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

AEROSPACE MATERIAL SPECIFICATION

AMS 6491

Issued 1-15-76
Revised

STEEL BARS, FORGINGS, AND TUBING
4.1Cr - 4.2 Mo - 1.0V (0.80 - 0.85C)
Premium Bearing Quality, Double Vacuum Melted

1. SCOPE:

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

1.2 Application: Primarily for critical parts, such as bearings, operating under heavy loads and high speeds at moderate temperatures and subject to very rigid inspection standards.

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 2300 - Premium Aircraft-Quality Steel Cleanliness, Magnetic Particle Inspection Procedure
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 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 Vacuum Arc Remelted Steel Bars and Billets
ASTM E45 - Determining Inclusion Content of Steels
ASTM E112 - Estimating the Average Grain Size of Metals
ASTM E350 - Chemical Analysis of Carbon Steel, Low-Alloy Steel, Silicon Electrical Steel, Ingot, and Wrought Iron

Printed in U.S.A.

2.3 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 approved analytical methods:

	min	max
Carbon	0.80	0.85
Manganese	0.15	0.35
Silicon	--	0.25
Phosphorus	--	0.015
Sulfur	--	0.008
Chromium	4.00	4.25
Molybdenum	4.00	4.50
Vanadium	0.90	1.10
Nickel	--	0.15
Cobalt	--	0.25
Tungsten	--	0.25
Copper	--	0.10

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 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 having hardness not higher than 229 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 having hardness not higher than 25 HRC or equivalent except that tubing ordered hot finished shall have hardness not higher than 99 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 Grain Size: Predominantly 7 or finer with occasional grains as large as 5 permissible, determined by comparison of a polished and etched specimen with the chart in ASTM E112.

3.3.2 Inclusion Rating: Steel from which the product is made shall be subjected to the macrostructure (3.3.2.1) test and to either the fracture (3.3.2.2) or microscopic (3.3.2.3) test as agreed upon by purchaser and vendor; in the absence of such agreement, the microscopic test (3.3.2.3) shall be performed.

3.3 2.1 Macrostructure: Visual examination of transverse sections from bars, billets, forging stock, and tube rounds or tubes, etched in accordance with ASTM A604 in hot hydrochloric acid (1:1) at 160° - 180°F (71.1° - 82.2°C) for sufficient time to develop a well-defined macrostructure, shall show no imperfections, such as pipe, cracks, porosity, segregation, and inclusions, detrimental to fabrication or to performance of parts. Except as specified in 3.3.2.1.1, macrostructure standards shall be equal to or better than the following macrographs of ASTM A604:

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

3.3.2.1.1 Macrostructure of Tubes: If tubes are produced directly from ingots or large blooms, transverse sections may be taken from tubes rather than tube rounds and standards shall be as agreed upon by purchaser and vendor.

3.3.2.2 Fracture: Specimens, approximately 0.375 in. (9.52 mm) in thickness, shall be annealed, hardened, and fractured through the approximate center of the cross section. Such specimens shall have hardness not lower than 55 HRC. The fractured specimens shall show no injurious imperfections such as pipe, segregation, and porosity. The fractured surfaces shall show no nonmetallic streaks over 1/32 in. (0.8 mm) in length and shall show a maximum average cumulative length of 1/16 in. (1.6 mm) per 10 sq. in. (64.5 cm^2). A rateable nonmetallic streak is defined as one not less than 1/64 in. (0.4 mm) in length.

3.3.2.3 Microscopic Test: Radial specimens, approximately 0.28 sq in. (1.8 cm^2) in surface area taken midway between center and surface of hardened fracture samples, shall be polished, on a face longitudinal to the direction of rolling, for micro-inclusion rating in accordance with the Jernkontoret chart, Method D, Plate III of ASTM E45. No specimen shall exceed the following limits:

	Inclusion Rating			
Type	A	B	C	D
Thin	1.5	1.0	1.0	1.5
Thick	1.0	1.0	1.0	1.0

3.3.2.3.1 For types A, B, and C thin combined, there shall be not more than three fields of No. 1.5 A type or No. 1.0 B and C types and not more than five other lower rateable A type thin fields per specimen. For type D thin, there shall be not more than three No. 1.5 fields and no more than five other lower rateable D type thin fields per specimen. There shall be not more than one field each of No. 1.0 A, B, C, or D type heavy per specimen.

3.3.2.3.2 A rateable field is defined as one which has a type A, B, C, or D inclusion rating of at least No. 1.0 thin or heavy in accordance with the Jernkontoret chart, Plate III, ASTM E45.

