excl.	108 to 120 excl.	120 to 144 excl.
Up to 1/4, excl.	1/2	1/2	1/2	3/4	1	1	1	1	1
1/4 to 3/8, excl.	3/4	15/16	1-1/8	1-3/8	1-3/4	1-7/8	2	2-1/4	2-3/8
3/8 to 1/2, excl.	3/4	7/8	15/16	15/16	1-1/8	1-5/16	1-1/2	1-5/8	1-7/8
1/2 to 3/4, excl.	5/8	7/8	13/16	7/8	1	1-1/8	1-1/4	1-3/8	1-5/8

Note 1: Flatness tolerances for length - The longer dimension specified is considered the length, and variations from a flat surface along the length should not exceed the tabular amount for the specified width in plates up to 12 ft in length, or in any 12 ft or longer plates.

Note 2: Flatness tolerances for width - The flatness variations across the width should not exceed the tabular amount for the specified width.

Note 3: When the longer dimension is under 36 in., the variation should not exceed 3/8 in. When the larger dimension is from 36 to 72 in., incl., the variation should not exceed 75% of the tabular amount for the specified width.

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TABLE V. Waviness tolerances for plates.

Flatness tolerance from table IV	When number of waves in 12 ft is:						
	1	2	3	4	5	6	7
5/16	5/16	1/4	3/16	1/8	1/8	1/16	1/16
3/8	3/8	5/16	3/16	3/16	1/8	1/16	1/16
7/16	7/16	5/16	1/4	3/16	1/8	1/8	1/16
1/2	1/2	3/8	5/16	3/16	3/16	1/8	1/16
9/16	9/16	7/16	5/16	1/4	3/16	1/8	1/8
5/8	5/8	1/2	3/8	1/4	3/16	1/8	1/8
11/16	11/16	1/2	3/8	5/16	3/16	3/16	1/8
3/4	3/4	9/16	7/16	5/16	1/4	3/16	1/8
13/16	13/16	5/8	7/16	5/16	1/4	3/16	1/8
7/8	7/8	11/16	1/2	3/8	1/4	3/16	1/8
15/16	15/16	11/16	1/2	3/8	5/16	3/16	3/16
1	1	3/4	9/16	7/16	5/16	3/16	3/16
1-1/8	1-1/8	7/8	5/8	1/2	3/8	1/4	3/16
1-1/4	1-1/4	15/16	11/16	1/2	3/8	5/16	1/4
1-3/8	1-3/8	1-1/16	3/4	9/16	7/16	5/16	1/4
1-1/2	1-1/2	1-1/8	7/8	5/8	1/2	3/8	1/4
1-5/8	1-5/8	1-1/4	15/16	11/16	1/2	3/8	5/16
1-3/4	1-3/4	1-5/16	1	3/4	9/16	7/16	5/16
1-7/8	1-7/8	1-7/16	1-1/16	13/16	9/16	7/16	5/16
2	2	1-1/2	1-1/8	7/8	5/8	1/2	3/8
2-1/8	2-1/8	1-5/8	1-3/16	7/8	11/16	1/2	3/8
2-1/4	2-1/4	1-11/16	1-1/4	15/16	11/16	9/16	3/8
2-3/8	2-3/8	1-13/16	1-5/16	1	3/4	9/16	7/16
2-1/2	2-1/2	1-7/8	1-7/16	1-1/16	13/16	9/16	7/16
2-5/8	2-5/8	2	1-1/2	1-1/8	13/16	5/8	7/16
2-3/4	2-3/4	2-1/16	1-9/16	1-1/8	7/8	5/8	1/2

NOTE 1: Waviness denotes the deviation of the top or bottom surface from a horizontal line, when the plate is resting on a flat surface, as measured in an increment of less than 12 ft of length. The waviness tolerance is a function of the flatness tolerance as obtained from table IV.

NOTE 2: When the flatness tolerance is 1/2 inch or less for plate thickness 1/2 inch and under, the waviness tolerance shall not apply.

3.2.6 Surface and internal soundness. Unless otherwise specified in the contract or purchase order (see 6.2), all plates shall be free from laminations, cracks, seams, laps and other imperfections which would adversely affect the strength, fabricability or ballistic performance of the armor.

