

AEROSPACE MATERIAL SPECIFICATION

Submitted for recognition as an American National Standard

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Superseding AMS 6525A

STEEL, BARS, FORGINGS, TUBING, AND RINGS
0.75Cr - 9.0Ni - 4.5Co - 1.0Mo - 0.09V (0. 17 - 0.23C)
Consumable Electrode Vacuum Melted

UNS K91472

1. SCOPE:

1.1 Form:

This specification covers a premium aircraft-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:

These products have been used typically for heat-treated parts requiring toughness and through-hardening to high strength levels and where such parts may require welding during fabrication, but usage is not limited to such applications.

2. APPLICABLE DOCUMENTS:

The following publications form a part of this specification to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order.

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2.1 SAE Publications:

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

AMS 2251 Tolerances, Low-Alloy Steel Bars
MAM 2251 Tolerances, Metric, Low-Alloy Steel Bars
AMS 2253 Tolerances, Carbon and Alloy Steel Tubing
MAM 2253 Tolerances, Metric, 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
MAM 2300 Premium Aircraft-Quality Steel Cleanliness, Magnetic Particle Inspection Procedure, Metric (SI) Measurement
AMS 2370 Quality Assurance Sampling and Testing, Carbon and Low-Alloy Steel Wrought Products and Forging Stock
AMS 2372 Quality Assurance Sampling and Testing, Carbon and Low-Alloy Steel Forgings
AMS 2750 Pyrometry
AMS 2806 Identification, Bars, Wire, Mechanical Tubing, and Extrusions, Carbon and Alloy Steels and Corrosion and Heat Resistant Steels and Alloys
AMS 2808 Identification, Forgings
AMS 7496 Rings, Flash Welded, Carbon and Low-Alloy Steels

AS1 182 Standard Machining Allowance, Aircraft-Quality and Premium Aircraft-Quality Steel Bars and Mechanical Tubing

2.2 ASTM Publications:

Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

ASTM A 370 Mechanical Testing of Steel Products
ASTM A 604 Macroetch Testing of Consumable Electrode Remelted Steel Bars and Billets
ASTM E 45 Determining the Inclusion Content of Steel
ASTM E 112 Determining the Average Grain Size
ASTM E 353 Chemical Analysis of Stainless, Heat-Resisting, Maraging, and Other Similar Chromium-Nickel-Iron Alloys
ASTM E 399 Plane-Strain Fracture Toughness of Metallic Materials

2.3 U.S. Government Publications:

Available from DODSSP, Subscription Services Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

MIL-H-6875 Heat Treatment of Steel, Process for

3. TECHNICAL REQUIREMENTS:

3.1 Composition:

Shall conform to the percentages by weight shown in Table 1, determined by wet chemical methods in accordance with ASTM E 353, by spectrochemical methods, or by other analytical methods acceptable to purchaser.

TABLE 1 - Composition

Element	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.

3.2 Melting Practice:

(R)

Steel shall be multiple melted using consumable electrode vacuum practice in the remelt cycle.

3.3 Condition:

The product shall be supplied in the following condition; hardness and tensile strength shall be determined in accordance with ASTM A 370.

3.3.1 Bars:

3.3.1.1 Bars 0.500 Inch (12.70 mm) and Under in Nominal Diameter or Distance Between Parallel Sides: Annealed, or normalized and tempered, and cold finished having tensile strength not higher than 180 ksi (1241 MPa) or equivalent hardness (See 8.2).

3.3.1.2 Bars Over 0.500 Inch (12.70 mm) in Nominal Diameter or Distance Between Parallel Sides: Hot finished, annealed, or normalized and tempered, 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 (See 8.3).

3.3.2 Forgings and Flash Welded Rings: Annealed, or normalized and tempered, in accordance with MIL-H-6875, and descaled having hardness not higher than 352 HB, or equivalent (See 8.3).

3.3.2.1 Flash welded rings shall not be supplied unless specified or permitted on purchaser's part drawing. When supplied, rings shall be manufactured in accordance with AMS 7496.

3.3.3 Mechanical Tubing: Annealed, or normalized and tempered, 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 (See 8.3).

