

INCH-POUND

MIL-DTL-46177C(MR)
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SUPERSEDING
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DETAIL SPECIFICATION

ARMOR, STEEL PLATE AND SHEET, WROUGHT, HOMOGENEOUS
(1/8 TO LESS THAN 1/4 INCH THICK)

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 wrought-steel homogeneous plate and sheet from 1/8 to less than 1/4 inch inclusive 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 V₅₀ 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)
- ASTM E110 Indentation Hardness of Metallic Materials by Portable Hardness Testers (DoD adopted)
- ASTM E290 Bend Testing of Material for Ductility (DoD adopted)
- ASTM E1417 Liquid Penetrant Examination (DoD adopted)
- ASTM E1444 Magnetic Particle Examination (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 4.2.1.1.2 and 6.2), a sample or 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 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. The manufacturer's declared chemical analysis must be submitted to the contracting agency and to the ballistic test agency. The ballistic test agency shall record the test results of the first article ballistic test plates submitted, showing the dates tested.

3.1.2 Potential suppliers. Potential suppliers wishing to qualify to this specification should follow the instructions in 6.6.

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3.2 Acceptance requirements.3.2.1 Materials.

3.2.1.1 Structure. Processes of manufacture shall be such as to produce steel plate having, as nearly as practicable, a homogeneous structure throughout.

3.2.2 Chemical composition. The heat analysis of all plates within a heat shall conform to the requirements of table I unless otherwise negotiated between the steel supplier and the contractor. In addition, those additives or hardening agents intentionally added shall be declared. All limits as specified in table I (including any deviations negotiated) shall be submitted in advance to the procuring activity. The contractor may establish and submit separate limits for each thickness of plate to be furnished (see 6.5). A statement showing the product analysis of each melt and complete details of the heat treatment of each lot shall be furnished to the procuring activity at no cost to the procuring activity. All elements of chemical composition shall be shown in the statement. The chemical composition range established by the producer and the chemical analysis of the material submitted shall be reported to the procuring activity. Also, some methods of sulfide shape control shall be used.

3.2.3 Heat treatment. All plates in each lot, including samples, shall receive the same heat treatment except for such variations in tempering temperature as may be necessary to produce the prescribed hardness. The austenitizing temperature for production plates may vary within a range of 50°F above the temperature used for test plates, but in no case shall it exceed 1700°F (see 6.4).

3.2.4 Processing controls.

3.2.4.1 Heating. Except for heating the plates below 450°F, local or general heating shall not be performed after the final quenching and tempering operation unless otherwise specified in the contract or order. A detailed outline of the procedure to be used in each operation of the following processes shall be submitted in writing to the procuring activity for authorization (see 6.2).

3.2.4.1.1 Edge preparation. Thermal cutting shall be permitted after final heat treatment provided the procedure is such that no cracks develop on any thermal cut edge.

3.2.4.1.2 Repairing. Unless otherwise approved by the procuring activity, weld repairs shall not be made on any plates. When permitted, weld repair shall be done prior to hardening treatment whenever possible (see 6.2).

3.2.4.1.3 Forming. After final quenching and tempering operations the plate material shall meet the bend test requirements as specified in 3.2.5.3.

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TABLE I. Chemical composition (product analysis). ^{1/}

| ELEMENT | MAXIMUM RANGE PERCENT | MAXIMUM LIMIT PERCENT |
|---------------------------|--------------------------|--------------------------|
| CARBON | 0.10 | 0.30 |
| MANGANESE: | | |
| Up to 1.00%, incl. | 0.30 | -- |
| Over 1.00% | 0.40 | -- |
| PHOSPHORUS | -- | 0.025 |
| SULFUR | -- | 0.015 |
| SILICON: | | |
| Up to 0.60% incl. | 0.20 | -- |
| Over 0.60% to 1.00% incl. | 0.30 | -- |
| Over 1.00% | 0.40 | -- |
| NICKEL | 0.50 | -- |
| CHROMIUM: | | |
| Up to 1.25% incl. | 0.30 | -- |
| Over 1.25% | 0.40 | -- |
| MOLYBDENUM: | | |
| Up to 0.20% incl. | 0.07 | -- |
| Over 0.20% | 0.15 | -- |
| VANADIUM | 0.10 | -- |
| BORON | -- | -- ^{2/} |
| COPPER | -- | 0.25 ^{2/} |
| TITANIUM | -- | 0.10 ^{3/} |
| ZIRCONIUM | -- | 0.10 ^{3/} |
| ALUMINUM | -- | 0.10 ^{3/} |
| LEAD | -- | 0.01 |
| TIN | -- | 0.02 ^{3/} |
| ANTIMONY | -- | 0.02 ^{3/} |
| ARSENIC | -- | 0.02 ^{3/} |

^{1/} This table lists the maximum range for elements of the manufacturer's established chemical composition.

