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INTERNATIONAL
400 Commonwealth Drive, Warrendale, PA 15096-0001

AEROSPACE MATERIAL SPECIFICATION

SAE AMS 6512C

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An American National Standard

Superseding AMS 6512B

STEEL BARS, FORGINGS, TUBING, AND RINGS
18Ni - 7.8Co - 4.9Mo - 0.40Ti - 0.l0Al
Consumable Electrode Vacuum Melted, Annealed

UNS K92890

1. SCOPE:

1.1 Form: This specification covers a premium aircraft-quality, maraging 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 parts requiring through hardening, without quenching, to a minimum yield strength of 240 ksi (1655 MPa) 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 SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order.

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

2.1.1 Aerospace Material Specifications:

AMS 2248 - Chemical Check Analysis Limits, Wrought Corrosion and Heat Resistant Steels and Alloys, Maraging and Other Highly-Alloyed Steels, and Iron Alloys
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 2300 - Premium Aircraft-Quality Steel Cleanliness, Magnetic Particle Inspection Procedure
MAM 2300 - Premium Aircraft-Quality Steel Cleanliness, Magnetic Particle Inspection Procedure, Metric (SI) Measurement

2.1.1 (Continued):

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 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

2.1.2 Aerospace Standards:

AS1182 - Standard Machining Allowance, Aircraft-Quality and Premium Aircraft-Quality Steel Bars and Mechanical Tubing

2.2 ASTM Publications: Available from ASTM, 1916 Race Street, Philadelphia, PA 19103-1187.

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 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 Standardization Documents Order Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

2.3.1 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, Ø determined by wet chemical methods in accordance with ASTM E 353, by spectrochemical methods, or by other analytical methods acceptable to purchaser:

	min	max
Carbon	--	0.03
Manganese	--	0.10
Silicon	--	0.10
Phosphorus	--	0.010
Sulfur	--	0.010
Nickel	17.00	19.00
Cobalt	7.00	8.50
Molybdenum	4.60	5.20
Titanium	0.30	0.50
Aluminum	0.05	0.15
Chromium	--	0.50
Copper	--	0.50

3.1.1 Additives: Prior to pouring, up to 0.05% calcium, 0.02% zirconium, and 0.003% boron shall be added to the air melted heat; analysis for these elements need not be made.

3.1.2 Check Analysis: Composition variations shall meet the requirement of AMS 2248.

3.2 Condition: The product shall be supplied in the following condition:

3.2.1 Bars, Forgings, Mechanical Tubing, and Flash Welded Rings: Annealed and descaled.

3.2.1.1 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.

3.2.2 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 Ø shall be annealed by heating to a temperature within the range 1500° - 1700°F (816°- 927°C), holding at the selected temperature within ±25°F (±14°C) for 1 - 2 hours, 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 Properties: The product shall conform to the following requirements; hardness and tensile testing shall be performed in accordance with ASTM A 370:

3.4.1 Heat of Steel:

3.4.1.1 Macrostructure: Visual examination of transverse sections as in 4.3.4 Ø from bars, billets, tube rounds or tubes, and stock for forgings or flash welded rings, etched in accordance with ASTM A 604 in hot hydrochloric acid, shall show no pipe or cracks. Except as specified in 3.4.1.1.1, porosity, segregation, inclusions, and other imperfections for product 36 square inches (232 cm²) and under in nominal cross-sectional area shall be no worse than the following macrographs of ASTM A 604; macrostructure standards for product over 36 square inches (232 cm²) in nominal cross-sectional area shall be as agreed upon by purchaser and vendor:

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

3.4.1.1.1 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.

3.4.1.2 Micro-Inclusion Rating: No specimen as in 4.3.3 shall exceed the Ø following limits, determined in accordance with ASTM E 45, Method D:

	Inclusion Rating				
Type	A	B	C	D	E
Thin	1.5	1.5	1.5	2.0	3.0
Heavy	1.0	1.0	1.0	1.5	1.5

3.4.1.2.1 Type E is titanium nitride and shall be rated in the same manner as Type B.

3.4.2 Bars, Forgings, Tubing, and Flash Welded Rings:

3.4.2.1 As Annealed:

3.4.2.1.1 Hardness: Bars over 0.500 inch (12.70 mm) in nominal diameter or distance between parallel sides, forgings, tubing, and flash welded rings shall have hardness not higher than 321 HB, or equivalent.

3.4.2.1.2 Tensile Strength: Bars 0.500 inch (12.70 mm) and under in nominal Ø diameter or distance between parallel sides shall have tensile strength not higher than 160 ksi (1103 MPa) or hardness not higher than 34 HRC, or equivalent.

3.4.2.1.3 Grain Size: Shall be as follows, determined in accordance with ASTM E 112; the procedure used shall be acceptable to purchaser.

3.4.2.1.3.1 Product Under 2.50 Inch (63.5 mm) in Nominal Section Thickness: Predominantly 6 or finer with occasional grains as large as 4 permissible.

3.4.2.1.3.2 Product 2.50 to 10.00 Inches (63.5 to 254.0 mm), Incl, in Nominal Section Thickness: Predominantly 4 or finer with occasional grains as large as 2 permissible.

3.4.2.1.3.3 Product Over 10.00 Inches (254.0 mm) in Section Thickness: As agreed upon by purchaser and vendor.

3.4.2.2 After Maraging Heat Treatment: Specimens shall have the following properties after being maraged by heating to 900°F ± 10 (482°C ± 6), holding at heat for 6 hours ± 0.5, and cooling in air to room temperature:

3.4.2.2.1 Tensile Properties: Shall be as specified in Table 1 and 3.4.2.2.1.1.

3.4.2.2.1.1 Tensile property requirements for product over 10.000 inches (254.00 mm) in nominal section thickness shall be as agreed upon by purchaser and vendor.