3.2.7 Identification marking. Identification marking shall be legibly painted and records shall be such as to ensure positive identification of all plates, including test samples and specimens, with the lot and corresponding heat from which they were produced. Traceability of plates from first to last in each lot shall be maintained. The key to identification symbols shall be furnished to the inspector prior to submittal for inspection. First article and acceptance ballistic test plates shall also be marked with the manufacturer's name or trademark, the number of this specification, and the ordered plate thickness in inches. First article plates shall be marked "PRE", acceptance plates "ACC", and retest plates will be marked "R1" and "R2". If a second set of retest plates are submitted they shall be marked "RR1" and "RR2". The primary plate rolling direction shall be identified.

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3.2.8 Workmanship. All plates shall be free from scale, pits, tears, folds and other surface imperfections which are of such a nature as to affect the fabricability or serviceability of the material.

3.2.9 Information Required. A report showing the complete details of the heat treatment of each lot shall be furnished to the procuring activity. A certification of the chemical composition of the steel shall be furnished with the ballistic test plates. All elements of the chemical composition shall be shown, including special additives or hardening agents, whether shown in table I or not. The method of sulfide shape control shall be reported. Hardness results for each plate and impact results for each lot shall be included in the report (see 6.2).

3.2.10 Ballistic test plate information. A property executed armor data report shall be submitted containing the information as specified in MIL-STD-662.

#### 4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for inspection. Unless otherwise specified in the contract or purchase order (see 6.2), 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.

#### 4.2 Classification.

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

1. First article inspection (see 4.4.1)
2. Quality conformance inspection (see 4.4.2)

4.2.1.1 First article inspection. When required (see 6.2), the first article samples submitted in accordance with 3.1 shall be examined for all the provisions of this specification applicable to end item examination. The approval of the first article samples authorizes the commencement of shipment but does not relieve the supplier of responsibility for compliance with all applicable provisions of this specification. The first article samples and test plates shall be manufactured by the process proposed for use on production armor.

4.2.1.1.1 First article tests. First article tests (see 6.2) shall consist of all the tests specified in 4.6.

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4.2.1.1.2 Waiving of first article ballistic test. Unless otherwise specified (see 3.1 and 6.2), the first article ballistic test shall not be required provided the manufacturer, within 37 months, has produced acceptable plates within the same nominal thickness ranges of table VI and the production conditions are the same as for previously accepted plates. A supplier who has previously met the first article requirements will furnish the procuring activity with the pertinent data relative to compliance with first article test.

4.2.1.2 Quality conformance (acceptance) inspection. The acceptance examination (see 4.5) and the tests (see 4.6) shall serve as a basis for the acceptance of individual production plates.

4.3 Lot. A lot shall consist of all production and ballistic test plates of the same melt of steel, of the same thickness, having the same treatment, and processed with the same thermal cycle in the same production furnace(s) in the same facility. When specified (see 4.3.1), production and ballistic test plates may be allowed to be heat treated separately. The test plate shall be heat treated in a production furnace.

4.3.1 Separately heat treated ballistic test plate. When a ballistic test plate is allowed to be heat treated separately from the production plates it represents, the production plates shall remain in the tempered condition until the results are received from the testing activity showing that the ballistic test plate has passed (see 3.2.2). If the ballistic test plate is separately heat treated it shall be reported to the procuring activity (see 6.2).

#### 4.4 Sampling.

##### 4.4.1 For first article.

4.4.1.1 Chemical analysis samples. One sample for chemical analysis shall be taken from each plate submitted for ballistic testing.

4.4.1.2 Impact samples. At least two impact test sample in the TL orientation and two impact test sample in the LT orientation shall be taken from each test plate submitted.

4.4.1.3 Ballistic samples. Two ballistic plates, of the same ordered thickness range shown in table VI below shall be submitted for ballistic testing and shall represent any other thickness in the range. One sample shall be taken from the first plate heat treated and one from the last plate heat treated in the initial lot produced. When only one plate is heat treated, a sample shall be taken from each end of the plate. The ballistic test plates shall be 12 inches by 36 inches.

