



AEROSPACE MATERIAL SPECIFICATION

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

AMS 6525

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Revised

STEEL BARS, FORGINGS, TUBING, AND RINGS
0.75Cr - 9.0Ni - 4.5Co - 1.0Mo - 0.09V (0.17 - 0.23C)
Premium Quality, Consumable Electrode Melted

1. SCOPE:

- 1.1 Form: This specification covers a premium-quality, low-alloy steel in the form of bars, forgings, mechanical tubing, flash welded rings, and stock for forging or flash welded rings.
- 1.2 Application: Primarily for heat-treated parts, such as pressure vessels, requiring toughness and through-hardening to high strength levels and where such parts may require welding during fabrication.

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
AMS 7496 - Rings, Flash Welded, Carbon and Low-Alloy Steels

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 Steel
ASTM E112 - Estimating the Average Grain Size of Metals
ASTM E353 - Chemical Analysis of Stainless, Heat-Resisting, Maraging, and Other Similar Chromium-Nickel-Iron Alloys
ASTM E399 - Plane-Strain Fracture Toughness of Metallic Materials

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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 E353, by spectrographic methods in accordance with Federal Test Method Standard No. 151, Method 112, or by other approved analytical methods:

	min	max
Carbon	0.17	0.23
Manganese	0.20	0.40
Silicon	--	0.20
Phosphorus	--	0.010
Sulfur	--	0.010
Chromium	0.65	0.85
Nickel	8.50	9.50
Cobalt	4.25	4.75
Molybdenum	0.90	1.10
Vanadium	0.06	0.12
Copper	--	0.35

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

3.1.2 For product 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 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: Annealed and cold finished having tensile strength not higher than 180,000 psi (1241 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, annealed, and descaled having hardness not higher than 341 HB or equivalent except that bars ordered annealed and cold finished may have hardness as high as 352 HB or equivalent.

3.2.2 Forgings and Flash Welded Rings: Annealed and descaled having hardness not higher than 341 HB or equivalent.

- 3.2.2.1 Flash welded rings shall not be supplied unless specified or permitted on purchaser's part drawing. When supplied, they shall be manufactured in accordance with AMS 7496.
- 3.2.3 Mechanical Tubing: Annealed and cold finished having hardness not higher than 38 HRC or equivalent except that tubing ordered hot finished and annealed shall have hardness not higher than 36 HRC or equivalent.
- 3.2.4 Stock for Forging or Flash Welded Rings: As ordered by the forging or flash welded ring manufacturer.
- 3.3 Properties: The product shall conform to the following requirements; hardness and tensile testing shall be performed in accordance with ASTM A370:
- 3.3.1 Grain Size: Predominantly 5 or finer with occasional grains as large as 3 permissible, ASTM E112, McQuaid-Ehn test.
- 3.3.2 Macrostructure: Visual examination of transverse sections from bars, billets, tube rounds or tubes, and stock for forging or flash welded rings, 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, macrostructure shall be equal to or better than the following macrographs of ASTM A604:

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

- 3.3.2.1 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 macrostructure standards shall be as agreed upon by purchaser and vendor.
- 3.3.3 Micro-inclusion Rating: Two-thirds of the total number of specimens, as well as the average of all specimens, shall not exceed the following limits, determined in accordance with ASTM E45, Method D, except that the length of any inclusion shall be not greater than 0.015 in. (0.38 mm):

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

3.3.4 Decarburization:

- 3.3.4.1 Bars, tubing, and flash welded rings 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, forging, or flash welding or to specified microstructural requirements shall be as agreed upon by purchaser and vendor.
- 3.3.4.3 Decarburization of bars and flash welded rings 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 0.375, 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 5.000, incl	0.045

TABLE I (SI)

Nominal Diameter or Distance Between Parallel Sides Millimetres	Depth of Decarburization Millimetres
Up to 9.52, incl	0.25
Over 9.52 to 12.70, incl	0.30
Over 12.70 to 15.88, incl	0.36
Over 15.88 to 25.40, incl	0.43
Over 25.40 to 38.10, incl	0.51
Over 38.10 to 50.80, incl	0.64
Over 50.80 to 63.50, incl	0.76
Over 63.50 to 76.20, incl	0.89
Over 76.20 to 127.00, incl	1.14

