

INCH - POUND

MIL-S-46850D

22 March 1991

SUPERSEDING

MIL-S-46850C (MI)

30 September 1986

MILITARY SPECIFICATION

STEEL: BAR, PLATE, SHEET, STRIP, FORGINGS, AND
EXTRUSIONS, 18 PERCENT NICKEL ALLOY, MARAGING,
200 KSI, 250 KSI, 300 KSI, AND 350 KSI, HIGH QUALITY

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

1. SCOPE

1.1 Scope. This specification covers steel bars, plate, sheet, strip, forgings and extrusions 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 steels covered in this specification are classified by type and grade as follows (see 3.1 and 6.2).

Type

- | | | |
|---------|---|---|
| Type I | - | Air arc melted (AM) steel. This steel shall be produced by basic air melting. |
| Type II | - | Vacuum degassed (VD) steel. This steel shall be produced by the vacuum degassing process. |

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

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- Type III - Vacuum arc remelt (VAR) steel. This steel shall be produced by multiple melting using the vacuum consumable electrode process in the final remelt cycle.
- Type IV - Vacuum induction melt, vacuum arc remelt (VIM/VAR). This steel shall be produced by multiple melting using the vacuum induction melt to make the vacuum arc consumable electrode for the final remelt cycle.

The specific grades of mill product covered by this specification are as follows:

Grade

200	-200 ksi nominal tensile strength
250	-250 ksi nominal tensile strength
300	-300 ksi nominal tensile strength
300A	-300 ksi nominal tensile strength
350	-350 ksi nominal tensile strength

NOTE: ksi = 1000 pounds per square inch

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

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MIL-STD-414 - Sampling Procedures and Tables for
Inspection by Variables for Percent
Defective

(Unless otherwise indicated, copies of the federal and military specifications, standards, and handbooks are available from the Naval Publications and Forms Center, 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).

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

ASTM A 700	-	Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment, Standard Practices for
ASTM E 8	-	Tension Testing of Metallic Materials (Metric), Standard Test Methods for
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 23	-	Notched Bar Impact Testing 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 Test Methods for
ASTM E 112	-	Determining 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
ASTM E 399	-	Plane-Strain Fracture Toughness of Metallic Materials, Standard Test Method of

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

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AEROSPACE MATERIAL SPECIFICATIONS (AMS)

AMS 2300	-	Premium Aircraft - Quality Steel Cleanliness - Magnetic Particle Inspection Procedure
AMS 2310	-	Qualification Sampling of Steels, Transverse Tensile Properties
AMS 2808	-	Identification, Forgings

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

(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.)

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 Material (see 1.2). Mill products shall be manufactured by the air arc melted (AM) process, vacuum degassed (VD) process, vacuum arc remelt (VAR) process, or the Vacuum Induction Melt, Vacuum Arc Remelt (VIM/VAR) process as specified. Sufficient discard shall be taken from each ingot to insure freedom from piping and undue segregation.

3.2 Material conditions. Unless otherwise specified, the material shall be furnished in the solution-annealed (A), descaled, and oiled condition. Solution annealing shall be accomplished by heating at $816 \pm 5^{\circ}\text{C}$ for 1 hour per inch of thickness, followed by air cooling to room temperature (see 6.4). If required (see 6.2), the surface condition shall be (1) as forged or rolled, (2) pickled, (3) ground or blast cleaned, (4) cold finished or (5) ground and polished.

3.3 Chemical composition.

3.3.1 Chemical composition (percent by weight). The chemical composition of bar, plate, sheet, strip, forgings and extrusions shall be as specified in table I. Individual determinations may vary from the specified range to the extent shown in the product analysis column except that the elements in any melt shall not vary above and below the specified range.

3.3.2 Melt analysis. The contractor shall furnish an analysis of the melt of each lot showing the percentage of each of the elements designated in table I.

TABLE I. Chemical composition (percent by weight).

