

AEROSPACE MATERIAL SPECIFICATION

Submitted for recognition as an American National Standard

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Superseding AMS-5586C

ALLOY TUBING, WELDED, CORROSION AND HEAT RESISTANT
57Ni - 19.5Cr - 13.5Co - 4.2Mo - 2.9Ti - 1.4Al - 0.08Zr - 0.006B
Consumable Electrode or Vacuum Induction Melted, Annealed

UNS N07001

1. SCOPE:

1.1 Form: This specification covers a corrosion and heat resistant nickel alloy in the form of welded tubing.

1.2 Application: Primarily for parts requiring high strength up to 1500°F (816°C) and oxidation resistance up to 1750°F (954°C).

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-2263 - Tolerances, Nickel, Nickel Alloy, and Cobalt Alloy Tubing

MAM-2263 - Tolerances, Metric, Nickel, Nickel Alloy, and Cobalt Alloy Tubing

AMS-2269 - Chemical Check Analysis Limits, Wrought Nickel Alloys and Cobalt Alloys

AMS-2371 - Quality Assurance Sampling of Corrosion and Heat Resistant Steels and Alloys, Wrought Products Except Forgings and Forging Stock

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

- ASTM E 8 - Tension Testing of Metallic Materials
- ASTM E 8M - Tension Testing of Metallic Materials (Metric)
- ASTM E 18 - Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials
- ASTM E 112 - Determining Average Grain Size
- ASTM E 139 - Conducting Creep, Creep-Rupture, and Stress-Rupture Tests of Metallic Materials
- ASTM E 354 - Chemical Analysis of High-Temperature, Electrical, Magnetic, and Other Similar Iron, Nickel, and Cobalt Alloys

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, determined by wet chemical methods in accordance with ASTM E 354, by spectrochemical methods, or by other analytical methods acceptable to purchaser:

	min	max
Carbon	0.02	0.10
Manganese	--	0.10
Silicon	--	0.15
Phosphorus	--	0.015
Sulfur	--	0.015
Chromium	18.00	21.00
Cobalt	12.00	15.00
Molybdenum	3.50	5.00
Titanium	2.50	3.25
Aluminum	1.20	1.60
Zirconium	0.02	0.15
Boron (3.1.1)	0.003	0.010
Iron	--	2.00
Copper	--	0.10
Nickel	remainder	

3.1.1 Boron may be less than 0.003, determined on tubing having nominal wall thickness under 0.050 inch (1.27 mm), provided the specified requirement is met on the stock from which sheet or strip for making tubing is rolled.

3.1.2 Check Analysis: Composition variations shall meet the requirements of AMS-2269.

3.2 Condition: Annealed and descaled. Annealing shall be performed in a suitable protective atmosphere at such temperature and for such time as will produce tubing meeting the requirements of 3.4. Cooling from the annealing temperature shall be at a rate equivalent to an air cool or faster.

3.3 Fabrication: Tubing 2.00 inches (50.8 mm) and under in nominal OD shall be cold worked after welding and prior to annealing.

3.4 Properties: Tubing 0.125 inch (3.18 mm) and over in nominal OD and 0.015 inch (0.38 mm) and over in nominal wall thickness shall conform to the following requirements; properties of tubing under 0.125 inch (3.18 mm) in nominal OD or under 0.015 inch (0.38 mm) in nominal wall thickness shall be as agreed upon by purchaser and vendor:

3.4.1 As Annealed:

3.4.1.1 Tensile Properties: Shall be as follows, determined in accordance with ASTM E 8 or ASTM E 8M:

Tensile Strength, maximum	145,000 psi (1000 MPa)
Yield Strength at 0.2% Offset, maximum	80,000 psi (552 MPa)
Elongation in 2 Inches (50.8 mm) or 4D, minimum	35%

3.4.1.2 Flareability: Specimens as in 4.3.1 shall withstand flaring at room temperature, without formation of cracks or other visible defects, by being forced axially with steady pressure over a hardened and polished tapered steel pin having a 74 degree included angle to produce a flare having a permanent expanded OD not less than 1.2 times the nominal OD.

3.4.1.3 Pressure Test: Tubing shall show no bulges, leaks, pin holes, cracks, or other defects when subjected to an internal hydrostatic pressure (P) of 15,000 psi (103 MPa) or pressure sufficient to cause a tensile stress of 40,000 psi (276 MPa) in the tubing wall, whichever is less. The hydrostatic pressure (P) shall be calculated from the following equation:

$$P = 2 \frac{ST}{D}$$

where, S = 40,000 psi (276 MPa) tensile stress
 T = Minimum wall thickness (nominal thickness minus maximum negative tolerance)
 D = Nominal OD

3.4.1.4 Grain Size: Predominantly 5 or finer with occasional grains as large as 3 permissible, determined in accordance with ASTM E 112.

3.4.2 After Solution, Stabilization, and Precipitation Heat Treatment: Tubing shall meet the requirements of 3.4.2.1, 3.4.2.2, and 3.4.2.3 after being solution heat treated by heating in a suitable atmosphere to $1825^{\circ}\text{F} \pm 25$ ($996^{\circ}\text{C} \pm 14$), holding at heat for 2 hours ± 0.25 , and cooling at a rate equivalent to an air cool or faster; stabilization treated by heating to $1550^{\circ}\text{F} \pm 15$ ($843^{\circ}\text{C} \pm 8$), holding at heat for 4 hours ± 0.25 , and cooling in air; and precipitation treated by heating to $1400^{\circ}\text{F} \pm 15$ ($760^{\circ}\text{C} \pm 8$), holding at heat for 16 hours ± 1 , and cooling in air.

