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400 COMMONWEALTH DRIVE WARRENDALE, PA 15096

AEROSPACE MATERIAL SPECIFICATION

AMS 6449B
Superseding AMS 6449A

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STEEL BARS, FORGINGS, AND TUBING
1.02Cr (0.98 - 1.10C) (SAE 51100)
For Bearing Applications

UNS G51986

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 bearing components 0.600 in. (15.00 mm) and under in nominal thickness, such as bearing balls and rolls, requiring a through-hardening steel, usually with hardness of approximately 60 HRC.

2. APPLICABLE DOCUMENTS: The following publications form a part of this specification to the extent specified herein. The latest issue of Aerospace Material Specifications (AMS) 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 2251 - Tolerances, Low-Alloy Steel Bars
AMS 2253 - Tolerances, Carbon and Alloy Steel Tubing
AMS 2259 - Chemical Check Analysis Limits, Wrought Low-Alloy and Carbon Steels
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 2806 - Identification, Bars, Wire, Mechanical Tubing, and Extrusions, Carbon and Alloy Steels and Heat and Corrosion Resistant Steels and Alloys
AMS 2808 - Identification, Forgings

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

ASTM A370 - Mechanical Testing of Steel Products
ASTM E45 - Determining the Inclusion Content of Steel
ASTM E112 - Estimating the Average Grain Size of Metals
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 Federal Standards:

Federal Test Method Standard No. 151 - Metals; Test Methods

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, by spectrographic methods in accordance with Federal Test Method Standard No. 151, Method 112, or by other analytical methods approved by purchaser:

	min	max
Carbon	0.98 -	1.10
Manganese	0.25 -	0.45
Silicon	0.15 -	0.35
Phosphorus	--	0.025
Sulfur	--	0.025
Chromium	0.90 -	1.15
Nickel	--	0.25
Molybdenum	--	0.10
Copper	--	0.35

3.1.1 Check Analysis: Composition variations shall meet the applicable requirements of AMS 2259.

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

3.2.1 Bars:

3.2.1.1 Bars 0.500 In. (12.50 mm) and Under in Nominal Diameter or Distance Between Parallel Sides: Cold finished, with microstructure of spheroidized cementite in ferrite matrix, having tensile strength not higher than 120,000 psi (827 MPa) or equivalent hardness.

3.2.1.2 Bars Over 0.500 In. (12.50 mm) in Nominal Diameter or Distance Between Parallel Sides: Hot finished, with microstructure of spheroidized cementite in ferrite matrix, having hardness not higher than 207 HB or equivalent except that bars ordered cold finished may have hardness as high as 248 HB or equivalent.

3.2.2 Forgings: As ordered.

3.2.3 Mechanical Tubing: Cold finished with microstructure of spheroidized cementite in ferrite matrix. Tubing ordered hot finished shall have hardness not higher than 95 HRB or equivalent.

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 Inclusion Rating: Shall be as follows, determined by the macrostructure test and by the micro-inclusion test unless use of the fracture test is agreed upon by purchaser and vendor:

3.3.1.1 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 3.3.1.1.1, porosity, segregation, inclusions, and other imperfections shall be no worse than the macrographs of ASTM E381 agreed upon by purchaser and vendor.

3.3.1.1.1 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.

3.3.1.2 Micro-Inclusion Rating: At least one specimen as in 4.3.4 from each ingot tested, as well as two-thirds of the total number of specimens and the average
Ø of all specimens, shall not exceed the following limits, determined in accordance with ASTM E45, Method A:

	Inclusion Rating			
Type	A	B	C	D
Thin	2.5	2.0	2.0	1.5
Heavy	1.5	1.5	1.5	1.5

3.3.1.3 Fracture: The fractured surfaces of specimens as in 4.3.5 shall show a fine-grained fracture of approximately No. 8 grain size, determined in accordance with ASTM E112, and no nonmetallic streaks over 1/8 in. (3.2 mm) in length and not more than one nonmetallic streak 1/16 - 1/8 in. (1.6 - 3.2 mm) in length on the fractured surfaces of two or fewer specimens. If more than two specimens show a nonmetallic streak over 1/16 in. (1.6 mm) in length the heat shall be retested after additional discard or shall be rejected.

3.3.2 Response to Heat Treatment: Specimens, as in 4.3.6, protected by suitable means or treated in a neutral atmosphere to minimize scaling and prevent either carburization or decarburization, shall have substantially uniform hardness not lower than 63 HRC at any point below any permissible decarburization after being placed in a furnace which is at 1525°F ± 10 (830°C ± 5), allowed to heat to 1525°F ± 10 (830°C ± 5), held at heat for 20 min. ± 2, and quenched in commercial paraffin oil (100 SUS at 100°F (38°C)) at room temperature.

