SAE The Engineering Resource For Advancing Mobility®

400 Commonwealth Dr., Warrendale, PA 15096

AEROSPACE MATERIAL SPECIFICATION

Submitted for recognition as an American National Standard

SAE AMS 6543A

Issued 9-15-75
Revised 1-1-86

Superseding AMS 6543

STEEL BARS AND FORGINGS, MARAGING
2.0Cr - 10Ni - 8.0Co - 1.0Mo (0.10 - 0.14C)
Double Vacuum Melted, Solution Heat Treated

1. SCOPE:

1.1 Form: This specification covers a premium aircraft-quality maraging steel in the form of bars 0.50 in. (12.5 mm) and over in nominal diameter or distance between parallel sides, forgings, and forging stock.

1.2 Application: Primarily for heat treated parts requiring a combination of high strength, toughness, and weldability.

2. APPLICABLE DOCUMENTS: The following publications form a part of this specification to the extent specified herein. The latest issue of Aerospace Material Specifications and Aerospace Standards shall apply. The applicable issue of other documents shall be as specified in AMS 2350.

2.1 SAE Publications: Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096.

2.1.1 Aerospace Material Specifications:

AMS 2248 - Chemical Check Analysis Limits, Wrought Corrosion and Heat Resistant Steels and Alloys, Maraging and Other Highly-Alloyed Steels, and Iron Alloys
AMS 2251 - Tolerances, Low-Alloy Steel Bars
MAM 2251 - Tolerances, Metric, Low-Alloy Steel Bars
AMS 2350 - Standards and Test Methods
AMS 2370 - Quality Assurance Sampling of Carbon and Low-Alloy Steels, Wrought Products Except Forgings and Forging Stock
AMS 2372 - Quality Assurance Sampling of Carbon and Low-Alloy Steels, Forgings and Forging Stock
AMS 2375 - Approval and Control of Critical Forgings
AMS 2630 - Ultrasonic Inspection, Product Over 0.5 In. (12.5 mm) Thick

2.1.1 (Continued):

AMS 2806 - Identification, Bars, Forgings, Mechanical Tubing, and Extrusions, Carbon and Alloy Steels and Heat and Corrosion Resistant Steels and Alloys
AMS 2808 - Identification, Forgings

2.1.2 Aerospace Standards:

AS 1182 - Standard Machining Allowance, Aircraft Quality and Premium Quality Steel Products

2.2 ASTM Publications: Available from American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM A370 - Mechanical Testing of Steel Products
ASTM A604 - Macroetch Testing of Consumable Electrode Remelted Steel Bars and Billets
ASTM E353 - Chemical Analysis of Stainless, Heat-Resisting, Maraging, and Other Similar Chromium-Nickel-Iron Alloys

2.3 U.S. Government Publications: Available from Commanding Officer, Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, PA 19120.

2.3.1 Military Specifications:

MIL-H-6875 - Heat Treatment of Steel, Process for

2.3.2 Military Standards:

MIL-STD-163 - Steel Mill Products, Preparation for Shipment and Storage

3. TECHNICAL REQUIREMENTS:

3.1 Composition: Shall conform to the following percentages by weight, Ø determined by wet chemical methods in accordance with ASTM E353 or by spectrographic or other analytical methods approved by purchaser:

	min	max
Carbon	0.10 -	0.14
Manganese	0.05 -	0.25
Silicon	--	0.10
Phosphorus	--	0.010
Sulfur	--	0.006
Chromium	1.80 -	2.20
Nickel	9.50 -	10.50
Cobalt	7.50 -	8.50
Molybdenum	0.90 -	1.10
Titanium	--	0.04
Aluminum	--	0.025
Oxygen	--	0.0025 (25 ppm)
Nitrogen	--	0.0075 (75 ppm)

3.1.1 Check Analysis: Composition variations shall meet the applicable requirements of AMS 2248. No variation is permitted for oxygen and nitrogen.

3.2 Condition: The product shall be supplied in the following condition; hardness shall be determined in accordance with ASTM A370:

3.2.1 Bars and Forgings: Hot finished, solution heat treated, and descaled, having hardness not lower than 42 HRC, or equivalent.

3.2.2 Forging Stock: As ordered by the forging manufacturer.

3.3 Heat Treatment: Bars and forgings shall be solution heat treated as in Ø 3.3.1 or 3.3.2, as applicable, holding at heat for sufficient time to ensure complete transformation, and quenching in agitated water sufficiently cool (See 8.2) to develop the mechanical properties specified herein. Furnace surveys and calibration of temperature controllers and recorders shall be in accordance with MIL-H-6875.

3.3.1 Product 2.0 In. (50 mm) and Under in Nominal Section Thickness: Shall be solution heat treated by heating in air to 1525°F ± 25 (830°C ± 15) and quenching.