^{2/} When the amount of boron is specified in the alloy, its content so determined by heat analysis shall not exceed 0.003 percent.

^{3/} When the amount of an element is less than 0.02 percent the analysis may be reported as 0.02 percent.

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3.2.4.2 Grinding. Grinding is not required but may be performed to remove minor defects not affecting the serviceability of the material provided that, unless otherwise authorized by the procuring activity, the grinding does not result in the reduction of the plate thickness in the ground areas to less than the tolerances specified in table II.

TABLE II. Thickness tolerances for ordered thickness, inches (over and under).

| Specified thickness inch | Tolerance (inch) for width of plate | | | | |
|-----------------------------|-------------------------------------|---------------------|---------------------|----------------------|-----------------------|
| | Up to 72" | 72" to 84" excl. | 84" to 96" excl. | 96" to 108" excl. | 108" to 120" incl. |
| 1/8 to less than 1/4 | .016 | .016 | .019 | .019 | .023 |

3.2.5 Mechanical properties.

3.2.5.1 Hardness. The average surface hardness of each plate including first article samples shall be within the range of Rockwell hardness (HRC) of 39 to 43 or Brinell hardness (HB) of 362 to 400 when tested in accordance with 4.6.2.

3.2.5.2 Impact resistance. The minimum Charpy V-notch impact resistance requirement of the armor plate shall be as shown in table III. The Charpy V-notch impact specimens shall be obtained in both the TL orientation (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 (parallel to the major direction of rolling).

3.2.5.3 Bend test. All bend test samples from a given lot shall be capable of being bent to the requirements below without cracking. Two bend test samples shall be tested in the transverse direction per ASTM E290, at room temperature through an included angle of 90 degrees (unrestrained) to the inside radii shown below. After bending, samples shall be free of cracks as determined by either liquid penetrant inspection per ASTM E1417 or magnetic particle inspection per ASTM E1444.

Plate thickness (T)

Inside Radius

1/8 to 1/4 inches

4T

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

3.2.7 Dimensions and tolerances.

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

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

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TABLE III. Minimum Charpy V-notch impact resistance requirements (at $-40^{\circ}\text{F} \pm 2^{\circ}\text{F}$).

| Rockwell Hardness (HRC) average | Brinell Hardness (HB) 3000-Kg load average | Impact resistance (avg. of 2 or more tests) ft-lb, standard depth specimens | |
|---------------------------------------|---|---|-----------|
| | | 1/2 Scale | 1/4 Scale |
| 39 | 362 | 9.0 | 4.5 |
| 40 | 371 | 8.5 | 4.3 |
| 42 | 390 | 8.0 | 4.0 |
| 43 | 400 | 7.5 | 3-8 |

3.2.7.3 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. Other tolerance requirements may be specified in the contract or order and shall be as agreed upon between the contractor and the procuring activity.

TABLE IV. Permissible variations for flatness.

| Specified thickness inch | Variations from a flat surface for specified widths, in. | | |
|--------------------------------|--|------------------|----------------|
| | Up to 60 excl | 60 to 72 excl | 72 and over |
| Up to 1/4, excl | 0.5 | 0.75 | 1.0 |

NOTE 1: Flatness tolerances for length. The longer dimensions 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 tolerance for width. The flatness variation across the width should not exceed the tabular amount for the specified width.

3.2.7.4 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.

3.2.8 Identification marking. Identification marking 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. 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 marking shall be legibly stenciled or marked with indelible ink and located along the edge with the lifting hole. The primary plate rolling direction shall be identified.

