

AEROSPACE MATERIAL SPECIFICATION



AMS 6512D

Issued MAY 1970
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Superseding AMS 6512C

Steel, Bars, Forgings, Tubing, and Rings
18Ni - 7.8Co - 4.9Mo - 0.40Ti - 0.10Al
Consumable Electrode Vacuum Melted, Annealed
(Composition similar to 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:

These products have been used typically 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, but usage is not limited to such applications.

2. APPLICABLE DOCUMENTS:

The issue of the following documents in effect on the date of the purchase order forms a part of this specification to the extent specified herein. The supplier may work to a subsequent revision of a document unless a specific document issue is specified. When the referenced document has been canceled and no superseding document has been specified, the last published issue of that document shall apply.

2.1 SAE Publications:

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

AMS 2248 Chemical Check Analysis Limits, 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

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2.1 (Continued):

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
AS1182	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 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

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	--	0.03
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 applicable requirements of AMS 2248.

3.2 Melting Practice:

Steel shall be produced by multiple melting using consumable electrode vacuum practice in the remelt cycle.

3.3 Condition:

The product shall be supplied in the following condition:

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

3.3.1.1 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.

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

3.4 Heat Treatment:

Bars, forgings, mechanical tubing, and flash-welded rings shall be annealed by heating to a temperature within the range 1500 to 1700 °F (816 to 927 °C), holding at the selected temperature within ± 25 °F (± 14 °C) for 1 to 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.

3.5 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, and stock for forgings or flash welded rings, etched in hot hydrochloric acid in accordance with ASTM A 604, shall show no pipe or cracks. 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 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

- 3.5.2 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 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

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

- 3.5.3 Hardness: Bars over 0.500 inch (12.70 mm) in nominal diameter or least distance between parallel sides, forgings, tubing, and flash welded rings shall have hardness not higher than 321 HB, or equivalent (See 8.2).
- 3.5.3.1 Bars 0.500 inch (12.70 mm) and under in nominal diameter or least distance between parallel sides shall have tensile strength not higher than 160 ksi (1103 MPa) or hardness not higher than 34 HRC, or equivalent (See 8.2).
- 3.5.4 Average Grain Size: Shall be as follows, determined in accordance with ASTM E 112.
- 3.5.4.1 Product Under 2.50 Inch (63.5 mm) in Nominal Section Thickness: ASTM No. 6 or finer (See 8.3).
- 3.5.4.2 Product 2.50 to 10.00 Inches (63.5 to 254.0 mm), Incl, in Nominal Section Thickness: ASTM No. 4 or finer (See 8.3).
- 3.5.5 After Maraging Heat Treatment: Specimens shall have the following properties after being maraged by heating to 900 °F $\pm$ 10 (482 °C $\pm$ 6), holding at heat for 6 hours $\pm$ 0.5, and cooling in air to room temperature:
- 3.5.5.1 Tensile Properties: Shall be as shown in Table 4.
- 3.5.5.1.1 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.
- 3.5.5.1.2 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.
- 3.5.5.1.3 Tensile properties in the longitudinal direction need not be determined on product tested in the transverse direction.
- 3.5.5.2 Hardness: Should be not lower than 48 HRC, or equivalent (See 8.2), but the product shall not be rejected on the basis of hardness if the tensile property requirements are acceptable, determined on specimens taken from the same sample as with the nonconforming hardness or from another sample with similar nonconforming hardness.
- 3.5.5.3 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.

- 3.5.5.4 Forging Stock: When a sample of stock is forged to a test coupon, having a degree of mechanical working not greater than the forging, and heat treated as in 3.4 and 3.5.5, specimens taken from the heat treated coupon shall conform to the requirements of 3.5.5.1 and 3.5.5.2, and, when specified, 3.5.5.3. If specimens taken from the stock after heat treatment as in 3.4 and 3.5.5 conform to the requirements of 3.5.5.1, 3.5.5.2, and, when specified, 3.5.5.3, the tests shall be accepted as equivalent to tests of a forged coupon.

TABLE 4A - Minimum Tensile Properties, Inch/Pound Units

Nominal Section Thickness Inches	Specimen Orientation	Tensile Strength ksi	Yield Strength at 0.2% Offset ksi	Elongation in 4D %	Reduction of Area %
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 4B - Minimum Tensile Properties, SI Units

Nominal Section Thickness Millimeters	Specimen Orientation	Tensile Strength MPa	Yield Strength at 0.2% Offset MPa	Elongation in 4D %	Reduction of Area %
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

- 3.5.6 Stock for Flash Welded Rings: Specimens taken from the stock after heat treatment as in 3.4 and 3.5.5 shall conform to the requirements of 3.5.5.1, 3.5.5.2, and, when specified, 3.5.5.3.

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.
- 3.6.2 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 cracks open to the ground, turned, or polished surface.
- 3.6.3 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.
- 3.6.4 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 reentrant grain flow.
- 3.7 Tolerances:
- Shall conform to all applicable requirements 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 Hardness (3.5.3) of each lot of bars, forgings, tubing, and flash welded rings as annealed and tensile strength (3.5.3.1) of each lot of bars as annealed.
- 4.2.1.3 Average grain size (3.5.4) of each lot of bars, forgings, tubing, and flash welded rings as annealed.
- 4.2.1.4 Tensile properties (3.5.5.1), hardness (3.5.5.2), and, when specified, fracture toughness (3.5.5.3) 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 (3.5.5.4) and of stock for flash welded rings (3.5.6) to develop required properties, and grain flow of die forgings (3.6.4), 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 as follows:

4.3.1 Bars, Mechanical Tubing, Flash Welded Rings, and Stock for Forgings and Flash Welded Rings: In accordance with AMS 2370.

4.3.2 Forgings: In accordance with AMS 2372.

4.4 Reports:

The vendor of the product shall furnish with each shipment a report showing the results of tests for chemical composition, macrostructure, micro-inclusion rating, and frequency-severity cleanliness rating of each heat, and for average grain size and annealed hardness tensile properties, hardness, and, when specified, fracture toughness of each lot after maraging heat treatment, and stating that the product conforms to the other technical requirements. This report shall include the purchase order number, heat and lot numbers, AMS 6512D, size, and quantity. If forgings are supplied, the size and melt source of stock used to make the forgings shall also be included.

4.5 Resampling and Retesting:

Shall be as follows:

4.5.1 Bars, Mechanical Tubing, Flash Welded Rings, and Stock for Forging or Flash Welded Rings: In accordance with AMS 2370.

4.5.2 Forgings: In accordance with AMS 2372.

5. PREPARATION FOR DELIVERY:

5.1 Sizes:

Except when exact lengths or multiples of exact lengths are ordered, straight bars and tubing will be acceptable in mill lengths of 6 to 20 feet (1.6 to 6.1 m) but not more than 10% of any shipment shall be supplied in lengths shorter than 10 feet (3 m).

5.2 Identification:

Shall be as follows:

5.2.1 Bars and Mechanical Tubing: In accordance with AMS 2806.