TABLE VI. Thickness ranges and corresponding test projectiles for first article and acceptance testing. <sup>1/</sup>

<u>Nominal thickness range (inches)</u>	<u>Test Projectile</u>
0.125 to 0.300 incl.	Caliber .30 AP, M2
0.301 to 0.590 incl.	Caliber .50 AP, M2

<sup>1/</sup> Minimum required ballistic limits are tabulated in table A-I and A-II of the appendix. The plates are tested at 30° obliquity.

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4.4.2 Sampling for quality conformance inspection.

4.4.2.1 Chemical analysis. At least one sample for chemical analysis shall be taken from each lot.

4.4.2.2 Hardness. Unless otherwise specified (see 6.2), the first and last plates from the first and last supplied ingots of each lot shall be tested. Hardness test shall be taken at each corner of the individual plate (3.2.3.1). All other plates in a given lot will be hardness tested on diagonal corners. The hardness shall be performed according to ASTM E10 or ASTM E18 (see 3.2.3.1) and shall be the average of at least three readings at one location.

4.4.2.3 For Charpy V-notch impact tests. A sample shall be taken from a plate representing each lot for Charpy V-notch impact tests. The sample shall be the same thickness as the plate it represents and large enough to obtain at least four specimens from the sample in accordance with 4.6.3.

4.4.2.4 For ballistic testing. One plate of each thickness to be supplied on the contract shall be randomly taken from each lot for ballistic testing. Unless otherwise specified, the plates shall be 12 inches by 36 inches.

4.4.2.5 For soundness. Unless otherwise specified (see 6.2), two samples shall be randomly taken from each lot for these tests; however, when an entire heat represents only one lot the samples shall be taken from the first and last usable portion of the heat.

4.5 Examination.

4.5.1 Visual. All steel plate shall be subject to visual inspection for compliance with the requirements for identification marking (see 3.2.7) and for workmanship (see 3.2.8).

4.5.2 Dimensional. All steel plate shall be subject to inspection for compliance with dimensional and tolerance requirements (see 3.2.5).

4.5.3 Preparation for shipment. Examination shall be made to determine compliance with the requirements for preparation for shipment (see 5.1).

4.6 Tests.

4.6.1 Chemical analysis. Chemical analysis shall be conducted in accordance with one of the applicable methods specified in ASTM A751.

4.6.2.1.2 Rockwell hardness tests. Rockwell C hardness tests in accordance with ASTM E18 will be used, where required, (see 3.2.3.1 and 4.4.2.2).

4.6.3 Charpy V-notch impact tests. At least four Charpy V-notch impact test specimens shall be taken from the sample and shall be prepared and tested in accordance with ASTM E23. Charpy V-notch impact test specimens shall be taken in both the TL orientation and in the LT orientation from locations midway between the top and bottom surfaces of the plate and at least 4 inches or 2T, whichever is less, from any quenched edge. The largest attainable subsized Charpy V-notch impact specimens shown in figure 4 of ASTM E23 shall be used. Specimen widths between those of the standard bar and the 1/4, 1/2 or 3/4 size width may be used. If widths between the recommended subsizes are used, the energy shall be proportioned or scaled so as to normalize the data to standard size bars. The normalized Charpy energy must then be compared to the standard width value of table I.

4.6.4 Ballistic tests. Ballistic testing of armor plate shall be conducted at an approved facility designated by the procuring activity (see 6.2). Testing shall be conducted in accordance with the requirements of the appendix of this specification.

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4.6.5 Soundness. Ultrasonic tests shall be carried out as agreed upon between the procuring activity and the contractor to determine if the requirements of 3.2.6 are met (see 6.2).

4.7 Reduced testing. At the discretion of the procuring activity, the amount of testing may be reduced provided the results on consecutive lots indicate that a satisfactory uniform product meeting the testing requirements is being produced. Reduced testing shall be in accordance with a system previously approved or established by the procuring activity involved (see 6.2).

4.8 Rejection and retest.

4.8.1 Rejection. Unless otherwise specified in the contract or order (see 6.2), failure of the first article samples to meet the requirements of this specification shall be cause for rejection of the process, failure of the acceptance samples to meet the requirements of this specification shall be cause for rejection of the lot.

4.8.2 Retest. Unless a specific retest procedure is specified in the contract or order (see 6.2), lots rejected for failure to meet the requirements of the specification may be resubmitted for test provided the producer has reworked the lots, as necessary, to correct the deficiencies or has removed the nonconforming material. First article retests shall not be permitted until the supplier has made the necessary corrections in the processing of the material to the satisfaction of the procuring activity.