3.3.2 Product Over 2.0 In. (50 mm) in Nominal Section Thickness: Shall be solution heat treated by heating in air to 1650°F ± 25 (900°C ± 15), quenching, reheating to 1525°F ±25 (830°C ± 15), and quenching.

3.4 Properties: The product shall conform to the following requirements; tensile and impact testing shall be performed in accordance with ASTM A370:

3.4.1 Bars and Forgings:

3.4.1.1 As Solution Heat Treated:

3.4.1.1.1 Macrostructure: Visual examination of transverse sections from bars, forgings, and forging stock, etched in accordance with ASTM A604 in hot hydrochloric acid (1:1) at 160° - 180°F (70° - 80°C) for Ø sufficient time to develop a well-defined macrostructure, shall show no pipe or cracks. Porosity, segregation, inclusions, and other imperfections for product 36 sq in. (230 cm^2) and under in nominal cross-sectional area shall be no worse than the following macrographs of ASTM A604; macrostructure standards for product over 36 sq in. (230 cm^2) in nominal cross-sectional area shall be as agreed upon by purchaser and vendor.

Class	Condition	Severity
1	Freckles	A
2	White Spots	A
3	Radial Segregation	B
4	Ring Pattern	B

3.4.1.2 After Maraging: Bars and forgings shall meet the requirements of 3.4.1.2.1, 3.4.1.2.2, and 3.4.1.2.3 after being aged by heating to 900° - 950°F (480° - 510°C), holding at the selected temperature within ±10°F (±5°C) for not less than 5 hr, and cooling in air.

3.4.1.2.1 Tensile Properties: Shall be as shown in Table I and 3.4.1.2.1.1.

TABLE I

Nominal Diameter or Distance Between Parallel Sides Inches	Tensile Strength psi, min	Yield Strength at 0.2% Offset psi, min	Elongation in 4D %, min	Reduction of Area %, min
0.500 to 2.000, incl	190,000	180,000	12	60
Over 2.000 to 4.000, incl	190,000	175,000	12	60
Over 4.000 to 8.000, incl	190,000	170,000	10	50

TABLE I (SI)

Nominal Diameter or Distance Between Parallel Sides Millimetres	Tensile Strength MPa, min	Yield Strength at 0.2% Offset MPa, min	Elongation in 4D %, min	Reduction of Area %, min
12.50 to 50.00, incl	1310	1240	12	60
Over 50.00 to 100.00, incl	1310	1205	12	60
Over 100.00 to 200.00, incl	1310	1170	10	50

3.4.1.2.1.1 Ø Tensile property requirements for product over 8.000 in. (200.00 mm) in nominal diameter or distance between parallel sides shall be as agreed upon by purchaser and vendor.

3.4.1.2.2 Impact Strength: Shall be as shown in Table II and 3.4.1.2.2.1.

TABLE II

Nominal Diameter or Distance Between Parallel Sides Inches	Charpy V-Notch at 0°F ft-lb
0.500 to 2.000, incl	60
Over 2.000 to 4.000, incl	50
Over 4.000 to 8.000, incl	40

3.4.1.2.2 (Continued):

TABLE II (SI)

Nominal Diameter or Distance Between Parallel Sides Millimetres	Charpy V-Notch at 0°F N·m
12.50 to 50.00, incl	81
Over 50.00 to 100.00, incl	68
Over 100.00 to 200.00, incl	54

3.4.1.2.2.1 Impact strength for product over 8.00 in. (200.0 mm) in nominal diameter or distance between parallel sides shall be as agreed upon by purchaser and vendor.

3.4.1.2.3 Fracture Toughness: Shall be as agreed upon by purchaser and vendor.
Ø

3.4.2 Forging Stock: When a sample of stock is forged to a test coupon and heat treated as in 3.3 and 3.4.1.2, specimens taken from the heat treated coupon shall conform to the requirements of 3.4.1.2.1 and 3.4.1.2.2. If specimens taken from the stock after heat treatment as in 3.3 and 3.4.1.2 conform to the requirements of 3.4.1.2.1 and 3.4.1.2.2, the tests shall be accepted as equivalent to tests of a forged coupon.

3.5 Quality:

3.5.1 Steel shall be multiple melted using vacuum induction melting plus vacuum consumable electrode remelting.

3.5.2 The product, as received by purchaser, shall be uniform in quality and
Ø condition, sound, and free from foreign materials and from imperfections detrimental to usage of the product.

3.5.2.1 Bars ordered ground, turned, or polished shall be free from seams, laps, tears, and cracks open to the ground, turned, or polished surfaces.

3.5.2.2 Product ordered to surface conditions other than ground, turned, or polished shall, after removal of the standard machining allowance, be free from seams, laps, tears, cracks, and other imperfections exposed to the machined surfaces. Standard machining allowance shall be in accordance with AS 1182.

3.5.3 All product shall be inspected ultrasonically in accordance with AMS 2630
Ø and shall meet Class AA quality requirements as defined therein. Hot-finished surfaces shall be suitably prepared prior to ultrasonic inspection.

3.5.4 Grain flow of die forgings, except in areas which contain end grain, shall follow the general contour of the forgings, showing no evidence of re-entrant flow.

3.6 Sizes: Except when exact lengths or multiples of exact lengths are ordered straight, bars will be acceptable in mill lengths of 6 - 20 ft (2 - 6 m) but not more than 10% of any shipment shall be supplied in lengths shorter than 10 ft or 3 m.

3.7 Tolerances: Bars shall conform to all applicable requirements of AMS 2251 or MAM 2251.

4. QUALITY ASSURANCE PROVISIONS:

4.1 Responsibility for Inspection: The vendor of the product shall supply all samples for vendor's tests and shall be responsible for performing all required tests. Results of such tests shall be reported to the purchaser as required by 4.5. Purchaser reserves the right to sample and to perform any confirmatory testing deemed necessary to ensure that the product conforms to the requirements of this specification.

4.2 Classification of Tests:

4.2.1 Acceptance Tests: Tests to determine conformance to the following Ø requirements are classified as acceptance tests and shall be performed on each heat or lot as applicable:

4.2.1.1 Composition (3.1) and macrostructure (3.4.1.1) of each heat.

4.2.1.2 Hardness (3.2.1) and ultrasonic quality (3.5.3) of each lot of bars and forgings as solution heat treated.

4.2.1.3 Tensile properties (3.4.1.2.1) and impact strength (3.4.1.2.2) of each lot of bars and forgings after maraging.

4.2.1.4 Tolerances (3.7) of bars.

4.2.2 Periodic Tests: Tests to determine conformance to the following requirements are classified as periodic tests and shall be performed at a frequency selected by the vendor unless frequency of testing is specified by purchaser:

4.2.2.1 Fracture toughness (3.4.1.2.3) of bars and forgings after maraging.

4.2.2.2 Ability of forging stock (3.4.2) to develop required properties.

4.2.3 Preproduction Tests: Tests of forgings to determine conformance to all Ø applicable technical requirements of this specification when AMS 2375 is specified are classified as preproduction tests and shall be performed prior to or on the first-article shipment of a forging to a purchaser, when a change in material, processing, or both requires reapproval as in 4.4, and when purchaser deems confirmatory testing to be required.

4.2.3.1 For direct U.S. Military procurement of forgings, substantiating test data and, when requested, preproduction forgings shall be submitted to the cognizant agency as directed by the procuring activity, the contracting officer, or the request for procurement.

4.3 Sampling: Shall be in accordance with the following:

4.3.1 Bars: AMS 2370.

4.3.2 Forgings and Forging Stock: AMS 2372.

4.3.3 Samples for composition shall be taken from a vacuum consumable electrode remelted ingot.

4.3.4 Ultrasonic Inspection: All product.

4.3.5 Samples for macrostructure (3.4.1.1.1) testing shall be full Ø cross-sectional specimens obtained from the finished billet or suitable rerolled product representing the top and bottom of at least the first, middle, and last usable ingots from each heat.

4.3.6 Periodic Tests and Preproduction Tests: As agreed upon by purchaser and vendor.

4.4 Approval: When specified, approval and control of forgings shall be in accordance with AMS 2375.

4.5 Reports:

4.5.1 The vendor of the product shall furnish with each shipment a report showing the results of tests for chemical composition and macrostructure of each heat, for hardness as solution heat treated, tensile and impact properties of each lot after maraging, and for internal soundness of each bar and forging. This report shall include the purchase order number, heat number, AMS 6543A, size, and quantity from each heat. If forgings are supplied, the part number and the size and melt source of stock used to make the forgings shall also be included.

4.5.2 The vendor of finished or semi-finished parts shall furnish with each shipment a report showing the purchase order number, AMS 6543A, contractor or other direct supplier of material, part number, and quantity. When material for making parts is produced or purchased by the parts vendor, that vendor shall inspect each lot of material to determine conformance to the requirements of this specification and shall include in the report either a statement that the material conforms or copies of laboratory reports showing the results of tests to determine conformance.

4.6 Resampling and Retesting: Shall be in accordance with the following:

4.6.1 Bars: AMS 2370.

4.6.2 Forgings and Forging Stock: AMS 2372.

5. PREPARATION FOR DELIVERY:

5.1 Identification: The product shall be identified as follows: