

INCH-POUND

MIL-S-47319A (MI)

26 November 1990

SUPERSEDING

MIL-S-47319 (MI)

8 July 1987

## MILITARY SPECIFICATION

### STEEL, BAR, BILLET AND FORGINGS COBALT-FREE MARAGING

This specification is approved for use by the U.S. Army Missile Command, 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 defines the requirements of two classes of one type of steel bar, forgings and stock for forging, cobalt-free maraging, containing 18 percent nickel and capable of attaining high ultimate tensile properties by means of a relatively low temperature heat treating process.

1.2 Classification. The steel shall be of the following type and classes, as specified (see 6.2):

1.2.1 Type. A type I steel is intended to provide a nominal tensile strength of 250,000 pounds force per square inch (lbf/in<sup>2</sup>).

Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: Commander, U.S. Army Missile Command, ATTN: AMSMI-RD-SE-TD-ST, Redstone Arsenal, AL 35898-5270 by using the Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

AMSC N/A

FSC 9515

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

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1.2.2 Classes.

- a. Class 1 - Vacuum Induction Melted (VIM) plus Vacuum Arc Remelt (VAR). This material shall be produced by multiple melting using the vacuum induction first melt followed by vacuum consumable electrode process in the final remelt cycle.
- b. Class 2 - Vacuum Arc Remelt (VAR) Steel. This material shall be produced by multiple melting using the vacuum consumable process in the final remelt cycle.

## 2. APPLICABLE DOCUMENTS

2.1 Government documents.

2.1.1 Specifications, standards, and handbooks. The following specifications, standards, and handbooks form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those listed in the issue of the Department of Defense Index of Specifications and Standards (DODISS) and supplement thereto, cited in the solicitation (see 6.2).

## STANDARDS

## FEDERAL

- FED-STD-48 - Tolerances for Steel Wrought Products, and for Centrifugally Cast Steel
- FED-STD-151 - Metals: Test Methods
- FED-STD-183 - Continuous Identification Marking of Iron and Steel Products

## MILITARY

- MIL-STD-129 - Marking for Shipment and Storage
- MIL-STD-163 - Steel Mill Products Preparation for Shipment and Storage
- MIL-STD-1190 - Minimum Guidelines for Level C Preservation, Packing and Marking

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(Unless otherwise indicated, copies of the federal and military specifications, standards, and handbooks are available from the Standardization Documents Order Desk, Bldg. 4D, 700 Robbins Ave., Philadelphia, PA 19111-5094.)

**2.2 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)

## AEROSPACE MATERIAL SPECIFICATION (AMS)

ASTM 2808 - Identification Forgings

(Application for copies of AMS publications should be addressed to the Society of Automotive Engineers, Inc., 400 Commonwealth Drive, Warrendale, PA 15096).

## AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

ASTM E 8	-	Tension Testing of Metallic Materials, Standard Test Method of
ASTM E 10	-	Brinell Hardness of Metallic Materials, Standard Test Method for
ASTM E 18	-	Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials, Standard Test Methods for
ASTM E 45	-	Determining the Inclusion Content of Steel, Standard Practice for
ASTM E 92	-	Vickers Hardness of Metallic Materials, Standard for
ASTM E 112	-	Determining the Average Grain Size, Standard Test Methods for
ASTM E 140	-	Standard Hardness Conversion Tables for Metals
ASTM E 381	-	Macroetch Testing, Inspection, and Rating Steel Products, Comprising Bars, Billets, Blooms and Forgings, Standard Method of

(Application for copies should be addressed to the American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.)

(Non-Government standards and other publications are normally available from the organizations that prepare or distribute the documents. These documents also may be available in or through libraries or other informational services.)

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

### 3. REQUIREMENTS

3.1 First article. When specified (see 6.2), a sample shall be subjected to first article inspection (see 6.3) in accordance with 4.4.

#### 3.2 Material.

##### 3.2.1 Manufacture and condition.

3.2.1.1 Manufacture. Bar, forgings and stock for forging or extrusions shall be fabricated from ingots which shall have been produced by either the VIM plus VAR or the VAR method. The specific procedure shall be specified by the purchaser of the product. Sufficient discard shall be taken from each ingot to insure freedom from piping and undue segregation (see 4.6.1).

3.2.1.2 Condition. Unless otherwise specified (see 6.2), bars and forgings shall be furnished in the solution annealed, descaled and oiled condition. Solution annealing shall be accomplished by heating one or more times to a temperature between 815° and 927° Celsius (C), for 1 hour per inch of thickness, followed by air cooling to room temperature. The precise temperature shall be that necessary to meet the end item requirements of this specification (see 4.6.1).