## 5. PACKAGING

5.1 Packaging. For acquisition purposes, the packaging requirements shall be as specified in the contract or order (see 6.2). When actual packaging of materiel is to be performed by DoD personnel, these personnel need to contact the responsible packaging activity to ascertain requisite packaging requirements. Packaging requirements are maintained by the Inventory Control Point's packaging activity within the Military Department or Defense Agency, or within the Military Department's System Command. 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 steel armor covered by this specification is military unique. The armor is intended for non-structural use in lightweight applications generally up to and including 1/2 inch in thickness, where resistance to ball and armor piercing types of ammunition and multiple hit capability are required.

6.2 Ordering data. Acquisition documents should specify the following:

- a. Title, number and date of this specification.
- b. Nominal thickness of steel armor plate (see 1.1).
- c. Issue of DoDISS to be cited in the solicitation, and if required, the specific issue of individual documents referenced (see 2.2.1 and 2.3).
- d. When first article is required (see 3.1).
- e. If plates may be furnished in a condition other than in 3.2.1.1.
- f. If additional heat treatment may be performed (see 3.2.2).
- g. Dimensions (see 3.2.5.1).
- h. Soundness acceptance criteria if other than in 3.2.6 and 4.6.5.
- i. Heat treatment of each lot, chemical composition of the steel armor material, method of sulfide shape control, hardness results for each plate, and impact results for each lot (see 3.2.9).

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- j. Name of inspection agency when inspection should be performed by other than the contractor (see 4.1)
- k. If first article testing is required (see 4.2.1.1)
- l. If first article ballistic testing may be waived (see 4.2.1.1.2).
- m. If ballistic test plate is separately heat treated (see 4.3.1)
- n. Production sampling if other than in 4.4.2.1 through 4.4.2.5.
- o. Where ballistic testing is to be conducted (see 4.6.4).
- p. The reduced testing plan when applicable (see 4.7).
- q. If rejection and retest differ from 4.8.1 and 4.8.2 respectively.
- r. Packaging requirements (see 5.1).

6.2.1 Armor material test reports. When this specification or specification requirements are used in an acquisition and data are required to be delivered, the data requirements identified in 3.2.10 should be developed and delivered in accordance with the approved Contract Data Requirements List (CDRL), incorporated into the contract. The data specified should be delivered by the contractor in accordance with the contract or purchase order requirements.

6.3 Fabrication. The armor plate covered by this specification is subject to fabrication involving cutting, drilling, forming, and welding. It is intended that selection and control of chemical composition, cleanliness, and plate processing will be such that the armor will be suitable for fabrication under procedures and controls such as specified in MIL-STD-1185, Welding, High Hardness Armor, however the mechanical properties in 3.2.3.1 and 3.2.3.2 take priority over weldability.

6.4 Instructions for potential suppliers. Potential suppliers who have not previously supplied armor plate to this specification and wish to have their material ballistically tested, may do so at their own expense. It is recommended that inquiries for testing be directed to Commander, U.S. Army Test and Evaluation Command, ATTN: AMSTE-TM-O, Aberdeen Proving Ground, MD 21005. Technical questions regarding testing may be directed to U.S. Army Aberdeen Test Center, ATTN: STEAC-LI, Aberdeen Proving Ground, MD 21005.

6.5 Metric conversion. When required the units for foot, feet per second, inch, foot-pound, and Fahrenheit may be converted to the metric equivalents by multiplying them by the following conversion factors:

<u>English unit</u>	<u>Multiplied by</u>	<u>Equals</u>	<u>Metric equivalent</u>
foot (ft)	0.3048	=	meter (m)
feet per second (ft/s)	0.3048	=	meter per second (m/s)
inch (in.)	0.0254	=	meter (m)
foot-pound (ft-lbf)	1.3558	=	joules (J)
Fahrenheit (°F)	$t_{\text{C}} = (t_{\text{F}} - 32)/1.8$	=	Centigrade (°C)

## 6.6 Definitions.

6.6.1 Contracting officer. The term "contracting officer" means the person executing a contract on behalf of the Government, and any other officer or civilian employee who is properly designated contracting officer; and the term includes, except as otherwise provided, the authorized representative of a contracting officer acting within the limits of his authority.