3.3.3 Response to Heat Treatment: Specimens protected by suitable means or treated in a neutral atmosphere or neutral salt to minimize scaling and prevent either carburization or decarburization, shall have average hardness not lower than 60 HRC after being heated to 2025 - 2050°F (1107.2° - 1121.1°C) by any convenient means, held to equalize at temperature, and either quenched into salt bath at 1100° - 1150°F (593.3° - 621.1°C), held in salt bath for 2 min. ± 0.2, and air cooled to room temperature or directly air cooled to room temperature, and tempered for 2 hr ± 0.25 at 1000° - 1025°F (537.8° - 551.7°C).

3.3.4 Decarburization:

3.3.4.1 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 Table II.

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 to which 3.3.4.1 or 3.3.4.2 is not applicable 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 0.500, incl	0.015
Over 0.500 to 1.000, incl	0.030
Over 1.000 to 2.000, incl	0.040
Over 2.000 to 3.000, incl	0.050
Over 3.000 to 4.000, incl	0.065
Over 4.000 to 5.000, incl	0.095

TABLE I (SI)

Nominal Diameter or Distance Between Parallel Sides Millimetres	Depth of Decarburization Millimetres
Up to 12.70, incl	0.38
Over 12.70 to 25.40, incl	0.76
Over 25.40 to 50.80, incl	1.02
Over 50.80 to 76.20, incl	1.27
Over 76.20 to 101.60, incl	1.65
Over 101.60 to 127.00, incl	2.41

3.3.4.3.1 Limits for 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.

3.3.4.4 Decarburization of all tubing to which 3.3.4.1 or 3.3.4.2 is not applicable shall be not greater than shown in Table II.

TABLE II

Nominal Outside Diameter Inches	Depth of Decarburization Inch
Up to 1.000, incl	0.025
Over 1.000 to 2.000, incl	0.035
Over 2.000 to 3.000, incl	0.045
Over 3.000 to 4.000, incl	0.055
Over 4.000 to 5.000, incl	0.080

TABLE II (SI)

Nominal Outside Diameter Millimetres	Depth of Decarburization Millimetres
Up to 25.40, incl	0.64
Over 25.40 to 50.80, incl	0.89
Over 50.80 to 76.20, incl	1.14
Over 76.20 to 101.60, incl	1.40
Over 101.60 to 127.00, incl	2.03

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

3.4 Quality:

3.4.1 Steel shall be premium-bearing-quality conforming to AMS 2300; it shall be double vacuum melted, using vacuum induction melting followed by vacuum arc consumable electrode remelting.

3.4.2 The product shall be uniform in quality and condition, clean, sound, and free from foreign materials and from internal and external imperfections detrimental to fabrication or to performance of parts.

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 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.

3.6.2 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: Tests to determine conformance to all technical requirements of this specification are classified as acceptance or routine control tests.

4.2.1 For direct U.S. Military procurement, qualification test material and supporting test data shall be submitted to the cognizant qualification agency as directed by the request for procurement, the procuring activity, or the contracting officer.

4.3 Sampling: Shall be in accordance with the following; a heat shall be the consumable electrode remelted ingots produced from steel originally melted as a single vacuum induction furnace charge:

4.3.1 Bars and Mechanical Tubing: AMS 2370.

4.3.2 Forgings and Forging Stock: AMS 2372.

4.3.3 Specimens for composition (3.1) shall represent the bottom of the first ingot and the top of the last ingot for complete analysis; in addition, carbon shall be determined on samples representing the top and bottom of all other ingots.

4.3.4 Specimens for inclusion rating (3.3.2) shall represent the full cross section of billet stock taken from the top and bottom of at least the first, middle, and last usable ingots of each heat. Samples for macrostructure testing (3.3.2.1) shall be full cross-sectional specimens obtained from the finished billet or a suitable rerolled product.

4.3.5 Specimens for response to heat treatment (3.3.3) of bars and billets shall be the full cross section of the product ground on both faces normal to the axis so that the length is 0.500 in. ±0.010 (12.70 mm ±0.25). Specimens from mechanical tubing shall be full sections of the tubing, shall have wall thickness of 0.625 in. (15.88 mm) or less with wall thicknesses over 0.625 in. (15.88 mm) being turned to 0.625 in. ±0.010 (15.88 mm ±0.25), and shall be ground on both faces normal to the axis so that length is 0.500 in. ±0.010 (12.7 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 of the results of tests for chemical composition, inclusion rating, grain size, and AMS 2300 frequency-severity rating of each heat in the shipment and for response to heat treatment of each size from each heat. This report shall include the purchase order number, heat number, material specification number, 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.