3.2.1.3 Stock for forging. As ordered by the forging manufacturer.

3.2.2 Tolerances. Tolerances shall conform to the applicable limits of FED-STD-48 (see 4.6.2).

3.2.3 Identification. Unless otherwise specified, each bar and billet shall be identified in accordance with FED-STD-183. The marking shall include the heat number, composition designation physical condition and the military part number. Forgings shall be identified by ink marking in accordance with AMS 2808 (see 4.6.3).

3.2.4 Chemical composition. The chemical composition of bar, billet, and forgings shall be as specified in table I (see 4.6.4).

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TABLE I. Chemical composition.

Element	Type I, class 1 & 2 analysis (percent)	Check analysis tolerance <u>1/</u> (percent)
Carbon	0.03, maximum	+0.005
Manganese	0.10, maximum	±0.03
Silicon	0.10, maximum	±0.02
Phosphorus	0.01, maximum	±0.002
Sulfur	0.01, maximum	±0.002
Nickel	18 to 20 --	±0.20
Cobalt	0.50, maximum	±0.10
Molybdenum	2.75 to 3.25	±0.10
Titanium	1.2 to 1.6	±0.10
Aluminum	0.05 to 0.15	±0.02
Copper	0.50, maximum	±0.10
Chromium	0.50, maximum	±0.10
Iron	Remainder	
Boron	0.003, typical	Certified as additions only
Zirconium	0.02, typical	
Calcium	0.05, typical	

1/ Individual determinations may vary from the specified range to the extent shown in the check analysis column, except the elements in any melt shall not vary both above and below the specified range.

3.2.4.1 Analysis. The contractor shall furnish an analysis of the metal of each lot showing the percentage of each of the elements designated in table I.

### 3.2.5 Cleanliness.

3.2.5.1 Macrograph quality. The macrograph quality shall be equal to or greater than S2, R2, C3 of ASTM E 381 (see 4.6.5).

3.2.5.2 Inclusion content. The size and frequency of inclusions in type I (class 1 and 2) steel shall not exceed the Jernkontoret limits specified in table II as indicated by "Designation of Length and Weight of Inclusions" (figure 5) of ASTM E 45 (see 4.6.6).

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TABLE II. Inclusion rating.

	ASTM identification code				
Series	A	B	C	D	E <sup>1/</sup>
Thin series	1.5	1.5	1.5	2.0	3.0
Thick series	1.0	1.0	1.0	1.5	1.5

<sup>1/</sup> Code E items are titanium nitrides and shall be rated by the same method as Code B.

3.2.6 Grain size. The grain size of bar and forgings shall be predominantly five or finer, with grains as large as three permissible. The grain size of stock for forging shall be subject to negotiation with the manufacturer (see 4.6.7).

3.2.7 Hardness of annealed steel. The hardness of annealed steel shall be not greater than Rockwell C-34 or equivalent (see 4.6.8).

### 3.3 Performance characteristics.

3.3.1 Response to heat treatment. Steel received in the annealed condition shall conform to the following requirements after being maraged for not less than 3 hours and not more than 15 hours, at  $482^{\circ} \pm 5.5^{\circ}\text{C}$  in air.

3.3.1.1 Tensile properties. The tensile properties of maraged bar, and forged products shall conform to table III (see 4.6.9.1).

3.3.1.2 Stock for forging. When a sample of stock is forged to a coupon and heat treated in accordance with 3.3.1, specimens taken from the heat treated coupon shall conform to the requirements of table III (see 4.6.9.1).

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TABLE III. Tensile properties of bar, plate, extrusions and forgings.

Longitudinal tensile properties	Type I, class 1 & 2	
Tensile ultimate strength, lbf/in <sup>2</sup> , minimum	250,000	
Tensile yield strength, lbf/in <sup>2</sup> , weight not less than 0.2 percent offset	240,000	
Elongation, percent	in 2 inches	in 1 inch
Bars (in 4D, round) and forgings	6.0	6.0
Transverse tensile properties	Type I, class 1 and 2	
Tensile ultimate strength, lbf/in <sup>2</sup> , minimum	250,000	
Tensile yield strength, lbf/in <sup>2</sup> , weight not less than 0.2 percent offset	240,000	
Elongation, percent, minimum	in 2 inches	in 1 inch
Sizes over 3 inches, including	5.0	5.0

3.3.1.3 Hardness of maraged steel. The hardness of maraged steel shall not be less than Rockwell C-51 or equivalent for type I material. Hardness shall not be a basis for rejection if tensile properties are met (see 4.6.9.2).

3.4 Workmanship. The bar, forgings, and stock for forging shall be uniform in quality and conditions, smooth, and free from defects, such as : porosity, slivers, scabs, rolled-in scale, fissures, gas cavities, sponginess, segregations, and nonmetallic inclusions which, due to their nature, degree, or extent, will adversely affect the suitability of the parts for service intended (see 4.6.10).