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

3.4 Heat Treatment:
(R)

Bars, mechanical tubing, and flash welded rings shall be annealed by heating to 1250 °F ± 25 (677 °C ± 14), holding at heat for 4 hours ± 0.25, cooling to room temperature in air or other atmosphere at a rate equivalent to an air cool, reheating to 1150 °F ± 25 (621 °C ± 14), holding at heat for 8 hours ± 0.25, and cooling to room temperature in air or other atmosphere at a rate equivalent to an air cool. Pyrometry shall be in accordance with AMS 2750.

3.4.1 When specified by purchaser, the product may be normalized prior to annealing by heating to (R) 1650 °F ± 25 (899 °C ± 14), holding at heat for not less than 1 hour per inch (25 mm) of maximum thickness but not less than 1 hour, and cooling to room temperature in air or other atmosphere at a rate equivalent to an air cool.

3.5 Properties:

The product shall conform to the following requirements; hardness and tensile testing shall be performed in accordance with ASTM A 370:

3.5.1 Macrostructure: Visual examination of transverse full cross-sections from bars, billets, tube rounds or tubes, and stock for forging or flash welded rings, etched in hot hydrochloric acid in accordance with ASTM A 604, shall show no pipe or cracks. Except as specified in 3.5.1.1, porosity, segregation, inclusions, and other imperfections shall be no worse than the macrographs of ASTM A 604 shown in Table 2.

TABLE 2 - Macrostructure Limits

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

3.5.1.1 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.

3.5.2 Micro-Inclusion Rating: No specimen shall exceed the limits shown in Table 3, determined in accordance with ASTM E 45, Method D.

TABLE 3 - Micro-inclusion Limits

Type	A Thin	A Heavy	B Thin	B Heavy	C Thin	C Heavy	D Thin	D Heavy
Worst Field Severity	1.5	1.0	1.5	1.0	1.5	1.0	1.5	1.0
Worst Field Frequency, maximum	-- ^a	1	-- ^a	1	-- ^a	1	3	1
Total Rateable Fields, Frequency, maximum	-- ^b	1	-- ^b	1	-- ^b	1	8	1

^a Combined A+B+C, not more than 3 fields
^b Combined A+B+C, not more than 8 fields

3.5.2.1 A rateable field is defined as one which has a type A, B, C, or D inclusion rating of at least 1.0 thin or heavy in accordance with the Jernkontoret Chart, Plate III, ASTM E 45.

3.5.3 Average Grain Size: Shall be ASTM No. 5 or finer, determined in accordance with (R) ASTM E 112 (See 8.4).

3.5.4 Decarburization:

3.5.4.1 Bars, tubing, and flash welded rings ordered ground, turned, or polished shall be free from decarburization on the ground, turned, or polished surfaces.

3.5.4.2 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.

3.5.4.3 Decarburization of bars and flash welded rings to which 3.5.4.1 or 3.5.4.2 is not applicable shall be not greater than shown in Table 4.

TABLE 4A - Maximum Decarburization, Inch/Pound Units

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 4B - Maximum Decarburization, SI Units

Nominal Diameter or Distance Between Parallel Sides Millimeters	Depth of Decarburization Millimeters
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

3.5.4.4 Decarburization of tubing to which 3.5.4.1 or 3.5.4.2 is not applicable shall be not greater than shown in Table 5.

TABLE 5A - Maximum Decarburization, Inch/Pound Units

Nominal Wall Thickness Inches	Depth ID Inch	Depth OD Inch
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 5B - Maximum Decarburization, SI Units

Nominal Wall Thickness Millimeters	Depth ID Millimeter	Depth OD Millimeter
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

- 3.5.4.5 Depth of decarburization on forgings shall be not greater than 0.060 inch (1.52 mm); forgings shall show no carburization.
- 3.5.4.6 Decarburization shall be measured by the microscopic method or by HR30N 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 decarburization thereon.
- 3.5.4.6.1 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 inch (0.13 mm) and the width is 0.065 inch (1.65 mm) or less.
- 3.5.5 Response to Heat Treatment: Specimens, taken from product 100 square inches (645 cm²) and under in cross-sectional area after heat treatment as in 3.5.5.1, shall meet the requirements of 3.5.5.2, 3.5.5.3, and, when specified, 3.5.5.4.
- 3.5.5.1 Heat Treatment:
- 3.5.5.1.1 Normalizing: Heat to 1650 °F ± 25 (899 °C ± 14), hold at heat for 1 hour per inch (25 mm) of maximum cross-section, and cool in air to room temperature.
- 3.5.5.1.1.1 Normalizing may be omitted if the product was supplied normalized and annealed.
- 3.5.5.1.2 Hardening: Heat to 1525 °F ± 25 (829 °C ± 14), hold at heat for 1 hour per inch (25 mm) of maximum section thickness but not less than 1 hour, and quench in oil at 60 to 150 °F (16 to 66 °C), cooling within 2 hours to -100 °F ± 25 (-73 °C ± 14), holding at -100 °F ± 25 (-73 °C ± 14) for not less than 1 hour, and warming in air to room temperature.
- 3.5.5.1.3 Tempering: Heat to 1050 °F ± 25 (566 °C ± 14), hold at heat for not less than 4 hours, and (R) cool in air to room temperature.