3.3.3 Decarburization:

3.3.3.1 Bars and tubing ordered ground, turned, or polished shall be free from decarburization on the ground, turned, or polished surfaces. Decarburization on tubing ID shall not exceed the maximum depth specified in 3.3.3.4.

3.3.3.2 Allowing decarburization of bars, billets, and tube rounds ordered for redrawing or forging or to specified microstructural requirements other than spheroidized cementite in ferrite matrix shall be as agreed upon by purchaser and vendor.

3.3.3.3 Decarburization of bars for anti-friction balls and rollers to which 3.3.3.1 or 3.3.3.2 is not applicable shall be not greater than shown in Table I.

TABLE I

Nominal Diameter or Distance Between Parallel Sides Inch	Depth of Decarburization Inch	
	Hot Finished	Cold Finished
Up to 0.250, incl	0.005	0.003
Over 0.250 to 0.500, incl	0.006	0.004
Over 0.500 to 0.750, incl	0.008	0.006
Over 0.750 to 1.000, incl	0.010	0.008

TABLE I (SI)

Nominal Diameter or Distance Between Parallel Sides Millimetres	Depth of Decarburization Millimetre	
	Hot Finished	Cold Finished
Up to 6.25, incl	0.13	0.08
Over 6.25 to 12.50, incl	0.15	0.10
Over 12.50 to 18.75, incl	0.20	0.15
Over 18.75 to 25.00, incl	0.25	0.20

3.3.3.4 Decarburization of bars and of the ID and OD of tubes to which 3.3.3.1, 3.3.3.2, or 3.3.3.3 is not applicable shall be not greater than shown in Table II.

TABLE II

Nominal Diameter or Distance Between Parallel Sides Inches	Depth of Decarburization, Inch				
	Bars			Tubes	
	Hot Finished	Annealed	Cold Finished	Annealed	Cold Finished
Up to 1.000, incl	0.012	0.015	0.012	0.012	0.010
Over 1.000 to 2.000, incl	0.017	0.022	0.015	0.020	0.014
Over 2.000 to 3.000, incl	0.025	0.030	0.025	0.030	0.019
Over 3.000 to 4.000, incl	0.035	0.045	0.035	0.035	0.024
Over 4.000 to 5.000, incl	0.055	0.065	0.055	0.040	0.028

TABLE II (SI)

Nominal Diameter or Distance Between Parallel Sides Millimetres	Depth of Decarburization, Millimetres				
	Bars			Tubes	
	Hot Finished	Annealed	Cold Finished	Annealed	Cold Finished
Up to 25.00, incl	0.30	0.38	0.30	0.30	0.20
Over 25.00 to 50.00, incl	0.43	0.56	0.38	0.50	0.35
Over 50.00 to 75.00, incl	0.64	0.76	0.64	0.75	0.48
Over 75.00 to 100.00, incl	0.89	1.14	0.89	0.88	0.60
Over 100.00 to 125.00, incl	1.40	1.65	1.40	1.00	0.70

3.3.3.5 Limits for depth of decarburization of bars and tubes over 5.000 in. (125.00 mm) in nominal diameter or distance between parallel sides shall be as agreed upon by purchaser and vendor.

3.3.3.6 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.

3.3.3.6.1 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. (0.13 mm) and the width is 0.065 in. (1.65 mm) or less.

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

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

3.4.2 Product 5.000 in. (125.00 mm) and under in nominal diameter or distance between parallel sides 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 defects
Ø exposed to the machined surfaces. Standard machining allowance shall be equal, but not in addition, to the decarburization limits of 3.3.3 for the form and condition of the product ordered.

3.4.2.1 Standard machining allowance for product over 5.000 in. (125.00 mm)
Ø in nominal diameter or distance between parallel sides shall be as agreed upon by purchaser and vendor.

3.5 Sizes: Except when exact lengths or multiples of exact lengths are ordered, straight bars and tubing 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 (3 m).

3.6 Tolerances: Unless otherwise specified, tolerances shall conform to all applicable requirements of the following:

3.6.1 Bars: AMS 2251.

3.6.2 Mechanical Tubing: AMS 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 Ø as required by 4.5. Purchaser reserves the right 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 Ø 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 on the first-article shipment of a forging to a purchaser, when a change in material and/or processing 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 (3.3.1.1) 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.