

AEROSPACE MATERIAL SPECIFICATION

an American National Standard

AMS 6409

Issued 1-1-87

STEEL BARS, FORGINGS, AND TUBING
0.80Cr - 1.8Ni - 0.25Mo (0.38 - 0.43C) (SAE 4340)
Special Aircraft Quality Cleanliness
Normalized and Tempered

UNS G43400

1. SCOPE:

- 1.1 Form: This specification covers a low-alloy steel in the form of bars, forgings, mechanical tubing, and forging stock.
- 1.2 Application: Primarily for parts required to meet stringent magnetic inspection criteria and having sections 3.5 in. (90 mm) and under in nominal thickness at time of heat treatment requiring a through-hardening steel capable of developing a minimum hardness of 30 HRC when properly hardened and tempered and also for parts of greater thickness but requiring proportionately lower hardness.
- 1.2.1 Certain design and processing procedures may cause these products to become susceptible to stress-corrosion cracking after heat treatment; ARP 1110 recommends practices to minimize such conditions.
- 1.2.2 These products are not recommended for use in parts heat treated to a tensile strength range having a maximum over 220,000 psi (1515 MPa) or where the high transverse properties of vacuum-arc-remelted or electroslag remelted steel are required (See 8.1).

2. APPLICABLE DOCUMENTS: The following publications form a part of this specification to the extent specified herein. The latest issue of Aerospace Material Specifications, Aerospace Standards, and Aerospace Recommended Practices 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.

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2.1.1 Aerospace Material Specifications:

- AMS 2251 - Tolerances, Low-Alloy Steel Bars
- MAM 2251 - Tolerances, Metric, Low-Alloy Steel Bars
- AMS 2253 - Tolerances, Carbon and Alloy Steel Tubing
- MAM 2253 - Tolerances, Metric, Carbon and Alloy Steel Tubing
- AMS 2259 - Chemical Check Analysis Limits, Wrought Low-Alloy and Carbon Steels
- AMS 2300 - Premium Aircraft-Quality Steel Cleanliness, Magnetic Particle Inspection Procedure
- MAM 2300 - Premium Aircraft-Quality Steel Cleanliness, Magnetic Particle Inspection Procedure, Metric (SI) Measurement
- AMS 2310 - Qualification Sampling of Steels, Transverse Tensile Properties
- 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 - Control of Forgings Requiring First Article Approval
- AMS 2759/1 - Heat Treatment of Carbon and Low-Alloy Steel Parts, Minimum Tensile Strength up to 220,000 psi (1515 MPa)
- AMS 2806 - Identification, Bars, Wire, 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

2.1.3 Aerospace Recommended Practices:

- ARP 1110 - Minimizing Stress Corrosion Cracking in Heat Treatable Wrought Low Alloy and Martensitic Corrosion Resistant Steels

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

- ASTM A255 - End-Quench Test for Hardenability of Steel
- ASTM A370 - Mechanical Testing of Steel Products
- ASTM E112 - Determining Average Grain Size
- ASTM E350 - Chemical Analysis of Carbon Steel, Low-Alloy Steel, Silicon Electrical Steel, Ingot Iron, and Wrought Iron
- ASTM E381 - Macroetch Testing, Inspection, and Rating Steel Products, Comprising Bars, Billets, Blooms, and Forgings

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, determined by wet chemical methods in accordance with ASTM E350 or by spectrographic or other analytical methods approved by purchaser:

	min	max
Carbon	0.38	0.43
Manganese	0.65	0.85
Silicon	0.15	0.35
Phosphorus	--	0.015
Sulfur	--	0.008
Chromium	0.70	0.90
Nickel	1.65	2.00
Molybdenum	0.20	0.30
Copper	--	0.35

- 3.1.1 Check Analysis: Composition variations shall meet the applicable requirements of AMS 2259.
- 3.1.2 For sizes over 200 sq in. (1290 cm²) in cross-sectional area, the chemical composition and check analysis tolerances shall be as agreed upon by purchaser and vendor.
- 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: Normalized at 1650°F + 25 (900°C + 15) and tempered having hardness at mid-radius not higher than 269 HB or equivalent. Bars shall have a turned, ground, polished, or burnished surface; surface hardness shall be not more than 3 points HRC harder than mid-radius hardness.
- 3.2.1.1 Hot finished or cold drawn surface may be specified; however, when hot finished or cold drawn is specified, bars with a turned or ground or polished or burnished surface with a surface hardness not more than 3 points HRC harder than at mid-radius as in 3.2.1 may be furnished.
- 3.2.2 Forgings: Normalized and tempered in accordance with MIL-H-6875 having hardness not higher than 269 HB, or equivalent.
- 3.2.3 Mechanical Tubing: Normalized and tempered having hardness not higher than HB 269, or equivalent; tubing 1.0 in. (25 mm) and under in nominal OD shall be cold reduced; larger sizes shall be hot rolled.
- 3.2.4 Forging Stock: As ordered by the forging manufacturer.
- 3.3 Properties: The product shall conform to the following requirements; hardness testing shall be performed in accordance with ASTM A370:

- 3.3.1 Macrostructure: Visual examination of transverse sections as in 4.3.3 from bars, billets, tube rounds or tubes, and forging stock, etched in accordance with ASTM E381 in hot hydrochloric acid (1:1) at 160° - 180°F (70° - 80°C) for sufficient time to develop a well-defined macrostructure, shall show no pipe or cracks. Except as specified in 3.3.1.1, porosity, segregation, inclusions, and other imperfections shall be no worse than the following macrographs of ASTM E381:

Section Size		Macrographs
Square Inches	Square Centimetres	
Up to 36, incl	Up to 230, incl	S2 - R1 - C2
Over 36 to 100, incl	Over 230 to 645, incl	S2 - R2 - C3
Over 100	Over 645	As agreed upon

- 3.3.1.1 If tubes are produced directly from ingots or large blooms, transverse sections may be taken from tubes rather than tube rounds. Macrostructure standards for such tubes shall be as agreed upon by purchaser and vendor.
- 3.3.2 Grain Size: Predominantly 5 or finer with occasional grains as large as 3 permissible, determined in accordance with ASTM E112.
- 3.3.3 Hardenability: Shall be J53=6 min and J50=20 min, determined in accordance with ASTM A255 on the standard end-quench specimen; the specimen shall be normalized at 1600°F $\pm$ 10 (870°C $\pm$ 5) and austenitized at 1550°F $\pm$ 10 (845°C $\pm$ 5).
- 3.3.4 Decarburization:
- 3.3.4.1 Bars not ordered hot finished or cold drawn shall be free from decarburization.
- 3.3.4.2 Allowable decarburization of bars, billets, and tube rounds ordered for redrawing or forging or to specified microstructural requirements shall be as agreed upon by purchaser and vendor.
- 3.3.4.3 Decarburization of bars ordered hot finished or cold drawn shall be not greater than shown in Table I.

TABLE I

Nominal Diameter or Distance Between Parallel Sides Inches	Depth of Decarburization Inch
Up to 0.375, incl	0.010
Over 0.375 to 0.500, incl	0.012
Over 0.500 to 0.625, incl	0.014
Over 0.625 to 1.000, incl	0.017
Over 1.000 to 1.500, incl	0.020
Over 1.500 to 2.000, incl	0.025
Over 2.000 to 2.500, incl	0.030
Over 2.500 to 3.000, incl	0.035
Over 3.000 to 4.000, incl	0.045

TABLE I (SI)

Nominal Diameter or Distance Between Parallel Sides Millimetres	Depth of Decarburization Millimetres
Up to 9.50, incl	0.25
Over 9.50 to 12.50, incl	0.30
Over 12.50 to 15.50, incl	0.35
Over 15.50 to 25.00, incl	0.42
Over 25.00 to 37.50, incl	0.50
Over 37.50 to 50.00, incl	0.62
Over 50.00 to 62.50, incl	0.75
Over 62.50 to 75.00, incl	0.88
Over 75.00 to 100.00, incl	1.12

3.3.4.3.1 Limits for depth of decarburization of bars hot finished or cold drawn over 4.000 in. (100.00 mm) in nominal diameter or distance between parallel sides shall be as agreed upon by purchaser and vendor.

3.3.4.4 Decarburization of mechanical tubing shall be not greater than shown in Table II.

TABLE II

Nominal Wall Thickness Inch	Depth of Decarburization, Inch	
	IO	OD
Up to 0.109, incl	0.008	0.015
Over 0.109 to 0.203, incl	0.010	0.020
Over 0.203 to 0.400, incl	0.012	0.025
Over 0.400 to 0.600, incl	0.015	0.030
Over 0.600 to 1.000, incl	0.017	0.035
Over 1.000	0.020	0.040

TABLE II (SI)

Nominal Wall Thickness Millimetres	Depth of Decarburization, Millimetre	
	ID	OD
Up to 2.75, incl	0.20	0.38
Over 2.75 to 5.00, incl	0.25	0.50
Over 5.00 to 10.00, incl	0.30	0.62
Over 10.00 to 15.00, incl	0.38	0.75
Over 15.00 to 25.00, incl	0.42	0.88
Over 25.00	0.50	1.00

3.3.4.5 Decarburization shall be measured by the microscopic method or by Rockwell Superficial 30-N scale or equivalent hardness testing method on hardened but untempered specimens protected during heat treatment to prevent changes in surface carbon content. Depth of decarburization, when measured by a hardness method, is defined as the perpendicular distance from the surface to the depth under that surface below which there is no further increase in hardness. Such measurements shall be far enough away from any adjacent surface to be uninfluenced by any decarburization or lack of decarburization thereon.