3.4.2.2.1.2 Longitudinal requirements apply to specimens taken with axis of specimens approximately parallel to the grain flow and to specimens taken in the radial direction and in the tangential direction at the rim of disc forgings. All other specimens shall be considered to be in the transverse direction.

3.4.2.2.1.3 Transverse test requirements apply only to product from which tensile specimens not less than 2.50 inches (63.5 mm) in length can be taken.

3.4.2.2.1.4 Tensile properties in the longitudinal direction need not be determined on product tested in the transverse direction.

3.4.2.2.2 Hardness: Should be not lower than 48 HRC, or equivalent, but the product shall not be rejected on the basis of hardness if the tensile property requirements are met.

3.4.2.2.3 Fracture Toughness: When specified, product shall be subjected to fracture toughness testing in accordance with ASTM E 399. Acceptance standards shall be as agreed upon between purchaser and vendor.

3.4.3 Forging Stock: When a sample of stock is forged to a test coupon, having
Ø a degree of mechanical working not greater than the forging, and heat treated as in 3.3 and 3.4.2.2, specimens taken from the heat treated coupon shall conform to the requirements of 3.4.2.2.1, 3.4.2.2.2, and, when specified, 3.4.2.2.3. If specimens taken from the stock after heat treatment as in 3.3 and 3.4.2.2 conform to the requirements of 3.4.2.2.1, 3.4.2.2.2, and, when specified, 3.4.2.2.3, the tests shall be accepted as equivalent to tests of a forged coupon.

TABLE I

Nominal Section Thickness Inches	Specimen Orientation	Tensile Strength ksi, min	Yield Strength at 0.2% Offset ksi, min	Elongation in 4D %, min	Reduction of Area %, min
Up to 4.000, excl	Longitudinal	255	250	6	45
	Transverse	255	250	4	35
4.000 to 10.000, incl	Longitudinal	245	240	5	30
	Transverse	245	240	3	20

TABLE I (SI)

Nominal Section Thickness Millimeters	Specimen Orientation	Tensile Strength MPa, min	Yield Strength at 0.2% Offset MPa, min	Elongation in 4D %, min	Reduction of Area %, min
Up to 101.60, excl	Longitudinal	1758	1724	6	45
	Transverse	1758	1724	4	35
101.60 to 254.00, incl	Longitudinal	1689	1655	5	30
	Transverse	1689	1655	3	20

3.4.4 Stock for Flash Welded Rings: Specimens taken from the stock after heat treatment as in 3.3 and 3.4.2.2 shall conform to the requirements of 3.4.2.2.1, 3.4.2.2.2, and, when specified, 3.4.2.2.3.

3.5 Quality:

3.5.1 Steel shall be premium aircraft-quality conforming to AMS 2300 or MAM 2300. It shall be produced by multiple melting using consumable electrode vacuum 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 imperfections detrimental to usage of the product.

3.5.2.1 Ø Bars and mechanical tubing ordered hot rolled or cold drawn or ground, turned, or polished shall, after removal of the standard machining allowance in accordance with AS1182, be free from seams, laps, tears, and crack open to the ground, turned, or polished surfaces

3.5.2.2 Ø 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.

3.5.3 Ø 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.

3.6 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 feet (1.6 - 6.1 m) but not more than 10% of any shipment shall be supplied in lengths shorter than 10 feet (3 m).

3.7 Tolerances: Shall conform to all applicable requirements of the following:

3.7.1 Bars: AMS 2251 or MAM 2251.

3.7.2 Mechanical Tubing: AMS 2253 or MAM 2253.

4. QUALITY ASSURANCE PROVISIONS:

4.1 Ø 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. 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 for 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 (3.4.1.1), micro-inclusion rating (3.4.1.2), and frequency-severity cleanliness rating (3.5.1) of each heat.

4.2.1.2 Hardness (3.4.2.1.1) of each lot of bars, forgings, tubing, and flash welded rings as annealed and tensile strength (3.4.2.1.2) of each lot of bars as annealed.

4.2.1.3 Grain size (3.4.2.1.3) of each lot of bars, forgings, tubing, and flash welded rings as annealed.

4.2.1.4 Tensile properties (3.4.2.2.1), hardness (3.4.2.2.2), and, when specified, fracture toughness (3.4.2.2.3) of each lot of bars, forgings, tubing, and flash welded rings after maraging heat treatment.

4.2.1.5 Tolerances of bars (3.7.1) and mechanical tubing (3.7.2).

4.2.2 Periodic Tests: Tests for ability of forging stock (3.4.3) and of stock for flash welded rings (3.4.4) to develop required properties are periodic tests and shall be performed at a frequency selected by the vendor unless frequency of testing is specified by purchaser.

4.3 Sampling and Testing: Shall be in accordance with the following; a heat Ø shall be the consumable electrode vacuum 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.

4.3.1.1 Specimens for tensile properties of bars shall be taken at the mid-thickness location.

4.3.2 Forgings and Forging Stock: AMS 2372.

4.3.3 Samples for macrostructure rating (3.4.1.1) shall be full cross-sectional specimens obtained from the finished billet or suitable rerolled product representing the top and bottom of each usable ingot.

4.3.4 Specimens for micro-inclusion rating (3.4.1.2) shall be obtained from the finished billet or suitable rerolled product and shall consist of not less than four specimens representing the top and bottom of the first and last ingot from a heat yielding 10 or fewer ingots or not less than six specimens representing the top and bottom of the first, middle, and last usable ingot from a heat yielding more than 10 ingots.