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TABLE V. Waviness tolerance for plates, inch.

| Flatness tolerance from table IV | When number of waves in 12 ft is: | | | | | | |
|-------------------------------------|-----------------------------------|--------|--------|--------|--------|--------|--------|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 1/2 | 0.50 | 0.375 | 0.3125 | 0.1875 | 0.1875 | 0.1250 | 0.0625 |
| 3/4 | 0.75 | 0.5625 | 0.4375 | 0.3125 | 0.2500 | 0.1875 | 0.1250 |
| 1 | 1.00 | 0.7500 | 0.5625 | 0.4375 | 0.3125 | 0.2500 | 0.1875 |

NOTE 1: Waviness denotes the deviation of the top or bottom surface from 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 plates up to 1/4 inch or less in thickness, the waviness tolerance shall not apply.

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 test results for each plate and impact test 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 to the procuring activity containing the information as specified in MIL-STD-662.

3.2.11 Workmanship.

3.2.11.1 Surface condition. The top and bottom surface of each plate shall be free from the following surface defects: slivers, laps, checks, seams, blisters, snakes, cold shuts, cracks, burning, mechanical seams, mechanical gouges and laminations (see 6.8). The surface of each plate shall be such that mill scale or oxidation product shall not interfere with determination of acceptability. Imperfections listed above which are of such a nature as to affect the fabrication of the material, are rejectable.

3.2.11.1.1 Depth of imperfections. The depth of rolled-in scale, scale pitting or snakes shall not exceed 0.015 inch and shall not reduce the steel thickness below the allowable minimum. Isolated individual pits over 0.015 inch deep but not over 0.03 inch deep and not within 6 inches of each other and which do not violate the minimum allowable thickness, as specified in the applicable drawings and fabrication documents, are acceptable.

3.2.11.2 Edge preparation. Thermal cutting shall be permitted after final heat treatment provided the procedure, which may include grinding after thermal cutting, is such that no cracks develop on any thermally cut edge whether detected by nondestructive inspection, or as agreed upon in the contract. The heat affected zone of thermally cut plates shall not exceed 1.2 times the plate

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thickness from the cut edge. In order to have the heat affected zone exceed these limits approval shall be obtained from the procuring activity.

3.2.11.3 Edge condition. Plate edge on plates delivered after heat treatment shall be free of cracks. The supplier shall practice such necessary process controls to prevent this condition.

3.2.11.4 Internal soundness. The steel supplier shall institute such necessary process controls such that any edges of any cut parts shall comply with the requirements of 3.2.11.4.1.

3.2.11.4.1 Acceptance criteria. In any four inches, a linear indication shall not exceed twice the plate thickness. Multiple linear indications shall not exceed 1-1/2 times the plate thickness if two or more lie in the same plane and the total length in one plane, in any four inch length, shall not exceed twice the plate thickness. No more than ten indications are permitted in any 4 inches of length. All cracks are rejectable. Large indications shall be removed by the manufacturer or processor by grinding provided the minimum plate thickness is maintained.

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:

- a. First article inspection
- b. Quality conformance inspection (acceptance)

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.

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4.2.1.1.1 First article tests. First article tests shall consist of all the tests specified in 4.6.

4.2.1.1.2 Waving of first article ballistic test. Unless otherwise specified (see 3.1 and 6.2), the first article ballistic test may be waived at the discretion of the procuring activity if the manufacturer within 37 months has produced acceptable plates, provided also that production conditions are the same as for previously accepted plates. When a supplier has previously met the first article requirements he will furnish the procuring agency with the pertinent data relative to compliance with first article tests.

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

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 heat treated in the same thermal cycle in the same production furnace(s) in the same facility. When specified by the procuring activity, (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 plates. When the procuring activity allows a ballistic test plate to be heat treated separately from the production plates it represents, it shall be so stated in the data to be supplied in accordance with MIL-STD-662 (see 6.2 and 6.4).

4.4 Sampling.

4.4.1 First article sampling. The number and sizes of test plates and samples for first article testing and examination shall be as follows: 3 ballistic test plates 12 x 36 inches x 0.1875 inch thick to represent plates in the ordered thickness range of 0.125 to less than 0.250 inch.

4.4.1.1 Chemical composition. Sample for chemical analysis shall be taken from each plate selected for the ballistic tests.