3.3.4.5.1 When determining the depth of decarburization, it is permissible to disregard local areas provided the decarburization of such areas does not exceed the above limits by more than 0.005 in. (0.12 mm) and the width is 0.065 in. (1.65 mm) or less.

3.3.5 Tensile Properties: After being heat treated in accordance with AMS 2759 to an ultimate tensile strength range of 180,000-200,000 psi (1240-1380 MPa), product shall have a transverse reduction of area value of 15% minimum at the mid-radius position.

3.4 Quality:

3.4.1 Steel shall conform to the cleanliness requirements of AMS 2300 or MAM 2300. It need not conform to the melting practice requirements of AMS 2300 or MAM 2300.

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

3.4.2.1 Bars not ordered hot finished or cold drawn, shall be free from seams, laps, tears, and cracks.

3.4.2.2 Bars ordered hot finished or cold drawn and mechanical tubing shall, after removal of the standard machining allowance, be free from seams, laps, tears, cracks, and other defects exposed to the machined surface. Standard machining allowance shall be in accordance with AS 1182.

- 3.4.3 Grain flow of die forgings, except in areas which contain flash-line end grain, shall follow the general contour of the forgings, showing no evidence of re-entrant flow.
- 3.5 Lengths: Except when exact lengths or multiples of exact lengths are ordered, straight bars and tubing shall be 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 (3 m).
- 3.6 Tolerances: Shall conform to all applicable requirements of the following:
- 3.6.1 Bars: In accordance with Table III except as in 3.6.1.1.

TABLE III

Specified Diameter		Tolerance, Minus Only	
Inches	Millimetres	Inches	Millimetres
Up to 1.00 Incl. in Coils	Up to 25, in Coils	0.003	0.080
Up to 1.50 Incl	Up to 37.5	0.004	0.100
Over 1.50 - 2.50 Incl	Over 37.5 - 62.5	0.005	0.130
Over 2.50 - 4.00 Incl	Over 62.5 - 100	0.006	0.150
Over 4.00 - 4.70 Incl	Over 100 - 120	0.008	0.200
Over 4.70 - 7.08 Incl	Over 120 - 180	0.016	0.400

- 3.6.1.1 Hot rolled and cold drawn bars shall conform to AMS 2251 or MAM 2251.
- 3.6.2 Mechanical Tubing: AMS 2253 or MAM 2253.

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 4.4. 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 all technical requirements of this specification are classified as acceptance tests and shall be performed on each heat or lot as applicable.
- 4.2.2 Preproduction Tests: Tests of forgings to determine conformance to all 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.

4.2.2.1 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 and Mechanical Tubing: AMS 2370.

4.3.2 Forgings and Forging Stock: AMS 2372.

4.3.3 Samples for macrostructure (3.3.1) testing shall be full 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 of each heat or, in the case of multiple ingots poured simultaneously, the top and bottom of 10% of the ingots from each pouring plate.

4.3.4 Samples for frequency-severity cleanliness rating (3.4.1) shall conform to AMS 2300 or MAM 2300 except as follows:

4.3.4.1 When multiple ingots are poured simultaneously, i.e., no pouring sequence is identifiable, the samples shall be taken from semi-finished or finished product representing the top and bottom of at least 20% of the ingots, evenly distributed among bottom plates, with not less than one ingot from each bottom plate. If the ingot pattern is asymmetrical, the ingots sampled shall include those most distant from the pouring sprue.

4.3.5 Samples for tensile testing as in 3.3.5 shall be selected and prepared in accordance with AMS 2310 except that, in the case of multiple ingots poured simultaneously, samples shall be taken from one end of billets or bars representing the top and bottom of two random ingots for heats of 3 to 9 ingots or from three random ingots for heats of 10 or more ingots.

4.4 Approval: When specified, approval and control of forgings requiring first article approval 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, macrostructure, tensile properties, grain size, hardenability, and frequency-severity cleanliness rating of each heat, and the frequency-severity cleanliness rating of each sample. This report shall include the purchase order number, heat number, AMS 6409, size, and quantity. If forgings are supplied, the part number and the size and melt source of stock used to make the forgings shall also be included.