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

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

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6.6.4 Procuring activity. The term "procuring activity" is that activity of the Government which actually initiates the request for procurement and maintains the records of the procurement.

6.7 Subject term (key word) listing.

Ballistic tests  
Brinell hardness  
Charpy V-notch impact tests

6.8 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.

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## APPENDIX A

## BALLISTIC TESTING OF HIGH STRENGTH, HIGH QUALITY STEEL ARMOR PLATE

## A.1 SCOPE

A.1.1 Scope. This appendix covers the minimum ballistic limits for acceptable requirements of high strength, high quality steel armor plate, when tested in accordance with the provisions of this specification. When there is a 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 Other Government documents, drawings, and publications. The following other Government documents, drawings, and publications form a part of this document to the extent specified herein. Unless otherwise specified, the issues are those cited in the solicitation.

USATECOM TOP 2-2-710      Ballistic Tests of Armor Materials

ITOP 4-2-805              Projectile Velocity and Time of Flight Measurements

(Application for copies should be addressed to the Defense Technical Information Center, 8725 John J. Kingman Road, Suite 0944, Fort Belvoir, VA 22060-6218.)

## A.3 DEFINITIONS

A.3.1 Ballistic limit, protection criteria ( $V_{50BL(P)}$ ). The  $V_{50BL(P)}$  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. thick 2024 T3 sheet of aluminum is placed  $6 \pm 1/2$  in. 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) are frequently used.

A.3.2 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.3.3 Fair impact. An impact should be considered fair when an unyawed 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.3.4 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.3.5 Partial penetration, (PP). Any impact which is not a complete penetration should be considered a partial penetration.

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A.3.6 Thickness, impact area. The thickness of ballistic test plates used for determining ballistic limits should be that area subjected to the ballistic testing.

A.3.7 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 ballistic limits shall be in accordance with the values shown in table A-I or A-II as applicable.

A.4.2 Resistance to cracking. Ballistic test plates when visually examined after testing shall not develop any through-crack greater in length than five calibers of the projectile.

## A.5 TESTS

A.5.1 Ballistic tests. V<sub>50</sub> ballistic tests shall be performed in accordance with USATECOM TOP 2-2-710, Ballistic Tests of Armor Materials, and ITOP 4-2-805, Projectile Velocity and Time of Flight Measurements, to determine compliance with the requirements of tables A-I and A-II.

A.5.1.1 Plate measurement. Plate thickness as measured by the ballistic test agency shall be used to determine the required ballistic limit for the plate. Individual thickness measurements are to be read from a micrometer to the nearest 0.001 inch and the average of these readings reported to the nearest 0.001 inch. At least one measurement shall be taken along each edge, but preferably in the area which will be impacted. The required ballistic limit will be determined by interpolation, if necessary, in the tables in the appendix.

A.5.1.2 Rejection and retest of ballistic plates.

A.5.1.2.1 First article tests (rejection). Unless noted otherwise in the contract or order, failure of either of the first article test plates to meet the minimum ballistic requirements as specified in the appendix to this specification indicates failure of the product and process.

A.5.1.2.2 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 must be submitted for first article testing and both must pass.

A.5.1.2.3 Acceptance tests (rejection). Unless otherwise noted in the contract or order, failure of a test plate to meet the ballistic requirements indicates failure of the lot, however, the final decision will depend on the outcome of retests, if submitted.

A.5.1.2.4 Acceptance tests (retests). If a test plate representing a lot fails to meet the ballistic requirements, the manufacturer immediately upon notification of the failure has the following options:

- (1) At manufacturer's expense submit two additional test plates from the same lot for ballistic retest, or
- (2) Retemper the lot and then submit a test plate from the retreated lot, or
- (3) Scrap the lot and submit a plate representing a new lot for acceptance.

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If the manufacturer chooses any one of these options and the ballistic retest plate (or plates) meets the requirements, then the lot represented is acceptable. If option (1) is chosen and one or both of the retest plates fail, the manufacturer may retemper the lot and submit a test plate from the retreated lot. If this plate fails, the lot is rejected. If option (3) is chosen and the test plate fails, the manufacturer may again resort to any one of the three options. The manufacturer shall report the processing used on the failed plates.