3.5.5.2 Tensile Properties: Shall be as shown in Table 6.

TABLE 6 - Minimum Tensile Properties

Property	Value
Tensile Strength	190 ksi (1310 MPa)
Yield Strength at 0.2% Offset	180 ksi (1241 MPa)
Elongation in 4D	12%
Reduction of Area	45%

3.5.5.3 Hardness: Shall be 41 to 45 HRC, or equivalent (See 8.3).

(R)

3.5.5.4 Fracture Toughness: Fracture toughness, when specified, shall be not less than 110 ksi $\sqrt{\text{inch}}$ (121 MPa $\sqrt{\text{m}}$) K_{IC} or K_{IQ} , determined in accordance with ASTM E 399 on any product from which a specimen of a standardized ASTM E 399 orientation can be extracted having dimensions not less than 1.50 inches (38.1 mm) in section thickness and not less than 4.00 inches (101.6 mm) in width.

3.5.6 Forging Stock: When a sample of stock is forged to a test coupon and heat treated as in 3.5.5.1, specimens taken from the heat treated coupon shall conform to the requirements of 3.5.5.2, 3.5.5.3, and, when specified, 3.5.5.4. If specimens taken from the unforged stock after heat treatment as in 3.5.5.1 conform to the requirements of 3.5.5.2, 3.5.5.3, and, when specified, 3.5.5.4, the tests shall be accepted as equivalent to tests of a forged coupon.

3.5.6.1 Forging stock from a heat meeting the requirements of 3.5.6 in one size need not be retested for use in a smaller size.

3.5.7 Stock for Flash Welded Rings: Specimens taken from the stock after heat treatment as in 3.5.5.1 shall conform to the requirements of 3.5.5.2, 3.5.5.3, and, when specified, 3.5.5.4.

3.6 Quality:

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

3.6.1 Steel shall be premium aircraft-quality conforming to AMS 2300 or MAM 2300 except that a maximum average frequency (F) rating of 0.10 and a maximum average severity (S) rating of 0.20 shall apply.

3.6.2 Bars, tubing, and flash welded rings ordered hot rolled or cold drawn, ground, turned, or polished shall, after removal of the standard machining allowance in accordance with AS1182, be free from seams, laps, tears, and cracks open to the ground, turned, or polished surfaces.

3.6.3 Grain flow of die forgings, except in areas which contain flash-line end grain, shall follow the general contour of the forgings showing no evidence of re-entrant grain flow.

3.7 Tolerances:

Shall be as follows:

3.7.1 Bars: In accordance with AMS 2251 or MAM 2251.

3.7.2 Mechanical Tubing: In accordance with AMS 2253 or MAM 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 the performance of all required tests. Purchaser reserves the right to sample and to perform any confirmatory testing deemed necessary to ensure that the product conforms to specified requirements.

4.2 Classification of Tests:

4.2.1 Acceptance Tests: The following requirements are acceptance tests and shall be performed on each heat or lot as applicable:

4.2.1.1 Composition (3.1), macrostructure (3.5.1), micro-inclusion rating (3.5.2), and frequency-severity cleanliness rating (3.6.1) of each heat.

4.2.1.2 Condition (3.3), average grain size (3.5.3), and decarburization (3.5.4) of each lot of bars, forgings, mechanical tubing, and flash welded rings.

4.2.1.3 Tensile properties (3.5.5.2), hardness (3.5.5.3), and, when specified, fracture toughness (3.5.5.4) 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 of forging stock (3.5.6) and of stock for flash welded rings (3.5.7) to demonstrate ability to develop required properties and grain flow of die forgings (3.6.3) are periodic tests and shall be performed at a frequency selected by the vendor unless frequency of testing is specified by purchaser.