3.3.4.3.1 Limits for depth of decarburization of bars and ring cross sections 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 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 Wall Thickness Inches	Depth of Decarburization, Inch	
	ID	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, Millimetres	
	ID	OD
Up to 2.77, incl	0.20	0.38
Over 2.77 to 5.16, incl	0.25	0.51
Over 5.16 to 10.16, incl	0.30	0.64
Over 10.16 to 15.24, incl	0.38	0.76
Over 15.24 to 25.40, incl	0.43	0.89
Over 25.40	0.51	1.02

- 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.
- 3.3.5 Properties After Heat Treatment: Test specimens as in 4.3.5 shall conform to the requirements of 3.3.5.2 and, when specified, 3.3.5.3. Properties shall apply to product having a cross-sectional area of 100 sq in. (645 cm²) or less. Properties shall be as agreed upon by purchaser and vendor for product having cross-sectional area greater than 100 sq in. (645 cm²).
- 3.3.5.1 Heat Treatment:
- 3.3.5.1.1 Normalizing: Heat to 1650°F $\pm$ 25 (898.9°C $\pm$ 14), hold at heat for 1 hr per inch (25 mm) of maximum cross-section, and cool in air to room temperature.
- 3.3.5.1.2 Hardening: Heat to 1525°F $\pm$ 25 (829.4°C $\pm$ 14), hold at heat for 1 hr per inch (25 mm) of maximum section thickness but not less than 1 hr, and quench in oil at 60° to 150°F (15.6° to 65.6°C), cooling within 2 hr to -100°F $\pm$ 25 (-73.3°C $\pm$ 14), holding at -100°F $\pm$ 25 (-73.3°C $\pm$ 14) for not less than 1 hr, and warming to room temperature.
- 3.3.5.1.3 Tempering: Heat to 1025° - 1075°F (551.7° - 579.4°C), hold at heat for not less than 4 hr, and cool in air to room temperature.
- 3.3.5.2 Tensile Properties:
- | | |
|--|------------------------|
| Tensile Strength, min | 190,000 psi (1310 MPa) |
| Yield Strength at 0.2% Offset, min | 180,000 psi (1241 MPa) |
| Elongation in 2 in. (50.8 mm) or 4D, min | 12% |
| Reduction of Area (round specimens), min | 45% |
- 3.3.5.3 Fracture Toughness: When specified, shall be determined by a suitable method. Standards for acceptance and method of test shall be as agreed upon by purchaser and vendor. ASTM E399 is a suggested method of test for product having nominal section thickness of 1.50 in. (38.10 mm) and over.
- 3.3.6 Stock for Forging or Flash Welded Rings: When a sample of stock is forged to a test coupon and heat treated as in 3.3.5.1, specimens taken from the heat treated coupon shall conform to the requirements of 3.3.5.2 and, when specified, 3.3.5.3. If specimens taken from the stock after heat treatment as in 3.3.5.1 conform to the requirements of 3.3.5.2 and, when specified, 3.3.5.3, the tests shall be accepted as equivalent to tests of a forged coupon.
- 3.4 Quality:
- 3.4.1 Steel shall be premium quality conforming to AMS 2300 except that a maximum average frequency (F) rating of 0.10 and a maximum average severity (S) rating of 0.20 shall apply. Material shall be multiple melted using consumable electrode process in the remelt cycle, unless otherwise permitted; at least one of the melting cycles shall be under vacuum.

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, tubing, and flash welded rings 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 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: 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 furnace charge:

4.3.1 Bars, Mechanical Tubing, Flash Welded Rings, and Stock for Flash Welded Rings: AMS 2370.

4.3.2 Forgings and Forging Stock: AMS 2372.

4.3.3 Specimens for tensile testing shall be machined from bars, forgings, mechanical tubing, and flash welded rings after heat treatment as in 3.3.5.1. Specimens shall be taken in the transverse direction from product from which a specimen not less than 2.50 in. (63.5 mm) long can be obtained; otherwise, specimens shall be taken in the longitudinal direction. Samples in the longitudinal direction need not be obtained from product tested in the transverse direction. Specimens shall be cut from parent metal of flash welded rings not including the weld-heat-affected zone. Specimens from forgings shall be taken from locations agreed upon by purchaser and vendor.

4.3.4 Specimens for macrostructure (3.3.2) testing shall represent the full cross-section of stock taken from the top and bottom of each ingot. Samples shall be full cross-sectional specimens obtained from the finished billet or suitable rerolled product.