4.4.1.2 Impact samples. At least one impact test sample shall be taken from each submitted test plate in accordance with 4.6.3 and each plate shall consist of enough material for four (4) impact specimens.

4.4.1.3 Bend test samples. Unless otherwise specified (see 6.2), two (2) samples shall be taken from each submitted test plate and shall be tested in accordance with 4.6.7 and shall meet the requirements of 3.2.5.3.

4.4.2 Sampling for acceptance tests.

4.4.2.1 For chemical analysis. At least one sample for chemical analysis shall be taken from each heat in accordance with the applicable method specified in ASTM A751 (see 6.5).

4.4.2.2 For hardness tests. Each plate in each lot shall be tested in at least two places on one face for hardness in accordance with 4.6.2.

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4.4.2.3 For Charpy V-notch impact tests. At least one 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 they represent and large enough to obtain at least two specimens, in each direction, from each sample in accordance with 4.6.3.

4.4.2.4 For ballistic acceptance samples. Unless otherwise specified in the contract or order (see 6.2), one test plate shall be submitted from each lot. The minimum plate size shall be 12 x 36 inches. Unless otherwise specified, the average thickness of each test plate shall be determined by taking the average of four thickness measurements. One measurement shall be taken along each edge at a distance of at least 1 inch from the edge. Thickness measurements for plates shall be read to the nearest 0.001 inch. If a producer submits plates outside the specified plate tolerances (see table II), the procuring activity shall be notified.

4.4.2.5 Bend test samples. Unless otherwise specified (see 6.2), two samples shall be randomly taken from each lot for these tests representing the entire lot of material; however, when an entire heat represents only one lot the samples shall be taken from the first and last usable portion of the heat. Testing shall be conducted in accordance with 4.6.7 and shall meet the requirements of 3.2.5.3.

4.5 Examination.

4.5.1 Visual. All steel plate shall be subject to visual inspection for compliance with the requirements for surface conditions (see 3.2.11.1), edge quality (see 3.2.11.2 and 3.2.11.3) and identification marking (see 3.2.8).

4.5.2 Dimensional. All steel plates shall be subject to inspection for compliance with dimensional and tolerance requirements (see 3.2.7).

4.5.3 Preparation for shipment. Examination shall be made to determine compliance with the requirements for preparation for shipment (see section 5).

4.6 Tests.

4.6.1 Chemical analysis. Chemical analysis shall be conducted in accordance with the applicable method specified in ASTM A751 (see 6.5). The analysis shall comply with the declared composition established in accordance with the requirements of table I (see 3.2.2).

4.6.2 Hardness test. The Rockwell hardness or the Brinell hardness test shall be conducted in accordance with ASTM E10 or ASTM E18 or ASTM E110 as applicable. Two readings shall be taken at diagonal corners on one plate surface only. Surface scale and decarburization shall be removed from the areas where the tests are to be made.

4.6.3 Charpy V-notch impact tests. At least two Charpy V-notch impact test specimens shall be taken from each 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 as well as outside the heat affected zone of any oxygen-cut edge. The largest attainable subsize Charpy V-notch impact specimens shown in figure 4 of ASTM E23 shall be used.

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4.6.4 Ballistic tests. Ballistic testing of the plate shall be conducted at a Government test facility specified in the contract or order (see 6.2). Testing shall be conducted in accordance with the requirements of the appendix to this specification.

4.6.5 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 (see 6.2). Reduced testing shall be in accordance with a system previously approved or established by the procuring activity involved.

4.6.6 Rejection and retest.

4.6.6.1 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, and failure of the acceptance samples to meet the requirements of this specification shall be cause for rejection of the lot (see 4.6.6.2).

4.6.6.2 Retest. Unless a specific retest procedure is specified in the contract or order (see 6.2), two retest samples shall be submitted for each failed sample. Failure of either of the retest samples (plates) shall be cause for rejection of the 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.

4.6.7 Bend test. The bend test shall be conducted in accordance with ASTM E290 using method Arrangement C.

4.6.8 Hardness traverse test. Prior to production to assure compliance to paragraph 3.2.11.2, the size of the heat affected zone for thermally cut edges shall be determined by taking Rockwell C hardness tests at 1/16 inch increments from the edge. Surface scale and decarburization shall be removed from the test surface. The distance at which there is no change in surface hardness shall be considered the depth of the heat affected zone. The contractor shall document the test results for each thickness and thermal cutting method used in production. The contractor is also responsible for documenting all heat input controls to assure the cutting process is under control. Re-verification of heat affected zone size for subsequent production lots is not required provided there is no change in the cutting method or heat input from that previously tested. The records shall be available for review by the cognizant government representative.

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.

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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 use on combat vehicles, where resistance to ball and armor piercing types of ammunition and multiple hit capability are required. The term "plate" as used throughout the specification refers to either plate or sheet depending upon the thickness of the material.

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 and sheet (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 sample is required (see 3.1).
- e. If local or general heating is permitted (see 3.2.4.1).
- f. If weld repairing is permitted (see 3.2.4.1.2).
- g. Dimensional (see 3.2.7.1), flatness (see 3.2.7.3), and waviness (see 3.2.7.4) requirements.
- h. 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).
- i. Name of inspection agency when inspection should be performed by other than the contractor (see 4.1).
- j. If first article testing is required (see 4.2.1.1).
- k. If first article ballistic testing is to be waived (see 4.2.1.1.2).
- l. If ballistic test plates are separately heat treated from the production plates, it represents (see 4.3.1).
- m. Bend test sampling if different (see 4.4.1.3).
- n. If ballistic acceptance sample should be other than in 4.4.2.4.
- o. Where ballistic testing is to be conducted (see 4.6.4).
- p. The reduced testing plan when applicable (see 4.6.5).
- q. If rejection and retesting differs from 4.6.6.1 and 4.6.6.2 respectively.
- r. Packaging requirements (see 5.1).
- s. If rejection of first article test plates differ from A.5.1.2.1.
- t. If rejection of the lot differs from A.5.1.2.3.

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-HDBK-1941, Metal-Arc Welding of Homogeneous Armor.

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6.4 Production plates. Material made to this specification has a tendency to develop stress cracks if not tempered as soon as possible after austenitizing treatment. To avoid this situation all plates should be left in the hot rolled or tempered condition while waiting for the ballistic test results.

6.5 Changes in composition. Changes in composition should not necessarily be cause for retesting but should be subject to review by the procuring activity to determine whether additional first article testing is required.

6.6 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.

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

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

6.8 Definitions.

6.8.1 Blisters. A raised area, often dome shaped, resulting from delamination under pressure of expanding gas trapped in a metal in a near sub-surface zone. Very small blisters may be called pinhead blisters or pepper blisters.

6.8.2 Burning. Permanently damaged metal due to overheating enough to cause incipient melting or intergranular oxidation. Note: This condition is usually obscured by normal cleaning methods and would require deep pickling and/or metallography to note the continuous oxidation (chicken wire effect) of the enlarged grain boundaries.

6.8.3 Checks. Numerous very fine cracks at the surface of a metal part. Checks may appear during processing or during service and are most often associated with thermal cycling or thermal treatment. Also called check marks, checking, heat checks.

6.8.4 Cold shuts. Freezing of the top surface of an ingot before mold is full.

6.8.5 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.

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

6.8.7 Homogeneous plate. A plate having uniform composition and heat treatment throughout.

6.8.8 Lamination. A type of discontinuity with separation or weakness generally aligned parallel to direction of the worked surface of the metal and may be the result of pipe, blisters, seams, inclusions, or segregation elongated and made directional by working.

6.8.9 Laps. A surface imperfection with the appearance of a seam, caused by hot metal, fins or sharp corners being folded over and thus being forged or rolled into the surface but without being welded.

6.8.10 Linear indication. For nondestructive examination purposes a linear indication is evidence of a discontinuity that requires interpretation to determine its significance.

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

6.8.12 Pit. A cavity or depressed area on the surface of a plate.

6.8.13 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.

6.8.14 Seams. An unwelded fold or lap that appears as a crack, usually resulting from a discontinuity on a metal surface.

6.8.15 Slivers. An imperfection consisting of a very thin elongated piece of metal attached by only one end to the parent metal into whose surface it has been worked.