Element	All Types Grade 200	All Types Grade 250	All Types Grades 300 & 300A	All Types Grade 350	Product Analysis Permissible Variation All Grades and Types
Nickel	17.0 - 19.0	17.0 - 19.0	18.0 - 19.0	18.0 - 19.0	+0.15
Cobalt	8.0 - 9.0	7.0 - 8.5	8.5 - 9.5	11.5 - 12.5	+0.10
Molybdenum	3.0 - 3.5	4.6 - 5.2	4.6 - 5.2	4.6 - 5.2	+0.10
Titanium	0.15 - 0.25	0.3 - 0.5	0.5 - 0.8	1.3 - 1.6	+0.05
Aluminum	0.05 - 0.15	0.05 - 0.15	0.05 - 0.15	0.05 - 0.15	+0.03
Carbon	0.03 Maximum	0.03 Maximum	0.03 Maximum	0.03 Maximum	+0.005
Manganese	0.10 Maximum	0.10 Maximum	0.10 Maximum	0.10 Maximum	+0.03
Silicon	0.10 Maximum	0.10 Maximum	0.10 Maximum	0.10 Maximum	+0.02
Phosphorus	0.01 Maximum	0.01 Maximum	0.01 Maximum	0.01 Maximum	+0.002
Sulfur	0.01 Maximum	0.01 Maximum	0.01 Maximum	0.01 Maximum	+0.002
Residual Elements	-	-	-	-	
Iron	Balance	Balance	Balance	Balance	
Selectable allowable maximum additions					
Boron	0.003	0.003	0.003	0.003	Certified as Additions Only
Zirconium	0.020	0.020	0.020	0.020	
Calcium	0.050	0.050	0.050	0.050	

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3.4 Hardness of annealed steel. The hardness of solution-annealed steel shall not be higher than Rockwell C32 or equivalent for grade 200, Rockwell C34 or equivalent for grade 250, Rockwell C36 or equivalent for grade 300 and 300A, or Rockwell C38 or equivalent for grade 350 material.

3.5 Response to heat treatment. Grades 200, 250, 300, and 300A, when received in the solution annealed condition, shall conform to the following requirements for mechanical properties after aging for 3 to 6 hours \pm 10 minutes at $482 \pm 5^\circ\text{C}$ followed by air cooling to room temperature (see 6.4). Grade 350, when received in the solution annealed condition, shall conform to the following mechanical properties after aging at $510 \pm 5^\circ\text{C}$ for 3 to 6 hours \pm 10 minutes followed by air cooling to room temperature (see 6.4).

3.5.1 Mechanical properties. Except for fracture toughness properties and impact (see 3.5.3), the mechanical properties of maraged bar, plate, forgings and extrusion products shall conform to table II. Except for fracture toughness properties and impact (see 3.5.3), the mechanical properties of maraged sheet and strip products shall conform to table III.

TABLE II. Longitudinal mechanical properties of bar, plate, forgings and extrusions. 1/

Mechanical Properties Types I, II, III, and IV	Grade 200	Grade 250	*Grade 300 ^{2/}	*Grade 300A ^{2/}	Grade 350
Tensile Yield Strength (ksi) at not less than 0.2 percent offset, minimum	200	240	280		330
Tensile Ultimate Strength (ksi) minimum				287 ^{3/}	
Elongation, in 2 inches, minimum percent Bars, Forgings	8.0	6.0	5.0	5.0 ^{4/}	2.8
Plate (over 0.380" thick), Extrusions	5.5	4.0	3.5	-	2.0
Toughness, Charpy V-notch Impact Energy, (Foot-Pounds) ^{5/} minimum	26	15	12	12	6

1/ Tensile Bars shall be taken parallel to the primary working direction of the material.

*2/ Critical stress intensity factor $K_{IC} = 60$ ksi-in not less than 0.5. The procuring activity is warned that nondestructive test procedures may have to be modified to insure routine detection of flaws which would be critical in application of this steel at stress levels above 200 ksi.

3/ Required in both the longitudinal and long transverse directions.

4/ Elongation in long transverse direction to be not less than 4.0 percent.

5/ Impact strength requirements pertain to the steel supplier's mill lot material.

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TABLE III. Longitudinal mechanical properties of sheet and strip products. 1/

Mechanical Properties Types I, II, III, and IV	Grade 200	Grade 250	Grade 300	Grade 350
Tensile yield strength (ksi) at not less than 0.2 percent offset	200	240	280	330
Elongation, in 2 inches, minimum percent Under 0.100" nominal thickness	4.0	3.0	2.0	1.0
0.100" to 0.380" thickness	5.0	4.0	3.0	1.8

1/ Tensile bars shall be taken parallel to the primary working direction of the material.