3.4.2.1 Tensile Properties: Shall be as follows, determined in accordance with ASTM E 8 or ASTM E 8M:

Tensile Strength, minimum	160,000 psi (1103 MPa)
Yield Strength at 0.2% Offset, minimum	105,000 psi (724 MPa)
Elongation in 2 Inches (50.8 mm), minimum	15%

3.4.2.2 Hardness: Should be 34 - 44 HRC, or equivalent, determined in accordance with ASTM E 18, but tubing shall not be rejected on the basis of hardness if the tensile property requirements of 3.4.2.1 are met.

3.4.2.3 Stress-Rupture Properties: Shall be as follows, determined in accordance with ASTM E 139; the test at 1500°F (816°C) need be run only if the tubing fails to pass the test at 1350°F (732°C) and tubing which passes the test of 3.4.2.3.2 will be acceptable:

3.4.2.3.1 At 1350°F (732°C): A tensile specimen, maintained at $1350^{\circ}\text{F} \pm 3$ ($732^{\circ}\text{C} \pm 2$) while a load sufficient to produce the initial axial stress shown in Table I is applied continuously, shall not rupture in less than 23 hours. The test shall be continued to rupture without change of load. Elongation after rupture, measured at room temperature, shall be not less than shown in Table I.

TABLE I

Nominal Wall Thickness Inches	Stress psi	Elongation in 2 Inches %, min
0.015 to 0.020, incl	62,500	4
Over 0.020 to 0.030, incl	65,000	4
Over 0.030 to 0.050, incl	67,500	4
Over 0.050	70,000	5

TABLE I (SI)

Nominal Wall Thickness Millimetres	Stress MPa	Elongation in 50.8 mm %, min
0.38 to 0.51, incl	431	4
Over 0.51 to 0.76, incl	448	4
Over 0.76 to 1.27, incl	465	4
Over 1.27	483	5

3.4.2.3.2 At 1500°F (816°C): A tensile specimen, maintained at 1500°F $\pm$ 3 (816°C $\pm$ 2) while a load sufficient to produce an initial axial stress of 37,500 psi (259 MPa) is applied continuously, shall not rupture in less than 23 hours. The test shall be continued to rupture without change of load. Elongation after rupture, measured at room temperature, shall be not less than 5% in 2 inches (50.8 mm).

3.4.2.3.2.1 The test of 3.4.2.3.2 may be conducted using a load higher than required to produce an initial axial stress of 37,500 psi (259 MPa) but load shall not be changed while test is in progress. Time to rupture and elongation requirements shall be as specified in 3.4.2.3.2.

3.4.2.3.2.2 When permitted by purchaser, the test of 3.4.2.3.2 may be conducted using incremental loading. In such case, the load required to produce an initial axial stress of 37,500 psi (259 MPa) shall be used to rupture or for 23 hours, whichever occurs first. After the 23 hours and at intervals of 8 - 16 hours, preferably 8 - 10 hours, thereafter, the stress shall be increased in increments of 2500 psi (17 MPa). Time to rupture and elongation requirements shall be as specified in 3.4.2.3.2.

3.5 Quality:

3.5.1 Alloy shall be produced by multiple melting using consumable electrode practice in the remelt cycle or shall be induction melted under vacuum. If consumable electrode remelting is not performed in vacuum, electrodes which have been produced by vacuum induction melting shall be used for remelting.

3.5.2 Tubing, as received by purchaser, shall be uniform in quality and condition and shall have a finish conforming to the best practice for high quality aircraft tubing. It shall be smooth and free from heavy scale or oxide, burrs, seams, tears, grooves, laminations, slivers, pits, and other imperfections detrimental to usage of the tubing. Surface imperfections such as handling marks, straightening marks, light mandrel and die marks, and scale pattern will not be considered injurious if the imperfections are removable within the tolerances specified for wall thickness but removal of such imperfections is not required.

3.5.3 If beads are present at the weld on the inner surface of tubing over 2.00 inches (50.8 mm) in nominal OD, such beads shall be not thicker than 0.010 inch (0.25 mm). The outer surface of all tubing and the inner surface of tubing 2.00 inches (50.8 mm) and under in nominal OD shall be free from beads.

3.6 Sizes: Except when exact lengths or multiples of exact lengths are ordered, straight tubing will be acceptable in mill lengths of 6 - 20 feet (1.8 - 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 AMS-2263 or MAM-2263.

4. QUALITY ASSURANCE PROVISIONS:

4.1 Responsibility for Inspection: The vendor of tubing shall supply all
Ø 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 tubing 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) of each heat.

4.2.1.2 Tensile properties (3.4.1.1) and grain size (3.4.1.4) of each lot as annealed.

4.2.1.3 Tensile properties (3.4.2.1), hardness (3.4.2.2), and stress-rupture properties (3.4.2.3) of each lot after solution, stabilization, and precipitation heat treatment.

4.2.2 Periodic Tests: Tests for flarability (3.4.1.2) and pressure test (3.4.1.3) of as-annealed tubing 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 AMS-2371 and the
Ø following; when consumable electrode remelted alloy is supplied, a heat shall be the consumable electrode remelted ingots produced from alloy originally melted as a single furnace charge:

4.3.1 Specimens for flarability test (3.4.1.2) shall be full tubes or sections cut from a tube. The end of the specimen to be flared shall be cut square, with the cut end smooth and free from burrs, but not rounded.

4.3.2 Pressure Test: Three samples from each lot.
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4.4 Reports: The vendor of tubing shall furnish with each shipment a report showing the results of tests for chemical composition of each heat and the results of tests on each lot to determine conformance to the other acceptance test requirements and, when performed, to the periodic test requirements. This report shall include the purchase order number, lot number, AMS-5586D, size, and quantity.

4.5 Resampling and Retesting: Shall be in accordance with AMS-2371.