6.8.16 Snakes. Any crooked surface imperfection in a metal plate, resembling a snake.

6.9 Subject term (key word) listing.

Ballistic test
Bend test
Hardness test
Impact resistance

6.10 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 STEEL PLATE AND SHEET, WROUGHT, HOMOGENEOUS

A.1 SCOPE

A.1.1 Scope. This appendix covers the requirements for ballistic testing of wrought homogeneous steel plate and sheet from 1/8 to less than 1/4 inch inclusive in thickness. 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 $6 \pm 1/2$ inch 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 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 Partial penetration, (PP). Any impact which is not a complete penetration should be considered a partial penetration.

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A.3.5 Thickness, impact area. The thickness of ballistic test plates used for determining ballistic limits should be that area subjected to the ballistic testing.

A.3.6 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.

A.4.2 Cracking. Ballistic test plates shall be visually examined immediately after testing to determine the presence of cracking. Cracks whose length exceed 3 test projectile diameters, measured from the center of impact, shall be cause for plate rejection.

A.5 TESTS

A.5.1 Ballistic tests. V₅₀ ballistic tests shall be performed in accordance with USATECOM test operations procedures for Ballistic Tests of Armor Materials, TOP 2-2-710, to determine compliance with the requirements of table A-I.

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 measurement 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 of the plate at a distance at least one inch from the edge.

A.5.1.2 Rejection and test of ballistic plates.

A.5.1.2.1 First article tests (rejection). Unless noted otherwise in the contract or order (see 6.2), failure of any one or more of the three first article tests 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. Three retest plates shall be submitted for first article testing and all three must pass.

A.5.1.2.3 Acceptance tests (rejection). Unless otherwise noted 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 will depend on the outcome of retests, if submitted.

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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) Reheat treat (quenching and tempering) the lot and then resubmit a test plate from the retreated lot, or
- (3) Scrap the lot and submit a plate representing a new lot for acceptance.

If the manufacturer chooses any one of these options and the ballistic retest plate (or plates) meet 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 reheat treat 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.

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 V_{50} ballistic limits (protection criteria)
firing obliquity: 30°; projectile: caliber .30 ball M2.

| Thickness inches | Required BL(P), fps | Thickness inches | Required BL(P), fps | Thickness inches | Required BL(P), fps |
|---------------------|------------------------|---------------------|------------------------|---------------------|------------------------|
| 0.102 | 1593 | 0.142 | 1968 | 0.182 | 2242 |
| 0.103 | 1603 | 0.143 | 1977 | 0.183 | 2247 |
| 0.104 | 1612 | 0.144 | 1987 | 0.184 | 2252 |
| 0.105 | 1622 | 0.145 | 1996 | 0.185 | 2257 |
| 0.106 | 1631 | 0.146 | 2006 | 0.186 | 2261 |
| 0.107 | 1640 | 0.147 | 2015 | 0.187 | 2266 |
| 0.108 | 1650 | 0.148 | 2024 | 0.188 | 2271 |
| 0.109 | 1659 | 0.149 | 2034 | 0.189 | 2275 |
| 0.110 | 1668 | 0.150 | 2043 | 0.190 | 2280 |
| 0.111 | 1678 | 0.151 | 2052 | 0.191 | 2285 |
| 0.112 | 1687 | 0.152 | 2062 | 0.192 | 2289 |
| 0.113 | 1696 | 0.153 | 2071 | 0.193 | 2294 |
| 0.114 | 1706 | 0.154 | 2080 | 0.194 | 2298 |
| 0.115 | 1715 | 0.155 | 2090 | 0.195 | 2303 |
| 0.116 | 1725 | 0.156 | 2099 | 0.196 | 2308 |
| 0.117 | 1734 | 0.157 | 2109 | 0.197 | 2312 |
| 0.118 | 1743 | 0.158 | 2118 | 0.198 | 2317 |
| 0.119 | 1753 | 0.159 | 2127 | 0.199 | 2321 |
| 0.120 | 1762 | 0.160 | 2137 | 0.200 | 2326 |
| 0.121 | 1771 | 0.161 | 2141 | 0.201 | 2330 |
| 0.122 | 1781 | 0.162 | 2146 | 0.202 | 2335 |
| 0.123 | 1790 | 0.163 | 2151 | 0.203 | 2339 |
| 0.124 | 1799 | 0.164 | 2156 | 0.204 | 2344 |
| * 0.125 | 1809 | 0.165 | 2161 | 0.205 | 2348 |
| 0.126 | 1818 | 0.166 | 2166 | 0.206 | 2353 |
| 0.127 | 1828 | 0.167 | 2171 | 0.207 | 2357 |
| 0.128 | 1837 | 0.168 | 2176 | 0.208 | 2362 |
| 0.129 | 1846 | 0.169 | 2180 | 0.209 | 2366 |
| 0.130 | 1856 | 0.170 | 2185 | 0.210 | 2371 |
| 0.131 | 1865 | 0.171 | 2190 | 0.211 | 2375 |
| 0.132 | 1874 | 0.172 | 2195 | 0.212 | 2380 |
| 0.133 | 1884 | 0.173 | 2200 | 0.213 | 2384 |
| 0.134 | 1893 | 0.174 | 2204 | 0.214 | 2389 |
| 0.135 | 1903 | 0.175 | 2209 | 0.215 | 2393 |
| 0.136 | 1912 | 0.176 | 2214 | 0.216 | 2398 |
| 0.137 | 1921 | 0.177 | 2219 | 0.217 | 2402 |
| 0.138 | 1931 | 0.178 | 2224 | 0.218 | 2406 |
| 0.139 | 1940 | 0.179 | 2228 | 0.219 | 2411 |
| 0.140 | 1949 | 0.180 | 2233 | 0.220 | 2415 |
| 0.141 | 1959 | 0.181 | 2238 | 0.221 | 2420 |