3.5.2 Hardness of maraged steel. The hardness of material maraged in accordance with 3.5 shall not be lower than Rockwell C42 or equivalent for Grade 200 material, Rockwell C48 or equivalent for Grade 250 material, Rockwell C52 or equivalent for Grade 300 and 300A material, or Rockwell C56 or equivalent for Grade 350 material. Failure to meet the hardness requirement shall be cause for rejection.

3.5.3 Fracture toughness. The plane strain fracture parameter (K_{IC}) shall be determined from each steel supplier's mill lot of material which has been heat treated in accordance with paragraph 3.5. The fracture toughness parameter requirements shall be not less than the following:

<u>GRADE</u>	K_{IC} (ksi - in 1/2)
200	100
250	75
300 & 300A	60
350	25

3.5.4 Transverse mechanical properties. If required (see 6.2), and mill products are of sufficient size to allow long transverse properties determination, measurements shall be made in accordance with ASTM E 8 and with the requirements of AMS 2310 for premium quality steels. These long transverse mechanical properties shall be not less than 90 percent of those specified in tables II and III. Long transverse is the direction which is perpendicular to both the longitudinal (the direction of maximum extension during rolling) and the short transverse (the direction of maximum contraction during rolling) directions.

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3.6 Grain size.

3.6.1 Grade 200 material (Types I, II, III and IV). In accordance with the applicable ASTM E 112 chart, the grain size shall be predominantly five or finer with grains as large as three permissible provided all are not found in a continuous band or localized area within the material.

3.6.2 Grade 250 material (Type I, II, III and IV). The grain size of sheet material shall be predominantly six or finer with grains as large as four permissible in accordance with the applicable ASTM E 112 chart. The grain size of plate material up to 0.625 inches in thickness shall be predominantly five or finer with occasional grains as large as three permissible. The grain size of plate material over 0.625 inches thick and all bar material shall be subjected to negotiation with the manufacturer.

3.6.3 Grade 300 and 300A material (Type I, II, III and IV). The grain size of this material for all sizes shall be predominantly six or finer with grains as large as four permissible in accordance with the applicable ASTM E 112 chart.

3.6.4 Grade 350 material (Type I, II, III and IV). The grain size of this material for all sizes shall be predominantly six or finer with grains as large as four permissible in accordance with the applicable ASTM E 112 chart.

3.7 Macrograph standards. If required (see 6.2), the macrograph standard of bars, plates, billets and slabs made from type I and II material shall be equal to or better than S2, R2 and C2 of ASTM E 381.

3.8 Inclusion content. The size and frequency of inclusions in type I, II, III and IV material shall not exceed the Jernkontoret limits specified in tables IV, V, VI and VII for grades 200, 250, 300, 300A and 350 respectively.

TABLE IV. Inclusion rating of grade 200 material.

Type	A	B	C	D	E*
Thin Series	2.0	2.5	2.0	2.5	3.5
Thick Series	1.5	1.5	1.5	2.0	2.5

* Type E are titanium nitrides and shall be rated by the same method as Type B.

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TABLE V. Inclusion rating of grade 250 material.

Type	A	B	C	D	E*
Thin Series	2.0	2.0	1.5	2.5	3.0
Thick Series	1.5	1.5	1.0	2.0	2.0

* Type E are titanium nitrides and shall be rated by the same method as Type B.

TABLE VI. Inclusion rating of grade 300 and 300A material.

Type	A	B	C	D	E*
Thin Series	1.5	1.5	1.5	2.5	3.0
Thick Series	1.0	1.0	1.0	1.5	1.5

* Type E are titanium nitrides and shall be rated by the same method as Type B.

TABLE VII. Inclusion rating of grade 350 material.

Type	A	B	C	D	E*
Thin Series	1.5	1.5	1.5	2.5	3.0
Thick Series	1.0	1.0	1.0	1.5	1.5

* Type E are titanium nitrides and shall be rated by the same method as Type B.

3.9 Tolerances. Tolerances shall conform to the applicable limits of FED-STD-48.

3.10 Identification. Each bar, plate, sheet, strip, or extrusion shall be identified in accordance with FED-STD-183. The marking shall include the heat number, composition designation, physical condition and this specification designation. Each forging shall be identified by ink marking in accordance with AMS 2808.

3.11 Workmanship. The bar, plate, sheet, strip, forging or extrusion shall be uniform in quality and condition, smooth, and free from defects, such as pits, laps, cracks, flakes, twists, seams, heat checks, slag, hard spots, porosity, slivers, scabs, rolled-in scale, fissures, gas cavities, sponginess,

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segregations, and non-metallic inclusions which, due to their nature, degree or extent will adversely affect the suitability of the parts for the service intended.

