

STEEL BARS, FORGINGS, TUBING, AND RINGS
1.0Cr - 7.5Ni - 4.5Co - 1.0Mo - 0.09V (0.29 - 0.34C)
Premium Aircraft Quality, Consumable Electrode Vacuum Melted, Annealed

1. SCOPE:

- 1.1 Form: This specification covers a premium-aircraft-quality, high-strength, 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 through hardening to high strength levels and when such parts may require welding. Certain processing procedures and service conditions may cause these products to become subject to stress-corrosion cracking; ARP 1110 recommends practices to minimize such conditions.

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), Aerospace Standards (AS), and Aerospace Recommended Practices (ARP) 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 - 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
AMS 7496 - Rings, Flash Welded, Carbon and Low-Alloy Steel

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

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- 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 Remelted Steel Bars and Billets
 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 E399 - Plane-Strain Fracture Toughness of Metallic Materials

- 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	0.29	0.34
Manganese	0.10	0.35
Silicon	--	0.20
Phosphorus	--	0.010
Sulfur	--	0.010
Chromium	0.90	1.10
Nickel	7.00	8.00
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.

- 3.2 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: Annealed and cold finished having tensile strength not higher than 165,000 psi (1138 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, annealed, and descaled having hardness not higher than 341 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 descaled having hardness not higher than 341 HB or equivalent.

3.2.4 Stock for Forging or Flash Welded Rings: As ordered by the forging or flash welded ring manufacturer.

3.3 Heat Treatment: Bars, forgings, mechanical tubing, and flash welded rings shall be annealed by heating to 1150°F ± 25 (620°C ± 15), holding at heat for 8 - 24 hr commensurate with section thickness, and cooling in air.

3.4 Properties: The product shall conform to the following requirements; hardness, tensile, and impact testing shall be performed in accordance with ASTM A370:

3.4.1 Grain Size: Predominantly 5 or finer with occasional grains as large as 3 permissible, determined in accordance with ASTM E112.

3.4.2 Macrostructure: Visual examination of transverse sections as in 4.3.3 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° - 82°C) for sufficient time to develop a well-defined macrostructure, shall show no pipe or cracks. Except as specified in 3.4.2.1, porosity, segregation, inclusions, and other imperfections shall be no worse than the following macrographs of ASTM A604:

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

3.4.2.1 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.

3.4.3 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	2.0
Heavy	1.0	1.0	1.0	1.5

3.4.4 Decarburization:

3.4.4.1 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 shown in Table II.

- 3.4.4.2 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.
- 3.4.4.3 Decarburization of bars and flash welded rings to which 3.4.4.1 or 3.4.4.2 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

- 3.4.4.3.1 Limits for depth of decarburization of bars and flash welded rings over 5.000 in. (127.00 mm) in nominal diameter or distance between parallel sides shall be as agreed upon by purchaser and vendor.
- 3.4.4.4 Decarburization of tubing to which 3.4.4.1 or 3.4.4.2 is not applicable shall be not greater than shown in Table II.

TABLE II

Nominal Wall Thickness Inches	Depth of Decarburization	
	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

3.4.4.5 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.

3.4.4.5.1 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.

3.4.5 Properties After Heat Treatment: Bars, forgings, mechanical tubing, and parent metal of flash welded rings, heat treated as in 3.4.5.1, shall conform to the requirements of 3.4.5.2, 3.4.5.3, and, when specified, 3.4.5.4. Product need not be annealed as in 3.3 before heat treatment to determine conformance to these requirements.

3.4.5.1 Heat Treatment:

3.4.5.1.1 Normalizing: Heat to 1650°F ± 50 (900°C ± 30), hold at heat for not less than 1 hr per inch (25 mm) of maximum section thickness, and cool in air to room temperature.

3.4.5.1.2 Hardening: Heat to 1550°F ± 15 (845°C ± 8), hold at heat for 1 hr per inch (25 mm) of maximum section thickness but not less than 1 hr, quench sections 4.0 in. (100 mm) and under in nominal thickness into room temperature oil or water and sections over 4.0 in. (100 mm) in nominal thickness into room temperature oil, cool to -100°F ± 10 (-75°C ± 5), hold at -100°F ± 10 (-75°C ± 5) for not less than 2 hr, and warm to room temperature.

3.4.5.1.3 Tempering: Heat to 1000°F ± 10 (540°C ± 5), hold at heat for not less than 2 hr, suitably cool to below 125°F (50°C), reheat to 1000°F ± 10 (540°C ± 5), hold at heat for not less than 2 hr, and cool in air to room temperature.

3.4.5.2 Longitudinal Tensile Properties:

Tensile Strength, min	220,000 psi (1517 MPa)
Yield Strength at 0.2% Offset, min	190,000 psi (1310 MPa)
Elongation in 4D, min	10%
Reduction of Area, min	40%

3.4.5.3 Impact Strength: The product shall have a Charpy impact value not less than 20 ft-lb (27 N·m), determined at room temperature using a V-notched specimen.

3.4.5.4 Fracture Toughness: When specified, shall be determined by a suitable method. The method of testing and standards for acceptance shall be as agreed upon by purchaser and vendor. ASTM E399 is a suggested method of test for product having nominal section thicknesses of 0.50 in. (12.5 mm) and over.

3.4.6 Stock for Forging or Flash Welded Rings: When a sample of stock is forged to a test coupon and heat treated as in 3.4.5.1, specimens taken from the heat treated coupon shall conform to the requirements of 3.4.5.2, 3.4.5.3, and, when specified, 3.4.5.4. If specimens taken from the stock after heat treatment as in 3.4.5.1 conform to the requirements of 3.4.5.2, 3.4.5.3, and, when specified, 3.4.5.4, the tests shall be accepted as equivalent to tests of a forged coupon.

3.5 Quality:

3.5.1 Steel shall be premium aircraft quality conforming to AMS 2300. It shall be multiple melted using vacuum consumable electrode practice in the remelt cycle.

3.5.2 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.

3.5.2.1 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.

3.5.2.2 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 surface. Standard machining allowance shall be in accordance with AS 1182.

3.6 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).

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

3.7.1 Bars: AMS 2251.

3.7.2 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 as required by 4.5. 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 the following requirements are classified as acceptance tests and shall be performed on each heat or lot as applicable:

4.2.1.1 Composition (3.1), macrostructure (3.4.2), and micro-inclusion rating (3.4.3) of each heat.

4.2.1.2 Condition (3.2), grain size (3.4.1), and decarburization (3.4.4) of each lot of bars, forgings, mechanical tubing, and flash welded rings.

4.2.1.3 Tensile properties (3.4.5.2) and, when specified, fracture toughness (3.4.5.4) of each lot of bars, forgings, mechanical tubing, and flash welded rings after heat treatment.

4.2.1.4 Tolerances (3.7) of bars and mechanical tubing.

4.2.2 Periodic Tests: Tests to determine conformance to the following requirements are classified as periodic tests and shall be performed at a frequency selected by the vendor unless frequency of testing is specified by purchaser: