Society of Automotive Engineers, Inc.
400 COMMONWEALTH DRIVE, WARRENDALE, PA. 15096

AEROSPACE MATERIAL SPECIFICATION

AMS6449A
Superseding AMS 6449

Issued 5-15-71
Revised 10-15-79

UNS G15116

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

1. SCOPE:

1.1 Form: This specification covers an aircraft-quality, low-alloy steel in the form of bars, forgings, mechanical tubing, and forging stock.

1.2 Application: Primarily for parts 0.600 in. (15.24 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) and Aerospace Standards (AS) shall apply. The applicable issue of other documents shall be as specified in AMS 2350.

2.1 SAE Publications: Available from Society of Automotive Engineers, Inc., 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

2.1.2 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 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 - Rating Macroetched Steel

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

Printed in U.S.A.

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:

ø	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. (12.70 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. (12.70 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.
ø 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-
ø 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 (71° - 82°C) for sufficient time to develop a well-defined macrostructure, shall Ø 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 Ø 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 from each ingot tested, as well as two-thirds of the total number of specimens and the average of all specimens, shall not exceed the following limits, Ø determined in accordance with ASTM E45, Method A, except that the length of any inclusion shall be not greater than 0.025 in. (0.65 mm).

	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 shall show a fine-grained fracture of approximately No. 8 grain size, determined in accordance with ASTM E112, and no nonmetallic streaks over Ø 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, 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 Ø ground, turned, or polished surfaces. Decarburization on tubing ID shall not exceed the maximum depth specified in 3.3.3.5.

3.3.3.2 Allowable decarburization of bars, billets, and tube rounds ordered for redrawing or forging or to Ø 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 6.35, incl	0.13	0.08
Over 6.35 to 12.70, incl	0.15	0.10
Over 12.70 to 19.05, incl	0.20	0.15
Over 19.05 to 25.40, incl	0.25	0.20

3.3.3.4 Decarburization of bars 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		
	Hot Finished	Annealed	Cold Finished
Up to 1.000, incl	0.012	0.015	0.012
Over 1.000 to 2.000, incl	0.017	0.022	0.015
Over 2.000 to 3.000, incl	0.025	0.030	0.025
Over 3.000 to 4.000, incl	0.035	0.045	0.035
Over 4.000 to 5.000, incl	0.055	0.065	0.055

TABLE II (SI)

Nominal Diameter or Distance Between Parallel Sides Millimetres	Depth of Decarburization, Millimetres		
	Hot Finished	Annealed	Cold Finished
Up to 25.40, incl	0.30	0.38	0.30
Over 25.40 to 50.80, incl	0.43	0.56	0.38
Over 50.80 to 76.20, incl	0.64	0.76	0.64
Over 76.20 to 101.60, incl	0.89	1.14	0.89
Over 101.60 to 127.00, incl	1.40	1.65	1.40

3.3.3.4.1 Limits for depth of depth of decarburization of bars over 5.000 in. (127.00 mm) in nominal diameter or distance between parallel sides shall be as agreed upon by purchaser and vendor.

3.3.3.5 Decarburization on the ID and OD of all tubing to which 3.3.3.1 or 3.3.3.2 is not applicable shall be not greater than 0.025 in. (0.64 mm).

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:

Ø 3.4.1 Steel shall be aircraft quality for bearing applications.

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

3.4.2.1 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.

3.4.2.2 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 defects exposed to the machined surfaces. Standard machining allowance shall be in accordance with AS 1182.

3.5 Sizes: Except when exact lengths or multiples of exact lengths are ordered, straight bars and tubing Ø will be acceptable in mill lengths of 6 - 20 ft (1.8 - 6.1 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.

Ø 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 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 perform such confirmatory testing as he deems 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 lot.

4.2.2 Preproduction Tests: Tests of forgings to determine conformance to all 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 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.

4.3.4 Samples for micro-inclusion rating (3.3.1.2) shall consist of not less than six specimens from each heat, selected so that the surface examined will be approximately parallel to the direction of rolling. The method of selection of specimens shall be such that a representative rating is ensured for the heat of steel being evaluated.

4.3.5 Specimens for fracture test shall be approximately 3/8 in. (9.5 mm) in thickness and shall be normalized, annealed, hardened, and fractured through the approximate center of the cross section. Such specimens shall have hardness not lower than 60 HRC.

4.3.6 Samples for response to heat treatment (3.3.2) shall be as follows:

4.3.6.1 Specimens from bars shall be full cross-sections of the bar, ground on both faces normal to the axis so that length is 0.30 in. ± 0.010 (7.6 mm ± 0.25).

4.3.6.2 Specimens from mechanical tubing shall be full cross-sections of the tubing, shall have wall thickness not over 0.625 in. (16 mm) with wall thicknesses over 0.625 in. (16 mm) being turned to 0.625 in. ± 0.010 (16 mm ± 0.25), and shall be ground on both faces so that length is 0.30 in. ± 0.010 (7.6 mm ± 0.25).

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 three copies of a report showing the results of tests for chemical composition and inclusion rating of each heat and for the response to heat treatment of each size from each heat. This report shall include the purchase order number, heat number, material specification number and its revision letter, 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.