A.5.1.3 Disposition of ballistic test plates.

A.5.1.3.1 First article test plates. Upon request of the applicant within 15 days after ballistic testing, first article plates will be returned "as is" to the applicant, at his expense, unless the plates were destroyed in testing.

A.5.1.3.2 Acceptance test plates. Acceptance test plates that comply with the requirements of this specification are considered as part of the lot of steel they represent and ownership of them 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 as part of the lot they represent and remain the property of the producer just as the rejectable lot does. The failed plates will be returned, upon request, as in A.5.1.3.1.

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TABLE A-I. Minimum required ballistic limits (protection criteria)  
caliber .30 AP M2 at 30 degrees obliquity.

Thickness, inches	Required BL(P), fps	Thickness, inches	Required BL(P), fps	Thickness, inches	Required BL(P), fps
0.100	1029	0.175	1885	0.255	2498
0.105	1106	0.180	1929	0.260	2531
0.109	1164	0.185	1972	0.265	2564
0.110	1178	0.190	2014	0.270	2597
0.115	1246	0.195	2055	0.275	2629
0.120	1311	0.200	2095	0.280	2661
* 0.125	1373	0.205	2135	0.285	2692
0.130	1432	0.210	2174	0.290	2724
0.135	1489	0.215	2212	0.295	2754
0.140	1544	0.220	2250	** 0.300	2785
0.145	1597	0.225	2287	0.305	2815
0.150	1648	0.230	2323	0.310	2845
0.155	1698	0.235	2359	0.315	2874
0.160	1747	0.240	2395	0.316	2880
0.165	1794	0.245	2429	0.320	2903
0.170	1840	0.250	2464		

\* Specification requirements begin for this ordered thickness.

\*\* Specification requirements end for this ordered thickness.

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

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## APPENDIX A

TABLE A-II. Minimum required ballistic limits (protection criteria)  
caliber .50 AP M2 at 30 degrees obliquity.

Thickness, inches	Required BL(P), fps	Thickness, inches	Required BL(P), fps	Thickness, inches	Required BL(P), fps
0.285	1976	0.410	2391	0.535	2746
0.290	1994	0.415	2406	0.540	2759
0.295	2012	0.420	2421	0.545	2772
0.300	2030	0.425	2436	0.550	2785
* 0.301	2034	0.430	2451	0.555	2798
0.305	2048	0.435	2466	0.560	2811
0.310	2065	0.440	2480	0.565	2824
0.315	2083	0.445	2495	0.570	2837
0.320	2100	0.450	2510	0.575	2850
0.325	2117	0.455	2524	0.580	2863
0.330	2134	0.460	2539	0.585	2876
0.335	2151	0.465	2553	0.590	2888
0.340	2168	0.470	2567	0.595	2901
0.345	2185	0.475	2581	0.600	2914
0.350	2201	0.480	2595	0.605	2926
0.355	2218	0.485	2609	0.610	2939
0.360	2234	0.490	2623	0.615	2951
0.365	2250	0.495	2637	0.620	2963
0.370	2266	0.500	2651	** 0.625	2976
0.375	2282	0.505	2665	0.630	2988
0.380	2298	0.510	2678	0.635	3000
0.385	2314	0.515	2692	0.640	3012
0.390	2329	0.520	2705	0.645	3025
0.395	2345	0.525	2719	0.650	3037
0.400	2360	0.530	2732	0.655	3049
0.405	2376				

\* Specification requirements begin for this ordered thickness.

\*\* Specification requirements end for this ordered thickness.

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

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CONCLUDING MATERIAL

Custodian:  
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Preparing activity:  
Army - MR

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(Project 9515-A079)

# STANDARDIZATION DOCUMENT IMPROVEMENT PROPOSAL

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### I RECOMMEND A CHANGE:

1. DOCUMENT NUMBER  
MIL-DTL-46193A(MR)

2. DOCUMENT DATE (YYMMDD)  
981009

DOCUMENT TITLE ARMOR PLATE, CONTROL ROLLED, STEEL, WROUGHT, HIGH STRENGTH, HIGH QUALITY

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

### 5. REASON FOR RECOMMENDATION

### 6. SUBMITTER

a. NAME (Last, First, Middle Initial)

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Weapons and Material Research Directorate

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