#### 4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for inspection. Unless otherwise specified in the contract or purchase order, the contractor is responsible for the performance of all inspection requirements (examinations and tests) as specified herein. Except as otherwise specified in the contract or purchase order, the contractor may use his own or any other facilities suitable for the performance of the inspection requirements specified herein, unless disapproved by the Government. The Government reserves the right to perform any of the inspections set forth in this specification where such inspections are deemed necessary to ensure supplies and services conform to prescribed requirements.

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

- a. First article inspection (see 4.4)
- b. Quality conformance inspection (see 4.5).

4.3 Inspection conditions. Unless otherwise specified herein, the following conditions shall be used:

- a. Temperature                      Facility ambient 16° to 90°C
- b. Altitude                              Facility ground
- c. Humidity                              Facility ambient up to 95 percent relative humidity

4.4 First article inspection. First article inspection shall consist of the examination and tests specified in 4.4.1. Quantity production shall be withheld until the first article sample has been pronounced satisfactory upon Government approval (see 3.1 and 6.2).

4.4.1 First article sample. The contractor shall submit a first article sample for inspection as specified. The first article sample shall consist of 6 feet of bar material, or not less than 6 sample forgings manufactured under the same conditions as those proposed for subsequent production and shall be representative of the production product. The first article sample shall be subjected to the inspection and tests specified in table IV, with the sequence of inspection at the option of the supplier.



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TABLE IV. First article inspection.

Inspection	Requirement paragraph	Test paragraph
Manufacture and condition	3.2.1	4.6.1
Macrograph quality	3.2.5.1	4.6.5
Inclusion content	3.2.5.2	4.6.6
Grain size	3.2.6	4.6.7
Tensile properties	3.3.1.1	4.6.9.1
Stock for forging	3.3.1.2	4.6.9.1
Hardness of maraged steel	3.3.1.3	4.6.9.2

4.5 Quality conformance inspection. The quality conformance inspection shall be conducted on a random sample selected from each inspection lot or less, in accordance with the sampling plan, table V.

TABLE V. Sampling plan.

Lot Size	Sample Size
2 to 3	All
4 to 25	3
26 to 50	5
51 to 90	6
91 to 150	7
151 to 280	10
281 to 500	11
501 to 1200	15
1201 to 3200	18
3201 to 10,000	22
10,001 and over	29
In all cases: Acceptance number is ZERO Rejection number is ONE	

4.5.1 Lot formation. The formation of a lot is a collection of the manufactured material from which a representative sample is drawn and inspected to determine conformance of the lot with applicable requirements. A lot shall consist of all the material manufactured in one continuous operation by the same process, by the same manufacturer in accordance with this specification and submitted at one time.

4.5.2 Examination. The steel bars shall be examined for compliance with 3.2 and 3.4. Unless otherwise specified, examinations for defects shall require the sample lot to be defect free. Inspection of the sample specified in 4.5 shall be in accordance with table VI, with the sequence of inspection at the option of the supplier.

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TABLE VI. Quality conformance inspection.

Inspection	Requirement paragraph	Test paragraph
Tolerances	3.2.2	4.6.2
Identification	3.2.3	4.6.3
Chemical composition	3.2.4	4.6.4
Hardness of annealed steel	3.2.7	4.6.8
Hardness of maraged steel	3.3.1.3	4.6.9.2
Workmanship	3.4	4.6.10

4.6 Methods of inspection.

4.6.1 Manufacture and condition. Manufacture and condition shall be certified by the supplier to establish compliance with 3.2.1.

4.6.2 Tolerances. Tolerances shall be examined visually to establish compliance with 3.2.2.

4.6.3 Identification. Identification of the bars and forgings shall be accomplished visually to establish compliance with 3.2.3.

4.6.4 Chemical composition. Determination of the chemical composition of the steel shall be performed in accordance with the sample selection defined in Method 111.1 or 112.1 of FED-STD-151. The steel shall meet the requirements of 3.2.4 and table I.

4.6.5 Macrograph quality. Macrograph quality shall be performed in accordance with ASTM E 381 and shall conform to 3.2.5.1.

4.6.6 Inclusion content. Inclusion content shall be determined in accordance with Method A of ASTM E 45, on the top and bottom of the first, middle, and last ingot of the heat or melt and each specimen shall conform to table II (see 3.2.5.2).

4.6.7 Grain size. One or more specimens from the beginning and end of each lot or heat shall be sectioned and polished to appropriate fineness by metallographic methods and suitably etched to reveal the grain structure. The grain size shall be determined in accordance with ASTM E 112 and shall conform to 3.2.6.

4.6.8 Hardness of annealed steel. Hardness of annealed steel shall be determined in accordance with ASTM E 10, ASTM E 18 and ASTM E 92. Conversions to Rockwell C shall be in accordance with Method E18 of ASTM E 140. The steel shall meet the hardness requirements of 3.2.7.