3.12 Cleanliness. Each lot of material intended for aerospace application shall be inspected in accordance with AMS 2300.

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.

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 Quality conformance inspection. Quality conformance inspections shall be as specified in table VIII.

4.3 Lot size. A lot shall consist of all material processed in the same manner to the same end product from the same heat or melt and offered for delivery at one time. A mill lot will consist of material of intermediate size from the original steel billet from which test samples can be removed for valid Charpy V-notch impact testing in accordance with ASTM E 23, and K_{IC} fracture toughness testing.

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TABLE VIII. Quality conformance inspection.

Inspection	Requirement paragraph	Test paragraph
Hardness	3.4	4.4.2
Mechanical properties	3.5.1, 3.5.2, 3.5.3, 3.5.4	4.4.3, 4.4.3.1
Fracture toughness	3.5.3	4.5.4
Critical stress intensity factor	3.5.1	4.5.4.1
Grain size	3.6	4.5.5
Macrograph test standards	3.7	4.5.6
Inclusion content	3.8	4.5.7

4.4 Testing. All tests required for testing the steel are classified as acceptance tests for which necessary sampling techniques and methods of testing are specified herein.

4.4.1 Chemical composition. Unless otherwise specified in the contract or order (see 6.2), three samples shall be taken at random from each lot for analysis of chemical composition. The sample shall represent the material from the top, center, and bottom portion of an ingot. Testing shall be in accordance with 4.5.1.

4.4.2 Hardness of as-received material. Unless otherwise specified in the contract or order (see 6.2), four samples shall be selected at random for testing. The hardness of the as-received-solution-annealed material shall be uniform through the lot and conform to requirements of 3.4. Testing shall be in accordance with 4.5.2.

4.4.3 Response to heat treatment (mechanical properties, hardness, and fracture toughness of maraged material). Unless otherwise specified in the contract or order (see 6.2), three samples shall be selected from each lot of steel that has been maraged and tested for the mechanical properties specified in tables II and III. The response to heat treatment shall be uniform throughout the lot and shall conform to the requirements of paragraph 3.5.1 through 3.5.4 inclusive, when tested in accordance with 4.5.2 for hardness, 4.5.3 for mechanical properties and 4.5.4 for fracture toughness.

4.4.3.1 Response to heat treatment, (tensile strength, elongation for type IV grade 300A only). Response to heat treatment shall be determined on samples which have been heat treated from material in the "as delivered" condition. Samples shall be randomly selected in accordance with MIL-STD-414, level IV. The response to heat treatment shall be uniform throughout the lot (lot size shall be equal to the number of bars) and shall conform to the requirements of 3.5.1 through 3.5.4 when tested in accordance with 4.5.2 through 4.5.4.

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4.4.4 Grain size. One or more samples shall be selected to represent each heat of steel from which material is submitted for delivery.

4.4.5 Macrograph testing. Three or more samples shall be selected from the lot. Specimens shall be cut from the ends of the samples and shall represent the full cross section of the bar, billet, slab, or forging. Testing shall be in accordance with 4.5.6. Type III material is not subject to macrograph inspection.

4.4.6 Inclusion content. Unless otherwise specified in the contract or order (see 6.2), samples for inclusion content shall be obtained from top and bottom of the first, middle, and last ingot. The samples shall be taken from a reroll slab product.

4.5 Test methods.

4.5.1 Chemical analysis. The analysis of the chemical composition shall be in accordance with Method 111 or 112 of FED-STD-151. The chemical composition shall be as specified in Table I. In case of dispute, the analysis by Method 111 shall be the basis for acceptance or rejection.

4.5.2 Hardness tests. Hardness tests shall be performed in accordance with ASTM E 10, ASTM E 18, or ASTM E 92. Conversion to Rockwell C from other scales shall be in accordance with ASTM E 140, but ASTM E 140 shall not be used for determining equivalent tensile strength.

4.5.3 Mechanical properties (after heat treatment). Testing for mechanical property requirements of Tables II and III, fracture toughness excepted, shall be in accordance with ASTM E 8. These mechanical properties shall meet the requirements of 3.5.1, 3.5.2 and 3.5.4.

4.5.4 Fracture toughness. Fracture toughness tests shall be performed in accordance with ASTM E 399. Fracture toughness properties shall meet the requirements of 3.5.3.

4.5.4.1 Critical stress intensity factor. Samples of maraging steel for determining critical stress intensity factor shall be determined in accordance with ASTM E 399 and shall meet the requirements of 3.5.1.

4.5.5 Determination of grain size. Specimens shall be sectioned and polished to appropriate fineness by metallographic methods and suitably etched to reveal grain structure. The grain size shall be determined using the method for austenitic steels (A3.2.2 of ASTM E 112). The grain size shall meet the requirements of 3.6.

4.5.6 Macrograph test methods. Macrograph quality shall be determined in accordance with ASTM E 381 and shall meet the requirements of 3.7.

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4.5.7 Determination of inclusion content. Inclusion content shall be determined in accordance with ASTM E 45 and shall meet the requirements of 3.8.

4.5.8 Examination of product. All material shall be inspected to assure compliance with surface condition, identification, tolerance, and workmanship as specified in 3.9 thru 3.11 of this specification.

4.6 Inspection of packaging. The sampling and inspection of packaging shall be in accordance with the requirements of MIL-STD-163, MIL-STD-129, and ASTM A 700 (see 5.1 and 5.1.1).

5. PACKAGING

5.1 Packaging requirements. The requirement for packaging shall be in accordance with MIL-STD-163, Level A or commercial.

5.1.1 Marking. Level A and C marking shall be in accordance with MIL-STD-129. Industrial marking shall be in accordance with ASTM A 700.

6. NOTES

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

6.1 Intended use. Material conforming to this specification is intended to be used for steel parts requiring high strength levels, such as rocket motors, structural components for aircraft, aerospace structural applications and high strength fasteners.

6.2 Acquisition requirements. Acquisition documents must 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. Grade and type of material (see 1.2)
- d. Physical and surface conditions if different from the surface condition specified (see 3.2)
- e. Size, thickness and quantity of bar, plate, sheet, strip, forgings or extrusions to be furnished
- f. Whether or not long transverse mechanical properties determination is required (see 3.5.4)

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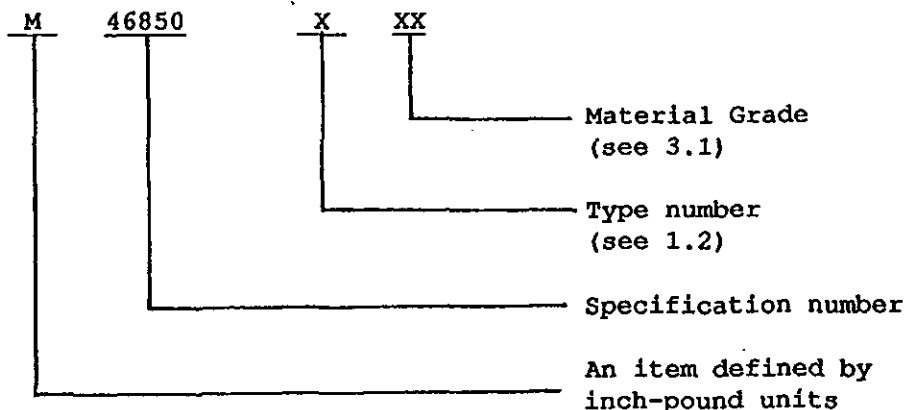
- g. Whether or not macrograph standards are required (see 3.7)
- h. Number of samples required for testing, if different from the number specified in 4.4.1 through 4.4.6
- i. Conditions for quality conformance (see 4.2)
- j. Applicable level of packaging and marking (see 5.1 and 5.1.1).

6.3 Physical and mechanical properties information. Information on the physical and mechanical properties of grades 200, 250, 300 and 300A steels conforming to this specification is available under Code 1220, 1223, and 1225 of the Aerospace Structures Metals Handbook.

6.4 Waiver statement. Other annealing or aging treatments can be negotiated with the Government provided an improvement in both the mechanical properties and fracture toughness can be documented.

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

6.6 Part or identification number (PIN).



6.7 Subject term (keyword) listing.

Mill products
Annealed metals
Metal alloys
Fracture toughness

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 extensiveness of the changes.

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Custodians:

Army - MI
Navy - AS

Preparing Activity:

Army - MI

Project No. 9515-0836

Review Activities:

Army - MR, AR
DLA-IS

User Activity:

Navy - OS