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TABLE A-I. Minimum required V₅₀ ballistic limits (protection criteria) firing obliquity: 30°; projectile: caliber .30 ball M2 - Continued.

| Thickness inches | Required BL(P), fps | Thickness inches | Required BL(P), fps | Thickness inches | Required BL(P), fps |
|---------------------|------------------------|---------------------|------------------------|---------------------|------------------------|
| 0.222 | 2424 | 0.239 | 2497 | 0.256 | 2568 |
| 0.223 | 2428 | 0.240 | 2501 | 0.257 | 2573 |
| 0.224 | 2433 | 0.241 | 2506 | 0.258 | 2577 |
| 0.225 | 2437 | 0.242 | 2510 | 0.259 | 2581 |
| 0.226 | 2441 | 0.243 | 2514 | 0.260 | 2585 |
| 0.227 | 2446 | 0.244 | 2518 | 0.261 | 2589 |
| 0.228 | 2450 | 0.245 | 2523 | 0.262 | 2593 |
| 0.229 | 2454 | 0.246 | 2527 | 0.263 | 2597 |
| 0.230 | 2459 | 0.247 | 2531 | 0.264 | 2601 |
| 0.231 | 2463 | 0.248 | 2535 | 0.265 | 2605 |
| 0.232 | 2467 | ** 0.249 | 2539 | 0.266 | 2610 |
| 0.233 | 2472 | 0.250 | 2544 | 0.267 | 2614 |
| 0.234 | 2476 | 0.251 | 2548 | 0.268 | 2618 |
| 0.235 | 2480 | 0.252 | 2552 | 0.269 | 2622 |
| 0.236 | 2484 | 0.253 | 2556 | 0.270 | 2626 |
| 0.237 | 2489 | 0.254 | 2560 | 0.271 | 2630 |
| 0.238 | 2493 | 0.255 | 2564 | 0.272 | 2634 |

* 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:
Army - MR

Preparing activity:
Army - MR

Review activities:
Army - MI
DLA - IS

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INSTRUCTIONS

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I RECOMMEND A CHANGE:

1. DOCUMENT NUMBER
MIL-DTL-46177C

2. DOCUMENT DATE (YYMMDD)
981024

ARMOR, STEEL PLATE AND SHEET, WROUGHT, HOMOGENEOUS (1/8 TO LESS THAN 1/4 INCH THICK)

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)*

b. ORGANIZATION

c. ADDRESS *(Include Zip Code)*

d. TELEPHONE *(Include Area Code)*
(1) Commercial
(2) AUTOVON
(if applicable)

7. DATE SUBMITTED
(YYMMDD)

8. PREPARING ACTIVITY

a. NAME

US ARMY RESEARCH LABORATORY

b. TELEPHONE *Include Area Code)*

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