4.6.9 Response of heat treatment.

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4.6.9.1 Tensile properties. Unless otherwise specified in the contract or purchase order, three specimens shall be selected at random from the steel that has been maraged as specified in 3.3.1. Tensile properties shall be determined in accordance with ASTM E 8 parallel to the primary working direction of the material. The results shall conform to 3.3.1.1 and table III.

4.6.9.2 Hardness of maraged steel. Unless otherwise specified in the contract or purchase order, three specimens shall be selected at random from the steel that has been maraged as specified in 3.3.1. The hardness shall be determined in accordance with ASTM E 10, ASTM E 18 and ASTM E 92. Conversions to Rockwell C from other scales shall be in accordance with Method E18 of ASTM E 140. The steel shall meet the hardness requirements of 3.3.1.3.

4.6.10 Workmanship. The maraging steel shall be visually examined to assure conformance to the workmanship requirements specified in 3.4.

4.6.11 Inspection of packaging. Preservation, packing, marking and preparation for delivery shall be in accordance with the requirements of section 5.

## 5. PACKAGING

### 5.1 Preservation and utilization of packing Level A, B or C (see 6.2).

5.1.1 Level A or B. Preservation and packing shall be in accordance with MIL-STD-163.

5.1.2 Level C. Preservation and packing shall be in accordance with MIL-STD-1190.

5.2 Marking. Marking shall be in accordance with MIL-STD-129. The marking shall include, but not be limited to the following:

- a. Steel bar, forgings and stock for forging (as applicable), 18 percent nickel (FREE-C0250)
- b. Part number
- c. Heat or lot number
- d. Physical and surface condition
- e. Size
- f. Quantity container (as defined in the contract).

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- g. Name of manufacturer
- h. Contract or purchase order number.

## 6. NOTES

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

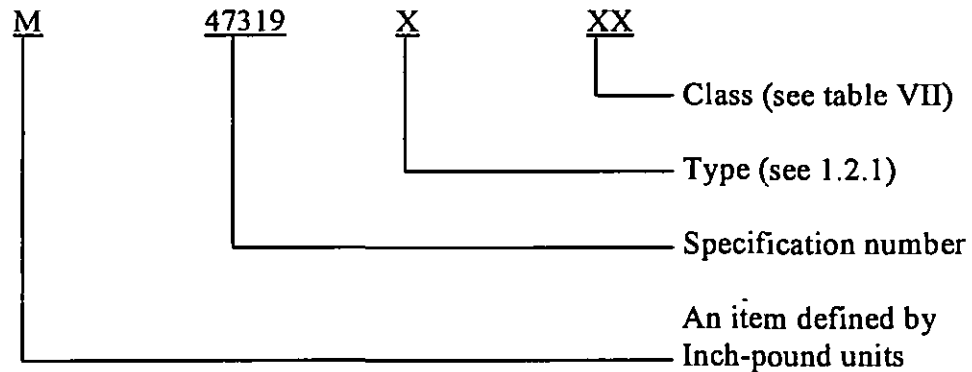
6.1 Intended use. Steel conforming to this specification is intended for high performance applications which require a high strength level with good fracture toughness.

6.2 Acquisition requirements. Acquisition documents should specify the following:

- a. Title, number, and date of the specification
- b. Issue of DODISS to be cited in the solicitation, and if required, the specific issue of individual documents referenced (see 2.1.1)
- c. Whether first article is required (see 3.1)
- d. Requirements for certification of manufacture (see 4.6.1)
- e. Size and thickness of bar, billet and forging
- f. Material condition required if different (see 3.2.1.2)
- g. Applicable level of preservation and packing required (section 5).
- h. Level of identification and marking required (see 3.2.3 and 5.3).

6.3 First article. When first article inspection is required, the contracting officer should provide specific guidance to offerers whether the item(s) should be a first article sample, a first production item, or a number of items to be tested as specified in 4.3. The contracting officer should include specific instructions in acquisition documents regarding arrangements for examination, approval of first article test results and disposition of first articles. Invitations for bids should provide that the government reserves the right to waive the requirement for samples for first article inspection to those bidders offering a product which has been previously acquired or tested by the Government, and that bidders offering such products, who wish to rely on such production or test, must furnish evidence with the bid that prior Government approval is presently appropriate for the pending contract.

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6.4 Part or identifying number.TABLE VII. Class identification.

Class	Class identification number
1	01
2	02

6.5 Metrication. Metric equivalents in accordance with FED-STD-376 are acceptable for use in this specification.

6.6 Subject term (keyword) listing.

Annealed metals  
 Casting ingots  
 Metal alloys  
 Metal strips, compressed

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

Custodian:  
 Army - MI

Preparing Activity:  
 Army - MI

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